REPORT

OF

THE SUPERINTENDENT

OF THE

COAST SURVEY,

SHOWING

THE PROGRESS OF THE SURVEY

DURING

THE YEAR 1854.

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1855.

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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ERRATA.

In the annual report of the Coast Survey for 1854.

Page 9, at middle, for Appendix No. 7, read Appendix No. 43.
Page 30, 11th line from bottom, for declinations, read declination.
Page 34, 15th line from bottom, for De Barres, read Des Barres.
Page 35, 19th line from top, for uncertainty, read indefinite.
Page 36, 16th line from top, for Succunesset, read Succonesset.
Page 36, 3d line from bottom, for Sketch No. 26, read Sketch No. 34.
Page 40, 20th line from bottom, for Barley's, read Baily's.
Page 43, 14th line from top, for Versalins, read Vervalins.
Page 49, 3d line from top, for New Point Comfort, read New Port News.
Page 73, 4th line from bottom, for sight, read site.
Page *27, at middle, for Kayo, read Cayo.
See page *138 for errata in Dr. B. A. Gould's reports.
Page *190, title of Appendix No. 53, for Sketch K, read Sketch No. 57.

In the list of geographical positions published in the annual report of the Coast Survey for 1851.

Page.	Line.	For—	Read—
185	13	70° 05′ 36″.39	70° 05′ 36″.59.
252	14	8.09 miles	5.85 miles.
252	15	1350.3, 1476.7, 0.84	13503.0, 14766.5, 8.39.

In the annual report of the Coast Survey for 1852, page 34, second line, for N. N.W., read S. S.E. ¾ E.

In the list of geographical positions published in the annual report of the Coast Survey for 1853.

Page.	Line.	For—	Read—
*15	12	Electro magnet telegraph	Electro magnetic telegraph.
*16, *et seq*		(*Heading of first column*)	Name of station.
*17	15	70° 49′ 50″.60	70° 49′ 50″.66.
*20	27	15721.9, 17193.0, 9.77	15771.9, 17247.7, 9.80.
*28	20	119° 32′ 03″	199° 32′ 03″.
*29	14th from below	1904.3 metres	1964.3 metres.
*31	40	3.93 miles	3.98 miles.
*32	5	Beaufort, commandant's house	Commandant's house.
*32	14th from below	35° 05′ 38″.32	32° 05′ 38″.32.
*33	12	5319.2 yards	5379.2 yards.
*34	10	189° 25′ 15″	189° 23′ 15″.
*36	16	3.02 miles	8.02 miles.
*42	13	83551.1 yards	8355.1 yards.

In the projection tables published in the annual report of the Coast Survey for 1853.

Page.	Column.	Line.	For—	Read—
*101	....	28th from above	Sin $\frac{1}{2}\theta$ 30 n sin L sin 1″	$\frac{1}{2}\theta = 30\,n$ sin L sin 1″.
*101	....	Throughout page	x, y	X, Y
*113	60″	15th from below	1885.47	1685.47.
*113	60″	5th from below	16 — 3.21	1683.21.
*114	10″	17th from above	9.9	279.9.
*115	....	5th from above	1′	1″.
*116	20″	5th from above	256.1	556.1.
*130	7″	5th from below	0.8	180.8.
*159	....	4th from above	10	10″.

33d Congress, 2d Session. | HOUSE OF REPRESENTATIVES. | Ex. Doc. No. 20.

LETTER

FROM THE

SECRETARY OF THE TREASURY,

TRANSMITTING

The report of the Superintendent of the Coast Survey.

December 22, 1854.—Laid upon the table, and ordered to be printed.

December 26, 1854.—*Resolved,* That 10,000 copies of the letter of the Secretary of the Treasury communicating the report of the Superintendent of the Coast Survey for the year 1854, in addition to the usual number, be printed—five thousand thereof for the use of the House, and the remainder for distribution by the Coast Survey office; and that the same be printed and bound, with the plates, in quarto form, and that the plates be printed under the direction of the Superintendent of the Coast Survey.

Treasury Department,
December 22, 1854.

Sir: I have the honor to submit, for the information of the House of Representatives, the report made to the department by Professor A. D. Bache, Superintendent of the Coast Survey, showing the progress of that work during the year ending November 1, 1854, with the accompanying map, prepared at the Coast Survey Office, in accordance with the provision of the act of Congress approved March 3, 1853.

Very respectfully, yours, &c.,

JAMES GUTHRIE,
Secretary of the Treasury.

Hon. Linn Boyd,
Speaker of the House of Representatives.

REPORT.

RAGGED MT. STATION, NEAR CAMDEN, MAINE,
November 22, 1854.

SIR: In conformity with law and the regulations of the Treasury Department, I have the honor to submit a report of the progress of the Coast Survey under my superintendence during the past year.

In all the States where the work is not essentially completed, on the coast of the Atlantic, Gulf of Mexico, and Pacific, it has, as during the two years last past, been in progress.

I propose to give an account of this progress under the following heads; the same which were used in my report of last year:

1. General statement and remarks.
2. A condensed notice of the progress during the past year, arranged geographically by sections and localities.
3. The estimated progress for the next fiscal year, with the estimates for securing that progress.
4. A detailed account of the work done in the field and afloat between November 1, 1853, and the same date in 1854, classed according to sections, corresponding with the programme of divisions of the coast, and arranged according to the different operations. The work of each officer is there noticed, and the statistics as reported by him. A brief summary of the work in the several sections precedes the details.
5. The office-work is next stated in the order of its different parts.
6. The appendix contains lists, reports, and other data referred to in the body of the report, classified under general heads.
7. Sketches showing the progress of the survey in the several sections, and sub-sketches where more detail is necessary, lettered from A onward, accompany the reports; those of the same section bearing the same letter, and the successive sketches in each section being numbered.

Sketches of important parts of the coast, harbors, channels, shoals, rocks, and ledges, of sites for light-houses, and diagrams of tides and currents, are given under the sections to which they belong, and designated by the letter of the section.

Diagrams of the Gulf Stream, general tidal results, and miscellaneous matters, have a special letter.

8. In addition to the tables of contents of the report and appendix and list of sketches, is an alphabetical index.

The first condensed statement of the progress of the survey seems necessary to bring the whole of it under examination in a body. It aims at giving a general idea of what the year's operations have accomplished, as introductory to the proposed progress for the next fiscal year, which accompanies the estimates, determines them, and is, in turn, determined by the appropriations.

Such a statement as this, though sufficient for purposes of general examination, necessarily excludes details in regard to places and persons which are nevertheless essential to the full history of the work. The details follow in which each operation is treated under the head of the section of the coast to which it belongs, under the subdivisions relating to the particular operation, and with the name of the officer executing it attached. It is due to the arduous character of the service that the labors of each should find a place in the report; and it serves to define and limit responsibility, so that no one may bear the burden of another. The sections form so many chapters, as it were, of greater or less size, determined by the extent of the operations conducted in them severally, or rather by the notice of them. The prefatory remarks to each section give, in a general way, what has been accomplished during the year. They are more detailed than the very brief statement in the first part of the report; serve to show what are the prominent points in the succeeding account, as well as to give a connected view of it. The office-work relating to the section is also presented in a brief way in the introductory remarks.

A detailed account of the office-work presents the advantages referred to as belonging to that of each section, and shows how, from year to year, the results of the survey are carried through their different forms until they appear in its publications.

The sketches are of two classes—one showing the progress of each operation by conventional signs, explained on the face of the sketch; the other giving some special result of practical or scientific interest, as the chart of a harbor, sketch of a shoal or channel, or a tidal or current diagram. In the second class are brought out immediately, usually without attempt at finish, some of the more important results of the surveying year.

The appendix to the report at first contained only a few lists and reports referred to in the body of the document; but it has been found desirable to place in it some of the results of the survey in a preliminary form—reports which are made from time to time on field operations, or in the office; discussions of scientific matters belonging to the survey, of matters relating to navigation, and accessories to navigation and commerce; tables of theoretical and practical results, and official lists and communications. These are so classified that the reader can choose or omit the division in which he does or does not find the subject he wishes to examine. The large distribution made of the report by Congress thus conveys to those interested in commerce and navigation, and the applied sciences, some of the immediate results of the survey.

The chain of triangulation of the Coast Survey now extends, with a single broken link of fifteen miles, from Penobscot bay, in Maine, to Bogue sound, in North Carolina. South of this it crosses Cape Fear entrance, and passes up the river to Wilmington; includes Winyah bay and Georgetown harbor, and the coast from the Ashley river to St. Helena sound, Calibogue sound and the Savannah river to the head of Argyle island and St. John's river entrance; connects the Florida reefs and keys from Cape Florida to Key Rodriguez, and from the Pine islands to Key West; extends from Crystal river offing to Cedar Keys, inclusive, on the Western coast of the Florida peninsula, over Ocilla river entrance; connects Mobile with New Orleans, and passes from Mobile to the Gulf and across Mississippi sound, and through Lake Borgne and Lake Pontchartrain, to New Orleans; includes Galveston lower and upper bays, and east and west bays, and the coast to the head of Matagorda bay, and covers the entrance of the Rio Bravo del Norte. In some cases the main triangulation leads, and in others follows, affording first or last the check which the minor work requires. It rests upon carefully-measured bases, which, when united, serve as bases of verification. A preliminary triangulation is made whenever a specially important locality requires survey out of the regular course, and is brought subsequently into the general scheme. Upon this series of points, determined by the triangulation, the plane-table surveys rest, furnishing the shore-line and details of topography, and with these the hydrography is readily and accurately executed. It gives the soundings, pointing out shoals and rocks to be avoided, and channels to be followed, the set and drift of currents, and the rise and fall of tides. It would be difficult to find a country which presents a greater variety in the coast to which different plans of survey should be adapted, or more varied features in the oceans which wash it, in all their relations of depth, of current, and of tide. The land-work finds its most interesting applications among the hills and mountains of the eastern coast, and on the islands and adjacent main of the Gulf of Mexico, and the hydrography in that remarkable stream which connects the Gulf of Mexico with the northern seas, in exploring the shoals and depths of the great gulf in which it has its source, and the depths and shoals of the north and east whence return is made for its flow. It might at first be supposed that in the beaten tracks of commerce and navigation, such a survey had merely to map down accurately and laboriously what was before imperfectly known and carelessly traced. But even the approaches to our great marts of commerce have not failed to yield actual discoveries, or developments so near akin to them that it is difficult to draw the line between them. Gedney's channel, off New York, has associated the name of that veteran hydrographer with discovery in the most frequented port of the Union. Blake's channel, in the Delaware; Davis' shoal and Davis' Bank, near Nantucket; Stellwagen's Bank, at the entrance of Massachusetts bay; Almy's shoal, off Cape Charles; Jenkins' channel, across Cape Fear shoals; Maffit's channel, at Charleston, and Rodgers' channel, at Key West, have connected their skill and patient research with the most thronged routes and customary approaches. The pilot or navigator follows the middle way without seeking to the right or to the left, sounding only when necessity requires, his object being to carry his single vessel into port; the surveyor explores the entire approach, carrying his vessel into places deemed both safe and unsafe, that he may develop their facilities or discover their dangers.

During the past year, though we have felt, in common with all who have had limited means to expend and considerable results to produce, the effect of the increase of prices of every sort, the survey has, in most of the sections, presented a fair degree of progress—not what under other circumstances it would have done, but as much as could justly be expected under those which it has had to encounter. The estimates which, under a former statement of things, would have carried us forward at the rate of nearly one-tenth of the remaining work during the year, could not accomplish as much when labor and supplies of every sort had so much increased in money value. The consequence of this I have presented to the Treasury Department, and, with the approval of its head, will also point out in a subsequent part of this report. If it were desirable to dwell upon the dark side of the year's picture, I could draw abundantly from the reports of the Atlantic, Gulf, and Pacific coast, and in part from personal experience, narratives of disappointments from fogs, winds, and fires, disasters from hurricanes, from fever and from cholera—all encountered from the necessity of the case, the parties having used all the means of success which human care and foresight suggested; but it is more pleasant, as well as profitable, leaving these behind, to show the real, substantial progress which has been made, and, besides that, to connect with it the names of the persons by whom it has been achieved. A rapid glance at the list of distribution of parties (Appendix No. 1) will give a general view of the field-work; and a similar one at the lists which follow it, (Appendix No. 31) of the office-work.

The names of officers of the army attached to the survey on the 1st of September, 1854, is given in Appendix No. 2 *bis*. The number was one greater than that on the same date of the previous year, and includes three officers from the Corps of Engineers, two from the Topographical Engineers, and nine from the line of the army. Notice has been given of the intention to relieve four of the officers whose names appear in the list, which will take four of the most experienced from the work. This rotation, though rapid, is not such as to cripple the efficiency of the details. Three officers whose names do not appear on the list, have been detailed and relieved within the year.

During the past year, the efficiency of the hydrography has been considerably increased by the favorable action of the enlightened head of the Navy Department. The want of officers in the naval service has, however, pressed heavily upon us, and until the act of Congress took effect relating to the pay of seamen, there was very great difficulty in filling up the number allowed with even very indifferent men, and desertions were so frequent as to be a serious drawback upon the parties. The item of transportation has borne heavily upon our funds, being no longer paid by the Navy Department, and officers being sometimes ordered for short periods only, to our parties, from considerable distances. It must be borne in mind that, as we are inflexibly limited to special amounts, every item of expense of this sort has to be paid for in loss of work. I doubt not that the present system, which still bears the impress of the past, can ultimately be more favorably arranged between the two departments, both having the same object—the good of the public service. It will be seen that the number of sea-officers attached to the Coast Survey September 1, 1853, has been reduced from sixty-one to fifty-five; that twenty-four or forty per cent. of the number in 1853, and forty-four per cent. of the present number, have thus been changed during the year, making nearly the half of each party to consist of officers new to the work and to be instructed before they can become efficient. Besides the fifty-five sea-officers on the first of September, there were ten naval engineers attached to the Coast Survey steamers. The number on September 1, 1853, was thirteen.

In this introductory part of my report, in presenting some of the principal developments and discoveries of the year, it is proper to observe that the line which separates these, though in some cases well marked, in others would be with great difficulty drawn. The determination of the exact depth upon a shoal, and its precise length and breadth, might be as important as the discovery of its existence. The development of the law of the tides at a port where they were unknown before, especially if some seeming irregularity, perplexing to the navigator, were explained by them, is hardly less important. So the determination, in a corrected form, of the set and drift of the tidal current, from a series of observations, borders on discovery. Again: it is difficult always to establish a discovery as such on a frequented coast, beyond all cavil. Nothing may exist in relation to a shoal or channel in print, but the tradition of pilots and fishermen may assert that one exists in a locality without knowing its precise position. A vessel touched upon the shoal; a fisherman plied his line upon the bank; a vessel under stress of weather passed through the channel; but the position of the vessel or fisherman's boat is not known. There may even be dim indications upon an old chart, by the rude conventional signs that cover sometimes so much space, that a shoal is supposed to exist, and yet for all purposes of navigation, in these several cases, the placing of that shoal may be as valuable as a discovery—indeed, may be considered as such; and in sifting the evidence it will be difficult to say that it is or is not such, so many minute circumstances must be weighed. By classing developments and discoveries together, the attempt to discriminate the nicer shades is avoided, and things of like importance are presented with like prominence. When after examination the claim to discovery is deemed to be established, a name is given to the shoal, rock, or channel, and usually that of the discoverer. In the case of Stellwagen's Bank, after finding it in the regular progress of surveying, and traversing it by lines of soundings, Lieutenant Commanding Stellwagen proceeded to inquire if it was known, and submitted to me the evidence, detailed under the head of hydrography of Section I, and in Appendix No. 9.

The bank was not on the most approved charts, though on a chart of less authority, one or two soundings, by shifting their places somewhat, might belong to it. A "middle ground" was supposed by the tradition of fishermen to be somewhere at the entrance, but parties desirous of fishing upon it have failed to find it. A shoal was inserted in a chart of one year and discarded in that of the next, or its position and name changed, showing a want of definite knowledge even of its existence. The best authorities rejected it altogether. As a mark for vessels entering Massachusetts bay, its value is so great that, had its existence been known with certainty, it would have been duly pointed out in the accredited publications. Finally, it had no definite name, and I have therefore given it that of its discoverer, Lieutenant Commanding Stellwagen.

The following is a list of the developments and discoveries of the past year. A similar list, in continuation of one in my last year's report, including the period from the beginning of the work to the end of the present year, is placed in Appendix No. 8.

1. Determination of the dimensions of Alden's Rock, near Cape Elizabeth, Maine.
2. A bank (Stellwagen's Bank,) with ten and a half to fourteen and a half fathoms of water on it, at the entrance of Massachusetts bay, and serving as an important mark for approaching Boston and other harbors.
3. A dangerous sunken ledge, (Davis' ledge,) to the eastward and in the neighborhood of Minot's ledge.
4. Several rocks in the fair channel way, in Boston harbor entrance.
5. The tidal currents of Nantucket shoals and the approaches.
6. The tidal currents of Long Island Sound.
7. The changes in New York harbor, near the city, between 1845 and 1854.
8. The general permanence of the Bodkin channel, and shoals in its vicinity, at the entrance of the Patapsco river, between 1844 and 1854.
9. A shoal (New Point shoal) in Chesapeake bay, with sixteen feet water on it, SE. from New Point Comfort light-house, off Mobjack bay.
10. A reconnaissance of the Wimble shoals, near Nag's Head, coast of North Carolina.
11. The general permanence in depth on the bar of Beaufort, North Carolina, with the change of position of the channel.
12. The changes in Maffitt's channel, Charleston harbor, South Carolina, from 1852 to 1854.
13. A harbor of refuge, (Turtle harbor,) to the northward and westward of Carysfort light-house, Florida reef, with a depth of water of twenty-six feet at the entrance.
14. A safe rule for crossing the Florida reef near Indian key.
15. Co-tidal lines for the Atlantic coast of the United States.
16. An increase of depth of water on the bar at Pass Fourchon, Louisiana.
17. A shoal at the entrance to the straits of Rosario, Washington Territory, giving good holding-ground in thirty-three feet.
18. Tides of San Diego, San Francisco, and Astoria.

No special discussion of the value of the different particulars of the foregoing list is necessary, but a few remarks may be desirable. While the first, Stellwagen's Bank, shows the navigator what to look for, the second shows what he should avoid. In entering Massachusetts bay, a broad bank, three to five miles wide, with ten and a half to fourteen and a half fathoms water on it, and deep water on each side, is an excellent mark, especially as it stretches for fifteen miles in length, so that a moderately accurate knowledge of position would enable the navigator to sound on it. The precept for entering Boston harbor from the south is to clear Davis' and Minot's ledges, and for this a special range is given. Almy's shoal is of interest to those navigating the lower part of Chesapeake bay in vessels of considerable draught. The development in regard to the Patapsco entrance may have an important bearing upon the improvements undertaken there by the city of Baltimore. The small decrease of depth at Beaufort, North Carolina, under the very different positions of the channel, is not only locally important, but is instructive in its contrast with other harbors on the same coast, and the cause is deserving of careful study for its general bearing. It is attributed, by some, to the protection of Cape Lookout; by others, to the fact that no considerable rivers empty into Beaufort harbor, and that it is almost simply an estuary, into and out of which the waters of the ocean flow. These causes lead to widely different inferences. The changes in Maffitt's channel have been actually made the basis of a change of plan in its improvement, and too much stress cannot, therefore, be laid upon the value of their minute and careful determination. This is the channel which has been decided by the common consent of all professional men who have examined it, to give the best hope of ready improvement of the entrance to Charleston harbor.

The harbor of refuge inside of the Florida reef, and the rule of entering at Indian Key, will do much to assist navigators at that part of the reef; and when the harbor is marked as proposed, and the signals along the reef established, great facilities will exist for using the inside passage, and the present route of navigation may, and probably will, be much changed. The general discussion of the currents of Long Island sound will explain, for the first time, some points which have much perplexed casual observers, and give definite ideas of the general set and drift of the tidal currents. The rule which gives a safe distance from the Nantucket shoals in a calm, is a curious instance of a practical precept, coming from what, at first sight, seems to be a pure speculation. The generalizing of the facts there, as to the direction of the current compared with that of the shoal, its velocity, with the distance from the land, and the drawing of lines, along which the current changes at the same time, must prove very useful to the navigator who will study it. The subject is not yet finally developed, and perhaps has not assumed its most simple form; but enough has been done to warrant its presentation as a contribution of marked interest. The connection of the tidal current directly with the moon's motion, instead of with the tide, is an innovation which may not be approved, and yet, after consulting hydrographers, the balance for and against that mode of presenting the subject was nearly at an equipoise. It is easy, if the plan does not prove generally acceptable, to recur to the former. In justice to the merit of the paper on this subject, I have presented it without change. The tidal discussions will, as they find their way among nautical men, give precise ideas, instead of the crude ones which casual observation has furnished, and will ultimately form the basis of prediction tables for the principal ports, which will replace the very rough approximations now in use, and finally bring the predictions as near to the occurrence as the nature of the disturbing cause of wind and weather will allow; that is, will make them accord with precision, on the average. In a scientific point of view, these generalizations are also of considerable value; a high authority has already pronounced this to be the case. The great Atlantic tide-wave, in reaching our comparatively shoal Atlantic shores, appears to be modified by them so that the co-tidal lines take their shape.

Of the developments on the Western coast, the most important yet reported seem to be, the existence of the shoal at the entrance of the strait of San Rosario, two rocks in San Rosario strait and one in the Canal de Haro, and a five-fathom bank in the straits of Juan de Fuca.

In regard to the Western coast, we claim to have done much work there in a short time, and to have adapted it to the special wants and rapid growth of the country; beginning with a general reconnaissance from San Diego to the Columbia river, following this up with preliminary charts of the bays and harbors, and anchorages, as commerce directed itself towards them, meanwhile revising the reconnaissance and making it more complete; substituting preliminary surveys of the more important harbors for general reconnaissances; filling in the surveys of minor ports and anchorages, and extending the work northward, while carrying on the regular operations at and near the central harbor of the coast; and furnishing topographical surveys of the sites of light-houses, and examinations needed for their location. A list of the surveys of various grades made in California, Oregon and Washington Territories, fifty-four in number, is in the Appendix No. 6. The difficulties with which the survey, especially in its introduction upon the Western coast, had to contend, will probably excuse the few omissions with which it may be charged.

My report of 1851 contained a list of geographical positions determined from preliminary computations, and that of last year an additional list for two years. As supplementary to this, will be found in the present report the no less important list of magnetic declinations or variations. The results obtained in the course of the survey are collected in Appendix No. 7. The local irregularities are such as careful examination has shown to result generally from the nature of the phenomena. Considerable pains have been taken in several localities, where there was a marked deviation from the variation which belonged to the geographical position, to verify the observations, and in others by examining various adjacent spots to find some one which would give normal results. The usual errors of observation with the instrument employed, especially where the azimuths have been determined by those of the sides of the triangles, are much less than the local magnetic deviations. The full discussion of these results, as well as of the interesting elements of the dip and horizontal intensity, obtained, usually, at the same time as the variation, is in progress.

At some of the principal magnetic stations, where it has been requested, meridian marks have been placed for the use of surveyors.

The tide tables presented with the report of last year have been improved by the addition of new observations, and by the progress of the reduction of the old ones. I give them in their new form in Appendix No. 51. The mean establishments of some of our principal ports on the Atlantic, Gulf of Mexico, and Pacific, are stated, by which the navigator can determine the time of high water from the tables of the moon's transit, in the Nautical Almanac. The mean rise and fall of the tide, and the rise and fall for spring and neap tides, are also given; and the duration of ebb and flood tide, and of slack water. The establishment or interval between the time of moon's transit and the time of high water, varying during the lunar month, as well as the rise and fall, the values corresponding to different ages of the moon, are given for some of the principal ports in the list, in a second series of tables, by which the time of high and low water, and the height, can be more closely determined than by the first approximation. For convenience, the establishment at each age is placed in the table, instead of the change of the quantity, and a table of heights is furnished, in which the number to be applied to the soundings upon a chart is denoted, to give the depth at high water, where the soundings upon the chart are reduced to mean low water, and when reduced to low-water spring tides; corresponding numbers are given for low water. When the diurnal irregularity or difference of height and time between the a. m. and p. m. tides is large, as at Key West and San Francisco, and other ports on the Western coast, tables of correction for the previous establishment are given. The tidal data for the places on the Gulf of Mexico where single-day tides prevail, are given as far as the discussion has advanced. The tides at Aransas Pass and the Brazos St. Iago have been added to this class by the observations of the past year.

The manner in which the results of observations in the triangulation were to be reduced, was a subject which early occupied my attention; and to which some of the best efforts of Mr. Hilgard, chief of the computing division of the Coast Survey, were directed. It is well known that there are two principal methods of deducing the value of the angles observed in a triangulation: one by the adjustment of the remaining small and incidental discrepancies in the angular quantities directly measured; the other by the adjustment of similar discrepancies in the several directions diverging from a station—the former equating angular spaces, the latter directions; and both are treated by the method well known to mathematicians as that of "least squares."

The results or conditions are afterwards subject to a second set of conditions, namely: those resulting from the geometrical relations in the figure of the triangulation with the application of the same method of least squares. The primary triangulation in Section I has been treated by both these methods, and the parallel between them carried as far as the stations near Portland; including a sufficient number of cases to determine the method to be adopted in the entire work. The details of this investigation are of course quite technical, and will be given in full in the volume of records and results of the Coast Survey. An abstract of the labors of Mr. Hilgard and of Mr. Schott, in the computing division, is given in the Appendix No. 33, in sufficient detail to enable the result to be followed by those familiar with the methods, who will be gratified to see the scale preponderating in favor of the adoption of the method of equating directions, to which the nature of the observations conforms most closely.

Probably the most elaborate series of observations and experiments yet made on the measurement of heights by different methods, was that by Captain T. J. Cram, U. S. Topographical Engineers, and assistant in the Coast Survey, in 1852 and 1853; including not only the differences of level of the usual Coast Survey stations, but extending to the height of Mount Washington. The object was to compare, once for all, the different modes of measuring heights, especially those most conveniently applicable to our work. These were by the spirit-level, by zenith distances or reciprocal vertical angles, and by the barometer, to which the boiling apparatus was added as involving only a moderate addition of labor and giving useful results. The stations were selected so as to afford different varieties in the use of the methods, and especially in the one by reciprocal zenith distances, in which I availed myself, in giving instructions, of the experience of our measurements to indicate the different circumstances which vary the refraction. One important result expected, was the determination of the co-efficient of vertical refraction under the different circumstances occurring in our usual observations.

Since closing his operations in the autumn of 1853, Captain Cram has been engaged in reducing his observations, and has presented reports upon the method by levelling, by the barometer, and by the boiling-point, and is now engaged in the much more laborious reduction and comparison of his results by zenith distances.

The data for difference of longitude between the stations of the Coast Survey and their connection with European observatories, and especially with Greenwich, to which our navigating longitudes are referred, have been added from year to year. Astronomical observations have been multiplied, and the theories upon which their use depends have been discussed; the telegraphic method which was used first in the United States for obtaining the difference of longitude between stations has been steadily followed up, and chronometers have been transported between the observatories of Cambridge and Liverpool.

In the chronometer plan we began by using the chronometers of the Cunard steamers which were on this side of the Atlantic, under the charge of Wm. Cranch Bond, esq., the director of the Cambridge observatory; and having gone as far in the approximation as this mode permitted, we next organized special chronometer expeditions, in which the experience acquired in one was used in arranging the details of the others. These were under Mr. Bond's immediate direction, with the full co-operation of Mr. Hartnup, the director of the Liverpool observatory. The observations during the ten expeditions of 1849, 1850, and 1851, have been reduced by George P. Bond, esq.; the investigation of the probable errors of the different determinations forming the basis of his work, and rising from this through the different details to the general resulting longitude. There is found a difference in the results shown by the voyages from Cambridge to Liverpool, and by the return voyages, which in the necessary absence of sea-rates leaves an uncertainty, traceable with some probability, as Mr. Bond has shown, to the different temperatures to which the chronometers are exposed at sea and on shore, in connection with the known fact that even those compensated for such changes do, notwithstanding, alter their rates at temperatures either above or below the point at which this compensation is made perfect. This remains for investigation, but it is a great point gained to have arrived at the difference of longitude as nearly as given in these results, say within the nearest second of time. A brief abstract of his work is given by Mr. Bond, (Appendix No. 42,) and the entire work will be published in the volume of records and results of the Coast Survey. The intermediate place which this determination takes between the discrepant longitudes given by the two principal astronomical methods, adds to its importance.

The observations for telegraphic difference of longitude have been pushed forward with increasing difficulties in passing southward. The progress made and the difficulties met with are ably stated in Dr. Gould's report, in the Appendix No. 41. The discussion of these difficulties may call the attention of scientific men to their removal. Interesting incidental observations on the effect of distant electrical discharges in producing a current in the telegraphic wire are reported. A brief notice is also given of the observations which had reached us up to the beginning of November, for telegraphic differences of longitude abroad. Appended to Dr. Gould's report is a very lucid notice of the remarkable paper of Professor Peirce on a criterion for the rejection of doubtful observations, with a most valuable set of tables for the application of the method, placing it within the ready reach of the observer and computer.

The solar eclipse of May 26, 1854, was observed as bearing upon the longitude problem, at the Coast Survey stations at Washington, D. C., and near Petersburg, Virginia. We were also prepared to observe near the central line of the annular eclipse at Mount Washington, New Hampshire, and Agamenticus, Maine, but the weather was unfavorable; this reason also rendered the preparation at the Wilmington (North Carolina) station of no avail. On the Western coast several series of observations were made near San Francisco by our parties, and one at Humboldt. At Monterey the weather was cloudy. Notice of these observations will be found under the head of the several sections, and the reported results in Appendix No. 40. Moon culuminations were also observed at the usual stations for the survey, and will be found noticed under the head of astronomical work in the several sections.

Professor Peirce has continued his investigation in reference to longitudes, and has thoroughly discussed the subject of moon culminations, and with results for which mathematicians and astronomers were probably quite unprepared. I give his learned report of progress in full in Appendix No. 36, as well for the immediate results as for the light which it sheds upon the important subject of probable errors in methods and observations.

The observations and discussion necessary to develop the local or general phenomena of the tides of our coast have maintained steady progress. The additional observations made during the year are stated in the Appendix No. 31, and the results of the labor of Mr. Pourtales, chief of the tidal division, and of those associated with him, are, many of them, recorded in the tables of Appendix No. 51, and in my discussions, Nos. 45 and 46. Tables for predicting the time of high and low water at the principal ports, are in preparation from the lists of Appendix No. 51, and other tables of a less simple character, derived from the observations and from theories checked by them. The navigator can use those now given, with confidence in the general accuracy of his deductions from them. The sketch of co-tidal lines (Appendix No. 45, and Sketch No. 26) will enable him to know how the tide table is to be applied to places not named in the list, and with what changes of time.

Since my last report, the tidal observations on the Western coast, under the direction of Lieutenant W. P. Trowbridge, of the Corps of Engineers, have come in, and the results from the three permanent self-registering gauges at San Diego, San Francisco, and Astoria, have been compared. The same large difference of height between the morning and afternoon high waters or low waters of the same day, shows itself at each of these places; and the corresponding inequality in time is also very large. The laws and amount of the inequality known as "diurnal inequality," are traced in the paper Appendix No. 46. The curves representing the rise and fall at the three places just named, (Sketch J, No. 49,) show, by the long and short branches, the phenomena of height in a very striking point of view, and it is only necessary to suppose a rock just covered by the higher branch of high water, to see what would occur when the lower branch should succeed the first. A rock bare by several feet at the lowest low water, might be a snare to the unwary at the highest one.

I have already noticed, in some detail, the interesting papers of Charles A. Schott, esq., of the computing division of the Coast Survey Office, on the tidal currents of Nantucket shoals and Long Island sound. (Appendix, Nos. 48 and 50.)

That of Muskeget channel (Appendix No. 49) is of the same character, but with a less field for original or striking deduction. It does not yield much to the others in utility, showing, in a connected form, the direction and velocity of the current in that somewhat intricate channel, which the navigator may expect to meet at different times of the tide.

My paper on the distribution of temperature in the Gulf Stream (Appendix No. 47) contains the results of careful comparison of the observations following the path pointed out by my first deductions, with the intelligent assistance of Professor A. G. Pendleton. The divisions of the stream are laid down according to the latest discussions of the observations; and the curve of temperature with depth, the curve of equal temperature across the stream at different depths, the curve of temperature at the same depth, and the configuration of the bottom of the sea, on certain sections, are presented from the mature reduction of the observations.

Among the instruments of every-day use in our work, to which much ingenuity has been applied, is that for bringing up specimens of the bottom of the sea. The use of Stellwagen's lead is common in all our parties, and the apparatus meets with general approval. Lieut. Comg. Craven has invented a box for bringing up deep-sea specimens while running lines, which is convenient and efficacious. The description, in Appendix No. 54, is brief, and the principle is there clearly explained. To the same officer we owe an adaptation of Massey's lead to very deep soundings, which is in the highest degree important, and the use of which has served to bring out in bold relief the imperfection of the ordinary sounding-line when thus applied. Lieut Comg. Craven has also made an instrument for measuring the set and drift of submarine currents, which he is engaged in perfecting by experiment. In this connection I should mention, also, the ingenious syphon tide-gauge of Lieut. Comg. Stellwagen, a model of which he has successfully tried, and which he is now authorized to put up on the full scale for a regular working trial.

The simple and very efficient tide-gauge of Mr. Henry Mitchell for outside stations in a rough sea-way, has been tested by the experience of the summer and autumn, outside of the island of Nantucket.

Assistant J. E. Hilgard has perfected an instrument for signals by reflection of a beam from the sun, turned by the wind, simple and apparently effective; it will, in the course of the next season, be more fully tried than has yet been practicable. A description of it will be found under the head of the primary triangulation in Section VIII.

A small transit instrument which, with adequate magnifying power, should yet be portable, has been quite a desideratum. W. Wurdeman, formerly mechanician in the Coast Survey, has supplied us with such an instrument, which has been used in the geographical determinations on the Western coast, by Assistant G. Davidson, with entire success. The discussion of Mr. Davidson's observations has shown (Appendix No. 39) that the probable error in the correction of the clock time, determined by one star, is less than one-tenth of a second of time. In many cases discussed, the instrument was set up and used on the same night.

Among the subjects to which I gave considerable attention soon after taking charge of the Coast Survey, was the construction of apparatus for measuring bases, which should be invariable in length at different temperatures and during changes of temperature, in which the level of contact should be applied in measuring, and which should be portable and capable of being used with rapidity. In this I was assisted by Wm. Wurdeman, esq., the able mechanician of the Coast Survey, to whom many of the details of construction of the apparatus finally made are due. This has been used in the measurement of bases at Dauphine island, 1846, at Bodies island, 1848, and at Edisto island, 1850. Notice of it has been given in my reports; but the publications in regard to other instruments of the same sort seeming to indicate that this was not sufficiently known, a description has been prepared by Lieut. E. B. Hunt, Corps of Engineers, and read before the American Association for the Advancement of Science. This description has been placed in Appendix No. 35, and drawings illustrating it are shown in Sketch A, No. 54. The application of the principles of specific heat and conducting power to determine the relative masses of the measuring bars, so that they should heat and cool together, was, I believe, new in this application when made, and I know that it originated in researches undertaken by me, and in part executed in Philadelphia, many years since.

It is sufficiently understood that the field-work of every party in the Coast Survey requires a corresponding kind and amount of office-work, and a general brief statement of that executed by the several field parties is given in connection with these operations. The results pass, also, to the office of the Coast Survey for re-computation, discussion, and combination, in a systematic form. The development of the office has been gradual as the survey has advanced, and a constant effort has been made to adjust the field and office work to each other, and the duties of the several divisions of the office among themselves. The office, under Captain H. W. Benham, of the Corps of Engineers, has maintained its efficiency, as will be shown by examining the results produced in a subsequent part of this report, and by the reports of the several divisions contained in the Appendix No. 31. I have already referred to the labors of the computing and tidal divisions. The progress of the drawing division will be seen by refering to the Appendix No. 31, where a list of the maps, charts, and sketches, seventy-eight in number, executed during the year, will be found. It will be seen that the drawing keeps close to the field-work, producing the results first in sketches and preliminary charts, and then in the finished maps and charts. A description of the Congress map, which will be presented with this report, will be found in Appendix No. 32. A useful branch of labor consists in comparative maps, showing the changes of those portions of our coast which are liable to special alteration, from which the improvement of its harbors is best to be studied. The engraving report (Appendix No. 31) will be found to contain the following lists of all the maps, charts, and sketches heretofore published, or in progress of engraving, arranged under three heads: 1st. List of maps and charts engraved, thirty-eight in number; 2d. List of preliminary charts and sketches, one hundred and twenty-five in number, the two subdivisions forming together the matter which has been engraved up to the 1st of November, 1854, consisting of one hundred and sixty-three maps, charts, and sketches; 3d. List of maps and charts in progress of engraving, thirty-one in number. To show the progress during the year, we have, 4th, a list of the plates which were in progress at the date of the last report, numbering twenty-eight; 5th. A list of plates commenced during the year, thirty-six in number, making, with the former, sixty-four; and, 6th. A list of plates finished during the year, including the progress sketches, fifty-seven, and omitting them in the enumeration, forty-three in number. Without counting the progress sketches, there are nineteen plates in hand. One hundred and eighty maps and charts, preliminary or finished, and sketches, are now in progress, or have been published. A complete list of them is given in Appendix No. 31, showing that one hundred and forty-nine are engraved, and thirty-one are engraving.

The maps and sketches which have been drawn, and in part engraved, and which will be completed for publication with this report, are fifty-eight in number. The smaller sketches have, as far as practicable, been grouped together to economize in their printing; hence several subjects are included under one head, in giving the number of them. The maps and sketches of localities in the several sections are marked from A to K, inclusive; those in Section I being designated as A, those in Section II as B, and so on. The sketch showing the progress of the operations of the survey in the section, is designated as No. 1; and where there are several maps or sketches in a section, they are numbered consecutively, as A No. 1, A No. 2, and so on. The miscellaneous diagrams are lettered.

The following is a list of the sketches, diagrams, and drawings accompanying this report:

1 to 14. Progress sketches in the several sections, marked from A to K, inclusive.
15. Reconnaissance of Eggmoggin Reach.
16. Portland harbor, (preliminary chart.)
17. York river and Cape Neddick harbors.
18. Portsmouth harbor, (preliminary chart.)
19. Gloucester harbor, (preliminary chart.)
20. Stellwagen's Bank, off Boston harbor.
21. Plymouth harbor, (preliminary chart.)
22. Monomoy harbor.
23. Bass river and approaches, (preliminary chart.)
24. Chart of Nantucket shoals.
25. Currents of Nantucket shoals.
26. Muskeget channel.
27. Tidal currents, Long Island sound.
28. Ship and Sand Shoal inlets, (preliminary chart.)
29. Seacoast of Virginia, No. 2, (preliminary chart.)
30. Reconnaissance of Wimble shoals, North Carolina.
31. Beaufort harbor, North Carolina, (preliminary chart.)
32. Gulf Stream explorations.
33. Gulf Stream diagrams.
34. Co-tidal lines of the Atlantic coast.
35. Winyah bay and Cape Roman shoals, (preliminary chart.)
36. Comparative map of Maffitt's channel, Charleston harbor, 1852–4.
37. Turtle harbor, Florida reefs.
38. Reconnaissance of Coffin's Patches, Florida reefs.
39. Cedar Keys, (preliminary chart.)
40. Reconnaissance of Pass Fourchon, Louisiana.
41. Entrance of Rio Grande (preliminary chart.)
42. Alden's reconnaissance from San Francisco to Umquah river.
43. Anacapa island and Smith's island light-house sketches.
44. Harbors of Santa Cruz and Point Año Nuevo.
45. Pulgas Base.
46. Shelter Cove, Mendocino City, and Crescent City harbors, and Port Orford or Ewing harbor.
47. Entrance to Umquah river.
48. Entrance to Columbia river.
49. Tidal diagrams of San Diego, San Francisco, and Astoria.
50. Grenville harbor, Washington Territory.
51. Reconnaissance of Port Townsend, Admiralty inlet, Washington Territory.
52. Reconnaissance of Duwamish bay and Seattle harbor, Washington Territory.
53. Preliminary survey of Canal de Haro and Rosario strait, and approaches, Washington Territory.
54. Base apparatus.
55. Craven's current indicator.
56. Craven's specimen box for deep-sea soundings.
57. Mitchell's tide-gauge.
58. Figures to illustrate Appendix No. 33, on application of least squares to the results of a triangulation.

The organization and development of the engraving division of the Coast Survey Office has been studied carefully at different times, and the experience of many different minds has been brought to bear upon the general arrangements and upon the details.. It has grown up gradually; and though, from want of time to record the successive stages of growth, some of the experience has been lost, yet enough remains to make a general view of the division, of interest to those who regard the progress of map engraving in the country, and especially to those interested in the results of the Coast Survey. I have therefore requested Lieut. E. B. Hunt, of the Corps of Engineers, who was recently for a time in charge of the division, to give an account of it, which is inserted in the Appendix No. 57. It shows how the division is organized; briefly, how it has attained its present form; the administration of it; its reference to engraving as a branch of high art, and as a technical art; and the training school for engravers which the office furnishes.

The steady progress of the electrotyping division, and the many interesting experiments in which Mr. Mathiot is engaged to substitute heliography and electrometallurgy for engraving, will be found under the office head in the body of my report, and in Appendix No. 31.

Some years since, Mr. Mathiot made a valuable contribution to electrical applications by the invention of a self-sustaining voltaic battery, at once simple in construction and effective in sustaining a constant action for long periods of time without requiring the renewal of the materials employed. He has kindly furnished a detailed description of the principles and working of this battery for the Appendix to the present report, (Appendix No. 56,) thus placing it within reach of the electrician and telegrapher for scientific or practical uses.

Sixty-eight calls for information from the archives have been answered, as shown by the list in the Appendix No. 5. Of these, twenty-eight were from departments of the government; thirty-seven from individuals or associations; and three from local authorities. By the regulations of the Treasury Department a special application is necessary to procure this information, and the survey is not to be put to expense in communicating it. Upon these liberal terms, the archives are rendered useful to individuals and the public in a great variety of ways, and by very different channels. The assistance rendered to compilers of State, county, and local maps—to hydrographers, geographers, and statisticians, has been very considerable in amount, and is one of the advantages of the work to the public generally, not directly connected with commerce or navigation.

When information is obtained which is deemed of sufficient interest to navigators to require immediate publication, a report is made at once to the Secretary of the Treasury, and authority asked to give publicity to it. In this way, during the past year, the following announcements have been made:

1. Stellwagen's Bank, in the entrance of Massachusetts bay.
2. Davis's ledge, off the Minot's, Massachusetts bay.
3. Determination of rocks near the entrance of Boston harbor.
4. New Point Comfort shoal and York Spit, Chesapeake bay.
5. Reconnaissance of Wimble shoals, North Carolina.
6. The longitude of Cape Florida.
7. Turtle harbor, near Carysfort reef, Florida.
8. A safe rule for crossing the Florida reef at Indian key.
9. Three-fathom shoal in Garden Key channel, Tortugas, Florida.
10. Non-existence of a shoal south of the Belize, in latitude 27° N.

The announcements themselves are given in the Appendix Nos. 9 to 18, inclusive.

The Coast Survey is indebted to Commander Davis, U. S. N., now Superintendent of the Nautical Almanac, who so much distinguished himself as a chief of one of the hydrographic parties, for the determination of the dangerous rocks of Minot's ledge, to which his name has been given, and of several important rocks in the entrance of Boston harbor; and to Gen. Joseph G. Totten, Chief Engineer, for the communication of the position of the shoal in Garden Key channel, determined by Lieut. H. G. Wright, of the Corps of Engineers. To the kindness of George W. Blunt, esq., of New York, who has done so much to advance hydrography in this country, I am indebted for early information of value, derived from the observations of ship-masters.

Several different parts of the volumes of records and results of the Coast Survey, for which an appropriation was made at the last session of Congress, are in preparation, and will appear in succession. A general plan of arrangement will be adopted, which, while it admits the publication of finished work without delay, will finally form a series of volumes, classed, as far as practicable, according to the relation of the subjects.

The want of an index to the earlier volumes of the Annual Report of the Survey has been seriously felt, and I am indebted to Lieut. E. B. Hunt, of the Corps of Engineers, for supplying that want in the reports of the last ten years—from 1844 to 1853, inclusive—by a general index, which is appended to the present report. The labor involved in such an index is formidable, and is amply entitled to this public acknowledgment.

Surveys of sites for light-houses, or examinations in regard to the expediency of erecting new light-houses, and their location under the laws of 1851, 1852, and 1854, have been made at the requisition of the Light-house Board, under instructions from the Treasury Department, in the following named places:

Eggemoggin Reach, Maine.
Isle au Haut Thoroughfare, Maine.
Southern island, Maine.
Noddle's island, Maine.
Dry Point, Maine.
York harbor, Maine.
Westport, Massachusetts.
Pine island, Connecticut.
Niantic, Connecticut.
Black Point, Connecticut.
Southport Connecticut.
Race Point, New York.
Horton's Point, New York.
Coffin's Patches, Florida reef.

Instructions for other examinations have been issued, and will be executed during the surveying season in the sections to which the localities belong. Most of them, it is believed, can be completed in time to present during the session of Congress. The following examinations are now in progress:

Absecom bar, New Jersey.
Bowers' beach, Delaware.
Mouth of Old Duck creek, Delaware.
Entrance to Vermilion bay, Louisiana.
Mouth of Calcasieu river, Louisiana.
Gallinipper Point, Texas.
Harbor of Santa Barbara, California.
Anacapa, or Santa Cruz island, California.
Harbor of Santa Cruz, California.
Harbor of San Pedro, California.

Point Lobos, California.
Punta de los Reyes, California.
Umquah, Oregon.
Cape Shoalwater, Washington Territory.
New Dungeness, Washington Territory.
Blunt's, or Smith's island, Washington Territory.

The particulars in regard to these examinations will be given under the head of light-houses, in each of the sections following the hydrography. A table stating the examinations made, the object of examination, the officer by whom made, and the result, is given in Appendix No. 68.

The official correspondence on the subject will also generally be found in the appendix.

I proceed next to give a condensed view of the operations of the past surveying year—November, 1853, to November, 1854—and to follow this up by the proposed progress and estimates for the next fiscal year—July, 1855, to July, 1856.

SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.* (*Sketches A Nos.* 1 *and* 2.)—Ragged mountain, near Camden, Maine, has been occupied as a primary station, astronomical and magnetic observations being also made there. The lines of sight reach forward to Mount Desert and Humpback mountain, in Brewster. The reconnaissance has been continued to the eastern boundary. The triangulation of Casco bay has been extended to Cape Small Point, entrance of the Kennebec. The topography of Baker's island, part of Cape Small Point, of the approaches to Portland harbor, of Cape Neddick, and to include Ogunquit harbor, in Maine, of the vicinity of Newburyport, Massachusetts, from the connection with the former work south of it, of part of the vicinity of Boston, to determine certain changes for the State commissioners, and of the approaches to Plymouth harbor, has been executed. A hydrographic reconnaissance of the eastern part of Eggemoggin Reach, Maine, has been made; some additional hydrography in and near Portland harbor, for the city commission, has been executed; the hydrography of Massachusetts bay has been commenced, including the sounding out of a fourteen-fathom bank at the entrance; the in-shore work from Nahant to Marblehead has been completed; a dangerous ledge off Minot's, and several rocks at the entrance of Boston harbor, have been determined; the off-shore work from the northward of Cape Cod to Monomoy has been commenced; deep-sea soundings have been made from the Nantucket shoals outwards, from southeast round to George's Bank. The hydrography of the north side of the Vineyard and Nantucket sounds, and eastward from the former work, including the sounding out of Horseshoe, Succonesset, and L'Homme Dieu shoals, has been completed. A portion of a section from Nantucket southeastwardly across the Gulf Stream has been run. The tides of these sounds, and their approaches, have been investigated. The regular tidal station at Boston has been kept up. The current observations of the Nantucket shoals and in Muskeget channel have been worked up. Views have been taken for the sheets of Salem and Gloucester harbors. The discussion of the results of the chronometer expeditions between Cambridge and Liverpool has been completed. Examinations in regard to the necessity for light-houses, and the selection of sites, have been made, under the law, at Baker's island, Eggemoggin Reach, Isle au Haut Thoroughfare, Castine, Tenant's harbor, South island, Damariscotta River entrance, Wood island, near Cape Small Point, and Kennebunk pier, Maine, and at Westport, Massachusetts. The computations and reductions of the season's work have been kept up. The following maps, charts, and sketches, belonging to this section, have been drawn or are in progress: Portland harbor, York harbor and Cape Neddick, Annisquam and Ipswich harbors, Gloucester harbor, Plymouth harbor, Monomoy shoals, Nantucket shoals, Bass River harbor, Muskeget channel, Eastern series Nos. 2 and 3, and current chart of Nantucket shoals. The engraving of the following plates has been completed during the year: Alden's Rock, Minot's ledge, Wellfleet harbor, Nantucket shoals, and Sow and Pigs reef, off Cuttyhunk; and the following are in progress: Portsmouth harbor, Newburyport harbor, Salem harbor, Boston harbor, Monomoy harbor, Muskeget channel, and Eastern series, from Point Judith to Nantucket shoals, three plates.

SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and Delaware.* (*Sketch B.*)—Observations for latitude, azimuth, and magnetic elements, have been made at Mount Rose station, New Jersey, and at Yard station, Pennsylvania. The triangulation of the Hudson has been carried from the limits of last year to Blue Point Hill, Ulster county, New York, and the topography and hydrography to near Fort Montgomery, and including the wide part of the river known as the Haverstraw bay. The East and North rivers have been resurveyed to determine the changes there, and systematic observations of currents made. The city shore has been re-determined, to connect with the survey just mentioned. Tidal observations have been continued at Governor's island with the self-registering gauge. Special current observations have been made at sea off the south shore of Long Island. Examinations of light-house sites have been made at Pine island, Niantic, Black Point, and Southport, Connecticut, and Race Point and Horton's Point, New York; and others are in progress at Absecom bar, Bowers' beach, and mouth of Old Duck creek.

Drawings have been made of Long Island sound No. 1, redrawn in part; comparative chart of Romer shoals and Flynn's knoll, 1835 to 1854; shore-line of part of Manhattan island; chart of currents of Long Island sound. The engraving is in progress, or completed, of Long Island sound No. 1; south side of Long Island, Nos. 2 and 3; current chart of Long Island sound, and of Romer shoal and Flynn's knoll.

SECTION III. *Coast of Delaware, Maryland, and Virginia.* (*Sketch C.*)—Observations of the solar eclipse of May 26 were made at the Seaton station, Washington, and Roslyn station, Petersburg. Telegraphic differences of longitude have been determined between Petersburg, Virginia, and Wilmington, North Carolina. The stations of the main triangulation of the Chesapeake, completed last year, have been generally secured. The secondary triangulation of James river, from Richmond to Harrison's bar, has been completed, and its extension is in progress. The topography of the ocean shore, near Drummondtown, has been continued from Metomkin to Wachapreague inlet; that of the Chesapeake has furnished the shore-line of York, Pocosin, and Back River entrances; has been carried up James river from its mouth to Warwick river, on one side, and to Day's Point on the other; has included the mouth of Nansemond river, and extended up Elizabeth river beyond Portsmouth and Norfolk, and along the shore to Turner's creek. The topography of the immediate shores of the Rappahannock has been carried from Port Royal to Tappahannock. Verification work has been done on Back river, Maryland, and Meekin's neck. The hydrography of Chesapeake bay proper has been completed, including the sounding of Hampton roads, and of the Elizabeth river and harbor of Norfolk. The hydrography of the Rappahannock has been carried to Port Royal, and that of James River entrance has been commenced and extended to the limits already stated for the topography. A resurvey has been made of the Bodkin channel and approaches, at the entrance of the Patapsco river, to test changes there. The tidal station at Old Point Comfort has been continued, and temporary stations on the James river have been occupied. Drawings have been made, or are in progress, of Chesapeake bay, sheets Nos. 1, 2, and 3, first series, and Nos. 1 and 2 of second series; of a general chart of the bay; of preliminary charts of the James and Appomattox rivers, and of the Rappahannock river and seacoast of Virginia No. 2. Sketches have been engraved of the seacoast of Virginia No. 2, Wachapreague, Machipongo, and Metomkin inlets, Virginia; of Ship and Sand Shoal inlets; of Cape Charles and the vicinity, and Cherrystone inlet and Pungoteague creek, Virginia; and maps of the Chesapeake bay No. 1 and No. 2, and of Patapsco river, re-engraving, are in progress.

SECTION IV. *Coast of Virginia and North Carolina.* (*Sketch D.*)—The difference of longitude of Raleigh, North Carolina, and Columbia, South Carolina, has been determined, as part of the connection between Washington and New Orleans, and the latitude and magnetic elements measured at Raleigh. Wilmington, North Carolina, has been connected with Petersburg, Virginia, for difference of longitude from Washington, and its latitude and magnetic elements determined. The secondary triangulation has been carried north of Currituck sound to within fifteen miles of Cape Henry, and southward over Bogue sound towards New river. The topography of Cape Fear river has been finished; that of Currituck sound has made some progress, in connection with the triangulation; and that of Beaufort harbor has been completed. The hydrography of Beaufort harbor, and its dependencies and approaches, has been completed. A reconnaissance of the Wimble shoals has been executed. Tidal observations have been made at Cape Hatteras, at Cape Lookout, and Beaufort entrance, and at Bald Head, Cape Fear. A line of levels for connecting the tidal stations has been run from Wilmington to Smithville, North Carolina. Maps and charts have been finished, or are in progress, of Beaufort harbor, Cape Fear river, reconnaissance of Wimble shoals, of the Gulf Stream, with diagrams of temperatures on different sections; charts of Albemarle sound, one sheet of a preliminary chart of the same sound, Nos. 1 and 2 of Beaufort harbor, of Wimble shoals reconnaissance, of Cape Fear entrance and New inlet, (new edition) of the Gulf Stream explorations and the diagrams, and of co-tidal lines of the Atlantic coast, have been engraved during the year or are in progress.

SECTION V. *Coast of South Carolina and Georgia.* (*Sketches E Nos.* 1 *and* 2.)—A general reconnaissance has been made from the Santee river to the Ashley. The latitude of Allston station, near Georgetown, South Carolina, approximate longitude, and the magnetic elements, have been determined. The telegraphic difference of longitude between Columbia, South Carolina, and Raleigh, North Carolina, part of the line from Washington to New Orleans, and the latitude and magnetic elements at Columbia, have been determined. Astronomical observations at Charleston were continued during part of the year. The primary triangulation between the Edisto base and Charleston has made some progress, and the secondary triangulation connected with it has been executed up the Wando river to Daniell's island. The secondary triangulation, east of Charleston, has been extended; that of Savannah River entrance and Calibogue sound to May river, has been completed. The topography of Seabrook and Kiawah island, of the mouths of the Stono and Kiawah rivers, of Cole's island, and part of John's and Folly islands, has been completed. Maffitt's channel has been resurveyed, and the important changes developed. The hydrography of the entrance to Savannah river has been completed. The tidal station in Charleston harbor has been kept up, and temporary stations there and at St. Simon's established. A comparative map of Maffitt's channel in 1852 and 1854 has been made, and one of Winyah bay and Georgetown harbor, and of Savannah river, commenced. The preliminary map of Charleston harbor is nearly completed; North Edisto river, new edition, is engraved.

SECTION VI. *Coast, keys, and reefs of Florida.* (*Sketches F Nos.* 1 *and* 2.)—A reconnaissance has been carried from the St. John's river to Jupiter inlet, on the eastern coast of the peninsula of Florida. Astronomical observations have been made to connect Key West and Mobile for difference of longitude. The secondary triangulation has been extended from East Harbor key to near Loggerhead key, outside of the keys, and inside over Card's and Barnes' sound to Grassy Point, and has furnished points near Coffin's Patches. The topography has been carried from Old Rhodes key, westward, to Wednesday Point, and from Boca Chica, north and east, over several keys, marking them for the Land Office. The hydrography of the reef has been executed from Pacific reef to near Key Rodriguez, and a reconnaissance of Coffin's Patches has been made. Turtle harbor, near Carysfort reef, has been surveyed. A winter exploration of the Gulf Stream has been made across it, on the St. Simon's and Cape Canaveral sections. Tides have been observed at St. Augustine harbor and entrance, at Cape Florida, and at Egmont key, Tampa bay. Drawings are completed of the reconnaissance of the eastern coast of the Florida peninsula; of Turtle harbor, Florida reef; and of Coffin's Patches; and the first sheet of the chart of Florida reefs has been commenced. The maps of St. John's River entrance and of Key West harbor have been engraved; a sketch of the reconnaissance of the western coast of the peninsula of Florida, and tidal diagrams for Key West harbor, have been engraved during the year.

SECTION VII. *Part of the Coast of Florida.* (*Sketch G.*)—A preliminary base has been measured at St. Andrew's bay, and a triangulation laid out. Determinations of latitude and longitude have been made at Cape San Blas and at St. Andrew's bay, and azimuth observations at the latter place. A small triangulation and topographical survey of Ocilla River entrance has been made. The topography of Cedar keys and approaches has been completed, and the hydrography has made considerable progress. Tidal observations have been taken near St. Mark's. The reconnaissance of the middle or main and western entrances of St. George's sound has been engraved.

SECTION VIII. *Coast of Alabama, Mississippi, and Louisiana.* (*Sketch H.*)—A reconnaissance has been made for the main triangulation from Lake Borgne to the Delta of the Mississippi; and from New Orleans to Barataria bay. Also for the triangulation from Atchafalaya to Vermilion bay. A special reconnaissance of Pass Fourchon entrance to Bayou La Fourche has also been made. The primary triangulation of Mississippi sound has been resumed. The secondary triangulation from Lake Pontchartrain to New Orleans has been completed so far as to connect Mobile and New Orleans. The in-shore hydrography of the gulf has been completed from the meridian of Round island westward to Chandeleur sound; and of Mississippi sound to the former work at Cat and Ship islands. Search has been made for a shoal reported south of the Belize, and its site has been sounded over. Tidal observations have been taken at Calcasieu. Drawings have been executed of the progress sketch of a chart of deep-sea soundings off the Mississippi, and of Pass Fourchon. The charts and sketches engraved during the year have been, besides the progress sketches, Horn Island Pass, (new edition,) Pascagoula River entrance, and Ship Island shoal, or Isle Dernière. Mobile bay Nos. 1 and 2 are in progress.

SECTION IX. *Coast of Louisiana and Texas.* (*Sketch I.*)—A triangulation and topographical survey of the entrance to the Rio Bravo del Norte, and for four miles up the river, have been made, and the hydrography of the entrance and approaches executed for the Boundary Commission. The tidal observations at Galveston and at Bolivar Point have been completed. The hydrography of Galveston bay, near Red Fish bar, and of part of East and West bays, has been completed. Tidal observations have been taken at Aransas Pass, and at the Brazos St. Iago, belonging to the general series for the Gulf of Mexico. The progress sketch, and a topographical sheet of the mouth of the Rio Grande, have been drawn. The sketches of Sabine Pass, of Galveston Bay entrance, of San Luis Pass, of Aransas Pass, and of the Rio Grande entrance, have been engraved within the year, or are in progress.

SECTIONS X AND XI. *Coast of California, and of Oregon and Washington Territories.* (*Sketches J and K, Nos.* 1 *and* 2.)—Observations for latitude and azimuth, and magnetic elements, have been made at Humboldt bay. Magnetic observations ha e also been made at San Diego, San Pedro, San Luis Obispo, and at Monterey. The primary triangulation, and secondary connected with it, resting on the Pulgas preliminary base, have been carried north to Ballenas bay, and south to Monterey; and the tertiary triangulation along the immediate shore has been commenced. A tertiary triangulation has been carried over Ballenas bay, and to Duxbury reef. The triangulation for connecting the Santa Barbara islands and main, resting on the Los Angeles base, has been carried from Las Bolsas to Point Duma, and Santa Catalina island has been connected with the main. The triangulation of the Gulf of Georgia, and approaches, has made good progress. The topography of San Francisco bay has been continued and extended to Point San Mateo; and that of the coast north, to Duxbury reef, has been completed. The topography of Monterey bay has been completed from the Salinas river, on the south, to north of Año Nuevo, and a party is at work towards Point Lobos, San Francisco entrance. The hydrography of Tomales bay has been executed. That of Humboldt bay, from Eureka, to include the entrance, and north to Eel river, has been finished; that of Lummi and other islands, in the Gulf of Georgia, executed. The hydrography of San Francisco entrance, and approaches, has been nearly completed; that of the inner bay has made some progress. Umquah River entrance has been sounded out. A bank off the coast of Oregon has been explored. Seattle harbor, and Port Townsend, Puget's sound, Washington Territory, have been sounded out. The hydrography of the Straits of Rosario, and approaches, has been completed, and that of the Gulf of Georgia continued. Examinations for light-houses have been made at Año Nuevo, Anacapa island; and others, for Punta de los Reyes, Point Lobos, harbor of San Pedro, harbor of Santa Cruz, bay of Monterey, harbor of Santa Barbara, Umquah, Blunt's or Smith's island, New Dungeness, and Cape Shoalwater, are in progress. Permanent tide-gauges have been established at San Diego, San Francisco, and Astoria, and temporary ones at San Pedro, San Luis Obispo, Monterey, Humboldt bay, and Port Orford. Drawings have been completed of Alden's reconnaissance, Nos. 2 and 3, of Santa Cruz harbor, of Point Año Nuevo, of Pulgas base, of Shelter cove, Mendocino City, Port Orford or Ewing harbor, and Crescent City, of Umquah river, and of tidal diagrams. The following maps and charts are in progress: Alden's reconnaissance No. 2, Santa Cruz, Point Año Nuevo, Shelter cove, Mendocino City, Port Orford or Ewing harbor, and Crescent City harbor and anchorages, and of Umquah River entrance. The following have been engraved during the year: Alden's reconnaissance San Diego to San Francisco (new edition,) the Cortez Bank, San Diego Harbor entrance, tidal diagrams for Rincon Point, the site of the Pulgas base, the tidal diagrams for San Diego, San Francisco, and Astoria.

The observations of the field parties, as they have been turned into the office, have been computed, and, when approved, passed into the archives. The topographical maps and hydrographical charts, with the computed results, have furnished the data from which the new maps and sketches referred to have been drawn and engraved. Some plates have been prepared for the annual report, not coming under the head of any of the sections. The engraved maps have been electrotyped, and from these plates impressions taken for publication. The numerous sketches of progress, and others accompanying the report, are in part from this data.

While every effort has been made to return the greatest possible number of results for the means employed, and the parties in the field, afloat, and in the office, have each, in turn, felt the pressure of the extraordinary increase of cost of every article which it was necessary to be supplied with, it has become obvious, especially during the past year, that the number of parties necessary to secure the desired progress could not be sent into all the sections, and be kept there sufficiently long, unless the means were adapted to the enhancement of prices of labor and supplies. Thus, along the coast of the Gulf of Mexico, from three to four parties should be employed in Sections VII, VIII, and IX, but the means have only served to keep between two and three at work in Sections VIII and IX.

While this state of things might possibly not be lasting, I refrained from remark, determined to make the best of matters, and to bear the temporary pressure. But it does not seem temporary, and I have therefore felt bound to present the subject fairly to the department, to ask your examination of it, and your decision whether our average progress should be diminished, or whether you would recommend additional supplies.

In my own judgment, the rate of progress of the survey ought not to be checked, but it should be brought to a termination within a moderate period. The progress is steady, and it is obvious that the connection of the parts and the completion of the whole work within such limited or reasonable time requires merely that the present plans be steadily pursued. We cannot expect to be the only exception in the country to the effect of the rise of prices. The enhanced wages of labor, prices of supplies of every sort, and of equipments used in the survey, necessarily require an increase of appropriation. Two years ago I adopted, from necessity, the plan of limiting each surveying party to a particular amount of expenditure, and stopping their work when that amount was expended. This was necessary in order not to overrun our means, and yet it frequently happened that circumstances would make it very desirable to prolong the working time. It has been further necessary within the past year to keep the number of parties carefully down t prevent an excess of expenditure, since contingencies must be provided for to make the administration of the work a safe one.

This has been most remarkable in reference to the repairs of our steamers and other vessels, instances occurring of a great excess in cost of repairs over the estimates made by officers of good judgment, thus crippling other parties of the work by absorbing the means intended for their purposes.

Congress has so often approved of the present scale of progress, and I am so sure that it is more economical than a smaller rate, that I could not recommend that alternative to the department.

The department is aware that the rates of pay fixed by it for the employés of the survey have fallen behind those paid for similar services generally, and that when legislation has acted on these rates it has increased them, and thus changed the relative positions of emolument unfavorably, and that there has even been a disposition manifested in Congress to increase these rates in certain other cases. It is not from this source, however, of compensation to officers of the survey, that our means have felt the change in money relations, but from the rise of the prices of supplies of every sort, and of the wages of ordinary labor.

From the prices of the past year, I have estimated that an advance of about twenty per cent. is necessary in the present appropriation for the Atlantic coast, and somewhat more than that for the Florida reefs and keys. The appropriation for the Western coast need not be increased, and that for the publication of records and results may be less than the one for last year.

Having submitted this subject to your decision, and found that, in your judgment, it was proper to make the estimates what was required to meet the usual rate of progress, I have arranged the plan of work and the estimates to be submitted to Congress accordingly, with the hope that they may receive favorable consideration.

The desire rather to urge on the work to completion, than to keep it lingering over a long period of years, has heretofore been fully responded to; and having now nearly, or quite, reached half way in its progress, it requires only a reasonable time at its present rate to push the work entirely through.

The estimates suppose the same aid which is now furnished under the law from the Navy and War Departments, by the detail of officers for the hydrography and land work respectively.

The items will run thus:

For continuing the survey of the coast of the Atlantic and Gulf of Mexico, (including compensation of the Superintendent and assistants, and excluding pay and emoluments of officers of the army and navy, and petty officers and men of the navy employed in the work,) per act of March 3, 1843 - - - - - -	$250,000
For continuing the survey of the Florida reefs, keys, and coast, (excluding pay and emoluments of officers of the army and navy, and petty officers and men of the navy employed in the work,) per act of March 3, 1849 - - - - - - -	40,000
For continuing the survey of the Western coast of the United States, per act of September 30, 1850 - - - - -	130,000
For publishing the observations made in the progress of the survey of the coast of the United States, per act of March 3, 1843 - -	15,000
For transportation, fuel, and quarters, and for mileage of officers and enlisted men of the army serving on the Coast Survey, no longer provided for by the quartermaster department - - -	10,000

The appropriations for the present fiscal year are—

For the survey of the Atlantic and Gulf coast of the United States, including the compensation of the Superintendent and assistants -	206,000
For continuing the survey of the Florida reefs and keys - -	30,000
For continuing the survey of the Western coast of the United States -	130,000
For publishing the observations made in the progress of the survey of the coast - - - - - - -	20,000
For fuel, quarters, &c., for officers and men of the army serving on the Coast Survey - - - - - - -	10,000

ESTIMATE FOR THE FISCAL YEAR 1855-'56.

General expenses for all the sections, namely: rent; fuel; materials for drawing; engraving and printing, and ruling forms; binding; transportation of instruments; maps and charts, and for miscellaneous office expenses; and the purchase of new instruments, books, maps, and charts - - - - - - - - - -	$19,000

SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.* FIELD-WORK.—To continue the primary triangulation in *Maine*, east of the *Penobscot*, to *Mount Desert*, and the astronomical and magnetic observations connected with it; to complete the reconnaissance and the selection of a site for the base of verification; to complete the secondary triangulation of *Casco bay*, and to extend it eastward over the entrance of the *Kennebec;* to continue the topography of *Casco bay* east of *Portland*, and that of the coast of *Massachusetts* from *Newburyport* eastward; to continue the hydrography of *Casco bay*, and to commence that of *Penobscot bay;* to continue the hydrography of *Massachusetts bay* and approaches, and that of *Cape Cod bay*, with the off-shore hydrography of the peninsula, and the hydrography of *Chatham harbor*, and to complete that of *Nantucket sound and approaches;* to continue observations of tides and currents at stations in the section, and to take views requisite for charts. OFFICE-WORK.—To make reductions and computations for the section; to complete the drawing of the chart of *Portland harbor* and approaches, the harbor charts of *Plymouth* and *Gloucester*, and the charts of the *Vineyard* and *Nantucket sounds;* to continue the engraving of the chart of *Portland harbor*, and to complete that of *York harbor* and *Cape Neddick;* to engrave sketches of *Eggemoggin reach* and of *Cape Small Point, Maine*, and to continue the engraving of the coast chart, Eastern series Nos. 1, 2, and 3, coasts of *Massachusetts and Rhode Island*,—will require - - - - - - $41,000

SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and Delaware.*—To continue the triangulation, topography, and hydrography of the *Hudson;* to execute verification work in the section, and to continue observations of tides and currents; to commence the drawing and engraving of the *Hudson river* sheets, and to continue the engraving of the third sheet south side of *Long Island*, and preliminary sketches for the section,—will require - 8,000

SECTION III. *Coast of Delaware, Maryland, and Virginia.* FIELD-WORK.—To make the astronomical and magnetic observations requisite at stations in the section; to continue the triangulation of the *James* and *Rappahannock rivers;* to continue the topography of the lower part of *Chesapeake bay*, of the *James and Rappahannock rivers*, and of the outer coast of *Maryland and Virginia;* to continue the off-shore hydrography of the section, the hydrography of *Chesapeake bay* and approaches, and to continue that of *James and Rappahannock rivers.* OFFICE-WORK.—To make the reductions and computations requisite for the work of the section; to complete the drawing of sheet No. 2, seacoast of *Maryland and Virginia*, and that of the second series south of the *Potomac*, as far as the field-work permits, and to continue the drawing of the sheets of the *James and Rappannock rivers;* to complete the engraving of sheet No. 1, and continue Nos. 2 and 3, *Chesapeake bay;* and to complete the engraving of the general chart of the bay and outside as far as the hydrography is completed,—will require - - - - - - 25,000

SECTION IV. *Coast of Virginia and North Carolina.* FIELD-WORK.—To make astronomical and magnetic observations at *Cape Fear entrance;* to continue the primary triangulation of *Pamplico sound*, and complete the approximate connection with the *Chesapeake* triangulation, following this with the topography; to continue the triangulation of the coast from *New river* to *Cape Fear*, and to extend it from *Cape Fear* southward; to follow with the topography of *Currituck sound* north, of *Bogue sound* south, and south of *Cape Fear;* to continue the hydrography of *Wimble shoals* and that of the outer coast south of *Hatteras;* to continue tidal observations at *Cape Fear*, and observations of currents in the *Gulf Stream.* OFFICE-WORK.—To make the reductions and computations of the section; to complete drawings of *Beaufort harbor* and approaches, and of *Cape Fear entrance* and river to above *Wilmington;* to make drawings of the preliminary sketches requisite for the season's work; to continue the engraving of sheets Nos. 1 and 2 of *Albemarle sound;* to commence sheets Nos. 1 and 2 of *Cape Fear entrance and river;* and to engrave the preliminary sketches of the section,—will require - - - - - - - $30,000

SECTION V. *Coast of South Carolina and Georgia.* FIELD-WORK.—To continue the primary triangulation, and the secondary connected with it, eastward between *Charleston* and *Bull's bay*, and to make the necessary astronomical and magnetic observations; to extend the secondary triangulation south of *Tybee entrance*, including *Ossabaw* and *Warsaw sounds;* to complete that of *St. Mary's entrance* and *approaches*, and to commence that of *Doboy inlet;* to extend the topography east from *Charleston harbor* and south from *Tybee*, following the triangulation; to complete that of *Romney marshes*, and to commence that of *St. Mary's* and *Doboy inlet;* to continue the hydrography of the ocean coast between *Charleston and Savannah entrances*, and from *Georgetown entrance* south, to include *Roman shoals;* to complete the hydrography of *Tybee entrance*, and extend it southward, and to commence that of *St. Helena sound*, *Beaufort entrance and harbor*, (*S. C.*) and *Doboy inlet*, and to continue that of *St. Mary's entrance* and *approaches;* to continue tidal observations along the coast of the section, and the exploration of currents in the *Gulf Stream.* OFFICE-WORK.—To complete the drawing of the chart of *Savannah river* entrance, and to commence that of the general coast chart sheet south of *Charleston;* to continue the drawing of the survey of *Romney marshes* and *St. Mary's* harbor, and of the reconnaissance of *Doboy inlet*, and drawings for the preliminary sketches of the section; to commence the engraving of the large sheet of *Charleston harbor* and approaches; to complete the preliminary chart of *Winyah bay* and *Georgetown harbor*, and to continue that of *Tybee entrance* and *Savannah river*,—will require - - 33,000

SECTION VI. *Reefs, keys, and coast of Florida.*—(See estimate for appropriation for that special object.)

SECTION VII. *Coast of Florida.* FIELD-WORK.—To make the necessary astronomical and magnetic observations, and complete the triangulation of *St. Andrew's* and *St. Joseph's bays;* to continue the triangulation of *Pensacola harbor*, and perhaps commence that of *Tampa bay;* to continue the topography of *St. Andrew's* and *St. Joseph's bays*, and to commence that of *Pensacola* harbor; to complete the hydrography of *Crystal river offing*, continue that of *St. Andrew's* and *St. Joseph's bays*, and commence that of *Pensacola harbor*, and to continue tidal observations at stations in the section. OFFICE-WORK.—To draw and engrave the preliminary sketches; to complete the sheet of *Cedar keys*, and commence that of the adjacent coast; to make the drawing of the sheet of *Ocilla river*, and commence that of *St. Andrew's bay;* to continue the engraving of the chart of *Cedar Keys harbor* and *Crystal river offing*, and commence that of *St. Andrew's bay*, and to complete the sheet of *Ocilla river*,—will require - - - - 35,000

SECTION VIII. *Coast of Alabama, Mississippi, and Louisiana.* FIELD-WORK.—To continue the special reconnaissance of parts of this coast, and the primary triangulation, and secondary triangulation in connection with it, outside of the *Chandeleur islands*, across to the mouths of the *Mississippi;* and the secondary triangulation of *Calcasieu bay*, and to commence that of *Vermilion bay;* to continue the topography of the shores of *Lake Pontchartrain*, and of the neck between the *lake* and the *Mississippi;* to commence the topography of *Calcasieu bay;* to complete the hydrography of *Louisiana sound*, and to continue the off-shore work of the coast of *Alabama, Mississippi, and Louisiana*, to the mouth of the *Mississippi;* and to continue observations of tides and currents, and observations for temperature, along the *Gulf* coast of the section. OFFICE-WORK.—To make the reductions and computations required for the section; to complete the drawing of the hydrographic sheet No. 2 of *Mississippi sound*, and continue sheet No. 3; to continue one of the sheets of *New Orleans* and approaches, and to commence that of *Calcasieu bay;* to continue the engraving of the sheet No. 1 of *Mississippi sound*, and commence sheet No. 2; and to engrave preliminary sketches for the section, and sketches for the general and special reconnaissances,—will require - - - - - - - - - - - - -	$33,000
SECTION IX. *Coast of Louisiana and Texas.* FIELD-WORK.—To make particular reconnaissances for the main triangulation; to extend the main triangulation southward and westward, and to make the astronomical and magnetic observations connected with it; to complete the secondary triangulation, and topography, of *Matagorda* and *Lavacca bays;* to complete the hydrography, in-shore and off-shore, from *Galveston*, southward and westward, and to continue that of *Matagorda bay.* OFFICE-WORK.—To make the requisite computations and reductions; to complete the drawing of *East and West bays*, in connection with the chart of *Galveston bay;* to continue the drawing of the coast sheet, south of *Galveston;* to engrave the preliminary sketches required by the work of the section; and continue the sheet of the *Rio Grande* entrance, and that of *Galveston* and *East and West bays*,—will require - - - - - - - - -	26,000
SECTIONS X AND IX. *Western coast—California, Oregon, and Washington.* (See estimate for special appropriation, as provided for last year.)	
Total, exclusive of *Florida reefs and keys*, and of *Western coast* - -	250,000

The estimate for the *Florida coast, reefs, and keys*, and for the *Western coast*, is intended to accomplish the following results, namely:

SECTION VI. *Reefs, keys, and coast of Florida.* FIELD-WORK.—To complete the general reconnaissance of the coast, and continue the triangulation of *reefs*, &c., outside; and of the keys from Indian key towards *Key West*, and from *Key Largo* eastward; that between the outer keys and main, and of the inner keys; to continue the triangulation of *Barnes' sound*, and that of *Florida bay;* to continue the topography of the keys, from the shores of *Key Largo* eastward, and that of the *Pine islands*, and eastward. OFFICE-WORK.—To make the reductions and computations required; to complete the drawing of sheet No. 1, and commence that of sheet No. 2, of *Florida reefs and keys;* to engrave the requisite preliminary charts and sketches; and continue the engraving of the large scale chart of *Key West*, and that of sheet No. 1 *Florida reefs and keys*,—will require - - $40,000

SECTIONS X AND XI. *California, Oregon, and Washington.* FIELD-WORK. To continue the primary triangulation south of Monterey and north of *San Francisco bay*, and the secondary triangulation in connection with it; to continue the secondary triangulation of *San Francisco bay* and of its approaches; to continue the triangulation of harbors as the developments of the survey may require, and of islands in the *Gulf of Georgia*, of the *Straits of Rosario*, and parts of *Puget's sound* and its harbors; to follow the triangulation with the topography of *San Francisco bay;* thence northward to *Sir Francis Drake's bay*, and southward to *Monterey*, and to make the topography corresponding to the triangulation in *Washington Territory;* to continue the hydrography of *San Francisco bay* and its dependencies, that of the coast to *Monterey*, of the *Bay of Monterey*, and of the *Gulf of Georgia* (*Washington Territory*) and its approaches; to commence the hydrography of *Puget's sound;* to complete some of its most important harbors, and to complete systematic tidal observations along the Western coast. OFFICE-WORK —To make the requisite reductions and computations; to continue the drawing of revised reconnaissance, with additions of harbors and of the coast, the drawing of *San Francisco entrance*, and sheet No. 1 of *San Francisco bay*, and to commence that of the *Gulf of Georgia*, the harbor of *Seattle*, *Puget's sound*, the preliminary chart of *Umquah*, and others; to engrave the reconnaissance of harbors; to engrave the chart of *San Francisco entrance* and commence the preliminary charts of *Seattle harbor* (*Washington Territory*) and the *Gulf of Georgia*, and to engrave the preliminary sketches for the sections,—will require - - - - 130,000

To continue the publication of the records and results of the survey, will require - - - - - - - - - - - - - - - 15,000

For transportation, fuel, and quarters, and for mileage of officers and enlisted men of the army serving on the Coast Survey, no longer provided for by the Quartermaster's department - - - - 10,000

I proceed next to the detailed account of the operations of the year, distributed according to geographical sections, and followed by those in the office at Washington.

SECTION I.—FROM PASSAMAQUODDY BAY TO POINT JUDITH, INCLUDING THE COAST OF MAINE, NEW HAMPSHIRE, MASSACHUSETTS, AND RHODE ISLAND. (SKETCH A.)

The progress of this section has been satisfactory. To make up for the late period at which means were available for the work, as many parties as could be supplied with means were put at work in August. One primary station (Ragged mountain, near Camden) has been occupied, and astronomical and geodetic observations made there. The primary triangulation is still in advance of the secondary. The secondary triangulation of Casco bay has been very nearly completed to Cape Small Point, keeping in its turn in advance of the topography. The topography of Portland harbor, Maine, and its approaches, has been continued eastward. That of Cape Neddick and the vicinity has been completed. That of the vicinity of Newburyport, Massachusetts, to the junction with the former work there, has been finished. The topography of the vicinity of Plymouth, Massachusetts, has been continued. Hydrography, from the Nantucket shoals eastward, on the south side of Nantucket island, along the coast of Cape Cod, and in-shore and off-shore in Massachusetts bay, has been executed. The hydrography of the Vineyard and Nantucket sounds has been nearly completed, including the soundings out of three important shoals. Tidal observations at Boston have been continued, and the tides of Martha's Vineyard and Nantucket sounds, and of the ocean in the vicinity, have been investigated.

Views have been taken for the charts of Salem and Gloucester harbors.

The hydrographer in Massachusetts bay has been rewarded for his labors by the discovery in the entrance of an extensive bank, of which he has given the position and defined the limits, with from ten and a half to fourteen and a half fathoms on it, lying across the entrance, and serving thus as an excellent mark for navigators entering this important bay. I propose to call this, from the name of its discoverer, Stellwagen's Bank.

Maps of Portland, York and Cape Neddick, Annisquam and Ipswich, Gloucester, Plymouth, Monomoy, and Bass River harbors, and of Muskeget channel, and Eastern series Nos. 2 and 3, have been drawn or are in progress. Finished maps of Portsmouth, Newburyport, Salem, Boston, and Monomoy harbors, of Muskeget channel, and Eastern series Nos. 1, 2, and 3, are engraving; and sketches of Alden's rock and of Minot's ledge have been engraved during the year.

The observations of currents on the Nantucket shoals and in Muskeget channel have been collected, and systematic results deduced. The computations of the chronometer expeditions between Cambridge and Liverpool have been completed. Considerable progress has been made in comparing the results of different methods of measuring heights, the examinations of which have been reported for two years.

By invitation of the city authorities of Portland, I joined a commission, consisting of General Totten, Commander Davis, and myself, to investigate the changes in the harbor, and to fix definite shore-lines.

Numerous examinations of light-house sites have been made, under the law, in this section.

Reconnaissance.—Brevet Major Henry Prince, U. S. A., assistant Coast Survey, has continued the reconnaissance for the primary triangulation to the boundary, including the examination of two sites for a base of verification, and the collection of information in regard to other localities, which must be examined before the selection of a site is finally made. As he is at this time in the field, the report of his operations will not be made in time to be more specially noticed.

Primary triangulation and astronomical observations.—In the last week of June, the operations of my party at Wilmington, North Carolina, were closed, and preparations made to proceed to Section I, as soon as means could be procured. While the station at Ragged mountain, near Camden, Maine, (see Sketch A, No. 1,) was preparing by Assistant George W. Dean and Mr. Thomas McDonnell, I took charge, personally, of the arrangements for tidal observations at Nantucket, Martha's Vineyard, and the south shore of Massachusetts, commencing geodetic observations at Ragged mountain early in August. This is an astronomical as well as a geodetic station, and the latitude and azimuth have been observed, as well as horizontal and vertical angles. The usual magnetic observations have also been made.

Between the 1st of August and 21st of November, fifteen hundred and fifty-five observations were made on eleven stations, with the thirty-inch theodolite (C. S. No. 1) by myself, assisted by Mr. G. W. Dean, and during part of the time by Mr. Stephen Harris. The longest side of the triangles formed at this point, is the one to Mount Pleasant—eighty-four miles; the shortest to Isle au Haut—twenty-eight miles. The large number of points visible from this one, and all requiring heliotropes, made the progress here necessarily slow; and the summer's drought which extended over the country, and the numerous and extensive fires in the woods, destroyed the transparency of the air near the horizon, rendering the seeing of even the nearest signals impossible, for several weeks together. The area of the triangulation estimated in the usual way, covered this year, is 2,200 square miles. Vertical angles were measured on four stations, by forty-three sets of five repetitions, by Assistant George W. Dean, with an eight-inch Gambey theodolite, (C. S. No. 57;) and on six stations with the micrometer of the thirty-inch theodolite.

The azimuth of a mark about three miles distant, and which was connected carefully with the points of triangulation, was determined by eight sets of observations on Polaris, at eastern elongation, the average number of observations in each set being twelve; and by two sets on Lamda, Ursæ Minoris, at upper culmination, twelve in each set. The occasion was taken to examine again the details of the different parts of the observations, by obtaining their probable errors. The observations were made generally by myself, assisted by Mr. Stephen Harris, and occasionally by Mr. Dean.

The latitude was determined by Assistant George W. Dean, by two hundred and twenty-eight observations on forty-eight pairs of stars, with a zenith telescope by William Wurdemann, (C. S. No. 5,) and by Mr. Stephen Harris by one hundred and thirty-eight observations on the same pairs. The object was to throw new light upon the personal equation found last year in using the zenith telescope, and care was taken that the stars employed should be the same, and that they should be observed in precisely the same way. The number of observations on each pair was, when practicable, not less than five, which had been found to give a probable error of observation of but about 0.25″ in the determination of the latitude. Of the pairs, twenty-two were from the Greenwich Twelve Year, and twenty-six from the British Association Catalogue. A very careful series of determinations for the value of the micrometer screw and level were made.

The time was determined by one hundred and forty observations on high and low stars, by Mr. Dean and Mr. Harris, with transit No. 8, C. S., by Troughton and Simms.

Magnetic observations.—As it was expected, from the geological structure of Ragged mountain, that considerable local magnetic attraction might exist, Mr. Dean made observations at various points to test this.

The magnetic declination was determined by observations on four days. For horizontal intensity, and moment of inertia, two sets of experiments were made upon two days. The dip was observed at two points; one N. N. E. about one hundred yards, and the other W. N. W. two hundred yards from the geodetic station. Two sets were observed at each locality on two days, and the results show the small difference of three minutes of arc, the inclination at the northern point being the least.

The magnetic declinations at Light House island, and Northeast Point near the eastern entrance to Camden harbor, was determined at each station from twenty repetitions with a five-inch magnetic theodolite, (Jones, C. S. No. 1.) At these two points the declination differed 37′.

Observations for declination, intensity, and dip, were also made near the southern entrance to the harbor. These consisted of two hundred and seventy-three observations, at intervals of fifteen minutes each, between 7 a. m. and 4½ p. m. on seven days. For horizontal intensity and moment of inertia, three sets were observed on three days, and two sets for dip of needle on two days.

Mr. Dean was assisted in the magnetic observations by Messrs. S. Harris and R. J. Breckenridge, jr.

Meteorological observations.—A meteorological journal was kept by Mr. James Searles, in which two hundred and eighty-six readings of mountain barometer No. 619 (Green, New York,) and two hundred and eighty-six readings of aneroid No. 8580 (Dent,) in connection with one hundred and sixty observations of the wet, and two hundred and eighty-six of the dry bulb thermometers, were recorded.

All the geodetic, astronomical, and magnetic original records have been made in duplicate, and the reduction of latitude and azimuth observations completed in the field. The latitude and magnetic records of observations made by Assistant G. W. Dean at Columbia, South Carolina, and Wilmington, North Carolina, between February and July, have been duplicated, and good progress made in the reductions of the observations.

Secondary triangulation.—The secondary triangulation of Casco bay, (see Sketch A, No. 2,) was continued from the approaches to Portland, eastward to Cape Small Point, by Assistant C. O. Boutelle, aided by Lieutenant A. W. Evans, U. S. A. All the stations, except Cape Small Point, intended to be occupied, were finished between the 1st of August and 3d of November, when it was necessary to make arrangements for resuming work in Section V. The weather was very unfavorable for work, the sea being so rough as frequently to render landing on the islands impossible, and the atmosphere being hazy and filled with smoke. The secondary triangulation will, notwithstanding, keep much in advance of the topography. The statistics of the work executed are thus referred to by Mr. Boutelle:

"Up to the present time (November 3,) there have been twenty-four stations occupied, at which seven hundred and fifty-three (753) angles upon six hundred and sixty-eight (668) objects have been measured by 6,424 observations. Vertical angles have been observed at ten stations, where eighty-four (84) angles upon eighty-four (84) objects by six hundred and one (601) observations have been made.

"Points are determined in Yarmouth, Freeport, and Brunswick, for the survey of those towns and their neighboring harbors.

"The positions of twenty points have been determined, computed, and furnished to Assistant Gilbert, for the topographical survey of Cape Small Point.

"Seventy-six signals of 1st, 2d, and 3d orders have been put up and observed upon, and many houses and other prominent objects, natural and artificial, have been determined for the use of the topographical and hydrographic parties."

Mr. F. P. Webber rendered acceptable service as aid to this party, and in computing part of the work of the previous season in Section IV; and Mr. C. A. Paudpaschaud as computer, temporarily employed on the astronomical work of the same section. The party had the use of the Coast Survey schooner Guthrie in their operations.

Topography.—The topography at Portland harbor, (see Sketch A, No. 2,) and the approaches to the northward and eastward, has been continued by Assistant A. W. Longfellow, who reports the following work done between July 1 and November 1: Number of miles of shore-line surveyed, sixty-one; of roads, thirty-one; and area, sixteen square miles. "The topography has the intricacy and great amount of artificial detail which characterizes the neighborhood of all considerable towns in New England." Tracings of this work have been furnished to the office and sounding party.

The topography of the vicinity of York harbor and Cape Neddick was continued eastward by Sub-Assistant A. S. Wadsworth, during the period of the summer when his services could be applied to this, after closing work in Section IV, and has been carried as far as to include Ogunquit harbor, in the town of Wells. The sheet contains an area of five square miles and twelve miles of shore-line. The ground is extremely rough and broken, and a large portion of it is covered with thick woods. Mr. Wadsworth is now under instructions to return to Section IV.

Assistant H. L. Whiting commenced, in August, the topography of the vicinity of Newburyport from the points at which he had left it last year, and continued in this vicinity until his services were requested by the commissioners of the State of Massachusetts to determine the changes, natural and artificial, since his previous survey of the vicinity of Boston harbor, when he was relieved by Sub-Assistant I. H. Adams.

Mr. Whiting's office-work consisted in the preparation for office use of the following topographical sheets, viz:

Cuttyhunk - - - - - - - - - - - - -	scale $\frac{1}{5000}$
Gay Head and No Man's Land - - - - - - - - - -	scale $\frac{1}{10000}$
Essex, Cape Ann, (part of sheet) - - - - - - - - -	scale $\frac{1}{10000}$
Ipswich, Cape Ann - - - - - - - - - - - - -	scale $\frac{1}{10000}$

The details on these maps are minute.

He is now under instructions to proceed to Section III.

Sub-Assistant I. Hull Adams continued the work above referred to, near Newburyport, to the close of the season. The topography there executed includes an area of about eight square miles and a shore-line of about eleven. The country is in part undulating and cultivated in farms, and in part salt marsh intersected by creeks and with oak hammocks. This work connects with that of a former season by Assistant A. W. Longfellow.

Mr. Adams is preparing for duty in Section VI, Florida reefs and keys.

Sub-Assistant R. M. Bache, on returning from Section V, was instructed to continue the topographical work near Plymouth harbor, commenced last season by Assistant S. A. Gilbert. The party began the survey on the 28th of August, and discontinued operations on the 15th of October. The work of the season includes Kingston and a portion of Duxbury, comprising an area of about six square miles. Fifteen miles of shore-line and twenty-four miles of roads were surveyed. The survey between these points is now complete, with the exception of the low-water line, which in some places lies far beyond the line of high water.

Hydrography.—The *in-shore* work of the party of Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, in the steamer Bibb, has consisted of soundings on the south side of Nantucket (see Sketch A, No. 2) to connect the hydrography of the Nantucket shoals with that of Muskeget channel and Martha's Vineyard; and in Massachusetts bay, from Nahant to Marblehead, supplementary to the in-shore soundings there in former years. The *off-shore* work has been carried from the Nantucket shoals southward and eastward, eastward and northward, and eastward, extending in that direction to George's Bank, along the shore of Cape Cod, and in Massachusetts bay.

The lines of deep-sea soundings off Nantucket shoals were first run, as shown on the sketch. The Nantucket Shoal light-boat was of the greatest service in the operation. Next, the stations were put upon the south side of Nantucket island, and the in-shore work completed. During this time frequent gales and dense fogs interrupted the soundings. Next, the line along Cape Cod was run, and then the in and off shore work in Massachusetts bay. The off-shore lines were the following: From Cape Cod to Minot's Ledge light-boat; from near Nahant, east twenty-one miles, sounding to the depth of sixty-one fathoms, and returning on a line nearly parallel with the former to Boston light; from Cape Ann (Eastern Point light) to Cape Cod (Race Point light;) from Cape Cod to Mamomet Point, thence to Gurnett lights, Plymouth; from Scituate, twenty-seven miles off shore, returning on nearly a parallel to Point Alderton.

During the progress of this work, Lieut. Comg. Stellwagen discovered the extensive bank before referred to, and subsequently ran six lines across its breadth and two in the direction of its length, so as to define its limits and the character of the bottom with considerable accuracy.

This bank lies chiefly outside of a line drawn from Race Point light, Cape Cod, to Thatcher's Island light, Cape Ann. Its greatest length is seventeen and a half nautical miles, in the direction nearly N. by W. and S. by E. by compass. Its greatest breadth is five miles, its least two and a half, and the mean breadth about three miles. Six lines of soundings have been run across it in different parts, and two in the direction of its length. The latitude of the north end of the bank, in twenty fathoms water, is nearly that of Nahant and of the south end, five minutes south of Scituate light. The least water on the bank is ten fathoms and a half at six and a half nautical miles N. $30\frac{1}{2}°$ W. (true) from Race Point light. Near this spot, and separated by deeper water from it, are two spots of thirteen fathoms, N. 17° W. (true) from Race Point, distant nine miles, and N. 12° W., distant eleven miles, from Race Point light; next fourteen fathoms N. $17\frac{1}{2}°$ W., (true,) distant thirteen miles and a half, and 9° W., distant fourteen miles and a half, from Race Point light; finally, fourteen fathoms and a half N. 23° W., distant twenty miles from Race Point. Considered as a twenty-fathom bank, it is continuous, one end being five miles from Race Point light, and the other fifteen miles from Cape Ann (Thatcher's Island) light. In general, it shoals less rapidly outside than in, being quite steep on the inside, except at the southwest extremity. At the south end, towards Race Point, it falls off very rapidly. The northern end of the bank has rocky bottom, with, however, a slight covering of fine black sand. The middle and southern parts are coarse white and yellow sand, with some pebbles. The bottom inside of the bank, in deep water—and this is quite an important observation—is generally a green unctuous mud, or ooze.

In reporting his examination of this bank, Lieut. Comg. Stellwagen observes:

"I have to announce to you the completion of the examination of a bank lying just outside of Massachusetts bay, and in the direct line of the approaches to Boston from east and southeast directions.

"I consider the promulgation of this discovery a very essential thing to navigators, and that the knowledge of it will highly benefit commanders of vessels and the great commercial interest of the city of Boston, as an invaluable aid to vessels bound in during thick weather by day or night. By it they can not only ascertain their distance to the eastward of the coast, but, by attention to the lead after passing inside, a good idea of the *latitude* may also be obtained. Thus three or four miles to westward of the northern half of the shoal the water deepens generally to fifty fathoms, while at the same distance inside of the southern half the greatest depth of soundings diminishes gradually from forty-five fathoms in latitude 42° 15′ N. to thirty-five fathoms, all the way across to the main land.

"The soundings on the northern end of the bank indicate rocky bottom, though the 'Stellwagen cup' brought up small pieces of stone and fine black sand (disintegrated rock) in small quantities. The middle and southern parts seemed to be coarse white and yellow sand, and occasionally pebbles, of which the sounding apparatus brought up full specimens. The bottom in the deep water inside is generally a green unctuous mud, or ooze. The bank forms gradually from the east, but rises very abruptly and steep on its western edge."

The results thus obtained were immediately plotted and sent to me for examination, together with the information which could be collected in Boston on the subject of the existence of such a bank.

Two views may be taken of this shoal formation, in one of which it may be con-

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sidered as a series of shoals separated by deeper water than that on the crest of the shoal, or as a continuous bank with several crests. In the first view, the ten-and-a-half fathom spot nearest to Race Point, the two thirteen-fathom spots, the two fourteen-fathom spots, and the fourteen-and-a-half-fathom spot nearest to Cape Ann, are shoals with deeper water, viz: fifteen to eighteen fathoms between them. In the second, this is a continuous bank with twenty fathoms, with four principal summits as far as the present season's examination has shown.

On the carefully-studied chart of Massachusetts bay, by Messrs. E. & G. W. Blunt, with soundings expressly made for it, this bank is not indicated; and this is the most recent and best authority.

The chart of Messrs. Imray & Son, of London, published in 1849, shows, upon the line from Race Point light to Cape Ann, no sounding less than twenty-nine fathoms until near Cape Ann. There is twelve fathoms marked due north from Race Point three and a half nautical miles, where Lieut. Comg. Stellwagen has deep water. Due north from Race Point thirteen nautical miles, there is marked a small shoal spot, extending seven miles east and west and two miles north and south, with eleven, thirteen, and fifteen fathoms marked on it and named "Barron Bank." In a subsequent edition of the same chart (1853) this name does not appear, but the soundings, eleven, twelve, and fifteen fathoms, are placed between a line north from Race Point and a line from the same point to Cape Ann, and eleven miles from Race Point. The hydrographer obviously had authority for eleven fathoms in this vicinity, but not such as would authorize him to fix it permanently on the chart or to call it Barron Bank; otherwise he would have retained the mark and name. Imray's chart of 1853 shows several other important alterations from that of 1849, giving the former the indeterminate nature of the hydrography of this great bay. On the line from Race Point light, Cape Cod, to Thatcher's Island light, Cape Ann, a sounding of fifteen fathoms is marked two miles from Race Point, twelve fathoms at seven miles, and fourteen fathoms at twenty-three miles and a half.

Lambert's chart, published in Salem, 1822, from which the new edition published in 1853 was taken, has a shoal rudely marked out, on a line from Race Point, Cape Cod, to Thatcher's Island light, Cape Ann, with fourteen fathoms as the least water on it, twenty-one nautical miles from Race Point. The shoal is made to extend within the forty-fathom mark, seven miles and a half northwest and southeast, by five miles and a half. On each side of the fourteen fathoms are twenty fathoms, distant four miles. This is marked "Middle Bank." There is no other sounding of less than thirty-five fathoms on this line. A twelve-fathom spot is marked on a survey of part of Massachusetts bay, made by J. F. W. De Barres in 1781, eight miles from Race Point, in the direction of Cape Ann; and this is probably the authority for the sounding marked on Imray's chart of 1853. The erroneous character of these determinations generally will appear from Sketch A No. 7, of Stellwagen's Bank. The fourteen-fathom sounding is a near approach to fourteen and a half at the north end of the bank.

Beforehand, we should doubtless have rejected these results, as Mr. Blunt has done, as vague and untrustworthy. Now that we have Lieut. Comg. Stellwagen's survey, we may say that the fourteen fathoms on Lambert's chart is actually near the spot assigned, though the rest of the determinations on the important line which has served as our line of reference are generally erroneous, and this appears to have been the authority for Imray's fourteen fathoms, nearly in the same place. That there was any connexion between the twelve-fathom sounding, the expunged "Barron Bank," and Lambert's "Middle Bank," does not appear to have occurred to any hydrographer.

That the sounding-line was not dropped on Stellwagen's Bank before he discovered it in 1854, cannot, I think, be affirmed. If we knew who had made the observations, I should incline to preserve their names in connection with the southwest and northwest spots respectively, though this might require consideration. But "Barron Bank," as such, has no existence, and was rightly expunged, and "Middle Bank," as such, has none; and all were, for vagueness, properly excluded from the chart.

A great bank, stretching across the entrance to Massachusetts bay, five miles from Race Point, to fifteen miles from Cape Ann, was unknown to the charts. But if we admit, which we cannot, that the ten-and-a-half-fathom spot and the fourteen and a half are two shoals previously known, then Lieut. Stellwagen has discovered two new ones between them; or if we substitute his accurate determinations for vague surmise, and assume that the ten and a half and fourteen and a half fathom spots were known, which we ought not to do, then Stellwagen's Bank stretches from nine miles to fourteen and a half miles from Race Point, and we sunder the continuity which he has found to exist.

The information of some of the most experienced pilots of Boston has been called out, and diligent inquiry has been made among underwriters. There was certainly an idea of a middle ground, but quite vague, and uncertainty as to depth and position. As a great mark in a fog, no such middle ground was known.

The position, general dimensions, and depths, are now laid down, the character of the bottom is shown, and the degree of shoaling of the bank determined. It was an original discovery, well worked out under many disadvantages. Vague rumor of its existence should not, and will not, deprive its zealous, persevering explorer of the title to place his name upon this capital sea-mark.

The statistics of the season's work are given in the annexed table.

	Miles.	Soundings.	Angles.	Fathoms.
INSHORE.				
1. South side of Nantucket	354	4,034	326	1—22
2. Nahant to Marblehead	91	1,006	115	
DEEP-SEA SOUNDINGS, (generally.)				
1. Approaches to Nantucket	688½	322	....	1—206
2. Chatham to Cape Cod	50	292	32	
3. Race Point to Minot's Ledge	29	83	14	
4. Nahant eastward	47	129	33	20—60
5. Cape Ann to Cape Cod; 6. Cape Cod to Manomet Point; 7. Manomet Point to Plymouth; 8. Scituate broad off shore, and back to Point Alderton	377	979	204	

While at work on the south side of Nantucket, the party had the opportunity of rendering important service to a vessel wrecked on Cape Poge, assisting in getting her off and towing her into port. The acknowledgment of Captain Hipson and of the agents of the underwriters were made in a letter given in the Appendix No. 58.

This party has executed the drawing and reduction of surveys made in the preceding season.

The Coast Survey is indebted to Commander Charles H. Davis, U. S. N., who, as chief of a hydrographic party, executed the survey of Boston harbor, for a continued interest in the perfection of the work there. It is not expected that, however much pains may be bestowed on the hydrography, where the bottom is rocky and rough, all the projecting points of rock can be determined by the survey. The sounding-lead must miss some of them, and even dragging with the deep-sea line fails to detect them all. The determinations made by Commander Davis during the past season are three in number, and will be found stated in Appendix No. 10, and marked on the chart of Boston harbor, now in the course of engraving. The determination of Davis' ledge, near the Minot's, has already been referred to; (see also Appendix No. 11.)

After completing the hydrography near New York, assigned to his party, Lieut. Comg. Woodhull commenced that in Martha's Vineyard and Nantucket sounds, in the schooners Gallatin and Madison. This hydrography (shown in Sketch A *bis*) touches that of Commander Blake on the west, and of Commander Davis and Lieut. Comg. McBlair on the south, Lieut. Comg. Woodhull's work of last season on the east, and surrounds that of Commander Davis and Lieut. Comg. McBlair near Hyannis and Bass river. It includes those very important shoals known as the "Horse Shoe," "Succunesset," and "L'Homme Dieu" shoals, and includes an area of two hundred and twenty square miles. In sounding, 1,320 miles were run, 15,300 casts of the lead made, and 1,360 angles measured. This excellent season's work was performed notwithstanding the alternate gales and fogs which prevailed and interfered materially with the progress. The distance of much of the sounding from the land should also be considered in estimating the progress of this party.

Lieut. Rutledge, in the schooner Madison, aided me in the early part of the season in the tidal observations at Great Point, Nantucket.

The investigation of currents off Long Island is referred to in Section II; it was made as Lieut. Comg. Woodhull proceeded to execute the light-house duty required in that section, at the close of October.

About the time of their beginning work in August, I visited this party, and was satisfied that the arrangements were calculated to insure a successful season.

There remains now but about one-fifth of the space included in these sounds to complete the hydrography.

The importance of the thoroughfare, in the hydrography of which Lieut. Comg. Woodhull has been engaged, will be understood by the statistics furnished by William Mitchell, esq., of Nantucket—collected by Captain Coleman, of the light-boat on the Horse Shoe shoal, Nantucket sound—of the number of vessels passing through the sound during the year ending November 15. These vessels were 23,487 in number, and consisted of five hundred and fifty (550) ships, three thousand and seventy-seven (3,077) brigs, sixteen thousand five hundred and forty-three (16,543) schooners, six hundred and sixty-three (663) sloops, and two thousand six hundred and fifty-four (2,654) steamers.

Returning from the light-house examination in the eastern part of the coast of Maine, Lieut. Comg. Craven executed the following hydrography, desired by the commission on Portland harbor, for the city authorities, viz: the sounding of Portland river, Back cove, and Presumpscot river, the observations of currents at nine, and of tides at four stations, and the collection of specimens of the bottom in particular localities in the harbor and vicinity.

Tides.—The complicated system of tides in Nantucket and Martha's Vineyard sounds, and in the sea outside of the islands giving names to the sounds, will be seen by a glance at the side sketch accompanying the chart of co-tidal lines, (Sketch No. 26.) This region forms the dividing space between the tidal establishments of eight hours and of twelve hours, or more properly of the co-tidal hours of XII and XV, and both these hours occur within the Vineyard sound. The observations already made pointed to the interference of the several tide-waves having access to this space, as the source of the seeming irregularities, and it was necessary to trace these by careful and multiplied observations, directed, first, by the knowledge we have already acquired, and followed up as the phenomena were developed by the observations themselves. In no other way could we expect to give to the numerous navigators of these sounds, through which so much of the coasting trade of the United States passes, any intelligent or consistent account of the tides and currents, which have been so long considered as curious and perplexing.

After arranging a general system of observations, and maturing some of the details, I intrusted the execution to Sub-Assistant Henry Mitchell and to Assistant George H. Fairfield, both of whom were attached to the tidal party, and knew, from the discussion of observations and practice in regulating the tidal stations, the necessary precautions to be taken, and how a definite result was to be attained. It had been my intention to place the whole work in the hands of Mr. Henry Mitchell, but the season was so far advanced that it was absolutely necessary to divide the labor. The very difficult part of the investigation outside of Nantucket, and the general discussion of the results, have been under his charge.

The first difficulty to be overcome in executing the observations, was to obtain a gauge which could be observed by night and by day, and which would stand when exposed to the open sea, as on the outside of Nantucket. We had found that the pipe-gauge placed there soon silted up, and was not to be relied on, though at first it seemed to work well.

Our next recourse was to a hollow tube, a gas-pipe, into which a post-auger was welded, which could be readily made to penetrate the sand vertically, and which would carry a float-rod with marks, visible from the shore through a telescope, and illuminated at night by a lamp drawn to it upon a wire. The details of this were carefully studied by Mr. Mitchell, and the difficulties which rose one after another were overcome. He thus sums up his experience: "A common copper box-gauge, fixed by a joint, upon which it can move in a vertical plane, to the ring of an anchor, and braced to three other anchors by rods and chains, is the whole. The auger is of no use, and may do harm. The joint need allow the box to turn but one way, as the ring lies horizontally on the bottom when the flukes are well buried, so that the stock rests in the sand. A surf-boat and three men are employed three or four hours in putting down these gauges."

The plan of observations was to establish gauges of reference at Wood's Hole, (Nobska,) Holmes' Hole, (West Chop,) and Brandt Point, (Nantucket,) to be kept up during the whole series, for the purpose of connecting them; to make separate examinations in groups of the north side of Nantucket; the east and south side of Nantucket and Martha's Vineyard; Muskeget channel; the north shore of Nantucket and Martha's Vineyard; the north shore of Nantucket and the Vineyard sounds from Monomoy to Wood's Hole. The local observations for comparison were continued for different periods from three days to a lunation, as the case appeared to require.

One of the most interesting results first developed was, that the whole difference in time of four hours occurred between the West Chop of Holmes' Hole and Menemsha Bight, (see Sketch A *bis*,) a distance of but twelve miles; then, that on the west side of the point or West Chop, the time of high water was the same nearly as inside, and that nearly the whole difference occurred between Cedar Tree Neck (see Sketch A *bis*,) and the West Chop, only six miles apart; and finally, that a difference in time of high water of three and a half hours actually occurred along the strait-shore of Martha's Vineyard island in a distance of four miles. In the same way, on the north shore, Point Gammon (see Sketch A *bis*) and Davis' Neck gave but a small part of the difference of 3*h.* 53*m.* between Nobska and Point Gammon, nearly the whole of the difference occurring in a distance of but two miles and a half.

Lines of levels are yet to be run by Mr. Mitchell connecting the bench-marks of the gauges.

Mr. Mitchell acknowledges, in terms of great praise, the services of Mr. G. Würdemann, of Mr. F. F. Nes, and Captain G. W. Coffin, of Nantucket.

These observations, when fully discussed, will, no doubt, show some defects to be remedied; but we shall learn from them the means of tracing these complicated tides in both their times and heights, and of showing exactly the tidal condition of these sounds at every part of the ebb and flood.

The observations made between 1846 and 1853, on the tidal currents of Nantucket shoals, have been discussed with great ability by Charles A. Schott, esq., of the computing division; and, as his method is quite original, I give his report or memoir in full in the Appendix No. 48. In it he discusses succinctly the following points: The nature of the currents, their direction at flood and ebb, the direction or set at the several stations of observation, the velocity or drift at each station, the "current establishment," or relation of the time of greatest flood and ebb current to the time of the moon's transit, and the curve described by a particle of water during the entire flood and ebb.

In regard to the first question, Mr. Schott shows that the currents are tidal, simply, and not mixed with any general current. "The general features of the current across the shoals are as follows: The ebb commences a short time before the high-water stand on the shore of Nantucket takes place, and runs a little to the eastward of south, with no indications of slack water; it then attains gradually its greatest velocity in a direction to the westward and southward; after this the current slackens—the minimum velocity being about one-fourth the maximum—and runs a little to the westward of north, and then in an opposite direction to that of the ebb, thus completing an entire circuit. The current may be observed to set in all directions of the compass during twelve lunar hours without ever being at rest, and turning in a direction in which we count our azimuths, or like the hands of a watch."

This is the main current outside, not the short current. In reference to the second head, the general direction of the current is that of the shore; except, near the old South shoal, where there is a tendency of the current in the direction of the longest line of the shoals. For nearly three hours, about the time of greatest velocity of ebb or flood, the current deviates but little in direction; this point is, therefore, well established.

The average direction at greatest velocity of flood and ebb are so nearly opposite, that they may be taken as exactly so, and give for the direction or set of flood of the northern group of stations, (see Sketch A, No. 12,) N. 32° E., (or north-east by north,) and in the southern group E. 13° N., (east by north.) The curves drawn indicate the directions over the whole space; those for the flood and ebb currents are distinguished as stated on the chart. The remark which was made in reference to the change of direction near the period of greatest velocity, applies also to the velocity, so that this also was determined to a near approximation. The velocities, as a rule, increase as the general depth increases—that is, as the place is more distant from the island of Nantucket. Dividing the stations into two groups—one just off the island, and the other at a distance, separated by a line shown on the chart—the greatest drift of the near stations is 1.7 knots for both flood and ebb current, and for the more distant 2.8 knots for flood, and 2.2 knots for ebb. The greatest velocity observed was four knots on the southern part of

Fishing Rip, on the 2d of August, 1852. From the approximate tidal data, Mr. Schott next investigates the interval between the times of greatest flood and ebb current, and the moon's transit next preceding; obtaining an interval which, from the analogy with the "establishment" for tides, he calls the "current establishment." These, of course, are at the present only approximate. They cannot fail, however, to be useful, practical data, and the lines of equal-current interval, or "co-current lines," drawn upon the charts for flood and ebb, show the progressive changes of the currents from place to place. To obtain these establishments, the observations at the different stations are grouped as explained in the report, and as marked on the chart. The mean interval between the time of moon's transit and high water (or mean tidal establishment) at Siasconsett, is about 11 hours 53 minutes. The "current establishment" of group VII is 10 hours 22 minutes, or the current at the locality of group VII changes 1 hour 31 minutes, on the average, before the water begins to fall, or rise, at Siasconsett. Tracing the motion of a particle of water, which is equivalent to tracing the motion of a floating object influenced only by the current, leads to the conclusion that an oval is described, of which the greatest axis is from four to six times the less, and to the important practical conclusions that "*a vessel cannot be set on any of the shoals by the current alone, if its distance from it exceeds the length of the major axis of motion*," or about nine nautical miles for the outer groups, and six miles for the inner.

Chronometer expeditions.—During the year, George P. Bond, esq., has completed the computations of the observations made during the years 1849–'50 and 1851, for the difference of longitude between Cambridge and Liverpool, to furnish a difference of longitude from a well-ascertained European observatory and the points upon our coast. The expedition had been under the immediate direction of William Cranch Bond, esq., astronomer of Harvard University; and a very elaborate plan of computation had been agreed upon on consultation between Mr. George P. Bond and myself, of which he had undertaken the execution. A preliminary report was presented in the appendix of my report of last year; and this year (Appendix No. 42) I give the final result, and Mr. Bond's general report of the mode of arriving at it. The details of the expeditions, of the observations made during them, and of the modes of reduction, will be presented in one of the volumes of Coast Survey Records and Results, for the publication of which an appropriation was made at the last session of Congress. The resulting longitude, from these expeditions, for Harvard Observatory, Cambridge, is W. of Greenwich *4h. 44m. 30.66s.* ± *0.20s.*

The difference of the results given by the expeditions of 1849–'50 and 1851 was 0.29*s.* The longitude derived from the eastern voyages is greater than that from the western by 3.02*s.* The cause of this Mr. Bond traces to the difference in the temperature at sea and on shore, the complete examination of which, with the elimination, if possible, of personal equations, must be left to further observations.

These are more than ever important from the conclusions to which we seem forced in regard to the present state of astronomical methods for longitude by the investigation of Professor Peirce.

Report on measurements of heights.—The report of Captain T. J. Cram, U. S. Topographical Engineers, Assistant in the Coast Survey, on the elaborate series of observations made by him for measuring heights, has been in considerable part completed.

The parts (numbered I, III, and IV) relating to the methods of levelling and their results, on the determinations by the barometer, and by the boiling-point apparatus, have been communicated to me. These observations and reductions will be hereafter presented in detail in the Records and Results of the Coast Survey.

They form a most valuable body of experiments and observations for reference by engineers and surveyors, and are directly available in the practice of our work. Their discussion alone is a work of very considerable labor. An abstract of the first part of his report, prepared by Captain Cram, is given in the Appendix No. 34.

In part I, Captain Cram examines the theoretical considerations entering into levelling, and criticises some of the rules given for returning apparent level to true. He discusses the effect of unequal refraction on the apparent level, and shows how to get rid of it altogether, or to reduce it to a very small quantity, by equi-distant fore and back sites—a method the advantages of which in the reductions of apparent to true level he points out. The precepts of this paper will be found valuable to observers. The determinations of heights were made by the level on forty-six lines, to serve as standards of comparison for other methods. They were selected to suit the conditions of investigation required by the other instruments, and comprised differences of height, up to 5,500 feet.

Part II of the report is known to me only from the abstract given in Appendix No. 34; the work being not yet quite completed. It will contain obviously a very useful and interesting discussion of the formulæ for determining heights by reciprocal vertical angles, and a searching investigation in reference to the co-efficient of refraction, and its variations, deduced from very numerous and varied observations.

Part III of Captain Cram's report begins with a description of the barometers which he used, (by Green, of New York,) their comparison with the Observatory standard at Cambridge, Massachusetts, (Newman's,) and the corrections to be applied to the observations with them. The importance of a careful study of the errors to which such measurements are liable is pointed out, especially at a time when so much reliance is placed on the barometer by parties making explorations requiring a considerable degree of exactness. The liability to change in the correction of a field barometer is pointed out, and the change measured of the one in use in the party. A division of the cases which occur in well-arranged determinations of heights by the barometer is laid down, and the best mode of reducing them shown. In reducing his results, Captain Cram uses the formulæ given by Captain Lee, U. S. Topographical Engineers, in his collection of Tables and Formulæ, (Barley's,) which is one of those containing no correction for moisture of the air. In the abstract, Appendix No. 34, will be found the comparative table of heights, determined in this way by the barometer and by the spirit-level; showing remarkable discrepancies, not only by amount, but in sign.

Next the cases are treated in which one barometer only is used in determining the heights, and the various systematic methods are discussed, in which it is attempted to give the observations the effect of simultaneous ones. These are also compared with the heights by levelling in numerous instances. (See table, Appendix No. 34.)

Another mode is discussed of using a simple barometer, in which, making a single observation at a station, the observer passed to the next, thus making a single observation, and returning, and so back to the first station, and an extended comparison is made; and lastly the case is treated where the observer proceeds from station to station along the line, making one or several observations, but not retracing the line. (Appendix No. 34.)

Among these comparisons is a series in which bench-marks at every five hundred feet of difference of elevation from the base of Mt. Washington to the summit were used, and another in which the differences were one hundred feet. The height assigned to this summit above the level of mean tide at Portland, by Captain Cram, from levelling, is 6,280 feet.

After a trial of the aneroid barometer, Captain Cram concludes that its workmanship, as now constructed, improves its usefulness to a great extent, and, from its convenience and other good qualities, recommends that an effort be made to give it all the perfection which nice instruments have attained, for a fair trial of its uses.

Part IV of Captain Cram's report contains a full discussion of the use of the boiling-point apparatus, in the form given to it by Mr. Würdemann, using thermometers of the ordinary form, and also those specially made for it. His conclusions are very unfavorable to this method, the heights being as before compared with those determined by the levelling instrument. (See table in Appendix No. 34.) In regard to this instrument, Captain Cram remarks: "From some cause an opinion has obtained in the minds of persons that this is a more convenient instrument, on account of transportation, than the barometer. There can hardly be an idea more erroneous than this. Having used one extensively, in the most compact form that has been given to it, I find the following objections:

"1. The apparatus, including all the necessary appendages, weighs quite as much as the mountain barometer, if not more.

"2. There are necessarily three different packages to carry—the boiling apparatus proper, a bottle of water, the box containing the thermometers; and to these may be added a bottle of alcohol extra, and a blanket or screen to guard the instrument against the effects of wind while the water is being brought to the boiling-point. To an observer accustomed to climbing a steep and rugged mountain, every additional package is a source of much annoyance.

"3. The time it takes for the water to boil is much greater than generally supposed by those who only try the experiment under the shelter of the roof and walls of a building. It varies, in the field, from half an hour to an hour and a quarter, depending upon the temperature and the wind. On a hill, where the wind is strong, I have been, with the best of matches, from a quarter to half an hour lighting the lamp, even with a blanket to screen it from the wind. This is vexatious.

"4. After the boiling-point is attained, the apparatus is too hot, for at least twenty minutes, for handling, and time is lost waiting for it to cool, before it can be repacked for moving it to another station. In this cooling process, great precaution must be observed to allow it to go on gradually, and not remove the heated thermometer from the boiler until the mercury in the stem has all descended into the lower bulb. The want of the strictest attention to this circumstance is productive of serious vexation; for, without this precaution, ten to one the mercury will be found separated in the stem, and a small part will there stick and be troublesome.

"5. The instrument is far more frail than the barometer, requiring greater care in handling it to prevent breaking. And in the process of boiling there is much danger of the bulb bursting. This was a cause of serious loss in my experiments.

"6. There is an inconvenience of no small magnitude in reference to the water to be boiled. If we boil one kind at the bottom and another at the top of the mountain, we incur the risk of an error. In my practice I carried along an extra bottle of water, so as to be sure of using the same kind at both stations, S and S'. I found a perceptible difference by actual experiment in the boiling-point of different waters under the same atmospheric influence. I suppose from this has arisen the idea of using distilled water.

"Supposing, therefore, the instrument to give as good results—which it does not—as the barometer, the foregoing objections are sufficient to place it far below the latter in point of practical convenience."

The defects inherent in the different parts of the instrument, as now made, are superadded to these considerations of comparative convenience, in causing its rejection from use.

The curves traced to show the heights given by these different methods in comparison with each other are very instructive.

Light-house examinations.—Examinations were made by Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, of the sites proposed for light-houses at Eggemoggin Reach, between Penobscot and Jericho bays; of Isle au Haut thoroughfare, at Castine, on the Penobscot; Tenant's harbor, and the entrance of Damariscotta river, both between the Penobscot and Kennebeck; of Noddle's island, near Small Point harbor, Casco bay; and of Kennebunk, near Portland. A hydrographic reconnaissance of Eggemoggin Reach, which is the channel through which the greater part of the coasting trade east of the Penobscot passes, was made by Lieut. Comg. Craven—it is given in Sketch A, No. 2. His report on these examinations will be given in the Appendix No. 69. Besides these examinations, Assistant W. E. Greenwell made, for the Light-house Board, a survey of Baker's island, near Mount Desert; and Assistant S. A. Gilbert a survey of Wood island and the adjacent shore, including Small Point harbor. This topographical survey was based on the triangulation of Assistant C. O. Boutelle.

The examination of a light-house site at Westport, Massachusetts, has been made by Lieut. Comg. H. S. Stellwagen and reported upon. (See Appendix No. 71.)

SECTION II.—FROM POINT JUDITH TO CAPE HENLOPEN, INCLUDING THE COAST OF CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE. (SKETCH B.)

The triangulation of the Hudson has been continued to stations above Poughkeepsie, and points for the revised topography near the city have been furnished. The topography of the river has been carried up to Fort Montgomery, above Peekskill. The hydrography has kept pace with it; and a resurvey of the Hudson and East rivers at and near the city of New York has been made, to determine the changes in the harbor caused by those of the shore-line. Observations for latitude and azimuth, and magnetic variation, dip, and intensity, have been made at Yard's station, Pennsylvania. Tidal observations have been continued at Governor's island, near New York. Current observations off the south side of Long Island have been made, and examinations for light-house sites in Connecticut, New York, New Jersey, and Delaware.

Astronomical and magnetic observations.—Assistant J. E. Hilgard has occupied Yard's station, Chester county, Pennsylvania, and reports the following observations:

"For latitude, thirty-one pairs of stars were observed, with from four to five nights' observations on each. The instrument used was a new zenith telescope by Würdemann, (C. S. No. 6,) of smaller dimensions than those heretofore employed, the performance of which was found quite satisfactory. Determinations of value of micrometer and level were made as usual.

"Observations of azimuth were made on Polaris with the two-feet theodolite, (C. S. No. 2,) two sets of observations being made in each of five positions of the instrument.

"The requisite observations for time, in connection with the above, were made with the zenith telescope, which is constructed to serve for that purpose.

"The magnetic observations, made at the same time, consist of three days' observations of declination and two determinations of absolute horizontal intensity, with declinometer No. 2, and two complete observations of dip, with a six-inch dip-circle belonging to the Smithsonian Institution."

Observations were made as usual for moon culminations by Prof. E. O. Kendall, at the High School observatory, during the early part of the year. These were discontinued on the removal of the instruments, but will be resumed after they shall be finally adjusted at the new observatory. Prof. Kendall's report on the number of observations will be found in Appendix No. 38

The solar eclipse of May 26th was observed by Assistant Edmund Blunt, at Brooklyn, L. I. (See Appendix No. 40.)

Triangulation.—The triangulation of the Hudson river has been continued, by Assistant Edmund Blunt, from the limits of last season's work, line Crow's Nest—Tompkins, to stations above Poughkeepsie. (See Sketch B.)

The larger triangulation occupies the hills, and numerous points on the river banks are determined for the topography and hydrography by the smaller triangulation, which has its checks in the larger. From *Tompkins* station, on the south, to *Versalins*, along the sides of the triangles, the distance is rather more than twenty-two miles.

Besides this work, Mr. Blunt has determined sixty-nine points, in the vicinity of New York, for the re-determination of the shore-line, and the examination of changes in the hydrography there.

The statistics of the season's work are as follows:

Number of stations occupied near New York - - - - - -	10
Number of observations made near New York - - - - - -	854
Number of stations occupied on and near Hudson river - - - - -	44
Number of observations made on and near Hudson river - - - -	2,787

Topography.—The topography of Hudson river was resumed at the southern limit of his last season's work by Assistant F. H. Gerdes, after his return from the Gulf of Mexico.

From Sing Sing, which is included in the first sheet of the survey, it has been carried up to Anthony's Nose, several miles above Peekskill, and comprises both sides of the river. (See Sketch B.)

In order to avoid delay in the hydrography, the topography of the district back of Haverstraw has been deferred, as also the filling up between the railroad and inner shore from Cruger's to Peekskill.

The sheets of this season will comprise forty-one miles of shore-line, and an area of about forty-five square miles.

Assistant Gerdes was occupied on this work between August 1 and September 20; and throughout furnished shore-line to the hydrographic party, which kept pace with his. He is at present engaged in the topography of the upper part of Manhattan island, and in determinations of the shore-line of the city for the new hydrography. His party is under instructions to resume work in Sections VII and VIII.

Hydrography.—As soon in the spring as the necessary arrangements for the purpose could be made, Lieut. Comg. Woodhull's party began a re-survey of the East and North rivers, near New York city, with a view to determine the changes which have occurred there since the previous survey. The work on the East river extended from Governor's island to Blackwell's island, and on the Hudson up to Fiftieth street, covering an area of about ten square miles closely sounded out. Eight thousand five hundred casts of the lead were made, four hundred and fifty miles of soundings run, and six hundred and twenty-five angles measured. Wherever the slips were sufficiently unobstructed to render it practicable, the soundings were run within the space they enclose. Tides were observed, in connection with the soundings, at three positions; and six sets of current-observations were made on the Hudson, and seven in the East river. The hydrography will be plotted as soon as Mr. Gerdes can furnish the shore-line, in the survey of which he is now engaged. When the work above referred to was completed, the party was transferred to Section I.

The hydrography of the Hudson has been continued, as far as the means were available, during the present season, by Lieut. Comg. Richard Wainwright, U. S. N., assistant in the Coast Survey, in the schooner Nautilus. Leaving the Rappahannock river in July, the party commenced work near Croton Point, and have accomplished about thirteen and a half miles in length of the river, to a line above Fort Montgomery, about five miles beyond Peekskill. The great width of the river at Haverstraw bay made the progress there comparatively slow, and the rapid current in the narrows above Peekskill, known as "the Race," made the sounding there difficult. Lieut. Comg. Wainwright reports a depth of twenty-eight fathoms in this part of the river. The following are the statistics of the hydrography:

Area covered	19 square miles.
Soundings run	180 miles.
Angles taken	1,677
Soundings taken	14,550

On completing this work in October, the party returned to the Rappahannock river, to continue there until the close of the season.

Tides.—The tidal observations at Governor's island, with the self-registering gauge, have been continued. The arrangements made by Professor W. Gibbs, at the beginning of winter, to prevent the gauge from becoming obstructed by ice, were effective last winter. The series is reduced as the observations come in, and bids fair to give satisfactory results.

Light-house surveys, &c.—Lieut. Comg. Stellwagen has made examinations for light house sites, &c., at Pine island in Fisher's Island sound, at Niantic; Black Point; the end of the breakwater at Southport, Connecticut; and at Race Point and Horton's Point, in Long Island sound.

Lieut. Comg. Woodhull has just completed the examinations required at Absecum bar, N. J.; at Bowers' beach, between Murderkill and Jones' creeks, Delaware; and at the mouth of Old Duck creek, in Delaware bay. (See Appendix No. 68.)

SECTION III.—FROM CAPE HENLOPEN TO CAPE HENRY, INCLUDING THE COAST OF DELAWARE, MARYLAND, AND PART OF VIRGINIA. (SKETCH C.)

The survey has made very good progress in this section. The primary triangulation was reported as completed last year, and also the secondary of the outer coast of Maryland and Virginia. This year the secondary work on the James and Rappahannock rivers has been pushed forward from Richmond to Harrison's bar on the former, and from below Port Royal to Tappahannock on the latter. The topography of the outer coast of Virginia has been continued, the sheet between Metomkin and Wachapreague inlets being finished. The shores of the Rappahannock within the limits of the triangulation have been finished. Those of the Chesapeake from York river to Back river, and of the James river from Newport News to Warwick river, and from Day's Point to Craney island, have been surveyed. The shore-line of the entire Chesapeake bay proper has thus been completed. Work of verification on Patapsco Neck and Back river has been executed. The hydrography has included the western part of the bay from the parallel of the head of Mobjack bay to near Cape Henry, finishing the bay itself and roads, and including the entrance of James river and the Elizabeth river, and harbors of Norfolk and Portsmouth.

The hydrography of James River entrance, from the line Newport News—Craney island, to Warwick river—Day's Point, has been executed.

The hydrography of the Rappahannock from below Fredericksburg to Port Royal has been done, and will, before the close of the season, be carried to the limits of triangulation of last summer. A re-survey of part of the Patapsco entrance has been made by request of the Engineer department, without, however, any considerable changes being developed. The regular tidal observations have been kept up at Old Point Comfort, and special ones have been made at the Patapsco and James River entrances. The necessary computations have kept up with the field-work. In the drawing division of the office the chart of Chesapeake bay No. 1 is completed, No. 2 nearly so, and Nos. 3, 4, 5, and 6, are in progress. A general chart of the bay on a smaller scale is also in progress. The map of the Appomattox has been completed; those of the James river from Richmond to Harrison's bar, and of the Rappahannock from Fredericksburg to Port Royal, are in progress. The sketch of the seacoast of Virginia No. 2 is completed. The following plates have been engraved during the year: Seacoast of Virginia No. 2, (upper part,) Sand Shoal inlet, Cape Charles, and the vicinity. Seacoast of Virginia No. 2 (lower part) has been commenced, and Chesapeake bay Nos. 1 and 2 are in progress.

Astronomical observations.—Observations for difference of longitude between Roslyn station, at Petersburg, and De Rosset station, at Wilmington, were commenced under the direction of Dr. B. A. Gould, jr., by himself and Assistant George W. Dean, in April last. It was soon necessary to relieve Dr. Gould, who had been requested to observe the solar eclipse of May at Agamenticus, in Maine, and Mr. Pourtales took his place. The observations which then passed under my immediate direction are described under the head of Section IV. The station arrangements were made, and the instruments at Roslyn adjusted, by Assistant George W. Dean.

It is proper here to acknowledge the essential services received from Messrs. Dowell and Marks, of the telegraph office at Petersburg, to whose knowledge and willing aid we were indebted for so many facilities in executing the work.

Observations of the solar eclipse of May 26th were made by Assistant C. O. Boutelle at the Seaton station, Washington, assisted by Capt. J. L. Reno and Thomas McDonnell, esq., and by Assistant L. F. Pourtales, at Roslyn station, near Petersburg. Their results are given in detail in Appendix No. 40. Mr. Boutelle observed with the telescope of the large vertical circle of Troughton and Simms, of the Coast Survey, the time being obtained by the astronomical clock intended for the Chilian observatory, kindly loaned by Lieut. J. M. Gillis, U. S. N., and noted by chronometers, for the use of which we are indebted to Lieut. M. F. Maury, director of the National Observatory. Mr. Pourtales observed with telescope No. 10, C. S., time being noted on a chronometer compared with the Hardy clock in use at the station.

I was indebted to the Secretary of the Smithsonian Institution, to the superintendent of the Nautical Almanac, and to Professor Alexander, for copies of the map, computations, and notes on the phenomena to be observed, which were distributed to the assistants of the survey. The prompt publication and distribution of Professor Alexander's memoir, read before the American Association, by the editor of the Astronomical Journal, requires acknowledgment.

A description of the meridian line marked by Assistant George W. Dean at Petersburg will be found in the Appendix No. 44.

Primary triangulation, station points.—The primary triangulation of Chesapeake bay having been completed by Assistant Edmund Blunt, the former assistant of his party, Lieut. A. H. Seward, U. S. A., assistant in the Coast Survey, after his return from Section VI, made an inspection of the triangulation points, with a view to secure them. This important service has been properly performed, and nearly all the points may be considered as permanently marked, requiring examination, however, from time to time, for their preservation.

Secondary triangulation.—The secondary triangulation between Richmond and City Point, at the junction of the James and Appomatox rivers, Virginia, (see Sketch C,) was continued between the 6th of October and the 6th of January following, by Assistant John Farley, aided by Sub-Assistant J. R. Offley.

Mr. Offley having been in the interval assigned to duty in Section VII, the triangulation was resumed by Assistant Farley in May, and completed by the 25th of July.

The character of the banks of the James river was found to be unfavorable to the rapid execution of this work. During the indisposition of the assistant, who was, however, able to direct the operations of the party, Mr. Offley measured fourteen angles in a chain of six triangles, by eight hundred and sixty measurements, with the ten-inch Gambey theodolite (C. S. No. 15) and Brunner theodolite, (C. S. No. 59.) The whole number of stations occupied during the year was twenty-two, the number of angles measured seventy-two, and observations made two thousand five hundred and four.

Mr. Farley accompanied the chief engineer of the Richmond and York River railroad on a reconnaissance of York river, prior to commencing his work in the spring.

A line of levels to connect the bench-marks of the tide-gauges at Racketts, below Richmond, Carl's Neck, and City Point, was run by Mr. Offley. The party has suffered much from sickness during the season.

The office-work, including the records and computations, has been executed by Mr. Farley, who is now engaged in continuing the triangulation of the James river, below City Point.

Early in the season the triangulation on the Rappahannock, from a point just above Port Royal, was continued down the river to stations Baylor—Brick Quarter, below Tobago bay, by Captain W. R. Palmer, Topographical Engineers, assisted by Lieut. D. T. Van Buren, U. S. A., assistant in the Coast Survey. (See Sketch C.)

Between October 24 and December 10, ten stations were occupied, and sixty-five angles were measured upon sixteen objects by six hundred and seventeen observations. The triangulation covers an area of sixteen and a half square miles. This work has been very favorably reported upon by the computing division of the office, with reference to the closing of the triangles; and also by the topographical party, as furnishing suitable and numerous points for the plane-table survey.

The services of Lieut. Van Buren being required for the survey at the entrance of Savannah river, Lieut. G. H. Gordon, U. S. A., assistant in the Coast Survey, supplied his place in the party of Captain Palmer.

The survey was resumed on the 27th of April, and prosecuted with energy and success until its close for the season on the 3d of July, below Tappahannock, at the line Jones—Carter, about midway between Fredericksburg and the mouth of the river. The course of the river, throughout an extent of twenty-four miles, was included in a series of twenty-seven small triangles, in which the same number of stations were occupied, and ninety-one angles were measured, upon thirty-one objects, by one thousand eight hundred and eight observations, with the six-inch Brunner theodolite, C. S. No. 59. The total area comprised in the triangulation of the river since last season, is about forty-four square miles. The note-books and duplicates, and the computations, were duly deposited in the office. It is gratifying to recognise the zeal, industry, fertility of resources, and accuracy which has characterized this triangulation.

Captain Palmer is at present engaged in the further extension of the survey towards Chesapeake bay, having Lieut. J. P. Roy, U. S. A., as his assistant. The schooner Bancroft has been assigned for the transmission of the party and equipments.

Topography.—The party of Assistant H. L. Whiting was engaged at the date of my last annual report in the verification of topographical work in Patapsco Neck, and continued operations until the 28th of November.

Resuming the re-survey in April of the present year, it was extended to the northern shore of Back river, including the neck below a line from Stansbury's Point, on the southern shore, to Holly Point, on Middle river. (See Sketch C.) The topographical sheet embraces also Miller's and Hart's islands, adjacent to Back River Neck and Pool's island.

The statistics of the work are as follows:

Shore-line, re-surveyed - - - - - -	84 miles.
Roads, re-surveyed - - - - - -	$54\frac{1}{2}$ miles.
Included area, re-surveyed - - - - -	26 square miles.

Mr. Whiting next resumed the topograpy of the coast of Massachusetts, near Newburyport, Section I; and, after the close of the season in October, was instructed to return to the Chesapeake.

In office-work a topographical sheet has been finished of the survey of Patapsco river made in the preceding season.

Assistant George D. Wise has continued the topography of the seacoast of Virginia, completing the sheet (see Sketch C,) between Metomkin and Wachapreague inlets. The topography covers an area of thirty-five square miles, and includes thirty-three miles of shore-line. Mr. Wise reports that this sheet will be put in ink and turned into the office by the 1st of November; soon after which he will proceed to St. Andrew's bay, Section VII.

Plane-table sheet No. 54, Back river, Chesapeake bay, (see Sketch C,) was continued by Sub-Assistant John Seib, and eleven miles of shore-line necessary to its completion determined since the date of last season's report.

In conformity with instructions, he next proceeded with the work of determining shore-line on the Rappahannock river, Virginia, and points for the hydrographic party which was to follow, and in the execution of general topography within the limits of the triangulation. (See Sketch C.)

Between Falmouth, above Fredericksburg, and Corbin's Neck, an extent of fifteen miles by the river-course is included in this survey, the details of which are as follows:

Shore-line - - - - - - - -	32 miles.
Roads - - - - - - - -	$14\frac{1}{2}$ miles.
Area - - - - - - - -	$7\frac{1}{2}$ square miles.

The topography occupied the party two months succeeding the 25th of October.

During the winter their topographical sheet was put in ink, and deposited in the office.

In April Mr. Seib resumed his work on the Rappahannock, and completed the topography from above Port Royal to Tobago bay. (See Sketch C.) He thus describes the topography of this part of the Rappahannock: "The river is narrow in many places, and the determination of its shores difficult. On one side the banks are high, steep, and wooded; on the other low and swampy, alternately.

But the topography is very pretty and varying. There are fine hills and banks—some as high as one hundred and sixty feet, and then again large plains of small height." The limits of the sheets containing this survey are shown on the sketch. They contain fifty-four miles of shore-line, and an area of sixteen square miles.

After indispensable repairs were made to the schooner Wave, used for the transportation of his party, Mr. Seib resumed his work on the Chesapeake, at York River entrance, (see Sketch C,) carrying it from Rock Point, in Mobjack bay, to Back river, (Sheets Nos. 52 and 53,) and furnishing the shore-line to the party of Lieut. Comg. Almy, working in the vicinity. This work covers an area of eleven miles, and furnished one hundred and one miles of shore-line.

Mr. Seib's next work was at James River entrance, (see Sketch C, sheets 57 and 58,) the shore-line of both sides of which, from Newport News to Warwick river on the north, and from abreast of Craney island to Day's Point on the south bank, was furnished to the party of Lieut. Comg. Maffitt, who had commenced the hydrography of the river. The hydrographic signals, houses, and other objects, which might be useful in the hydrography, were determined by Mr. Seib. The shore-line thus mapped was forty-four miles in extent.

Mr. Seib also determined the shore-line of Elizabeth river for the hydrographic party of Lieut. Comg. Almy, furnishing also numerous points for working, and adding thirty-one and a half miles to the shore-line already determined by him.

The total shore-line determined by Mr. Seib this season, and for immediate use by the hydrographic parties, has been two hundred and thirty miles—a most excellent season's work.

Hydrography.—By request of the Chief Engineer, General Totten, a re-survey was made of a portion of the entrance of the Patapso river, including the Bodkin channel, with a view to the decision of a question in regard to the best line for dredging. Capt. Henry Brewerton, of the Corps of Engineers, at whose suggestion the survey was made by a hydrographic party of the Coast Survey, furnished a steam-tug for executing the work; and the party of Lieut. Comg. Richard Wainwright, U. S. N., assistant in the Coast Survey, was employed in making it, and in plotting the work as finished. Tidal observations were made at the Bodkin light-house for thirty days, day and night; and the soundings were referred, through one of the observed low-waters, to a bench-mark on the light-house. The channels and shoals appear to have changed but little since the survey in 1845, by the late Lieut. George M. Bache, U. S. N.; the two surveys not differing more than "must necessarily occur in making two separate surveys of a place showing such peculiar irregularities of bottom."

The finished hydrography of the Rappahannock river, for the Engineer department, has been carried to a point about six miles below Port Royal by the party of Lieut. Comg Wainwright.

This officer, in command of the schooner Nautilus, commenced operations on the 2d of June, and extended the work as far as the limits of the plane-table survey. In its prosecution, he reports having run one hundred and thirty-eight miles of soundings, measured five hundred and ninety-five angles, and made nineteen hundred and sixty-one casts of the lead.

Lieut. Comg. Wainwright has since been engaged in the survey of the Hudson, a notice of which is given in Section II. He has now returned to the Rappahannock to continue the hydrography.

The hydrography of the Chesapeake bay has been completed during the present season, by Lieutenant Comg. J. J. Almy, in the steamer Hetzel and schooner Graham. The work begins at the head of Mobjack bay, and thence passes to the limits of last season's hydrographic sheets, at the middle of the bay, and, connecting with the work of 1852 and 1853, continues to Cape Henry, embracing Lynn Haven and Hampton roads, Elizabeth river and harbor of Norfolk and Portsmouth, to the line of Craney Point, New Point Comfort, where it joins the work of Lieut. Comg. Maffitt. The area closely sounded over is two hundred and forty-five square miles. The following statistics are reported: "One thousand six hundred and eighty-seven nautical miles have been run in sounding; seventy thousand two hundred and sixty-nine soundings have been taken, in from one foot to seventeen fathoms water; one thousand angles have been measured with theodolites for hydrographical position, and four thousand two hundred and ninety-four angles with sextants for the same purpose; one hundred and twenty-six high and the same number of low tides have been observed; and the number of tidal observations is four thousand seven hundred and forty-seven. Twenty specimens of bottom have been taken, ten current stations have been occupied, twenty currents observed, and three hundred and twenty-seven current observations have been taken."

An interesting notice of the increasing commerce of the lower part of Chesapeake bay, by Lieut. Comg. Almy, is given in Appendix No. 24. This party had the occasion to render assistance to two vessels in distress, for which they received hearty thanks.

The announcement in regard to York Spit and New Point shoal is given from Lieut. Comg. Almy's special report on the subject, in Appendix No. 12.

Seven sheets of the work executed by this party in 1853 have been finished and turned into the office, viz:

Seacoast of Virginia, from Hog island to Cape Henry - - - - - -	scale $\frac{1}{40000}$
Chesapeake bay north, from Cape Henry, east side - - - - - -	scale $\frac{1}{40000}$
Chesapeake bay, from Wolf Trap to New Point Comfort light - - -	scale $\frac{1}{40000}$
Sand Shoal inlet, coast of Virginia - - - - - - - - - -	scale $\frac{1}{20000}$
Ship Shoal inlet, coast of Virginia - - - - - - - - - -	scale $\frac{1}{20000}$
Occohannock creek, Chesapeake bay - - - - - - - - -	scale $\frac{1}{20000}$
Hunger's and adjacent creeks, Chesapeake bay - - - - - - -	scale $\frac{1}{20000}$

The tide-books and records of soundings and angles have been copied and deposited in the archives.

The hydrography of James river, near its entrance, was commenced, at the close of his work in Section V, by Lieut. Comg. J. N. Maffitt, U. S. N., assistant in the Coast Survey, and has been carried from the limits of Lieut. Comg. Almy's work up the James to Warwick river. Special tidal observations have been made in connection with the work.

Tides.—The regular series of tidal observations has been kept up at Old Point Comfort, with the Saxton self-registering gauge. Special observations at the Bodkin and James river have been made under the direction of Lieuts. Comg. Wainwright and Maffitt. An attempt was made to put up a pipe-gauge, with register attached, similar to the one used at Nantucket, at Cape Henry, for comparison with that at Old Point; but it proved unsuccessful.

The reduction of the Old Point observations by Mr. Lubbock's method, and the comparison with theory, is nearly completed. One of the James River stations has been reduced by Prof. Airy's method for comparison with the theory of river tides.

SECTION IV.—FROM CAPE HENRY TO CAPE FEAR, INCLUDING PART OF VIRGINIA AND NORTH CAROLINA. (SKETCH D.)

The general progress, as will be seen from the statements under the several heads in this section, has been satisfactory. The astronomical positions of Raleigh and Wilmington have been determined, and magnetic observations have been made at both places—the first-named as a link in the chain for difference of longitude by telegraph between Washington and New Orleans. The secondary triangulation has been carried northward towards Cape Henry, Virginia, and southward towards Cape Fear, North Carolina, and that of the Cape Fear river has been finished. The topography has kept up with the triangulation in the upper part of Currituck sound, and has been carried from Cape Lookout to include Beaufort harbor, Shepherd's Point and the opposite banks, and part of the shores of Bogue sound. The hydrography of Beaufort harbor has been executed in the most thorough manner, and the results (including a report from the accomplished hydrographic officer making the survey) furnished to the honorable Secretary of the Navy, at whose request the immediate execution of the hydrography was undertaken. A reconnaissance of the dangerous shoals north of Hatteras, known as the Wimble shoals, has been made. Tidal observations have been made at Fort Macon, Beaufort harbor, in connection with those at Cape Lookout, and a self-registering tide-gauge has been established at Baldhead, Cape Fear entrance.

Projects have been made for a complete chart of Cape Fear entrance and approaches, and of Cape Fear river to the head of Eagle's island, and the drawing has been commenced. The drawing of Beaufort harbor has made progress. The drawing of Albemarle sound, sheet No. 1, is nearly completed. Sketches of Beaufort bar and Wimble shoals have been drawn. The engraving of Albemarle sound, No. 1, has made considerable progress, and the sketches just referred to will be completed for the present report. The engraving of the Beaufort chart is in progress.

Astronomical observations.—The longitude station at Raleigh, North Carolina, was again occupied to make a connection for telegraphic difference of longitude between Washington and New Orleans, by uniting Raleigh with Columbia, South Carolina. It was intended that Assistant George W. Dean should occupy the Raleigh station, and Dr. B. A. Gould, jr., the station at Columbia, and that after sending and receiving telegraph signals for transits of stars, according to the programme previously arranged by Dr. Gould, they should exchange stations and again observe. The telegraph line was so rarely in condition to afford the desired facilities for working, that it became necessary to depart, in a degree, from the contemplated arrangement. A certain number of transits were, however, exchanged, and personal equations were compared at Columbia before and after the exchange of transits by telegraph, by the observers both repairing to that station. These observations are now in the hands of Dr. Gould for reduction, and a detailed notice of them will be found in his report, Appendix No. 41. The latitude of Raleigh was determined by Dr. Gould, with zenith telescope No. 2, in 1853.

While at Raleigh, Assistant George W. Dean observed for the magnetic variation, intensity, and dip; the two former with the portable apparatus of the British Association, C. S. No. 1, (declinometer D 22, Jones,) and the latter with a ten-inch dip-circle (C. S. No. 4) by Barrow. One hundred and five observations, on five different days, were made for variation, and ten sets for horizontal intensity and moment of inertia on the other days. The dip was determined by four sets of observations on four different days.

Mr. Dean established at Raleigh a meridian-mark, which may be very useful for future reference, especially in surveys made by the compass. It is described in Appendix No. 44, which contains extracts from his report.

Observations for difference of longitude between Wilmington and Petersburg, and at Wilmington, for latitude and azimuth, were made chiefly under my immediate direction between the 8th of May and the 28th of June. The stations at Roslyn, near Petersburg, and De Rosset, in Wilmington, were prepared under the direction of Dr. B. A. Gould, jr., and Assistant G. W. Dean; and when Dr. Gould was relieved to observe in Section I, the eclipse of May 26th, Assistant L. F. Pourtales took his place at Roslyn, and the operations passed under my direction.

An extended programme for examining the various circumstances influencing the observations had been arranged by Dr. Gould, to which I added one for examining the possible influence of inductive currents. The matter of personal equation had entered largely into our views in maturing the entire programme, and but for the condition of the telegraph line, quite a complete experimental series would have been executed. As it was, the perseverance of Mr. Pourtales and Mr. Dean executed a considerable part of what had been laid out, notwithstanding the advanced state of the season. I was indebted to Mr. Dean for very complete mechanical arrangements, requisite for the observations proposed to be made on the eclipse and recorded upon the telegraphic register; but the day proved entirely unfavorable, the sun being obscured by clouds at the beginning and end of the eclipse, and showing itself at but rare intervals during its progress.

Star signals were exchanged between Mr. Pourtales, at Roslyn, and Mr. Dean, at De Rosset, on the 27th of May, and 6th of June, when they exchanged stations, and again worked successfully on the 20th and 23d of June. In the intermediate time various experimental trials were made with the line, which must in all probability give interesting results from their discussion, though there were unexpected difficulties in the execution of the programme, from causes beyond the control of the parties and of the telegraph operators. Mr. Dean, before closing work, returned to Wilmington, and compared personal equations with Mr. Pourtales.

We were indebted to Messrs. Carleton, Bingham, and Lumsden, the operators in the telegraph office at Wilmington, for much assistance in connecting the station with Roslyn, and in offering every facility for our experiments, in the success of which they took great interest.

The observations for latitude at Wilmington, by Assistant George W. Dean, consisted of two hundred and three observations on forty-one pairs of stars, with the zenith telescope No. 5, C. S., from the Greenwich Twelve-year Catalogue, and that of the British Association; two hundred and fifty observations upon 51 Cephei at elongation, for the value of the micrometer screw; and fifty-two upon a collimator, for the value of the divisions of the level. One hundred and two observations for magnetic variation were made on four different days with declinometer No. 1, C. S., (D. 22, Jones;) two sets for horizontal intensity and moment of inertia; and two sets with the ten-inch Barrow dip-circle (C. S. No. 4) on two different days.

Mr. Dean placed a meridian-mark at Wilmington, by which a ready comparison of the variation of the compass may at any time be made. It is described in Appendix No. 44.

The azimuth observations were made by Assistant C. P. Bolles, on Polaris at elongation, with the two-foot theodolite, (C. S. No. 2.)

The arrangements of the buildings at the stations were made by Thomas McDonnell, artificer.

We were specially indebted to the liberal and kind attentions of public-spirited citizens of Wilmington for great facilities in the execution of this work. As they are public officers, we may be permitted to mention the names of General McRae, president of the Wilmington and Raleigh railroad, and J. L. Fleming, esq., chief engineer of the Wilmington and Manchester road.

Secondary triangulation.—The triangulation has been carried southward from Beaufort harbor, twenty-five miles along the coast, by Sub-Assistant A. S. Wadsworth. The chain of triangles, as shown in Sketch D, crossing from one side of

Bogue sound to the other, will afford hydrographic points by openings through the ridge of woods bordering on the ocean.

This work, which followed the topography of the southern part of Beaufort harbor, was begun on the 14th of February, and completed on the 2d of May. Additional points were, in the mean time, furnished to the hydrographic party working in Beaufort harbor.

The area covered by the triangulation is fifty square miles, in which twenty-three stations were occupied; and, in connecting twenty-eight objects, seventy-nine angles were measured by two thousand seven hundred and eighty (2,780) observations, with a six-inch Gambey repeating theodolite. The weather was unfavorable for work during the season.

The stations have been marked in a manner which, in the opinion of Mr. Wadsworth, must insure their permanence.

The facilities afforded and difficulties presented by the country over which he passed, for the extension of the main chain of triangles, were examined by Mr. Wadsworth; also the possibility of procuring frequent bases suited to a small main triangulation, in case that system should be finally resorted to.

On closing his operations and having completed his computations, Mr. Wadsworth reported at the office, and was assigned to the topographical work in Section I, near York harbor, Maine.

The triangulation of Currituck sound, and reconnaissance for its extension up Back bay, connected with the former, (see Sketch D) have been continued by the party of Assistant J. J. S. Hassler.

Extending northward along the coast of North Carolina from the opening of Albemarle sound, seventeen stations were occupied, (some of them, however, for the second time,) exclusive of several subsidiary points used in their connection. The result of the reconnaissance, which during the season was carried across the Virginia line, will be the connection between this triangulation and that terminating at Cape Henry. The extension of the triangulation has been in a degree delayed by the necessity for remeasuring certain angles, by the difficult character of the country, and the unusually stormy weather of the season.

Mr. Hassler reports twelve stations determined by two thousand one hundred and eighty-four (2,184) observations, and enclosing an area of seventy-five square miles.

In addition to this regular work, six hydrographic points south of Cape Henry were determined by Mr. Hassler for the party of Lieut. Comg. Almy.

Topography.—The topography of Beaufort harbor was extended southward, and that of Bogue sound in connection with it, commenced by Sub-Assistant A. S. Wadsworth. The sheet embracing his work is marked on Sketch D, No. 4. This party was organized in December, but owing to an accident to the vessel carrying the instruments and equipments, actual operations were not begun until the 14th of January. The sheet was completed on the 9th of February, put in ink and sent to the office, in order that the chart of Beaufort harbor might be early taken in hand. It includes thirty-five miles of shore-line and an area of five and a half square miles.

Mr. D. E. Montgomery served as aid in this party.

Hydrography.—Supplementary work on the Cape Fear bars and entrance was executed by the party of Lieut. Comg. Maffitt, U. S. N., assistant in the Coast Survey, in the autumn of 1853, when the sailing-vessel which had been used by his party was transferred to another, and the steamer Legare was fitted out for his use. The repairs required by the steamer proving much greater than had been expected, the party was detained in making them until the middle of February, when they proceeded to Beaufort for a complete survey of that harbor and its approaches. The party next proceeded to Charleston harbor, where they re-surveyed Maffitt's or the Sullivan's Island channel, obtaining results of much importance, which will be noticed under the head of hydrography in Section V.

An interesting report on Beaufort harbor by Lieut. Comg. Maffitt will be found in Appendix No. 14. It shows the great value and importance of that harbor; proves that the depth has been nearly permanent in all changes of position of the main channel from the earliest records; points out the perfectly protected character of its roads, and its facilities for the purposes of a naval depot, accessible at high water by "sloops-of-war and second-class steamers, while brigs, schooners, and third-class steamers could come in at any stage of the tide." There is at present nearly sixteen feet of water upon the bar, (a sketch of which accompanies Lieut. Comg. Maffitt's report,) and the distance across it is but three hundred and seven (307) yards; the depth rapidly passes to three and a quarter and three and a half fathoms. The average rise and fall of the tide is four and a half feet, so that at high water there is twenty feet on the bar.

The wearing away of Shackelford's Point, at the entrance to Beaufort harbor, is pointed out by Lieut. Comg. Maffitt, and its probable consequences clearly shown.

"The geographical position of Beaufort is favorable, not only for the purposes of commerce, but as offering protection during northeast and eastwardly storms. Cape Lookout affords a natural breakwater in gales from those points, with excellent and well-protected anchorage under the land, the light-house bearing east."

In the hydrography of Beaufort approaches, entrance, and harbor, seven hundred and eighty-five miles of soundings were run, two thousand seven hundred and fifty-five angles observed for positions of soundings, 37,260 casts of the lead made, thirty-four specimens of the bottom procured, and sixteen current stations occupied.

As office-work, the party has completed two sheets of Beaufort entrance and approaches, and two others of Beaufort harbor, scale $\frac{1}{10000}$, besides current diagrams and tables.

I visited this party while engaged in the survey of Beaufort harbor, taking the opportunity, when inspecting the progress of the operations, to become personally familiar with the localities under survey.

It was intended to make a complete survey of that part of the coast of North Carolina between Nag's Head and Hatteras, including, especially, the dangerous Wimble shoals; and Lieut. Comg. Craven, U. S. N., assistant in the Coast Survey, in the steamer Corwin, had actually commenced the work, when the cholera broke out on board his vessel, and he was obliged to leave the section, after completing a reconnaissance of the Wimble shoals, on which he gives three fathoms as probably the least depth. Lieut. Comg. Craven's report, with a description of the shoals, is given in Appendix No. 13, and a sketch of the reconnaissance, marked D, No. 3.

Tides.—Observations were made by Mr. F. Muhr at Hatteras inlet, and, in consequence of the many irregularities which they seemed to show in the tides, were continued for four months.

Cape Lookout not affording proper facilities for tidal observations, it was determined to have a regular series made in Beaufort harbor, and a comparative set at Cape Lookout, observing day-tides when the sea was smooth. The series at Beaufort was kept up for three months and a half, and that at Cape Lookout for about three months. At Baldhead, Cape Fear entrance, advantage was taken of the wharf constructed by Captain D. P. Woodbury, of the Corps of Engineers, in charge of the improvement of Cape Fear entrance, to erect a Saxton self-registering tide-gauge, so that a complete comparison might be made with the elaborate series of tidal observations by Lieut. Comg. Maffitt at Smithville. This gauge is still in operation. It was put up by Assistant George A. Fairfield, in charge of the tidal series along the coast, and has, with some intermissions, worked well.

A line of levels was run by Lieut. D. T. Van Buren, U. S. A., connecting the bench-marks of the tidal stations at Wilmington and Smithville.

SECTION V.—FROM CAPE FEAR TO THE ST. MARY'S RIVER, INCLUDING THE COAST OF THE STATES OF SOUTH CAROLINA AND GEORGIA. (SKETCH E.)

Six parties have been employed in this section, and generally during the whole of the season. The reconnaissance from the Ashley river to the Santee has been made. The latitude, approximate longitude, and magnetic elements of Georgetown, were determined. The difference of longitude between Columbia, South Carolina, and Raleigh, North Carolina, has been ascertained by telegraph, and latitude and magnetic observations have been made at Columbia. The primary triangulation, and secondary connected with it, has advanced eastward. The triangulation of Savannah River entrance and of Calibogue sound to May river has been completed. The topography between the Stono and North Edisto has made good progress. Some hydrography in Charleston harbor and at the entrance of the Savannah river has been executed. Tidal observations have been made near Charleston light-house and in the harbor, and a gauge established at St. Simons.

A communication to the Engineer department from Captain A. H. Bowman, of the Corps of Engineers, called my attention to the probability that changes had occurred in the channel near Sullivan's island, known as Maffitt's channel, and I accordingly directed Lieut. Comg. Maffitt to make the re-examination of this channel and its approaches. Very remarkable changes were developed by the resurvey, tending to render the channel much more available even than when recommended for improvement in 1852. A chart exhibiting these changes accompanies this report, Sketch E, No. 4. By request of the Engineer department, I served with Lieut. Davis, U. S. N., and Captain J. F. Gilmer, U. S. Corps of Engineers, on a commission to re-examine the plans of improvement which had previously been suggested, and visited Charleston for that purpose in the latter part of the month of June, returning to Wilmington, North Carolina, on the completion of the examination and report of the commission. The services rendered by Lieut. Comg. Maffitt and the officers of his party, then in Charleston harbor, in facilitating the work of the commission, and in making current and other observations, were very valuable. To the efficiency of his arrangements and knowledge of localities and changes they owed, in a considerable degree, the promptness with which they were able to arrive at their conclusions.

Maffitt's channel itself (see Sketch D) was found to have moved northward while retaining its general direction, to have diminished in width, and slightly increased in depth. The bulkhead closing the west end of it near Bowman's jettee had much diminished in width, and the average depth on the bulkhead had increased nearly two feet.

A drawing has been made during the year of the re-survey of Maffitt's channel, and a comparative map of this and former surveys prepared; these have been engraved. The drawing of the chart of Georgetown harbor and of Tybee entrance and Savannah river has been commenced. The engraving of the preliminary chart of Charleston harbor has been nearly completed, and the drawing of the final chart will soon be commenced. The sketches of progress in this section have been remodelled and engraved.

Reconnaissance.—A reconnaissance of the coast of South Carolina, from the Ashley river to the Santee, meeting there his former work, has been made by Brevet Major Henry Prince, U. S. A., assistant in the Coast Survey. Within these limits the relative positions of many intermediate points were examined with reference to their connection by triangulation. These include Cape Roman, Bull's island, Eagle island, Racoon keys, and numerous localities within a range several miles in breadth, extending along the coast. Much minute and valuable information is, as usual, contained in Major Prince's report, which serves to give definite ideas as to the character of the operations northward from Charleston.

Astronomical and magnetic observations.—The party of Assistant C. O. Boutelle encamped in the last week of November at Allston station, near Georgetown, South Carolina, and were there engaged in the usual routine of an astronomical station until the 25th of January. Observations for latitude, azimuth, local time, and for magnetic declination and intensity, were made. For difference of longitude five chronometers were transported between Allston station and Professor Lewis R. Gibbes' observatory in Charleston.

The party consisted of Lieut. A. W. Evans, U. S. A., assistant in the Coast Survey, who joined it on the 22d of December; Sub-Assistant B. Huger, jr., and Mr. F. P. Webber, the latter transferred from the party of Captain Cram in November

The observatory at Allston was completed on the 13th of December, between which time and January 21—on twenty-six nights—six hundred and ninety-eight observations for latitude were made upon one hundred and fourteen stars, with the zenith telescope C. S. No. 5, (Würdemann.) Of these, thirty-nine stars were from the Greenwich Twelve-year Catalogue. On thirty-two nights, between December 10th and January 24th, three hundred and twenty-five transits of fifty-two stars were observed with C. S. transit No. 4.

Observations for azimuth were made between the 1st and 17th January, with the two-feet theodolite C. S. No. 2, in the usual manner, upon Polaris at elongation—five eastern and six western elongations being observed; three hundred and two observations were made on the star and mark, and on thirteen objects; twelve angles were measured by two hundred and eleven observations, to connect the observed azimuths with the secondary triangulation of Winyah bay.

For magnetic declination one hundred and eighty-eight half-hourly readings were taken on eight days with declinometer, D- 22; sixty-four observations of deflection and eighty-four of vibration were made on three days, and sixty-four observations for dip on two days. The approximate magnetic variation at Allston station is 2° 07′ east.

Five journeys, each with five chronometers, from Allston station to Charleston, and four journeys, with five chronometers, from Charleston to Allston, were made between January 4th and 25th, giving in all forty-five results for difference of longitude. Observations for local time at Charleston were made by Professor Lewis R. Gibbes, but under very unfavorable circumstances of weather. On completing the astronomical field-work, the party returned to Charleston, preparatory to resuming the triangulation of the section.

Duplicates of all the observations at Allston were made at the geodetic station, and have been deposited in the Coast Survey Office. The computations are now in progress.

Observations for difference of longitude between Columbia and Raleigh were commenced by Dr. B. A. Gould at the former, and Assistant George W. Dean at the latter place, in January; the observers exchanging stations on the 13th of February, to eliminate the effect of personal equations, and the work being closed on the 14th of March. Full details of the observations at these places are given by Dr. Gould in his report, (Appendix No. 41,) in which will also be found interesting remarks on the conditions requisite to insure the transmission of signals by the telegraph line, and their reception at its extremities; on the disturbance by currents, induced by discharges of atmospheric electricity, even when distant from the line; and on the progress of the application in Europe of the electro-magnetic telegraph to determinations of longitude. The self-sustaining galvanic battery, invented by Mr. Mathiot, of the Coast Survey, is highly praised for its efficiency by Dr. Gould. A description has been prepared, and is appended to this report, (Appendix No. 56.) The use made of the valuable "criterion for the rejection of doubtful observations" by Professor Peirce will prove of very considerable interest, and the tables for its ready use, furnished by Dr. Gould, Appendix No. 41, will be found of great value to observers generally.

At the Columbia station a double series of observations for latitude was made for the purpose of clearing up the difficulty found at Sebattis last year, by Assistant J. E. Hilgard, (see Coast Survey Report for 1853, page 28,) where the different observers, using different instruments, and observing the same pairs of stars, found latitudes differing by a small but noticeable amount. The zenith telescopes (Nos. 2 and 5, C. S.) were employed, and the same stars (twenty-five pairs) were observed with each by Dr. Gould and by Mr. Dean. Each series on the several pairs consisted of five observations by each observer—a number which had been found to give a probable error of observation of but 0.2″. The value of the micrometer of zenith telescope No. 2 was determined by each observer, by two hundred and twenty observations of Polaris at eastern and western elongation, and of No. 5 by two hundred and forty-four observations of Polaris, and 51 Cephei, at elongations. The values of the level divisions were determined by fifty observations with the micrometer or collimator adjusted to a sidereal focus, and placed a few feet from the zenith telescope.

The magnetic determinations were made in the southwestern part of the Capitol square. They consisted of one hundred and fifteen observations for variation, on five different days, with declinometer No. 22 Jones, (No. 1 C. S.;) two sets for horizontal intensity and moment of inertia, on two days; and three sets for dip, with the ten-inch Barrow dip-circle, (C. S. No. 4,) on three different days.

It was expected to extend the telegraph operations to Macon, Georgia, this season; but the various impediments from storms which interrupted the working of the line, from business on the line, and from bad weather, had so far protracted the work as to render this impossible. Mr. McDonnell has prepared the station at Macon for occupation next season.

On the 28th of March I visited the station, and found a very neat and effective set of arrangements for the work.

Primary and secondary triangulation.—On completing the astronomical field-work at Allston, as before noticed, Assistant C. O. Boutelle transferred his camp to Elliott's Cut, a central point in the triangulation, laid out for the season. (See Sketch E.) The secondary triangulation has been extended up Wando river to Daniell's island, and northeasterly along the coast to include Long island, north of the entrance to Charleston harbor. New points on the seacoast were determined where the old ones had been washed away by the severe storms of December and January. The primary line from Elliott's Cut to Daniell's island was traced across Charleston Neck—a very difficult work, on account of the great number of intervening residences and ornamental trees; and that from Elliott's Cut to Breach inlet was opened.

Three primary stations were occupied, and thirty-two angles were determined upon forty objects by 3,451 observations. Eighteen secondary stations were occupied, at which eighty-four angles were measured upon ninety-two objects by 1,060 observations. This work was executed between the 24th of February and the

13th of May; but during the greater part of March, observations were much hindered by haze.

A small part only of secondary triangulation necessary to connect the triangulation of Wadmelaw sound with that of Stono river is yet required; some cutting, however, will be necessary in its execution. The connection of the work in Charleston harbor with the triangulation from the Edisto base is now complete through both the primary and secondary series.

The camp at Elliott's Cut was broken up on the 5th of May; but Sub-Assistant Huger continued the secondary triangulation of Long island until the 13th, in the schooner Bancroft, which had been in charge of the party since the 15th of December. Assistant Boutelle reported at the office in Washington, where, as already stated, (Section III,) he observed the solar eclipse of May 26th. Since then he has been engaged in the computation and reduction of his work in this section, and, as noticed in its place, in the secondary triangulation in Section I. I visited Mr. Boutelle's station at Elliott's Cut during the season, and went over some of the ground of the secondary work with him.

Lieut. D. T. Van Buren, U. S. A., assistant in the Coast Survey, has completed the secondary triangulation on Tybee bay, including Savannah River entrance from the junction with the work of the previous season by Captain E. O. C. Ord, U. S. A., and that on Calibogue sound as far as May river. (See Sketch E, No. 2.)

This survey extends over level tracts intersected by numerous navigable creeks. Lieut. Van Buren remarks: "Many of these creeks are navigated at all times, and most of them when the tide serves. Thus, Cooper river is used by the steamers taking the inland route between Savannah and Charleston; these same steamers touching at Bluffton, a town of considerable trade in cotton, &c., the town being situated on May river, about five miles from its entrance into Calibogue sound."

The party have had the use during the season of the schooner "Meredith," for transportation.

This party was visited by me during the season, and, by request of the Savannah Chamber of Commerce, I gave directions for the survey of the inland passes near Romney marshes; but the advanced period of the season when the other work was completed rendered this impracticable. It will be taken up at the opening of the next season.

The statistics of the work between February 1st and May 4th are as follows:

Number of stations established	15
Number of stations occupied	13
Number of angles measured	70
Number of observations	1,642
Area of triangulation (square miles)	34

In connection with the establishment of intermediate tidal stations, a line of levels, found to be requisite, was run by this party between Wilmington and Smithville, North Carolina, previous to the commencement of the triangulation. The officer in charge during the season mentions, in high terms, the aid afforded by Sub-Assistant John Rockwell, and his hearty co-operation in the execution of the survey. The computations and duplicate records have been returned to the office.

Topography.—The minute topographical survey in this section, north and south of Charleston harbor, has been executed by the party of Sub-Assistant R. M. Bache.

On the south side along the seaboard, the work embraces Seabrook's island, near the entrance of North Edisto river, Kiawah island, stretching towards the mouth of Stono river, which is also included in the survey, together with Kiawah river, parts of John's island in Colleton parish; and north of the Stono, Cole's island, and part of the outside shore of Folly island.

The area covered by topography in these several localities is about thirty-two square miles, and about two hundred and four miles of shore-lines were surveyed between January 2 and May 1.

The topographical work north of Charleston harbor was confined to the survey of Long island between the 18th and 27th of May. This work includes seventeen and a half miles of shore-line within an area of four square miles.

Sub-Assistant Bache has since been engaged in putting in ink the foregoing work, and in field-work near Plymouth, Massachusetts, in Section I.

I inspected the progress of this work during the season, and found it entirely satisfactory.

Hydrography.—After completing Beaufort harbor, North Carolina, the hydrographic party of Lieut. Comg. Maffitt, U. S. N., assistant in the Coast Survey, made the re-survey of the channel known by his name near Sullivan's island, to which reference has been made in the introductory remarks of this section.

It was intended that a reconnaissance of Port Royal inlet and Beaufort harbor, South Carolina, should next have been made, but the communications addressed to Lieut. Comg. Maffitt failed to reach him in time for the purpose; and that work yet remains for the next season, in the instructions for which it will be included.

The party next took up the completion of Savannah River (Tybee) entrance, which was interrupted by an accident to the steamer requiring repairs, which, in consequence of the occupation of the railway and marine dock at Savannah, could not be made there, and made necessary the return of the vessel to Charleston. Here the party rendered valuable service to the commission on the improvement of that harbor which had been re-assembled by the Engineer department, in current and other observations. The vessel being repaired, they undertook the Gulf Stream work which had been directed—namely, an extension of the previous examination of the bottom on the Charleston section and north of it, in which the previous summer's work had developed such curious and important inequalities—but had hardly made a beginning, when the vessel sprang a leak, requiring all the efforts of officers and men to bring her safely into port at Norfolk. Here the steamer was exchanged for a sailing-vessel, and the schooner John Y. Mason, Lieut. Comg. Maffitt, executed the hydrography of James River entrance in Section III.

The statistics of the work thus executed are as follows:

	Charleston, S. C.; supplementary.	Savannah.	Gulf Stream.	Total.
Number of miles of soundings run	41	567	100	1,493
Number of angles observed	406	1,193	.....	4,354
Number of casts of the lead	3,280	14,815	.....	55,368
Number of specimens of the bottom	8	17	8	67
Number of current stations occupied	8	5	.....	29
Number of stations occupied	.....	.....	4	.....

The office-work turned in by his party consists of a sheet of Maffitt's channel, (scale $\frac{1}{5000}$,) and various current diagrams. That reported as partially completed in October consists of duplicates of journals, a chart of Tybee entrance, (scale $\frac{1}{20000}$,) current diagrams, and abstracts.

Tides.—A self-registering tide-gauge was established by Assistant G. A. Fairfield, near the light-house on Morris' island, for the purpose of comparing the results of the ocean tide with those in the harbor. It did not work successfully, however; and the pipe leading to it soon became choked by sediment. The observations for comparison still remain to be made. The tide-gauge at Castle Pinckney is one of those which are kept up for central reference. It has been carefully observed and continuously, except for a short time after the disastrous gale of September 6, which damaged the wharf, and carried away the box. A tide-station was established also by Mr. Fairfield at St. Simon's; but the observations were not long continued, and the work there remains to be done.

GULF STREAM.

In my last annual report I gave the conclusions which a preliminary discussion of the observations of the Gulf Stream, especially those for temperatures, up to that time, had developed. Following the methods adopted in that discussion, Professor Pendleton, U. S. N., assistant in the Coast Survey, under my immediate direction, went carefully over all this work; re-plotting the diagrams, re-computing the tables, enlarging upon many of the incomplete deductions, and in general working over the whole matter anew. Closer numerical results were of course obtained in many cases, but the conclusions were undisturbed. This discussion will be given in full detail in the volumes of Records and Results of the Coast Survey, with the observations themselves; for the present I have placed in the Appendix No. 47 the outline of it, which was communicated, under authority from the Treasury Department, to the American Association for the Advancement of Science, at its meeting in Washington. Plate No. 24 gives the determination of the stream from this discussion, the temperatures being marked by the darker and lighter shades; the darker corresponding to the higher temperatures, and the alternate bands of high and low temperature being shown by the alternations of the shades. The diagrams giving the law of change of temperature with depth, the changes of temperature at any given depth across the section of the stream, the variation of depth for a given temperature, and the character of the bottom, are shown in Plate No. 25. It will not be necessary to notice these further here, as they are referred to in the paper very fully.

The subjects treated are:

1. The distribution of temperature at different depths, which is shown in the cold counter-current to take, after a certain depth, the form of equilibrium, due to the conduction of heat by water, a bad conductor, and, under the Gulf Stream proper, curves varying from the form of equilibrium. The existence of the polar current underlying this body of warm water from the tropical regions is discussed.

2. The distribution of temperature at the same depth on the several sections perpendicular to the stream from prominent points of the coast. The curious facts in regard to the "cold wall" limiting the inner side of the hot water of the Gulf Stream are here brought out; and the division into alternate warm and cold bands of the waters of the ocean in and near this mighty stream.

The permanency of the divisions of the stream in different years is tested; the summer stream, by the results of running the same section in different years, and by the agreement or variance of the results obtained at a particular depth with those at other depths. The uncertainty of position of one of the points of highest or lowest temperature is there found to be, on the average, seven miles; and of the best determined bands the hottest, and those near to it, five and a half nautical miles. The differences in the temperature of the whole mass of water at the same season in different years are often more considerable than the differences of distribution. The other form of discussion, which takes in, generally, only accidental variations of temperature, gives for the probable uncertainty of the position of the axis or hottest part of the stream, two miles and a half, in those parts of the stream where it is well defined.

The correspondence between the figure of the bottom and the general divisions of the stream, as brought out from the observations of Lieuts. Comg. Craven and Maffitt, is here shown.

3. The "cold wall" is traced in the southern sections as well as the northern, varying only in the amount of change.

The changes in position of the remarkable points in the stream with the seasons, and other circumstances, are not disposed of.

The observations have been made, as far as practicable, in the summer, when the exposure to the observers is least, and when the temperatures of the surface-water and of the air would be most nearly the same, and therefore the least disturbing action would be produced by the air.

Since my last report Lieut. Comg. Craven has run two sections of the stream—in February, 1854—to give the winter temperatures; and has attempted a northern section, imperfectly run before, but with incomplete results, from the giving out of parts of the engine of his vessel in the rolling sea of the Gulf.

In running the first two sections across from Cape Canaveral, Florida, and St. Simon's, Georgia, Lieut. Comg. Craven also re-investigated the depths at which bottom was found, with his improved Massey's sounding-machine, instead of the sounding-line, which, as has been before stated, could, probably, not be relied upon to give such great depths accurately. The ratio is of course a very variable quantity; but in the comparisons on the St. Simon's section, indicates but seventy per cent. of the depths obtained by the line in a depth of about five hundred fathoms. Thus bottom was found at about one hundred and twenty-nine miles from the land on the St. Simon's section, in 1853, with the line at five hundred fathoms; and in 1854 with the Massey at three hundred and fifty fathoms; and again at about one hundred and forty-one miles, in 1853, with the line, at five hundred and twenty fathoms; and in 1854, with the Massey, at three hundred and ninety-five fathoms. The proportion is shown by other comparisons to be a variable one. The form of the bottom, which was deduced from the observations of last year, is confirmed by these.

In regard to the temperatures observed in February, if we had no others to guide us, such is the irregularity which reigns, we should be led to despair of a result. The beautiful curve of equilibrium, and others which we obtain in the summer observations for the change of temperature with depth, is replaced in winter, as the known changes would lead us to expect, by irregular forms. The temperature from some twenty to one hundred, and sometimes one hundred and fifty fathoms, remains nearly the same, and then suddenly falls very rapidly. The temperatures at fifty fathoms are sometimes greater than those at and near the surface. On the Canaveral section, a vertical line would represent the law of temperatures from the surface to one hundred and fifty fathoms, for four of the positions. Then the fall is extremely sudden, amounting in the next hundred and fifty fathoms, in many cases, to twenty degrees Fahrenheit.

While the hottest part of the Canaveral section at five fathoms depth, in June, 1853, was 81½° Fahrenheit, in February, 1854, it was but 77° Fahrenheit. In the *summer*, the two curves of temperature for five fathoms, and for one hundred and twenty-five fathoms, differed, on the average, about 16° Fahrenheit, while in the *winter* of 1854, the difference was about 5° Fahrenheit. At five fathoms below the surface on the St. Simon's section, in June, 1853, the highest temperature was 80¼° Fahrenheit, and in February, 1854, 77½° Fahrenheit. In the summer of 1853, the curves representing the temperatures at five fathoms, and at one hundred and twenty-five fathoms, differed some 17°, while in the winter of 1854 they were but 5° to 6° asunder.

The double division of the stream is shown at Canaveral, the section of which is carried further than in 1853, by some thirty miles. The first maximum was about seven miles nearer to the cape than in 1853, and the second one was the higher. What would be generally taken by navigators as the Gulf water, was sixty-five nautical miles from the cape. The nearer maximum, forty-five miles from the cape, was but little lower in temperature than the furthest, until the depth of more than one hundred fathoms was reached. The St. Simon's section showed the highest temperature about one hundred and seven miles from the land in the curves near the surface; but there had obviously been some great disturbance of temperature just before these results were obtained, in three cases: after a very sudden fall of temperature from the surface to ten and fifteen fathoms, there is as sudden a rise to twenty fathoms.

The lowest temperature recorded on the Canaveral section was 50° at three hundred and fifty fathoms, ninety-five miles from the cape; and on the St. Simon's section, 47° at three hundred and forty-five fathoms; but no casts were made deeper than four hundred fathoms.

In the region of the Gulf Stream, on a section from Nantucket or Cape Cod, difficulty might be expected in obtaining well-characterized results; and it has so happened that in the cruises of 1845 and of 1854, directed to this same section, an accident in each case prevented the prosecution of the work sufficiently far, requiring the return of the vessel. The indications are, that the hottest water of the stream was some forty to fifty nautical miles further south and east in October, 1854, than in August, 1845. The highest temperature registered at twenty-five fathoms by Lieut. Comg. Davis in 1845, was 75½° Fahrenheit; by Lieut. Comg. Craven, at thirty fathoms, in October, 1854, was 70° Fahrenheit. Both observers passed through the first warm branch of the stream; the first for about ninety to one hundred and sixty miles from Nantucket, and the second for about one hundred and twenty-five to two hundred miles. The Gulf water forms quite a superficial stratum for about one hundred and sixty miles from Nantucket. At a depth of nine hundred fathoms, Lieut. Comg. Craven found a temperature of 35°, which, he remarks, is the lowest he has noted in any of his explorations. This is but eleven degrees lower than was found on the section off Cape Canaveral, Florida, in June, 1853. Twenty fathoms below the surface, here the temperature was 67°, and at Canaveral 74°.

In examining the Gulf Stream sections from Cape Canaveral and St. Simon's, Lieut. Comg. Craven reports the following work done:

	Miles.	Positions.	Observations.
St. Simon's section	140	11	74
Cape Canaveral section	100	8	58

Two current-bottles were found on the eastern coast of Florida, which had been thrown over from Coast Survey vessels, and the cards within them were kindly transmitted to the office in Washington. One of these had been thrown from the steamer Walker in the longitude of Mobile, in the latitude of Pass à l'Outre, at the mouth of the Mississippi, two months before it was found by Mr. Douglass Dummett just south of Mosquito inlet. The other, from the steamer Corwin, fourteen miles ENE. from Cape Florida light, was found by Mr. John Adams near Jupiter inlet. The first will be further noticed under the hydrography of Section VIII. We do not know the date at which the second probably came ashore. They concur, as far as the latter part of their course is concerned, showing the same direction of the current onward and shoreward.

SECTION VI.—FROM THE ST. MARY'S RIVER TO ST. JOSEPH'S BAY, COAST OF FLORIDA, AND INCLUDING THE FLORIDA REEFS AND KEYS. (SKETCH F.)

The largest number of parties which the appropriation permitted has been at work in this section during the whole time that funds were available. They consisted of a reconnaissance party, two triangulation parties, two topographical parties, and a hydrographic party; with a steam-vessel for outside work, and a sailing-vessel for inside. Tidal observations were made continuously for five months at Cape Florida; at St. Augustine for three months; and at Tampa bay for three months; and were attempted at Indian River inlet.

The outer triangulation of the keys and reefs now reaches from Virginia key, westward, to Key Rodriguez, (see Sketch F, No. 2,) and from the western extremity of the Marquesas to Point Dora, which is five-eighths of the whole. The inner triangulation extends over Key Biscayne bay, Card's sound, and part of Barnes' sound, about one-third of the whole. The proper time has come for the minute measurement of the Key Biscayne and Cape Sable bases; which I propose to undertake myself next spring. The plane-table work has followed the triangulation on the outside from Old Rhodes key to Wednesday Point, and from the Marquesas to the Pine islands; including the marking of the keys east of Key West, and inside over Key Biscayne bay. The hydrography outside reaches from the same point of beginning to Carysfort light; and from the Tortugas, including Rebecca and Isaac shoals, eastward to include Key West and its approaches, and Bahia Honda; and inside, Key Biscayne bay and the greater part of Card's sound. The parties generally in this section during the past year have accomplished a fair proportion of this work, considering, of course, their increased number.

The reconnaissance of the eastern coast of the peninsula has determined the practicability of a main triangulation there. The division of, and marking nineteen small keys, has been made. The triangulation outside has furnished points for the topography of the next year, east of Saddle Hill. That inside has completed Barnes' sound behind Key Largo. The hydrography has discovered an important harbor, Turtle harbor, near Caysfort light-house; and a system of buoys and a sea-mark have been recommended for it. The sea-marks have been prepared for erection on the points of the reef, approved by the Light-house Board. A reconnaissance of Coffin's Patches has been made in reference to the erection of a light-house there.

I am indebted to the Chief Engineer, Gen. J. G. Totten, for information of a shoal, not on the charts, in Garden Key channel, Tortugas; the light-house on Garden key being due south. There is scant three fathoms of water on the shoal, and six and a half and seven fathoms on each side of it. The notice is derived from Lieut. H. G. Wright, of the Corps of Engineers, (see Appendix No. 17,) and Sketch F.

The office-work of the field parties has been brought up, including the inking of the plane-table sheets, the computations, and plotting the hydrographic sheets. In the office of the Coast Survey the chart of Key West, on the largest scale, and Florida reef and keys, No. 1, have been commenced; the sketch of Turtle harbor has been drawn and engraved; and the sketches for the report are prepared and in the course of engraving. The tidal observations at Egmont key, Tampa, have been discussed under my immediate direction, and those at St. Augustine and Cape Florida are in the course of reduction.

Reconnaissance.—A reconnaissance of the eastern coast of Florida, from the St. John's to Jupiter inlet, was made by Brevet Major Henry Prince, U. S. A., assistant in the Coast Survey, in January, February, and part of March. He passed usually by the sounds and rivers near the coast, and occasionally by land, in conveyances furnished by the way; noticing minutely the difficulties and facilities for a triangulation, and collecting all the information which might be useful to the parties which were to follow him. He met everywhere with a kind disposition to forward the objects of his reconnaissance, and to furnish him every desirable information. After passing over the route twice, going and returning to St. Augustine, he collected in the office of the Surveyor General there the plats of the public-land surveys, and compiled a series of highly useful reconnaissance-sheets. From the information obtained by him, the outline on Sketch F is drawn. The original maps include a belt of from about three to ten miles from the ocean shore, and about two hundred and sixty miles in length, upon which the general features of the country are sketched. As an introductory work to the survey of the peninsula, this reconnaissance is of great value; showing the resources upon which the parties may rely, the difficulties they may expect to meet, and the leading facilities which may be expected in their operations. The sounds and lagoons, with occasional reaches in the rivers near the coast, and the ridge of sand-hills near the ocean shore, present, as usual, the main facilities for the triangulation. There are a few mounds, one of which, near old Fort Jupiter, Major Prince estimates at twenty-five to thirty feet in height; the ridge from Fort Pierce to Mount Elizabeth, fourteen miles, at sixty feet; and Turtle mound, about twelve miles from Mosquito inlet, at forty to fifty feet high. These, however, are exceptions to the general character of the coast.

Major Prince's conclusions are of decided interest, especially when it is considered that his experience in the different parts of the survey has given him ample means of forming an accurate judgment. He states that a main triangulation of the smallest size along the coast seems quite feasible, and that the route of the secondary or small triangulation is decidedly indicated by suitable openings along the whole extent of coast, and that the main triangulation would find open country to cross the peninsula on the line from Lake Washington to Charlotte harbor. The lines through the swamps would be the most difficult; but these would cross them, not lie in them.

Jupiter inlet was opened artificially in 1844, at a time when the water in the everglades was high, by merely cutting a small trench. It remained open until 1847; then closed, and again re-opened in 1853.

From oral and other information collected, Major Prince infers that south of Jupiter inlet "the opening for the smaller triangulation appears to be hardly inferior to that along the rest of the Atlantic coast of Florida." The distance from Jupiter inlet to Cape Florida is about seventy-five miles.

Major Prince also furnished a compilation from the Surveyor General's office of the western coast of the peninsula of Florida.

Astronomical observations.—Under the direction of Assistant F. H. Gerdes, observations were made for connecting Mobile and Key West, by chronometers, for difference of longitude. Sub-Assistant J. G. Oltmanns observed for time at the astronomical station at Pascagoula, and then at that at Key West. Next passing to the Tortugas, he observed, with the transit instrument, (C. S. No. 9,) for time, near the light-house there, and also with the zenith telescope (C. S. No. 1) for latitude, returning to Key West, and again mounting the transit and making time observations with it. Sixty-seven transits were observed and seven pairs of stars with the zenith telescope. Mr. Oltmanns was indebted for facilities in his work to Lieut. H. G. Wright, of the Corps of Engineers, and to Lieut. Randolph, of the revenue marine service.

Secondary and tertiary triangulation.—Lieut. James Totten, U. S. A., assistant Coast Survey, continued the triangulation eastward of Key West from the limits of his work of last year, about ten miles, to Johnson's key—Point Dora, twenty-five miles from Key West. (See Sketch F, No. 2.) The occupation of two more stations outside will carry it to Loggerhead key.

During the season Lieut. Totten measured a short base on Grassy key, and made a small triangulation to enable Lieut. Comg. Craven to execute the hydrography of Coffin's Patches.

The statistics given by Lieut. Totten in his report are as follows:

Number of stations occupied, including four reoccupied - - - -	29
Number of angles measured, including twenty-seven remeasured - -	193
Number of observations in measuring angles - - - -	7,904
Number of observations in remeasuring angles - - - -	1,501
Area in square miles - - - - - - - -	104

The services of Mr. C. T. Iardella, as aid to the party, are acknowledged with praise.

The office-work of the party has been brought up, and Lieut. Totten has been engaged in superintending the repairs of his vessel and the construction of the signals for the Florida reef.

Lieut. A. H. Seward, U. S. A., assistant in the Coast Survey, continued the interior triangulation from the points in Card's sound where it was left by the late lamented Lieut. Joseph S. Totten, to Grassy Point, in Barnes' sound—(see Sketch F, No. 2)—a distance of about eighteen miles. At this point the main land and inner keys are separated from Key Largo by merely a small creek, and no water communication with the outside exists between Angelfish and Tavernier creeks, a distance of nearly thirty miles; and Key Largo, which is from three quarters to a mile in width, and heavily timbered, separates the interior from the exterior triangulation.

"The bay inside is cut up into several small divisions by low marshy keys jutting out from the main shore. These smaller bays are connected with each other by narrow creeks, with bars at their entrances, over which not more than two and a half feet can be carried."

This survey was commenced on the 28th of December, 1853, and between that date and the 14th of May, 1854, the following work was done:

Number of signals erected, viz: 13 first order, 28 second - - -	41
Number of stations occupied, viz: 13 first order, 12 second - -	25
Number of sets of repetitions for measurement of angles - - -	796
Number of observations made for measurement of angles - - -	4,402
Area covered by the triangulation (square miles) - - - -	52

The instrument used was the twelve-inch Gambey theodolite, (C. S. No. 32.) Mr. C. B. Baker assisted Lieut. Seward in his observations. The party had the Coast Survey schooner Hassler for transportation.

Topography.—The topographical survey of the Florida keys, next to and within the reef, has been carried on by two parties; one of which was, besides, specially employed in marking and dividing the keys for the General Land Office. This work, which was commenced in the spring of last year at Boca Chica, east of Key West, was continued during the past season by Sub-Assistant I. H. Adams. (See Sketch F, No. 2.) The following-named keys were surveyed, marked, and measured: West Harbor key, the most northwesterly of the group referred to; East Harbor keys, Cayo Agua, Desolation, Hawk, Middle, Eagle Nest, Snake, Rockland, East Rockland, Big Coppett or Coppice, Half Moon, Shark, O'Hara, Geiger's key, South Saddle Hill, Round, Wall, Bird, and Pelican keys. These are all small keys, the aggregate area being forty-six square miles, and the total length of shore-line seventy miles and three quarters. The intersections of meridional with section and quarter-section lines were marked by numbered stakes planted at each intersection.

A tracing of the drawing of Mr. Adams has been communicated to the Commissioner of the General Land Office, and the determinations of Mr. Wainwright have also been placed at his disposal. (See Appendix No. 19.)

South Saddle Hill, so called, is the first object seen by navigators approaching this part of the coast, and has been mistaken for elevated ground. It owes its form, however, to a growth of tall mangroves, the inner trees of the group rising highest, and giving a rounded shape to the whole.

Mr. G. W. Parrish served as aid in this party, and his zeal and efficiency in the discharge of duty are specially referred to.

The report of Mr. Adams contains some interesting remarks and general information in regard to the character of the keys upon which the party was employed. (See Appendix No. 19.)

The party of Sub-Assistant S. A. Wainwright began operations in February, where the party of Mr. Adams had left them the previous season, at Old Rhodes key, (Sketch F, No. 2,) and proceeded in a southwesterly direction to Wednesday Point and Point Perry, on Key Largo North. This work includes several small keys, separated by narrow and intricate passages. The aggregate area is seven square miles, and the whole length of shore-line forty miles. This party also traced the shore-line of a portion of Bahia Honda for the hydrographic party. Mr. Wainwright left Washington in December to commence this work, but owing to the delay and injury to the vessel intended to furnish him transportation, (the schooner Joseph Henry,) was not able to commence operations until late in February.

The general features and character of the keys here referred to are described in the report of Sub-Assistant Wainwright. (See Appendix No. 19.)

Hydrography.—Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, having in charge the steamer Corwin, resumed operations in this section on the 15th of April, and has carried the hydrographic survey between the keys and reef from Pacific reef southward, and westward to Basin Bank, a distance of fourteen miles, and inside of the keys, over Card's sound. (See Sketch F, No. 2.)

A reconnaissance of Coffin's Patches, on the Florida reef, based upon the triangulation of Lieut. James Totten, U. S. A., assistant, has also been made during the season. (See Sketch F, No. 2.)

When on his way to the reef, Lieut. Comg. Craven repeated the observations for temperature and depth, made during the previous season on the St Simon's and Cape Canaveral sections of the Gulf Stream, noticed in my report of last year. The results, which confirmed those of the previous season, are given under the head of the "Gulf Stream."

Touching at Havana, on his way to Key West, Lieut. Comg. Craven was called upon, in behalf of the Department of State, by the consul at Havana, to convey to Charleston, South Carolina, the despatches in relation to the seizure of the steamship Black Warrior by the authorities of Cuba. On his return thence, the survey of the reef was commenced and continued until the 1st of June, when sickness broke out among his crew, one case of which terminated fatally, and obliged him to return to New York.

While engaged on the Florida reef a convenient harbor of refuge was discovered by the hydrographic party, near Turtle reef, and which, from its position, Lieut. Comg. Craven has named Turtle harbor. This harbor is four and a half miles to the northward and westward of Carysfort light-house, and when marked by a beacon and buoys, will become an important harbor of refuge. Twenty-six feet of water can be carried into the anchorage, where the bottom is soft clay. The particulars of this discovery were communicated to the department and published, (see Appendix No. 15,) and the recommendations of Lieut. Comg. Craven in regard to a beacon and buoys at the entrance of the harbor have been communicated to the Light-house Board. A sketch of Turtle harbor is prepared for this report. (Sketch F, No. 3.)

Lieut. Comg. Craven has reported the following statistics of the season's work:

Number of miles run in sounding	774
Square miles of area surveyed	131
Whole number of soundings	41,522
Number of angles used	1,714
Greatest depth of water (fathoms)	64

Lieut. Comg. Craven subsequently made a hydrographic reconnaissance of Wimble shoals, on the coast of North Carolina, referred to under the head of Section IV, ran a portion of a section of the Gulf Stream off Cape Cod, made numerous light-house examinations on the coast of Maine, and current, tidal, and other observations in Portland harbor. The details of these valuable and long-continued labors are stated in the notice of the hydrography and light-house examinations of Section I.

It is known to navigators that there are passages at particular points through the Florida reef by which safe and comparatively protected navigation may be had; but where these positions are, is not generally known. One important object of the sea-marks in course of erection on these reefs, will be to enable navigators to ascertain precisely their position along the reef, and to be able to avail themselves of such passages through it as the Coast Survey points out. The important observation has been made by Lieut. Comg. Craven, (see Appendix No. 16,) that bringing Indian key to bear in any direction from N. to N.W. by N. and standing for it, will carry vessels safely over the reef in not less than eighteen feet water.

Tidal observations were made in St. Augustine harbor on a staff-gauge, and others for comparison, during the day-time, near the light-house. The former were continued as long as was deemed necessary for the comparison with other stations; they were under the direction of Assistant George A. Fairfield.

The same officer made the arrangements for establishing a self-registering gauge at Cape Florida, where Mr. L. E. Tansill, who had been in charge of the gauge at Bolivar Point, was stationed. These observations were closed in October, and the observer was directed to repair to Indian key to establish a gauge there.

Lieut. Comg. Craven stationed a tidal observer at Indian inlet, but the washing away of the gauge in a storm, and the sanding up of the channel, soon interrupted the observations.

On his way to Cedar keys, Lieut. Comg. Berryman, U. S. N., assistant in the Coast Survey, established a self-registering gauge at Egmont key, Tampa bay, and left

Corporal Thompson, of the engineer company A, in charge. The observations were continued until August, when the observer was transferred to St Mark's.

Light-house examinations, &c.—A sketch of the reconnaissance of Coffin's Patches (see Sketch F, No. 4) was transmitted, with the suggestions of Lieut. Comg. Craven in regard to a light for the vicinity, in a letter addressed to the Secretary of the Light-house Board, a copy of which is given in the Appendix, No. 73.

The report of Lieut. James Totten, U. S. A., assistant in the Coast Survey, on the mode of establishing sea marks and their places upon the Florida reef, having been approved by the Light-house Board, he was requested to execute the plan under the appropriation for the purpose, and has prepared the necessary drawings and had the castings made in conformity with the specifications. These will, it is expected, be completed in time to erect the signals during the coming season.

SECTION VII.—FROM ST. JOSEPH'S BAY TO MOBILE BAY, INCLUDING PART OF THE COAST OF FLORIDA AND ALABAMA. (SKETCH G.)

There were no means particularly appropriated to this section, but at the close of the first half of the surveying year, such as could be spared from other sections were applied to beginning or continuing some of the most pressing work. As I have several times stated, this section can hardly by any exertion be brought up to the line of progress of the others. The estimates for the next fiscal year contain an item for the section which had been inserted in the approved estimates, and which will secure greater progress for the next year. As the case stands, however, more progress would have been made in the land-work, but for a series of mishaps which retarded the parties sent to execute it.

Interesting information in regard to Cedar keys, in reply to inquiries by Hon. D. L. Yulee, will be found in the letters of Assistant F. H. Gerdes and Lieut. Comg. Berryman, (Appendix Nos. 26 and 27,) and in relation to Tampa bay, by Lieut. Comg. Berryman, (Appendix No. 25.)

Besides the reconnaissance and progress-sketches of this section, a map of Cedar keys has been commenced, and the tidal results for Tampa computed. Like Cedar keys, the tide at Egmont key (Tampa) has a large diurnal inequality; but the rise and fall is less, being at Cedar keys 2.5 feet, and at Egmont key 1.7 foot. Corporal Thompson is now observing at St. Mark's.

Astronomical and magnetic observations.—Observations were made at Cedar keys, (Depot key,) St. Blas, and St. Andrew's bay, with a portable transit, for time, giving the approximate difference of longitude. The latitudes were only a rough approximation, as a failure in transportation had deprived Mr. Gerdes of the usual appliances. Observations for magnetic variation were made at the astronomical stations, which were duly marked for reference. Two nights' observations for difference of longitude were made at St. Blas, and two at St. Andrew's.

Triangulation and topography.—The preliminary triangulation and topography were continued at Cedar keys in December, (see Sketch G, No. 2,) four new signals erected, and five old ones re-established and determined. The topography covered about twenty-one square miles of area, the shore-line of islands being about forty miles, and of marsh and main land about one hundred miles. This extension of the topography was for immediate use by a hydrographic party. A preliminary base was laid out at St. Andrew's and marked, and its azimuth determined; and a general reconnaissance for a triangulation of the entrance was made. I expected that the secondary triangulation and topographical party sent to St. Andrew's would have had the advantage of Mr. Gerdes' presence, in commencing their work; but the extraordinary delay of the small vessel having the instruments and men of the party on board, and other circumstances, interfered entirely with my arrangements, and the only operations at St. Andrew's bay were those above referred to.

A preliminary triangulation was made at Ocilla river, Apalachicola bay, by Sub-Assistant J. R. Offley; and the topography, by Assistant George D. Wise, followed the triangulation closely. (See Sketch G.) A local base was measured with a chain; five station-points were established, four of which were occupied; and nineteen angles measured by one hundred and eighty-nine observations upon nine different objects. The plane-table survey of Mr. Wise embraces two miles at the entrance of the river, and extends three miles up the stream. These two parties had the use of the Coast-Survey schooner Franklin, transferred by Mr. Wise from Section III.

Hydrography.—The party of Lieut. Comg. O. H. Berryman, U. S. N., assistant in the Coast Survey, having in charge the schooner Crawford, reached Cedar keys on the 14th of March, and, after being employed a short time in erecting necessary signals, proceeded to execute the hydrography of that vicinity. This work includes Sea Horse reef, and a considerable portion of the space between it and the Oyster reefs, in the direction of Crystal River offing, together with the very numerous channels and shoals between the keys. (See Sketch G, No. 2.)

The following is an extract from the report of Lieut. Comg. Berryman, in relation to the natural features of Cedar keys and their approaches:

"The whole vicinity of these keys exhibits a series of flats, frequently exposed at low water, and covered occasionally with a thin mud which sustains a fine growth of grass.

"The best entrance to the keys for sea-going vessels is through the main ship channel from the south; the approach is easy, and the anchorage good in all winds from west-southwest to east by the north.

"The bar is distant two miles from Sea Horse key, and has, at ordinary low tides, ten feet of water on it; but the depth is considerably reduced by easterly, and increased by westerly gales. It cannot be safely crossed in a gale, or when the swell is high.

"All the channels leading to Depot key are narrow and crooked."

Further information in regard to these keys and their approaches will be found in the Appendix No. 26.

Lieut. Berryman closed the operations of his party in this section in the middle of June, and reports the following statistics:

Number of lines of soundings run	1,531
Number of soundings	57,400
Number of angles	3,009
Number of miles of soundings	985

The office work of the party has been completed, including the hydrographic sheet of the present season.

On his way to Cedar keys, Lieut. Comg. Berryman put up a tide-gauge at Egmont key, landing Corporal Thompson to take charge of it.

A hydrographic reconnaissance of Tampa bay, included in my instructions to Lieut. Berryman, was rendered impracticable by desertions from his crew and other causes. Some important information, however, in regard to the channel and anchorages, based upon general observations, or collected from local sources, will be found in extracts from a letter written by that officer. See Appendix No. 25.

At the end of December, a request was made by the Light-House Board for information upon which to base estimates of appropriation for the beaconage and buoyage of Apalachicola bay, Florida. This was accordingly included in my instructions to Assistant Gerdes; but as action thereon had been anticipated by the Chamber of Commerce of Apalachicola, his report, in which is expressed a general concurrence with the views of the petitioners to Congress, is not further referred to.

SECTION VIII.—FROM MOBILE POINT TO VERMILION BAY, INCLUDING THE COAST OF MISSISSIPPI AND PART OF LOUISIANA. (SKETCH H.)

In this section the officers of the Survey have had, during the past season, more trials of endurance, and less of the reward of success, than usually falls to their lot. Not only was the weather generally unfavorable to work, but the hurricane of March 30–31 swept over the coast where two of our small vessels were employed, stranding one and capsizing and sinking the other. Happily, no lives were lost in either case; but the stranded vessel was put afloat, and the sunken one raised, at a loss of time and means that told heavily upon the operations of the parties using them. In neither case could human care or foresight have availed to prevent the result. The progress of the primary triangulation party was thus cut short, and that of the reconnaissance party much abridged. It will be seen, however, that the coast has been examined from Fort Jackson, on the Mississippi, to Chandeleur bay, with promising results as to the triangulation, and with hardly less promise from Pass Fourchon, across Barataria bay, to New Orleans; that a special reconnaissance has been made of Pass Fourchon, developing an increased depth on the bar; and that a triangulation has been laid out for Atchafalaya, Cote Blanche, and Vermilion bays, part of which will be executed this season. The secondary triangulation has encountered many minor difficulties also, but has been carried to a line from the marine hospital, opposite New Orleans, to Greenville. The hydrography, both in and off shore, has made good progress, covering Mississippi and Chandeleur sounds, and extending off-shore from its former limit to the meridian of the western end of Horn island. Valuable results have been developed in regard to temperatures and depths, which will be found stated under the head of hydrography in this section. A shoal supposed to exist in latitude 27° N., south of the Belize, has been looked for, but no bottom found at one hundred fathoms on its alleged site. The information collected by Assistant F. H. Gerdes in regard to the coast of Louisiana is quite interesting, and is embodied in an article in the Appendix No. 20. Another tidal station at Calcasieu has been added to those heretofore occupied in this section, leaving but a few more stations to be made on the Gulf coast for the full development of tidal results.

A map of the coast of the section from his reconnaissances and other information has been prepared by Assistant Gerdes, and will accompany this report. The general chart of Mobile bay has been published. The larger chart is nearly engraved. Mississippi sound No. 1 is nearly engraved, and a second sheet is in the hands of the draughtsman. The progress sketch, accompanying this report, has been made to show some of the prominent results of the hydrography.

Reconnaissance.—The schooner used by the party of Assistant F. H. Gerdes left Cedar keys on the 8th of March, and passing around the Delta of the Mississippi, arrived soon after in Atchafalaya bay. Passing down the Mississippi from New Orleans to Fort Jackson and Fort St. Philips, Mr. Gerdes reconnoitred, in boats, near the Battledore islands, Isle au Breton, Beach island, and through Swan bay and the adjacent rivers, (see Sketch H,) to determine the practicability of connecting these various points by triangulation with Lake Borgne. A series of triangles was projected, which will, in his opinion, serve the desired purpose. The location of the upper points on the lake was, however, prevented by the severe gale of March 30th and 31st, which made further progress in that vicinity, at the time, impossible.

Having returned to New Orleans, Mr. Gerdes reconnoitred, by way of Bayou Plaquemine, westward to the Atchafalaya, through a country offering no facilities for triangulation.

In the hurricane of March 31st, the schooner "Gerdes," then in charge of a capable sailing-master, was driven on the shore east of Bayou Lafourche. Mr. Gerdes took the necessary steps for her relief and subsequent repairs; but the time consumed in these prevented, of course, his work from making the expected progress.

Though deprived of the use of his vessel, Mr. Gerdes made a special reconnaissance of Pass Fourchon, the principal outlet of Bayou Lafourche. (See Sketch G, No. 2.) He reports that within two years the depth of water has nearly doubled on the bar of this pass, and that now eight feet can be carried across it. A description of the pass will be found in Appendix No. 20. Mr. Gerdes recommends a light here, and also a day-beacon on the east side of the pass.

Mr. Gerdes continued a reconnaissance (see Sketch G, No. 2) through Lake Rondo and Barataria bay, Bayou St. Denis, and so onward into Lake Salvadore and to Lafayette, finding no obstacle to a triangulation along the whole route, except the fringe of woods on the edges of the bayous and lakes, and on the bank of the Mississippi. A general description of the coast of Louisiana west of Atchafalaya bay, chiefly from information collected from intelligent residents, is given from Mr. Gerdes' report, in the Appendix No. 20. The general closing remarks on the development of the Gulf coast of Louisiana within the last ten years, and the increasing facilities for communication, will be found of particular interest.

Mr. J. G. Oltmanns has rendered efficient aid as sub-assistant in this party during the season. The records of the work, (16 volumes,) in duplicate, were turned into the office in September last.

Mr. Gerdes, in August, resumed the survey of Hudson river, reference to which is made under Section II.

Primary triangulation.—The progress of the primary triangulation in this section had been suspended for several years past on account of other important duties of Assistant Gerdes, who had it in charge. These duties continuing during the present year, Assistant J. E. Hilgard was charged with its prosecution.

On examining the stations, it was found that from changes in the coast, caused chiefly by the hurricane of August, 1852, it was necessary to fall back upon the line East Pascagoula to Horn Island East as the base for the continuation of the primary triangulation.

Mr. Hilgard took the field early in January, assisted by Mr. Stephen Harris. The season proving very unfavorable, little progress was made until the latter part of March, when the observations at stations East Pascagoula, Horn Island East, Horn Island West, and Bellefontaine were nearly completed. On the 31st of March the schooner Phœnix, which was used by Mr. Hilgard in the work, was capsized and sunk at her anchorage by a tornado. Mr. Hilgard and his party, who were on board at the time, providentially escaped in a boat, after incurring great peril. Measures were immediately taken for the recovery of the vessel; but, owing to boisterous weather and other difficulties, three weeks elapsed before she was raised and the property on board recovered.

The records of the work already done, together with other valuable papers, had disappeared; having, probably, been washed to pieces or drifted out to sea. The instruments were damaged to a considerable extent, but great pains were taken to prevent further destruction by rust after their recovery. An interesting notice of the action of sea-water on metals will be found in Appendix No. 55.

Owing to this disastrous occurrence, the work of primary triangulation has again remained stationary. It was deemed inadvisable to continue it then, as the vessel required extensive repairs and the season had already far advanced; in addition to which, the funds available for the purpose had been exhausted by the expenditures incurred for recovering the vessel. This work will be resumed as early as practicable by Mr. Hilgard.

Assistant Hilgard made use of a new kind of signal intended to replace heliotropes in localities where heliotropers cannot well be posted. The plan was suggested some years ago by Assistant Wm. M. Boyce, and the signal was put in the present form by Mr. Hilgard. It consists of three curved reflectors, each a segment of a cylindrical surface, the axis of which is horizontal, three inches wide, and eighteen to twenty-four inches high, with a curvature of from 23° to 30°. These are arranged on a frame, revolving about a vertical axis, and provided with wings, so as to be turned by the breeze, which scarcely ever fails on the coast or on heights. The reflectors send a rapid succession of bright flashes all around the horizon, which frequently appear continuous. They have been made of common sheet-tin, with good effect. German silver is preferred, as less liable to tarnish, which makes it even preferable to silver, though the latter, in the form of the common daguerreotype plate, could be readily employed.

The site of the base-line on Dauphine island, which was encroached on by the gale of August, 1852, as stated in my last annual report, was examined by Assistants Gerdes and Hilgard, who, having assisted in the measurement, were able to bring their personal recollection to bear on the recovery of marks. They report that the monument at the west end of the base has been dislodged by the sea, as well as the stones which had been placed for the verification of the monument. They found undisturbed, however, two accurate marks, which were made at the time of measurement, at distances of 714 and 1,470 metres from the monument. From them the position of the monument may be recovered by a remeasurement, or a new terminus may be established, a short distance to the eastward of the former ones, in a position, possibly, less liable to the encroachment of the sea.

Mr. Hilgard has been in charge of the computing division since his return to the office, and has also executed field-work in Section II, of which a notice will be found in its place.

Secondary triangulation.—The secondary triangulation of Lake Pontchartrain has been carried to New Orleans during the past season by Assistant S. A. Gilbert. As was the case with the other parties, this one was much delayed by bad weather and by the consequences of severe storms. A house had been built at Greenville, near New Orleans, across one of the lines opened last year, causing a new delay, by the necessity for finding and opening another line. A signal, erected with much labor near the middle of the lake, was wantonly destroyed, causing further delay. These obstacles were finally overcome, and the triangulation was carried on according to the scheme shown in Sketch H. The work was commenced at the end of December, and closed early in June, six stations having been occupied, and twenty-four angles measured with a repeating theodolite (C. S. No. 23) by Gambey.

After the close of the season, Mr. Gilbert was occupied in putting in ink the topography of a sheet of Plymouth harbor, surveyed in 1853, and in making duplicates and reductions of his observations of the past season. He has since made a plane-table survey in Section I, near Cape Small Point, for the site of a light-house.

Hydrography.—The hydrographic work of the party of Lieut. Comg. B. F. Sands, U. S. N., assistant in the Coast Survey, was unavoidably delayed by the difficulty of procuring men for the steamer Walker, under his command, at Pensacola, where the vessel had been laid up, so that it was not commenced until the middle of March. The weather, too, throughout the season was more than usually unfavorable in this section. The first work executed was the search for a shoal in latitude 27° N. and longitude 89° W., south of the Belize, which resulted in disproving its existence. Two hundred and eighty miles were run over the supposed location without finding any shoal water. (See Appendix No. 18.)

In going to and returning from the search just mentioned, lines of deep-sea soundings for depths and temperatures were run; and in prosecuting the general hydrographic work of the section, lines of the same character were run—one fifteen miles distant from and parallel to the coast, outside of off-shore work of the previous season, another from the east end of Horn island to Pensacola, and a third from the east end of Ship island southeasterly until off soundings in the direction of Key West.

Between latitude 28° to 26° 40′, and within thirty minutes of longitude of Pass à Loutre, (the latitude of the entrance of the pass being 29° 10′,) the temperature of the water at the surface was found to be from 77° to 78° Fahrenheit, the air being from 72° to 77°. At thirty fathoms, within the same limits, the temperature was about 77°, but the sub-surface temperatures were very irregular. These observations were made on the 5th, 6th, and 7th of April, 1854. North of latitude 28° 40′, 1° east of Pass à Loutre, the temperatures at the surface were 70°, 69°, and 68°, on the 8th and 9th of April; the air being 71° and 70°, and the temperature at fifteen fathoms 70.5° and 68°, showing, within forty nautical miles, a fall in the temperature of the surface, and below, of some eight degrees Fahrenheit. This remarkable change requires further investigation, as it must produce currents of considerable strength, and other results important in the navigation of the Gulf.

What is not a little curious is, that the bottle thrown overboard in latitude 28° 58′, in the longitude of Mobile, where the surface temperature was 69°, was found near Jupiter inlet, on the eastern coast of Florida, having found its way, probably by wind and counter-currents, into the comparatively warm current of the Gulf Stream. (See Appendix No. 52.)

Notwithstanding the adverse circumstances of weather, before alluded to, Lieut. Comg. Sands succeeded in carrying the outside soundings from the meridian of Round island, off Horn island, twelve miles to sea, and westward to the entrance between Cat and Ship islands, in Chandeleur sound, joining his previous work in Nassau roads, and that of Lieut. Comg. Patterson off Ship island.

Some boat-work, attempted at the entrance between Horn and Ship islands, proved to be impracticable on account of the weather.

Sketch H shows the character and limits of the work, the statistics of which are as follows:

	Area.	Miles run in sounding.	Casts of lead.	Angles.
Off the Belize	....	280	53	....
Deep-sea soundings	....	347	288	....
Outside of Horn and Ship islands	163	540	11,602	546
	163	1,167	11,943	546

Lieut. Sands closed the season's operations on the 1st of June, taking the steamer to Philadelphia for repairs, and returned to execute his office-work in Washington.

A very instructive fact as to the course of the Gulf Stream was obtained from finding a bottle on the eastern coast of the Florida peninsula, near Mosquito inlet, which had been thrown over by Lieut. Comg. Sands seventy-eight nautical miles south of the west end of Dauphine island. The bottle was thrown over on the 8th of April, and found on the 6th of June. Mr. Douglas Dummett, to whom we are indebted for this information, (see Appendix No. 52,) remarks, that he had passed over the beach four days before without seeing the bottle. We are sure of the direction of the current, the place upon the shore agreeing with the motion onward and outward from the axis of the Gulf Stream. The distance gone over, if the bottle took a direct course, was about seven hundred and fifty nautical miles, and the time fifty-nine days; this, if the motion were uniform, would be at the rate of nearly thirteen miles per day—an inference which, however, cannot be drawn with any certainty.

Tidal observations.—At Calcasieu, Louisiana, Mr. Gustavus Würdemann was engaged from February 24th until May 25th in recording, half-hourly, the height of the tide, and in hourly meteorological observations in connection with the tidal.

The tides here present an exception to the general rule of single-day tides west of St. George's, agreeing in this respect with Galveston, nearly. Though the double tides are small and irregular, and much influenced by the wind, yet there are distinctly two ebbs and two floods, as a rule, in one lunar day. The faithfulness of Mr. Würdemann's observations is in no manner more strikingly shown than in developing opposite peculiarities with the greatest certainty, passing from Aransas Pass, where the tides are single, to Calcasieu, where they are double, and yet being entirely unprejudiced as to what the phenomena should be, and seizing the double character of the Calcasieu tides as readily as the single ones of Aransas.

SECTION IX.—FROM VERMILION BAY TO THE BOUNDARY, INCLUDING PART OF THE COAST OF LOUISIANA AND THAT OF TEXAS. (SKETCH I.)

The resources of this section have, in a great degree, been taken up by a renewal of the outfit for the hydrographic party. The schooners Morris and Belle, when transferred to the Coast Survey, were old vessels, and have been repaired from time to time, until, at the close of the last season, they were condemned as unseaworthy—the first after being left in Pensacola harbor by her officers, in a sinking condition, and the second having sunk in a gale in Galveston bay. The frequent changes of officers, which were unavoidable in this section, and the heavy comparative expenses for supplies of every kind, have rendered the progress of the work there less than it would otherwise have been. The assistant in charge of the land-work having resigned, and the hydrographic officer having been necessarily transferred to replace one of the chiefs of parties detached from the survey, the officers in the section this season were new to the localities, and the chief of the hydrographic party to the duties of the Coast Survey. We have now an effective vessel, the schooner Arago, expressly arranged for this section, where light draught and good qualities as a sea-boat must be combined. The party is preparing at once to commence work afloat.

Triangulation and topography.—The work on the southwestern boundary, executed in the present season by Assistant W. E. Greenwell, included the measurement of a base-line, for which, after reconnaissance, he selected a sight on the Texan side of the Rio Grande. He remarks, in reference to it: "The site is a good one, running over level prairie, and its approximation to the river gave several collateral advantages for ready measurement. The line was first surveyed with the plane-table and chain—stakes being placed at intervals of eight hundred metres. It was finally measured with two four-metre bars of iron, placed on beds of pine, the cross-sections of which were angular.

"The base measured four thousand three hundred and forty metres, or two miles and four-fifths, nearly.

"Six persons were required in the measurement, which occupied twenty working hours, and the last hundred bars were remeasured, with a result nearly identical with the first measurement."

Between the 7th of November, on which day the party landed at Brazos St. Iago, and the 12th of April following, the triangulation was extended from the line joining that station with Point Isabel, about nine miles north of the Rio Grande, to a point five miles south of that river. (See Sketch I, No. 2.) The accuracy of this work is unquestionable, most of the triangles closing within one second in angular measurement. In the series eight stations were occupied, ten signals erected, and forty-four angles measured by two hundred and seventeen sets of observations. The whole number of single observations was two thousand six hundred and ten, within an area of forty-three square miles.

The instrument used was the eight-inch Gambey theodolite, (C. S. No. 36.)

The topography carried on in connection with the triangulation was extended by Assistant Greenwell beyond its limits, covering sixty-three square miles. Within this area fourteen miles of roads, seventy-six miles of outline of lagoons, and one hundred and nine miles of shore-line, were surveyed.

The schooner Guthrie was, during the season, in charge of the party of Assistant Greenwell, who makes the following remarks on her passage, in reference to the purposes incidentally subserved by Coast Survey signals on the Florida coast and the published sketches:

"We ran down inside the reef, from Cape Florida to Key West, without a pilot; and, though no one on board had been previously inside, we found our way without difficulty. The sketch of this part of the coast, published in the Coast Survey Report of 1851, was of great service. I was enabled by it to identify the islands; and the screw-pile signals on the reef served as beacons, pointing out dangers otherwise concealed.

"These must be advantageous to vessels trading in and out of the Gulf, and, with a good look-out, cannot fail to prove in the day-time aids to the safe navigation of the coast."

Mr. P. C. F. West served as aid in the party of Mr. Greenwell, and his services are mentioned in terms of praise.

Interesting information, collected incidentally by Assistant Greenwell while engaged on duty in this section, will be found in extracts from his report. (Appendix No. 21.)

This survey has been communicated to the Commissioner and Astronomer of the Mexican boundary, Lieut. Col. Emory, at whose instance, under the authority and by request of the former Commissioner, General Robert B. Campbell, it was undertaken, and the connected triangulation and topography pressed forward to completion.

The station-points used by Mr. Greenwell have been carefully secured.

Hydrography.—The hydrography has been under the charge of Lieut. Comg. E. J. De Haven, U. S. N., assistant in the Coast Survey, by whom the schooner Arago was equipped early in March last. On the way out, the condition of the light-vessel on Ship shoal (Isle Dernière) was ascertained by Lieut. Comg. De Haven, at the request of the Light-house Board. On arriving at Galveston, it was found that the schooner Belle, which had sunk in Galveston bay, could not be repaired, so as to be available for work without considerable expense and delay; hence the soundings required near Red Fish bar, and in East bay, were made at a great disadvantage with the Arago. The operations were also delayed by bad weather, and by desertions. The additional hydrography at the Rio Grande was attempted, but, from bad weather and other causes, was not executed. The work in West bay was commenced; and the schooner Belle, having been raised, was placed under repair. The number of soundings made was 13,292; number of miles of soundings run, 264; number of angles observed, 498.

The charts resulting from the work have been plotted and returned to the office.

Tides.—The great irregularities of the tides at Galveston required a long series of observations there, which was closed in 1853, and the discussion of which has been steadily in progress under my immediate direction. Comparative observations were also made at Bolivar Point, and the self-registering gauge there gave good results for the law of rise and fall. The tides at East Bayou, at the entrance of the Mississippi, and also at Isle Dernière, west of it, being of the class which ebbs and flows but once in twenty-four hours, except at special times of the month, we were not prepared for the frequent occurrence of the double tides at Galveston. The observations show, however, in ninety-seven tides, twenty of the single ebb and flood in the twenty-four hours, and seventy-seven of the double. This, it appears, however, is not an isolated case, as the observations of Mr. Würdemann at Calcasieu show a similar exception there. The tides have so small a rise and fall at Galveston, and are so much influenced by the wind and by its action on the expanse of water of Galveston bay, as to have much increased the difficulty in discussing these results. The observations were made by Mr. F. Muhr and Mr. L. E. Tansill.

When the tidal observations at the Brazos were completed in October last, by Mr. Gustavus Würdemann, he occupied a station at Aransas Pass for three months, and next repaired to Calcasieu. Since closing his work there he has been engaged in observing the tides of Nantucket sound and the adjacent coast, Section I.

The tides at the Brazos St. Iago, and at Aransas, are single-day tides, as completely as those of Pensacola or Fort Morgan, not breaking, as the moon crosses the equator, into two small tides, but retaining their special character through the whole lunar month. The curves for all these stations have been drawn, and they have been discussed, according to my method of decomposition, under my direction, by Assistant L. F. Pourtales and Mr. H. Heaton. The careful and consciencious observations of Mr. Würdemann show their full value in these discussions. The results will be published as completed.

It may be of interest to present a condensed table showing the character of the tides from East Bayou, Mississippi entrance, passing by Isle Dernière, Calcasieu, Galveston, and Aransas, to the Brazos St. Iago.

	Total number.	1. No. of single-day tides.	2. No. of double tides.	
E. Bayou, mouth of Mississippi, February.	28	28	0	Scarcely any tide when moon crosses equator.
Isle Dernière, April	26	15	11*	*Two days before and two days after moon crosses equator, double tides.
Calcasieu, May	26	4	22	
Galveston, March and April	106	14	92	Smallest number single-day tides.
Galveston, May and June	89	27	62	Largest number single-day tides.
Aransas Pass, November and December	61	45	16*	*One to two days before and after moon crosses equator.
Brazos St. Iago, August	29	21	8*	*One to two days before and after moon crosses equator.

1. One ebb and and one flood in twenty-four lunar hours. 2. Two ebbs and two floods in twenty-four lunar hours.

SECTIONS X AND XI.—COAST OF CALIFORNIA, AND OF OREGON AND WASHINGTON TERRITORIES.

The survey has made good progress in both these sections. The year, which has been so unfavorable to the work on the eastern coast, has been generally the reverse on the Pacific. The great mass of preliminary surveys and reconnaissances required there have been nearly executed, and the regular operations have, in part, taken their place. Astronomical and magnetic stations have been added to those previously determined; and observations for longitude, by the solar eclipse of May 26, were made at Humboldt, near San Francisco, and at Benicia. The regular system of primary triangulation has been commenced by measuring the Pulgas base, and carrying the triangulation both northward and southward, so that now it extends from Sonoma Mount, in latitude 38° 16′, to Salinas Mount, in latitude 36° 24′, one hundred and twelve minutes of latitude, or from Ballenas bay to Point Pinos, Monterey bay. The preliminary base, measured near San José, for beginning the triangulation of San Francisco bay and its dependencies, has been connected with, and verified satisfactorily by, the Pulgas base.

A preliminary triangulation of the Straits of Rosario and Canal de Haro has been made, and the shore-line sketched in. Vertical angles for heights have been measured.

Humboldt harbor has been triangulated, and a topographical survey of it made, from Eureka to a point one and a half mile south of the entrance. Upon the base, measured on the plain near Los Angeles, a triangulation has been carried northward and southward, determining the position of Santa Catalina island, and intended to connect the Santa Barbara islands and the main.

The topography of the shores of San Francisco bay has been executed, and that of the outer coast has been carried from Point Año Nuevo to Monterey, and then north of Point Año Nuevo, nearly to the connection with San Francisco bay. That of the shores of Tomales bay has been executed; that of the main coast, from north of Duxbury reef, along Ballenas bay, has been completed, to connect with San Francisco bay.

The hydrography of the Straits of Rosario and Canal de Haro and approaches has been completed, and a reconnaissance made of Duwamish bay and Seattle harbor, and of Port Townsend anchorage. The reconnaissance from Puget's sound to the Columbia has been revised, and additional work has been done for the general reconnaissance of the coast.

In the course of this northern work, a four-and-a-half-fathom bank has been discovered at the entrance to the Straits of San Rosario.

The survey of San Francisco entrance has been completed, and that of Duxbury reef and Ballenas bay connected with it. Some work has been done in the interior of the bay.

Special surveys for light-houses have been made at Point Bonita, Point Año Nuevo, Santa Cruz, and Anacapa.

The systematic observations of tides have been continued with excellent results. Permanent self-registering gauges have been kept at Astoria, San Francisco, and San Diego; the number of temporary stations required between San Diego and San Francisco has been completed; and in the next division north, nearly so. The developments from these observations have been of a useful and interesting kind—most useful to navigators, as showing the laws of the diurnal inequality, which in the Pacific is large, causing a marked difference in the morning and afternoon tides of the same day.

Within the year, drawings have been completed of the progress sketches for the two sections, of Santa Cruz harbor, Point Año Nuevo, Pulgas base, San Francisco entrance, Alden's reconnaissance north of San Francisco; tides of San Diego, San Francisco, and Astoria; of anchorage at Shelter cove, Mendocino city, Crescent city, Point St. George, Ewing harbor, Umquah river.

The engraving of Alden's reconnaissance San Diego to San Francisco, Cortez Bank, San Diego entrance, Rincon Point tidal diagrams, Pulgas base, tidal diagrams of San Diego, San Francisco, and Astoria, has been completed during the year, and the others are in progress.

Astronomical and magnetic observations.—Finding it impossible to reach Cape Mendocino to occupy an astronomical station there, Assistant George Davidson established one at Humboldt bay, in connection with the triangulation which he had laid out, and made the usual observations for time and latitude, until he received instructions to proceed to Washington Territory for the continuation of the triangulation of last year in the Gulf of Georgia.

Mr. Davidson observed the beginning and end of the solar eclipse of May 26 at Humboldt, and the transit of the moon's second limb, and of the sun's second limb during the eclipse. The details of his observations will be found in Appendix No. 40, where his report is given at length.

The statistics of his astronomical and magnetic work for 1853, which were not received in time for my annual report of last year, are as follows:

Localities in Sections X and XI.	Longitude.				Lat'tude.			Magnetic variat'n.	
	No. of stations.	No. of observations.	Moon.	Moon culminating stars.	No. of stations.	No. of observations.	No. of pairs and triplets.	No. of stations.	No. of observations.
San Francisco	1	1,332	47	265					
Northern reconnaissance	15	307	1	4	10	158	147	1	50
	16	1,639	48	269	10	158	147	1	50

The statistics of astronomical work in Humboldt bay are as follows:

For longitude, three hundred and twenty-six observations of the moon and moon culminating stars with transit C. S. No. 2, and an occultation of *i* Leonis. For latitude, eleven hundred and eighteen (1,118) observations on eighty-three pairs of stars with the zenith telescope C. S. No. 3, besides one hundred and fifty-one observations for the value of the micrometer screw. For magnetic declination, two hundred and thirty-seven observations were made upon nine different days with a Jones declinometer No. 3. Meteorological observations, eight hundred and eighty-two in number, were also taken.

Assistant R. D. Cutts observed the eclipse at Black Mountain station, one of the primary points of triangulation near San Francisco, (Sketch J,) that station being selected as lik ly to overlook the fog prevailing at this season of the year. The details of the observations, extracted from Mr. Cutts' report, are given in Appendix No. 40, omitting those for the time observations. Mr. Cutts exerted himself successfully to induce other observers to co-operate with him. The observations of Prof. Nooney, made at Benicia, are given in the Appendix No. 40. Others made near San Francisco are defective in reference to local time, and cannot be presented without further information in regard to them.

Lieut. W. P. Trowbridge, Corps of Engineers, assistant in the Coast Survey, made preparations at Monterey to observe the solar eclipse of May, but the weather there was cloudy.

I was indebted to R. T. Paine, esq., of Boston, (whose persevering labors in the prediction of occultations and eclipses have earned so much approval,) for timely computations for points on the Western coast, which were forwarded to the assistants there. It will be seen that generally they were received in time to make the necessary arrangements for observing, and that the zeal of some of the officers had anticipated the instructions to observe.

In addition to the charge of the tidal observations in these sections, Lieut. W. P. Trowbridge was instructed to make the usual magnetic observations whenever opportunity offered. During the year he has observed for declination, (variation,) dip, and intensity at four stations, namely: San Diego, San Pedro, San Luis Obispo, and Monterey. The observations for declination and horizontal intensity were with the portable declinometer of Weber and Lloyd, (C. S. No. 2;) for dip, with a Barrow dip-circle, (C. S. No. 2.)

At San Diego one set of results was obtained for declination, one for absolute horizontal intensity, and three, on three different days, for dip. At San Pedro, San Luis Obispo, and Monterey, seven sets for declination in connection with the azimuth of a mark, one for intensity, and three for dip. (See Appendix No. 30.)

Measurement of Pulgas base.—The preliminary measurement of Pulgas base was executed during June, 1853, by Assistant R. D. Cutts. This base-line is situated about thirty miles southward of San Francisco, on the low lands bordering the bay, and presents every essential requisite for its purpose. Nearly twelve working-days, between June 11th and June 27th, were expended in the actual measurement of 2,627 four-metre boxes, and the final corrected length was found to be 10,512.06 metres, or about six miles and a half. The extremities were marked by permanent monuments, the eastern end being 127.281 feet, and the western one 5.568 feet above high-water mark. Each of these monuments consists of an underground brick structure, enclosing a free-stone block, in which a copper bolt is sunk, and the extremity of the base is marked by cross-lines on the bolt-head, over which a stone cap is laid.

The measurement was executed with two iron rods of a half-inch diameter, each of which was four metres long. The ends were squared, and one side of each was plated and marked with the limiting line. Ten comparisons of each with the Hassler two-metre bars E and H were made before and after the measurement; the value of the micrometer divisions having been deduced from twenty-five measurements of the graduations on a $\frac{1}{1000}$ metre scale. Two inflexible oak-plank boxes and four trestles were employed for carrying and supporting the rods. Previous to each contact, the rod was levelled by a spirit-level with blocks and wedges. The alignment was made by a ten-inch Gambey theodolite, from one hundred and fifty to three hundred metres in advance. The contact was observed by means of the silk thread of a plumb-bob suspended in a bucket of water; and when this was correctly adjusted, the advanced rod was clamped and the rear box carried forward. The reading of an attached thermometer was recorded for each contact, and Hassler's proportional rate of expansion, 0.000006963535, was used in making the temperature reduction.

Primary and secondary triangulation.—The primary triangulation of the coast, and the secondary and tertiary connected with it, have, under the charge of Assistant R. D. Cutts, taken their regular form and made excellent progress. Proceeding from the Pulgas base, (Sketch J,) and bringing the San José base into the series, the triangulation covers San Francisco bay and its dependencies, extending north to Ballenas bay, and south to Monterey, a distance of about eighty-five miles.

The triangulation connects the astronomical stations of San Francisco, Santa Cruz, and Point Pinos, and determines the position of all the principal towns from Benicia to Monterey, and of the different light-houses on this part of the coast.

As primary points immediately along, or commanding a view of the coast, could not be had, a series of tertiary triangles were laid from Point Piedras to Santa Cruz. This series was commenced by Mr. C. M. Bache, under Mr. Cutts' direction.

From the line Red Hill—Contra Costa, (see Sketch J,) the triangulation extends northward and southward, with sides varying from fifteen and a half to forty-three and a half miles. Great elevations were selected for station points, in order to be above the fog; and experience has fully confirmed this course, for while the valleys are covered with fog, Mr. Cutts states that his primary observations have gone on without interruption, from January, when it was commenced, to late in September, the date of his report. The vapor-plane, or fog-plane, generally does not rise higher than about 1,800 feet above the level of the sea. Signal-poles were generally used, a heliotrope being required at but one station. The stations have been carefully marked with stones, intended to furnish permanent marks of reference.

The following are the statistics of the work for the year ending September 30, 1854:

Primary stations occupied	8
Secondary stations occupied	6
Number of angles measured	116
Number of measurements	5,880
Number of signals erected	33
Heights determined by level	1
Heights determined trigonometically	5
Vertical angles measured	70
Area of triangulation in square miles	1,612

The measured length of the San José base, (merely a preliminary base,) of nine hundred and forty one metres, (0.58 mile,) is stated to have differed from the computed length brought from the Pulgas base, through seventeen (17) triangles, but 0.03 metre, or one inch and two-tenths.

Mr. Cutts observes: "Each angle belonging to the primary triangulation has been determined by one hundred to one hundred and twenty measurements, divided into eight or ten series of twelve repetitions each, six in the direct and six in the reversed positions of the telescope. These series were taken on different days, and under the usually varied condition of the atmosphere, and their arithmetical mean was adopted as the value of the angle. After deducting the spherical excess, the six primary triangles close with the following errors: (—2.05″) (+0.44″) (—1.99″) (—1.77″) (—1.69″) (—1.77″)."

In relation to the names of the hills occupied as stations, Mr. Cutts, in his report, states that "every endeavor has been made to find out the original or popular names of the different hills and mountains selected for primary stations. So far as ascertained, with one or two exceptions, they are recognised by no regular designation. I have, therefore, given them names characteristic either of their appearance, form, or material, or from their vicinity to some well known ranch or village. The general sketch will be sufficiently accurate to show their position, with respect to other and surrounding features of the country."

A triangulation of the Straits of Rosario, Washington Territory, was commenced last season, by Assistant George Davidson; the signals were put up by Mr. James S. Lawson, and preliminary observations made upon them for the use of the sounding party. In February last the party went to Humboldt bay, and after a long detention off the bar, in gales, fogs, and hail-storms, succeeded in entering, and established the astronomical stations shown in Sketch J, connecting it with a tertiary triangulation from Eureka to about a mile and a half below the entrance of the bay.

Mr. Davidson has suffered very much during the past year with chronic rheumatism; persisting, however, in keeping the field, that his work might be closed up at the end of the season, when he had received instructions to report on the Atlantic coast.

The observations at Humboldt were completed in June, and Mr. Davidson returned to San Francisco to procure a vessel for the northern work; and after fitting her out, proceeded to Washington Territory. In compliment to the memory of one of the most meritorious officers of the Coast Survey, who died from exposure in its service, the vessel has, at Mr. Davidson's request, been called the "*R. H. Fauntleroy.*" Finding that he would be detained through the best portion of the working season if he waited until the appropriation for the fiscal year became available, Mr. Davidson advanced his private means for carrying on his work, and left San Francisco in July for Puget's sound.

This season was not favorable, from the prevalence of fogs and variable weather; but a rapid triangulation was made, and the shore-line sketched in within the limits shown by Sketches J and K, No. 4. This work was computed and plotted, and a copy furnished to the hydrographic party. A preliminary survey of Strawberry bay formed part of the work of the season.

Measurements for the heights of some of the principal hills were made with the sextant.

Mr. Davidson's report is up to October 2. He was assisted, especially in the details of triangulation and topography, by Sub-Assistant James S. Lawson.

The statistics of the tertiary triangulation, by Sub-Assistant J. S. Lawson, at Humboldt bay, are thus reported by Mr. Davidson: Twenty-one signals erected, eight stations occupied, fifty-eight angles measured by seven hundred and seventy-six observations. At one station, vertical angles were measured for heights of several stations with a six-inch Gambey theodolite, vertical circle, No. 20.

In the triangulation of the Straits of Rosario and the Canal de Haro, thirty-two stations were occupied, one hundred and thirty-five angles measured by nineteen hundred and sixty-eight (1,968) single measurements, and seventy-nine signals were erected. The heights of forty objects were determined by vertical angles measured at eleven stations.

The report of Assistant George Davidson for 1853 not having been received before the date of closing my report for that year, I was unable to present the statistics which are essential to give an idea of the labor which he had performed. Those of the astronomical and magnetic work having been already given under their appropriate head, I now subjoin in the following table those relating to the triangulation.

Localities in Sections X and XI.	Triangulation.					Preliminary azimuth.	
	Stations occupied.	No. of measurements.	Angles measured.	Primary objects.	Tertiary objects.	No. of stations.	Observat'ns on star and mark.
Northern reconnaisance	20						
Santa Barbara channel	2	136	6	6			
Washington Territory	24	587	101	108	226	1	12
	46	723	107	114	226	1	12

In September, 1853, Captain E. O. C. Ord, U. S. A., assistant in the Coast Survey, took the place of Assistant George Davidson, who had been temporarily in charge of the triangulation of the islands off the coast of California, and occupied in the course of the first season the six stations marked on the Sketch J, Northwest beach, West beach, Dominguez Hill, San Pedro, Las Bolsas, and Los Ceritos; the triangulation resting upon the Los Angelos base measured by Mr. Davidson, and determining the position of Santa Catalina island from the base San Pedro—Los Ceritos. The dotted lines of the sketch show how Santa Barbara island is reached in the scheme of triangulation. The examination of the main, near the Santa Barbara islands, showed that no base of suitable length could be had nearer than the plains, where the measurement was made in the winter of 1852–'53. Captain Ord was prepared, at the date of his report in July, to take the field as soon as the appropriation for the year was available. His triangulation covers an area of about four hundred and twenty-one square miles, and in the course of it twelve hundred observations were made. The computations have been sent to the office.

Topography.—Sub-Assistant James S. Lawson, under the direction of Assistant George Davidson, executed the topography of Tomales bay, coast of California, entrance and approaches. (See Sketch J.) In attempting to enter the bay, the vessel in which he had taken passage was wrecked, and the persons composing the party were only saved by the presence of mind and exertions of Mr. Lawson. (Appendix No. 60.) They succeeded in getting the instruments and the greater part of the stores and equipments safely on shore before the vessel went to pieces. Mr. Lawson sent intelligence of their disaster to San Francisco, and proceeded at once to execute his work, finishing it in the latter part of January.

Subsequently the shore-line of Humboldt bay was run by Mr. Lawson in connection with his own triangulation.

The topography of Tomales bay furnished eight miles of shore-line, and about one and a half square miles of area. That of Humboldt bay determined twenty-six miles and a half of shore-line, and ten square miles of area.

Mr. Lawson assisted Mr. Davidson in sketching the shores of the Straits of Rosario, Washington Territory, in the preliminary survey already noticed.

A tertiary triangulation, connecting with the work near San Francisco bay, was made by Sub-Assistant A. F. Rodgers, on which he based a plane-table survey of Ballenas bay and Duxbury reef. (Sketch J; Sheets Nos. 9, 13, and 14.) The shore-line, from Point Avisadera, San Francisco bay, towards Point Mateo, was determined and furnished to Lieut. Comg. Alden, for the use of the hydrographic party; and subsequently Plane-table Sheet No. 16 was finished between the two points just named. The topography of Point San Pedro was executed, thus completing the southern approaches.

Mr. Rodgers reports that the most difficult portion of the topography of San Francisco bay is completed; whether regard is had to the difficulties of the ground, or to those arising from fogs, winds, and variable weather.

In the execution of the above triangulation, Mr. Rodgers occupied seven stations, observed on twelve objects, and measured forty-three angles by seven hundred and ninety-six observations.

Sub-Assistant Rodgers has continued the topography of the coast north of San Francisco, shore of Ballenas bay, completing two sheets, Nos. 13 and 14, (Sketch J,) one extending nearly to Duxbury reef, and the other passing about three miles north of it. This work rests on a tertiary triangulation made by him and extends towards the local survey made by Assistant Davidson near Point Reyes, Sir Francis Drake's bay. The ground is of a very difficult character to represent, consisting of abrupt hills and deep gorges. Mr. Rodgers has also completed Sheet No. 16, (Sketch J,) from Point Avisadera, San Francisco bay, south of the city, to Point San Mateo, near the Pulgas base.

Mr. Rodgers presents the following statistics of his topographical work: sixty-three miles of shore-line surveyed, twenty miles of roads run; area embraced, thirty-one and three-quarters square miles. He also reports forty miles of shore-line in revision of former work. Three plane-table sheets have been inked and returned to the office, together with duplicates of his observations and computations of the tertiary triangulation.

During the season Mr. Cutts reports that the topographical sheet embracing Guano island and San Mateo was completed by Mr. C. M. Bache, sub-assistant in his party, and who had also made some progress in the next sheet at the date of his resignation in August.

The topography of Monterey bay, from Point Año Nuevo (see Sketch J, No. 4) to the Pajaro river, was completed by Assistant A. M. Harrison, before leaving the Western coast, in March last. The survey included one of Santa Cruz and its vicinity, and of Point Año Nuevo for light-house purposes. There are four sheets of this work; which are very creditable specimens of topography, and show this bold coast to great advantage.

The winter was remarkably mild and favorable for work, and advantage was taken of every opportunity for its execution. Mr. Harrison was one of the pioneers of the survey on this coast; being one of four young officers of the survey, who, at a time when our resources were crippled by the sudden changes in California, undertook to work their way forward under any difficulties that might occur. They faithfully redeemed their pledge, and Mr. Harrison's services there have well earned the praise now bestowed. In returning to the Atlantic coast, Mr. Harrison's party was placed in charge of Sub-Assistant W. M. Johnson, detailed to relieve him, and who had for some months been at work with him.

Mr. Johnson proceeded with this work from the mouth of the Pajaro river to the junction with the sheet of Monterey, surveyed by Assistant R. D. Cutts, completing three sheets by the 10th of July. Referring to the country which he had surveyed, Mr. Johnson says: "The contrast between this (near Monterey) and the country north of the Salinas is most striking. There, all is beauty and fertility, and settlers are rapidly converting, by their labor, the rich meadow and table-lands into garden-spots unequalled for productiveness, even in the prolific State of California; here, on the other hand, nothing is to be seen but one wild desert of sand, producing sparingly but the coarsest grasses and shrubs, and entirely destitute of fresh water. This waste extends from the Salinas to Monterey, and back for some miles from the coast. The water used in this camp we are compelled to haul from the Salinas river."

Landing at Pigeon Point, north of Año Nuevo, in September, Mr. Johnson has commenced the topography between the last named point and Point San Pedro, which will give a continuous belt of shore topography from Point Lobos, San Francisco bay, to Point Pinos, Monterey bay.

Mr. Johnson reports the following statistics of his season's work:

Number of miles of shore-line, 84¼; area surveyed, 18 square miles.

Some interesting remarks, also contained in his report, will be found in Appendix No. 22.

Hydrography.—Previous to the date of my last report, Lieut. Comg. James Alden, U. S. N., assistant in the Coast Survey, had returned from his reconnaissance in Washington Territory, chiefly of the Gulf of Georgia. During the cruise, the steamer Active obtained at the Hudson's Bay Company's mines, on Vancouver's island, through the kindness of Governor Douglass, a supply of coal of excellent quality, which was put on board the steamer by the natives in canoes, at a very reasonable rate. Coal was also obtained at Bellingham bay, where mines had just been opened.

After completing the work of reconnaissance on returning, Lieut. Comg. Alden was called upon to end a disturbance between the whites and natives at New Dungeness, arresting an alleged murderer, an Indian, who had taken refuge among the tribe, encamped on the sand-spit opposite the settlement. A refusal to give up the offender had resulted in a battle between the parties, in which blood was shed. The man was secured and delivered to the commanding officer at Fort Steilacoom, to await the requisition of the civil authorities.

The hydrography of San Francisco entrance has been completed by Lieut. Comg. Alden; and on the northern side, Ballenas bay and Duxbury reef have been sounded out and connected with the entrance. Some work has also been done near Point Avisadera, and between that and Point Bruno.

The steamer Active requiring repairs, was taken to Benicia for that purpose; and the amount expended absorbing that allotted to the party for the season, the vessel was temporarily placed at the disposal of the War Department, under an arrangement with Major General John E. Wool, commanding the department of the Pacific, and with the approval of the Hon. Secretary of War. The means thus obtained enabled Lieut. Comg. Alden to continue his work in San Francisco bay, while he rendered effective service to the War Department, and enabled the General to avoid the large outlay which must otherwise have been incurred.

Lieut. Comg. Alden acknowledges the facilities offered in repairs by the dry dock at Benicia, and returns acknowledgments to Mr. Dean, the superintendent, in a letter to Commodore Smith, chief of the Bureau of Yards and Docks. (Appendix No. 62.)

In referring to his work in Washington Territory, Lieut. Comg. Alden says: "The only discovery of importance which we made, was of a shoal place between the island of Lucia and the main, near the entrance to Rosario strait; the least water found on it was four and a half fathoms. The knowledge of this will enable sailing-vessels in calm weather to anchor when the tide is adverse.

At his anchorage in San Francisco bay, May 8th, application was made to Lieut. Comg. Alden, by the owners of the steamer "Sea Bird," to relieve that vessel, which had been rendered entirely unmanageable by an accident to her machinery. The vessel was found under Point Conception, near El Coxo, after having drifted two hundred miles; and being taken in tow by the Active was secured at San Francisco. Liberal acknowledgments of this service have been made.

The incidents of the search will be found in detail in a letter from Lieut. Comg. Alden. (Appendix No. 61.)

While engaged in the survey of Duxbury reef and Ballenas bay, on the 14th of June, Lieut. Comg. Alden relieved the steam-packet Peytona, which had become disabled on her passage from San Francisco to Oregon. The vessel was safely brought to port in tow of the Active.

At the close of July, Lieut. Comg. Alden proceeded to Columbia river, and thence along the coast, for the correction of his previous reconnaissance. He supplied the steamer with coal at Bellingham bay, and then passed up Admiralty inlet and made a hydrographic reconnaissance of Duwamish bay, about forty miles from the entrance of the inlet on its east side, and of the harbor of Seattle, which forms part of the bay. A similar reconnaissance was also made of Point Townsend anchorage. The survey of the Straits of Rosario and the Canal de Haro, and their approaches, was completed by the 19th of September, and the steamer returned southward, making deep-sea soundings, and re-determining the position of Point Grenville. The distance run between the time of leaving San Francisco and returning is reported as two thousand three hundred and sixty (2,360) miles; in the course of which, four hundred and four (404) miles of soundings were run.

Tides.—The tidal observations under Lieut. W. P. Trowbridge, Corps of Engineers, assistant in the Coast Survey, have made excellent progress. At the three more permanent stations we have now more than twelve months of observations, while the plan for the intermediate ones has been filled up between San Diego and San Francisco, and partly so between San Francisco and Astoria. This has been accomplished with much effort, and great credit is due to Lieut. Trowbridge and those who aided him in the work. I give entire, in the Appendix No. 30, his report of the year's work, to September, 1854, which, with the reference to Sketch J, where the positions of the tide-gauges are shown, will make the details of the work more clear. Lieut. Trowbridge commends especially, among his observers, T. A. Szabo, Corporal Wayne, Mr. A. Cassidy, and Mr. James A. Black.

The self-registering tide-gauge of Mr. Saxton has proved invaluable in these observations, on the score both of accuracy and economy. The observations have been kept up for two or more lunations, according to circumstances, at all of the intermediate stations. Of these, San Diego, San Pedro, San Luis Obispo, Monterey, and San Francisco, form a set from a degree to a degree and a half of latitude apart.

Higher up the coast there is more difficulty in occupying stations, from the scarcity of settlements and the difficulty of access from the sea or by land. Humboldt and Port Orford had been selected, and results returned from both, and I doubt not that whatever can be done to carry out the full plan will be accomplished by Lieut. Trowbridge.

The sheets of observations have been transmitted with regularity to the office, where the results are tabulated, and put into the appropriate forms for reduction.

Owing to the care taken to instruct the observers in the use of the meteorological instruments, the observations made in connection with the tides will have considerable interest. My attention was called by Assistant Pourtales to the fact that during the last summer, at Port Orford, latitude 42° 44′ N., (that of Newburyport, nearly,) longitude 124° 28′ W., between the 21st of July and 21st of August the thermometer had not at any time risen above 71°; and that at Humboldt bay, latitude 40° 44′, (nearly that of New York,) longitude 124° 09′ W., during the same period, it had not risen above 61°, presenting a most desirable summer climate. I have directed that the observations be reduced, that we may at once obtain the conclusions to be derived from them.

The magnetic observations made by Lieut. Trowbridge will be found noticed under their appropriate head.

In the Appendix No. 46 will be found a paper read by me before the American Association for the Advancement of Science, containing, as the first fruits of the observations of Lieut. Trowbridge, a comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria. This inequality so affects the tides on the Western coast, that the difference in height of a morning and afternoon high-water at Diego may amount to two feet and seven-tenths, at San Francisco to two feet, and at Astoria to two feet and two-tenths; and the interval between the time of moon's transit over the meridian and the time of high water may vary between the morning high water and afternoon high water, two hours at Astoria, two hours and a quarter at San Francisco, and three hours at San Diego. Its importance to the navigator is therefore very great. The discussion for low water as well as for high is made, and simple relations connecting the inequality with the moon's declination are given. I do not repeat these results in this place, because they are so readily found in the article itself in the Appendix, and the diagrams serve to render them more clear than a mere verbal statement alone would do. I have shown above, that, in certain cases, this inequality is of importance, and the average result given below will establish this still more strongly, especially as the inequality of low water is even greater than that of high.

	Average inequality.				Greatest inequality.			
	Time.		Height.		Time.		Height.	
	H. W.	L. W.	H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
	h. m.	*h. m.*	*Feet.*	*Feet.*	*h. m.*	*h. m.*	*Feet.*	*Feet.*
San Francisco	1 21	0 47	1.36	2.36	2 17	1 17	2.01	3.75
San Diego	1 25	1 02	1.28	1.97	3 10	2 27	2.68	3.09
Astoria	0 59	0 46	1.23	2.17	2 00	1 21	2.54	3.85

That it follows a simple law, as the moon recedes from the equator, is shown by the series of numbers for increasing declinations, as at Astoria 0.0, 0.3, 0.7, 1.1, 1.4, 1.6, 1.7, 1.8, corresponding to the greatest declination, north or south.

Light-houses, &c.—The question of the expediency of placing a light-house at Santa Cruz, California, (see Sketch J, No. 4,) was referred to the Light-house Board, under the law, and an examination was made by Lieut. Comg. T. H. Stevens, in the schooner Ewing, and by Assistant A. M. Harrison. There being no seacoast light at Año Nuevo, and the superior importance of that object being obvious, their examination included both points. The report of Lieut. Comg. Stevens was transmitted, with his approval, by Lieut. Comg. Alden, the chief of the hydrographic party, and will be found in the Appendix No. 67. The subsequent report of Mr. Harrison, which was forwarded with the topographical sheets of Point Año Nuevo and Santa Cruz, will be found also in Appendix No. 67, with my letter containg a review of the action in the matter.

Anacapa island was also examined, in reference to placing a light-house upon it, by Lieut. Comg. T. H. Stevens, in the schooner Ewing. His report, giving the reasons why he considers the erection of a light there undesirable, is contained in Appendix No. 66; and the sketch of the island, in Sketch J, No. 3.

Instructions have been given for the re-examination of the site at San Pedro, and for examinations at Punta de los Reyes, Point Lobos, harbor of Santa Cruz, harbor of Santa Barbara, Anacapa, or Santa Cruz island, California; Umquah, Oregon Territory; and Blunt's, or Smith's island, Straits of Fuca, New Dungeness, and Cape Shoalwater, Washington Territory; upon which progress has been reported. I am advised by Lieut. Comg. Alden that reports may be expected on the sites in Washington Territory, which he was directed to examine.

OFFICE-WORK.

The office has continued during the past year under the charge of Captain H. W. Benham, of the Corps of Engineers, who has devoted successfully all the energies of a strong mind, directed by ample preparation, to its administration. Keeping up the efficiency of those divisions which were already the most effective, he has labored assiduously to bring the others to the same point, and will, I doubt not, ultimately succeed in so doing.

The computing and tidal divisions have again carried off the palm of greatest usefulness. The drawing division has gained; and probably the engraving, though there is, in my judgment, still great room for improvement in zeal and effectiveness. If the hopes entertained of applying photography to engraving are realized, the electrotype division will again take the lead of all competitors, for usefulness.

Captain Benham reports in general favorably of those engaged in office duty, and of the amount of work as compared with that of former years. He remarks: "The services of Passed Midshipman W. D. Whiting, U. S. N., assigned to the office some time since as hydrographic officer, have proved of great value in the revision of the sailing-lines and directions for our new charts, and in the general verification of hydrography, as also in the duties with which he has been charged in relation to the repairs and refitting of the vessels of the survey, at the ship-yards in Baltimore, &c.

"I feel assured that the services of a faithful and intelligent officer of the navy are indispensable for these duties, and I have great pleasure in acknowledging the efficient manner in which they have been performed by Mr. Whiting, and his cordial aid and co-operation on all occasions when called on."

Captain Benham acknowledges the assistance derived from Mr. Hein, general disbursing agent of the survey, and from Mr. Saxton, assistant in weights and measures, in their relations to the office; and from Captain Gibson, U. S. A., when in charge of the office during the temporary absences of the assistant in charge.

The divisions of the office are the same as last year, with one exception, viz: 1st, the COMPUTING; 2d, the TIDAL; 3d, the DRAWING; 4th, the ENGRAVING; 5th, the ELECTROTYPING; 6th, the PRINTING; 7th, the PUBLISHING, DISTRIBUTING, and SALE; 8th, the INSTRUMENT MAKING, and CARPENTRY; and, 9th, the ARCHIVES AND LIBRARY.

The plan of work adopted at the beginning of the year has necessarily been varied from to an unusual degree, but the endeavor to conform to its arrangements is useful, as preventing wide deviations from system. The changes, especially in the army officers engaged in the office, have rendered the administration of details less steady than was desirable. On these subjects Captain Benham in his annual report to me remarks:

"The arrangement for the administration of the duties has continued essentially the same as heretofore, attempts having been made to secure as far as possible that great desideratum for the continued successful progress of the office duties—a *permanence* of the personnel, in reference to the employés of the several divisions, as well as in the more important cases of those charged with the responsibilities of their management. Without this permanence, the valuable information acquired in any one month or year may be lost in the next, as is too often the case now, in reality leading so frequently to the conviction that more important facts have been *known* and *lost* than all that are at the present time retained in the memory of the persons employed; thus producing great irregularity and confusion, loss of labor and the means of the survey, in the proper carrying out of the different duties This conviction has, I fear, been too often brought to your own mind, from the frequent calls upon yourself (so much increasing your labors) for decisions and for information that you have appeared to feel had been many times given by yourself previously."

It is well known that no written forms or detailed directions will supply the place of personal experience; and I have cordially seconded the endeavors of Captain Benham to place in the office, as his general assistant, a permanent officer capable of relieving him from numerous details which press him, as well in the immediate control of the office as in acting for the Superintendent, in very many cases with the departments, other government officers, and with Congress, and of taking his place in cases of temporary absences for inspection of parties or on the business of the work.

In following the progress of the divisions of the office, I shall quote largely from Captain Benham's report. While I take personal cognizance by monthly reports of the progress of each division of the office, and study carefully the laying out of the work and the execution, the assistant in charge gives his personal supervision and attention to the details as well as the general progress of the whole establishment.

"The *computing* and *tidal divisions*, from the continuance of the same persons in charge, as well as from the fact that the principal members remain the same, have proved to be the most regular, efficient, and economical, in relation to their duties, of any of the branches of the office.

"Of the *computing division*, on the excellent organization of which I have previously remarked, I have again to express, as in confirmation of my report of last year, my satisfaction with reference to the industry, faithfulness, and efficiency of the officers in charge—Assistant J. E. Hilgard, chief of the division, (present but a few months of the year,) and Mr. Charles A. Schott, upon whom the duties have devolved during Mr. Hilgard's absence in the field.

"From the increased experience of its members this division has been enabled to report a greater amount of work executed in the present, compared with the previous year. The occupations have been, from time to time, varied, thus giving to each person a general facility in the duties of the division. The current field-work of the year has been brought up as it came in, and all calls from the office for information have been promptly responded to.

"In addition to the usual duties, the officers in charge have been occupied in adjusting and computing various geodetic and astronomical observations, and in conducting experiments with magnetic instruments at the Smithsonian Observatory, where some interesting results were obtained in connection with observations made during the solar eclipse of May, for the reports of which, as well as the details of the distribution of the different classes of work among the members of the computing division, I would respectfully refer to the report of Mr. Schott, herewith submitted." (See Appendix No. 31.)

The general distribution of duties among the members of the division has been as follows: *Mr. E. Nulty* has made the computations for azimuth and latitude; *Mr. J. Main* has made the reductions of transits and of differences of longitude by chronometers, and has revised astronomical and magnetic computations; *Mr. T. W. Werner* has computed the triangulations generally; and *Mr. G. Rumpf* has made the revisions and adjustments, and has attended to the register of geopraphical positions; *Mr. J. Wiessner* has reduced moon culminations, and other miscellaneous, astronomical, and geodetic observations; *Mr. J. T. Hoover* has acted as clerk to the division, and has made miscellaneous computations. *Mr. Hilgard* and *Mr. Schott* have both rendered valuable services in the discussion of various physical observations connected with magnetism, tidal currents, &c.

2. *Tidal division.*—It has been found convenient to recognise this division, in a portion of its relations, as one of those of the office, as constant reference must be made to its results for the maps and charts, and its archives form a part of those of the office. The observations are under my more immediate direction, with Assistant Pourtales as the chief of the party, and the investigations are necessarily carried on in the same way. The results obtained by the observers and computers have been noticed in their appropriate places in the body of the report, as well as those of Lieut. Trowbridge, Mr. Fairfield, Mr. Mitchell, and Mr. Würdeman. Captain Benham observes: "In the *tidal division*, under the charge of Assistant *L. F. Pourtales*, whose faithful devotion to his duties, and kindly action in the work under all circumstances, it gives me pleasure to acknowledge—the directions being still given by, and the reports made to, yourself—the accompanying statement of the chief is submitted, as requiring, perhaps, less of remark on my part than other cases.

Mr. Pourtales, in remarking upon the zeal and interest manifested by the members of the division generally, makes special mention of Messrs. Mitchell, Avery, and Heaton, and the tabular statement accompanying his report gives in brief the sum of the information, as far as received, in relation to the character of the observations at the thirty-three tidal stations occupied on our Atlantic and Pacific coasts, including dates, names of observers, &c., &c.; (see Appendix No. 31.) The more permanent officers of this party have been engaged as follows: *Mr. H. Mitchell* was employed chiefly in the discussion of the Boston tides, and has been assisted by *Mr. R. S. Avery* and *Mr. Kincheloe; Mr. Heaton* in the discussion of tides in the Gulf of Mexico, under my more immediate direction; *Mr. D. A. Burr*, temporarily attached, has discussed a station of river-tides, by *Mr. Airy's* method, and *Mr. Hawley* has read off the self-registering tide-sheets, and made reductions in the ordinary forms; *Mr. C. Fendall*, *Mr. Nes*, and *Mr. Blanchard* have also been engaged in the ordinary reductions; *Mr. L. W. Meech* has been engaged, under my immediate direction, in investigations connected with the mathematical theory of the tides and their practical application.

3. *Drawing division.*—"In the drawing division, by far the most important and responsible of the whole, as far as the publication of the results of the survey is concerned, its chief, *Captain A. A. Gibson*, has, from his long experience in the division, shown a knowledge of its necessities and of its duties in the regulation of the work, adapting it generally to the capacities and fitness of the draughtsmen, with much extended information and aptitude in the important subject of the preparation of projects of the maps of the survey, that with his untiring industry and activity would, with *this responsibility and care alone* resting upon him, have left but little to be desired for the entirely successful and efficient direction of the force of this main-spring division of the office.

"This division, I have the satisfaction of reporting, has remained essentially the same as to the principal members, and, as a consequence, the labors upon our finer charts have progressed with the usual rapidity and excellence."

"In the continued improvement in the already superior execution of our first-class draughtsmen, though the reductions from the larger field-drawings of every minute detail with such unsurpassed accuracy, as well as their subsequent transfer to the copper, by the skill of the most accomplished engravers, may protract the publication of our finer maps, and make the first cost of the preparation of these specimens of topographical art appear somewhat large. It is, however, gratifying to feel that this expense would seem to be comparatively trifling in consideration of the fact that, these plates once obtained, from the assured skill of our electrotype division we can reproduce, by chemical means, an indefinite number of others—fac similes of the original plates—at a trifling expense above the mere cost of the crude copper, and which may yield any number of proof impressions of the maps required for the supply of the commerce of the world; and all from these single fine original plates."

The duties of the division have been distributed nearly as follows, (see Appendix No. 31:) Assistants *W. M. C. Fairfax* and *M. J. McClery*, and *Mr. Joseph Welsh*, have been occupied in the finer reductions of topography; *Mr. J. J. Ricketts* and *Mr. J. R. P. Mechlin* in the higher grades of hydrographic reduction. *Mr. L. D. Williams* has been engaged on the Congress map, and with *Mr. J. R. Key*, *Mr. W. T. Martin*, *Mr. Lindenkohl*, and *Mr. Frederick Fairfax*, on harbor maps and charts, sketches, and other miscellaneous reductions. *Mr. Shultz*, *Mr. B. Hooe, jr.*, and artificer *A. Campbell*, have been employed on tracings and miscellaneous work.

Engraving division.—The increasing general demand for first-class topographical engravers (perhaps somewhat enhanced by the large orders of Congress for their work) has presented difficulties in the maintenance of a force in this division sufficient to keep even pace with the supply of material by the field parties, and its preparation in the other branches of the office; Captain Benham has, with measurable success, given his personal attention to the subject, with a view to provide remedies against further inconvenience in this respect. He has succeeded in attaching several reliable and skilful artists to supply the places of those who have left the division, and confidently expresses the expectation of being enabled to maintain the usual force. He alludes with satisfaction to the increased skill of the apprentices; and intimates the probability of having ready for publication, perhaps by the close of the year, a larger number of charts than usual at that period, and of having other first-class charts of harbors on the Atlantic, Gulf, and Western coasts well advanced for publication in the ensuing year.

Captain Benham remarks: "The division has, since the month of April, been under the charge of Lieut. J. C. Clark, of the army, whose industry and faithful attention to the duties, even in their minor details, will, with his constantly-increasing information, enable him, I feel assured, to be very useful in that branch of the office." "The labors of this division have progressed steadily, and, as anticipated in my last report, a large number of charts are expected to be ready for publication by the close of the year, among which are the three first-class charts of Long Island sound, a similar chart of Salem harbor, Massachusetts, and the harbors of Newburyport, Massachusetts, and Charleston, South Carolina, and a second sheet of Alden's reconnaissance of the Western coast. Others, including charts of Boston harbor, Muskeget channel, south side Long Island (No. 2,) Albemarle sound, and Mobile bay, have been so much advanced as to give the expectation of their publication in the ensuing year.

"The sketches for the annual report of last year occupied the greater part of the time of the second-class engravers and apprentices from the date of that report until the month of June, the sketches being all prepared before they were needed by the transfer printer.

"The engravers have since been occupied on the small harbor charts and the sketches in preparation to accompany this report, which afford ample variety, in the character of the work, and give useful employment to all the apprentices now engaged in the office.

"The change of arrangements in the engaging of apprentices, by which they are now paid only for work of value, as suggested in my report of last year, has been very satisfactory, and such as to encourage the continuance of the system, with a limited number of young men of good character and industrious habits, who may eventually supply all the necessities of the office.

"Accompanying this is submitted the report of the engraving division, in which the different charts in hand during the year, and the persons occupied on each respectively, are specified, and the titles of the charts completed, in progress, &c." (See Appendix No. 31.)

The fine work of topography and hydrography has been executed by Messrs. *F. Dankworth*, *A. Rollé*, and *J. Young*, and the fine lettering by *J. Knight*, in the office, and on contract by Messrs. *E. F. Woodward* and *E. Yeager*, of Philadelphia, and by *Mr. G. McCoy*, of New York. Messrs. *S. Siebert*, *W. Smith*, *H. Knight*, and *J. V. N. Throop*, have also been employed during part of the year. Four apprentices—*J. J. Knight*, *R. F. Bartle*, *S. W. Bradley*, and *F. W. Benner*—have been employed on the preliminary charts and sketches during the year; and three—*H. C. Evans*, *J. S. Pettit*, and *C. F. Smith*—during a great part of the year.

Parts of several maps have been executed out of the office, on contract, by other engravers.

Electrotyping.—In this division most important experiments have been in progress for obtaining by chemical means, directly from the drawings, engraved plates for printing. This is a double application of photography and electro-metallurgy, in both of which *Mr. Mathiot*, the chief of the electrotype division, is an adept. The results thus far obtained are very encouraging. Captain Benham, in his report, remarks: "To provide, however, if possible, the means of getting out our charts more expeditiously, and, as it may be hoped, to dispense to a great degree, if not entirely, with the slow and tedious process of engraving by the hand on copper, Mr. Mathiot has been furnished with the necessary means and directed to make experiments in order to ascertain the possibility of accomplishing this object. His special report upon the experiments already made is hereto appended, (Appendix No. 31;) and, although he has not yet accomplished all that is desirable, the specimens from his *Photengraph*, or *photo-electro* engraved plates, are most interesting, and such as to warrant strong hopes of ultimate success. In the copy of a part of one of the finer plates, the hachures of the hills, lettering, outlines, &c., are remarkably distinct; and, with some slight retouching by the graver, the plate might insure a saving of at least half the labor spent upon a duplicate engraved by the usual method.

"It is hoped that one or more of the sketches for the annual report may be successfully engraved by the means now referred to, as samples of what may be accomplished with the present advancement in the experiments. Such of the drawings as it is thought may be most successfully copied by the new process are now in preparation for this purpose.

"In the regular work of the division, seventy-seven plates have been made; of the whole number of castings, forty-two were bassos or printing plates, and thirty-five altos; in addition to which, several plates have been prepared for the use of the engravers at a cost of little over one-third of that of planished plates obtained by purchase."

The following work is reported by Captain Benham from the *Printing Division*, under *Mr. S. D. O'Brien*, with *Mr. John Rutherdale*, as assistant printer; the work being under the special supervision of Lieut. Clark, of the engraving division: "Forty-eight thousand three hundred impressions from plates of C. S. maps and sketches, including twenty-four hundred proofs for distribution, quarterly records, &c.,

and twenty-one thousand five hundred on thin paper for the sets of maps, now being prepared in atlas form, as ordered for special distribution; the above number of sheets being over double that of those reported last year, with the same force, and expenditure for services, in this division.

"The number of impressions taken has been sufficient to meet the demand from our agents, and for the distribution to libraries and other institutions authorized by the Treasury Department. The report in detail of the several plates printed from is hereto appended. (Appendix No. 31.)

"Nine thousand impressions of eleven different charts have been distributed from the office to the principal departments, and to institutions designated by the members of the House of Representatives in their respective districts throughout the country.

"The *distribution* of the Superintendent's annual report of 1852 has not been entirely completed, owing to the failure of the Senate binder to deliver, until towards the close of October, some fourteen hundred copies. The report of distribution of maps, and of the Superintendent's annual report, is given in detail in Appendix No. 31.

"There have been added to the *archives and library*, during the past year, two hundred and thirty volumes, of which one hundred and twenty-two of the most necessary scientific works were purchased. The remainder have been presented by foreign governments, and by institutions in this country.

"In the *instrument-shop* repairs have been made upon some eighty of the most important instruments, including in the number twenty-nine theodolites, six reconnoitring telescopes, fifteen plane-tables, twenty-three sextants, six self-registering tide-gauges, one aneroid barometer, and seventeen clocks and watches.

"Among the instruments constructed in the shop are four self-registering tide-gauges, four plane-tables, six deep-sea thermometers, and parts of five others, six heliotropes, two stands for theodolites, three reconnoitring telescopes, four three-armed and two circular protractors, and many other instruments required in the work of the survey, as scales, triangles, shade-glasses, and tools of various kinds.

"The force in the shop now consists of three first-class instrument makers, including the chief; two of the second class, and three apprentices; and a blacksmith, who is also, when required, an assistant to the electrotypist.

"In the *carpenter shop* there have been made, during the year, eight plane-table boards, ten drawing-boards, twenty-four cases for instruments, such as heliotropes, deep-sea thermometers, protractors, &c., a large case for the archives, and all necessary repairs to the office buildings, and additions to the office furniture. All the instruments required by field and hydrographic parties having been packed in the shop, and in addition to the ordinary work, a portable observatory has been constructed."

Captain Benham speaks in terms of approval of the services of *Mr. V. E. King*, in charge of the map room, and distribution of maps and reports, and of *Mr. C. B. Snow*, in charge of the archives.

He also makes special mention of the faithful and efficient services of *Mr. A. W. Russell*, the chief clerk of the office, in charge of the clerical force, and of the office files and accounts.

The services of *Mr. J. Vierbuchen*, in charge of the instrument-making; of *Mr. W. T. Wood*, in charge of the carpentry; and the carefulness and fidelity of the office messengers and watchmen, and especially of the chief messenger, *Daniel Flynn*, are strongly commended.

The services of *Lieut. E. B. Hunt*, of the Corps of Engineers, have already been mentioned in various parts of the report. Besides the duties referred to, and contributions made by the investigation of different special subjects, he has had charge of the transfer printing of the plates accompanying my report of 1853, printed by order of the Senate and House of Representatives.

Prof. Pendleton, U. S. N., has, in addition to the Gulf Stream discussions, been employed in continuing computations for longitudes.

I cannot close this report without expressing my sense of the faithful and zealous services of *Samuel Hein, Esq.*, the general disbursing agent of the Coast Survey. The numerous accounts with the separate parties, and with individuals, are kept with the greatest order and method, so that he is at all times able to furnish promptly the minute information necessary in regard to these, in directing the various operations of the Survey. Charged with the care of the property of the Survey when not in the hands of the officers for use, his economy and system make themselves also felt in this department. His scrupulous execution of every part of his duty cannot be too highly praised.

The faithful discharge of duty, and the system and order of the clerk to the Superintendent, *W. W. Cooper, Esq.*, deserve also my acknowledgment.

Respectfully submitted, by

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. James Guthrie,
Secretary of the Treasury.

APPENDIX.

APPENDIX No. 1.

Distribution of the parties of the Coast Survey upon the coast of the United States during the surveying season of 1853–'54.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
I	From Passamaquoddy bay to Point Judith, including the coast of Maine, N. Hampshire, Massachusetts, & Rhode Island.	No. 1	Geodetic, astronomical, & magnetic observations.	A. D. Bache, superintendent; G. W. Dean, assistant; Steph'n Harris, aid, (during part of the season.)	Ragged Mountain, near Camden, Waldo county, Me.; geodetic, astronomical, and magnetic observations. (Part of season. See also Sections IV and V.)
		2	Reconnaissance ...	Bvt. Major Henry Prince, U. S. Army, assistant.	Extension of reconnaissance east of line Mt. Desert—Humpback. (See also Sections V and VI.)
		3	Secondary triangulation.	C. O. Boutelle, assistant; Lieut. A. W. Evans, U. S. Army, assistant.	Casco bay triangulation continued to near Cape Small Point. (See also Section V.)
		4	Topography	A. W. Longfellow, assistant.	Approaches to Portland harbor, city of Portland, and Casco bay east of Portland.
		5	Topography	A. S. Wadsworth, sub-assistant.	Coast of Maine from Cape Neddick eastward, to include Ogunquit harbor. (Part of season. See also Section IV.)
		6	Topography	H. L. Whiting, assistant; I. Hull Adams, sub-assistant, (part of season.)	Coast of Massachusetts, near Newburyport. (See also Sections III and VI.)
		7	Topography	H. L. Whiting, assistant..	Re-examination of Mystic river and approaches, and of Great South bay, for commissioners of Boston harbor. (See also Section III.)
		8	Topography	R. M. Bache, sub-assistant	Topography and shore-line between Kingston and Duxbury, Mass., completed. (See also Section V.)
		9	Hydrography	Lieut. Commanding H. S. Stellwagen, U. S. Navy, assistant.	Deep-sea soundings from Nantucket shoals eastward to deep water; from Monomoy to northeast of Cape Cod; inshore hydrography completed from Nahant to Marblehead; sounding of Mass. bay, and of Stellwagen's bank, entrance of Mass. bay. (See also Section II.)

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
I	From Passamaquoddy bay to Point Judith—Continued.	No. 10	Hydrography......	Lieutenant Commanding Maxwell Woodhull, U. S. Navy, assistant.	Nantucket sound, north shore, completed. Sounding of Horse Shoe, Succonesset and L'Homme Dieu shoals. (See also Section II.)
		11	Hydrography	Lieutenant Commanding T. Aug. Craven, U. S. Navy, assistant.	Portland harbor, and reconnaissance of Eggemoggin Reach. Examinations for light-house sites on the coast of Maine. (See also Sections IV, VI, and Gulf Stream.)
		12	Tidal observations.	H. Mitchell, sub-assistant.	Shores of Nantucket and Martha's Vineyard.
				G. A. Fairfield, assistant..	South shore of Massachusetts, from Monomoy to Wood's Hole. Observations at Boston Dry-dock, continued. (See also Sections IV, V, and VI.)
		13	Views............	Captain Aug. A. Gibson, U. S. Army, assistant.	Views of Salem and Gloucester harbors.
		14	Inspection........	A. D. Bache, superintendent; Captain H. W. Benham, Corps of Engineers, assistant.	Inspection of topographical parties.
		15	Measurement of heights.	Captain T. J. Cram, U. S. Top. Eng., assistant.	Preparation of report on observations made in 1852 and 1853 for measurement of heights.
II	From Point Judith to Cape Henlopen, including the coast of Connecticut, New York, New Jersey, Pennsylvania, and Delaware.	1	Astronomical and magnetic observations.	J. E. Hilgard, assistant...	Observations for latitude and azimuth, and magnetic elements at Mount Rose, N. J., (1853,) and at Yard's Station, near Philadelphia, (1854.) (See also Section VIII.)
		2	Triangulation	Edmund Blunt, assistant; C. P. Bolles, assistant; G. H. Bagwell, aid.	Hudson river, continued from line Crow's Nest—Tompkins to stations near Poughkeepsie, and determination of points near New York city.
		3	Topography.......	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant.	Hudson river, from Sing Sing to Anthony's Nose, above Peekskill, Manhattan island, and shore-line at New York city. (See also Sections VII and VIII.)
		4	Hydrography	Lieutenant Commanding M. Woodhull, U. S. Navy, assistant.	Resurvey of East river and of Hudson river at and near New York city. Experiments on currents, south shore of Long island. Examinations for light-house sites, coast of New Jersey and in Delaware bay. (See also Section I.)
		5	Hydrography	Lieutenant Commanding Richard Wainwright, U. S. Navy, assistant.	Hudson river, continued from Croton Point to Fort Montgomery, above Peekskill. (See also Section III.)
		6	Hydrography	Lieutenant Commanding H. S. Stellwagen, U. S. Navy, assistant.	Examinations for sites of light-houses in Long Island sound. (See also Section I.)
		7	Tidal observations.	....	At Governor's island, continued with self-registering tide-gauge.

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
III	From Cape Henlopen to Cape Henry, including the coast of Delaware, Maryland, and Virginia.	No. 1	Astronomical observations.	Dr. B. A. Gould, jr., assistant; L. F. Pourtales, assistant.	Telegraphic difference of longitude between Petersburg, Va., and Wilmington, N. C. Observations of solar eclipse. (See also Sections IV and V.)
		2	Primary triangulation.	Edmund Blunt, assistant; Lieut. A. H. Seward, U. S. Army, assistant.	Preservation of stations on Chesapeake bay. (See also Sections II and VI.)
		3	Secondary triangulation.	John Farley, assistant; J. R. Offley, sub-assistant, (part of season.)	Reconnaissance of part of York river; connection of triangulation on James river from Richmond southward, and City Point northward.
		4	Secondary triangulation.	Captain W. R. Palmer, U. S. Top. Eng., assistant; Lt. D. T. Van Buren, U. S. Army, assistant, (part of season;) Lieut. G. H. Gordon, U. S. Army, assistant.	Rappahannock river, Virginia, from above Port Royal, to stations Baylor—Brick-Quarter, below Tobago bay, and thence to stations Jones—Carter, below Tappahannock.
		5	Topography.......	J. J. S. Hassler, assistant.	Determination of hydrographic points near Cape Henry. (See also Section IV.)
		6	Topography.......	H. L. Whiting, assistant..	Verification work at Meekin's neck and Back River neck, Chesapeake bay. (See also Section I.)
		7	Topography.......	George D. Wise, assistant.	Seacoast of Virginia between Metomkin and Wachapreague inlets. (See also Section VII.)
		8	Topography.......	John Seib, sub-assistant; D. E. Montgomery, aid.	Shore line of Rappahannock river from near Fredericksburg to near Port Royal, and thence to Tobago bay; entrance of York river; shore-line of Chesapeake bay continued. James river entrance from Newport News to Warwick river: Elizabeth river, including Norfolk harbor.
		9	Hydrography	Lieutenant Commanding J. J. Almy, U. S. Navy, assistant.	Hydrography of Chesapeake bay completed from Mobjack bay to channel, and southward to Cape Charles, including the entrance of James river and Elizabeth river; harbors of Norfolk and Portsmouth; Hampton roads and Lynn Haven roads.
		10	Hydrography.......	Lieutenant Commanding R. Wainwright, U. S. Navy, assistant.	Rappahannock river, hydrography carried below Port Royal; resurvey of Swash channel and approaches; entrance of Patapsco river; for Engineer department. (See also Section II.)
		11	Hydrography.......	Lieutenant Commanding J. N. Maffitt, U. S. Navy, assistant.	Entrance of James river, and west of line Newport News and Craney island; tides at James river entrance. (See also Sections IV and V.)
IV	From Cape Henry to Cape Fear, coast of Virginia and North Carolina.	1	Astronomical and magnetic observations.	A. D. Bache, superintendent; G. W. Dean, assistant; C. P. Bolles, assistant.	Difference of longitude between Wilmington, N. C., and Petersburg, Va.; latitude, azimuth, and magnetic elements at Wilmington, N. C. (See also Sections I, II, and V.)

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
IV	From Cape Henry to Cape Fear—Continued.	No. 2	Astronomical and magnetic observations.	Dr. B. A. Gould, jr., assistant; G. W. Dean, assistant.	Difference of longitude between Raleigh, N. C., and Columbia, S. C.; latitude and magnetic elements at both stations. (See also Sections III and V.)
		3	Secondary triangulation and topography.	J. J. S. Hassler, assistant.	Verification of triangulation of narrows of Currituck sound continued: near Virginia and North Carolina line. (See also Section III.)
		4	Secondary and tertiary triangulation and topography.	A. S. Wadsworth, sub-assistant; D. E. Montgomery, aid.	Beaufort harbor completed; coast south of Beaufort harbor, towards New Inlet, N. C. (See also Section I.)
		5	Hydrography......	Lieutenant Commanding J. N. Maffitt, U. S. Navy, assistant.	Beaufort harbor and approaches completely surveyed; tides at Beaufort and Cape Lookout. (See also Sections III and V.)
		6	Hydrography......	Lieutenant Commanding T. A. Cravén, U. S. Navy, assistant.	Hydrography of Wimble shoals commenced. (See also Sections I and VI, and Gulf stream.)
		7	Tidal observations.	G. A. Fairfield, assistant..	Tides at Beaufort, Cape Lookout, Hatteras, and Cape Fear entrance. (See also Sections I, V, and VI.)
		8	Inspection	A. D. Bache, superintendent.	Work of Beaufort harbor and approaches.
V	From Cape Fear to St. Mary's river, including the coast of South Carolina and Georgia.	1	Reconnaissance....	Brevet Major H. Prince, U. S. Army, assistant.	From Santee river, S. C., to Ashley river. (See also Sections I and VI.)
		2	Astronomical and magnetic observations.	C. O. Boutelle, assistant; Lieuten't A. W. Evans, U. S. Army, assistant; B. Huger, jr., sub-assistant.	Observations for latitude, azimuth, and magnetic elements at Georgetown, S. C.; for difference of longitude by chronometers between Georgetown, S. C., and Charleston. (See also Section I.)
		3	Astronomical and magnetic observations.	Dr. B. A. Gould, jr., assistant; G. W. Dean, assistant.	Difference of longitude between Columbia, S. C., and Raleigh, N. C.; latitude and magnetic elements at both places. (See also Sections I, III, and IV.)
		4	Primary and secondary triangulation.	C. O. Boutelle, assistant; B. Huger, jr., sub-assistant.	Occupation of primary stations—Elliott's cut and New cut; secondary triangulation of Wando river to Daniell's island; secondary triangulation of Long island, near Charleston, S. C., including Charleston harbor. (Part of season. See also Section I.)
		5	Secondary triangulation.	Lieut. D. T. Van Buren, U. S. Army, assistant; John Rockwell, sub-assistant	Completion of Savannah river entrance, and of Calibogue sound to May river.
		6	Topography	R. M. Bache, sub-assistant.	Minute topography of Seabrook and Kiawah islands; mouths of Stono and Kiawah rivers, Cole's island; parts of John's and Folly islands; and coast of South Carolina. (See also Section I.)

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
V	From Cape Fear to St. Mary's river—Continued.	No. 7	Hydrography	Lieut. Comg. J. N. Maffitt, U. S. Navy, assistant.	Resurvey of Maffitt's channel and approaches, Charleston harbor; Savannah river entrance completed. (See also Sections III and IV.)
		8	Tidal observations.	G. A. Fairfield, assistant	Tides at Charleston, S. C., and at St. Simon's island. (See also Sections I, IV, and VI.)
		9	Inspection of parties.	A. D. Bache, superintendent.	Triangulation and topographical parties on John's and Kiawah islands, and on Savannah river.
V & VI	Gulf Stream		Hydrography	Lieut. Comg. T. A. Craven, U. S. Navy, assistant.	Exploration of the stream in winter across the St. Simon's and Cape Canaveral sections. (See also Sections I, IV, and VI.)
VI	From St. Mary's river to St. Joseph's bay, on the western coast of Florida.	1	Reconnaissance	Brevet Major H. Prince, U. S. Army, assistant.	For triangulation of the eastern coast of Florida from St. John's river to Jupiter inlet. (See also Sections I and V.)
		2	Secondary triangulation.	Lieut. James Totten, U. S. Army, assistant; C. T. Iardella, aid.	Inside and outside keys on Florida reef, from East Harbor key to stations near Loggerhead key, and points for the hydrographic reconnaissance of Coffin's Patches.
		3	Secondary triangulation.	Lieut. A. H. Seward, U. S. Army, assistant.	Triangulation from Card's sound to Grassy Point, in Barnes' sound, and securing signals. (See also Section III.)
		4	Topography	I. Hull Adams, sub-assistant; G. W. Parrish, aid.	Florida keys, north and east of Key West, marked in sections for General Land Office. (See also Section I.)
		5	Topography	S. A. Wainwright, sub-assistant; H. S. Du Val, aid.	Keys near Spanish harbor, Florida reef, from Old Rhodes key to Wednesday Point.
		6	Hydrography	Lieut. Comg. T. A. Craven, U. S. Navy, assistant.	Florida keys from Pacific reef to Basin bank; hydrographic reconnaissance of Coffin's Patches; tides at Cape Florida and near Carysfort reef; and tides at Indian River inlet. (See also Sections I, IV, and Gulf Stream.)
		7	Hydrography	Lieut. Comg. O. H. Berryman, U. S. Navy, assistant.	Tides at entrance to Tampa Bay. (See also Section VII.)
		8	Tidal observations.	G. A. Fairfield, assistant	St. Augustine harbor and entrance. (See also Sections I, IV, and V.)
VII	From St. Joseph's bay to Mobile bay, including part of the coast of Florida and Alabama.	1	Preliminary survey and astronomical observations.	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant.	Preliminary measurement of base at St. Andrew's bay; observations for difference of longitude, azimuth, and magnetic declination at Cape St. Blas and St. Andrew's bay. (Part of season. See also Sections II and VIII.)
		2	Preliminary survey	Geo. D. Wise, assistant; J. R. Offley, sub-assistant.	Preliminary triangulation and topography of Ocilla river, Florida. (Part of season. See also Section III.)
		3	Topography	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant.	Topography of Cedar Keys and vicinity completed. (Part of season. See also Sections II and VIII.)

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
VII	From St Joseph's bay to Mobile bay—Continued.	No. 4	Hydrography	Lieut. Commanding O. H. Berryman, U. S. Navy, assistant.	Hydrography of Cedar Keys. (See also Section VI.)
VIII	From Mobile bay to Vermillion bay, including the coast of Alabama, Mississippi, and part of Louisiana.	1	Reconnaissance ...	F. H. Gerdes, assistant; J. G. Oltmanns, sub-assistant.	For primary triangulation from Lake Borgne to Barataria bay; and general reconnaissance from Atchafalaya to Vermillion bay. (Part of season. See also Sections II and VII.)
		2	Primary triangulation, astronomical and magnetic observations.	J. E. Hilgard, assistant; Stephen Harris, aid.	Triangulation continued on Mississippi and Chandeleur sounds; azimuth and magnetic elements; examination of Dauphine Island base. (See also Section II.)
		3	Secondary triangulation.	S. A. Gilbert, assistant...	Connection made with New Orleans from Lake Pontchartrain.
		4	Hydrography	Lieut. Commanding B. F. Sands, U. S. Navy, assistant.	Off-shore work in the Gulf of Mexico, between Horn island and mouths of the Mississippi river. Search for shoal south of the Belize, in lat. 27° N., long. 89° W. of Greenwich. Temperatures observed. In-shore work from meridian of Round island westward to former work.
		5	Tidal observations.	G. Würdemann..........	Half-hourly observations at the entrance of Lake Calcasieu. (See also Section IX.)
IX	From Vermillion bay to boundary, part of Louisiana and coast of Texas.	1	Triangulation and topography.	W. E. Greenwell, assistant; P. C. F. West, aid.	At the entrance of the Rio Grande and vicinity, for the Mexican boundary commission.
		2	Hydrography	Lieutenant Commanding Edwin J. De Haven, U. S. Navy, assistant.	Soundings near Red Fish bar, and in East and West bays, Galveston.
		3	Tidal observations.	G. Würdemann..........	Half-hourly observations at Brazos St. Iago, and hourly at Aransas Pass, (St. Joseph's island.) (See also Section VIII.)
X, XI	Western coast of the United States, California, Oregon and Washington Territories.	1	Primary and secondary triangulation.	R. D. Cutts, assistant....	Primary and secondary triangulation from Ballenas bay to Monterey. Tertiary triangulation commenced.
		2	Triangulation	Captain E. O. C. Ord, U. S. Army, assistant.	Triangulation of coast, preliminary to the survey of the Santa Barbara islands.
		3	Triangulation and astronomical determinations.	Geo. Davidson, assistant..	Canal de Haro, strait of Rosario, and islands in the Gulf of Georgia.
		4	Topography.......	James S. Lawson, sub-assistant.	Tomales bay, Humboldt bay, islands in the Gulf of Georgia, and shores of Rosario strait.
		5	Topography.......	A. M. Harrison, assistant.	Santa Cruz and Año Nuevo, and south to Pajaro river, on Monterey bay.
		6	Topography.......	W. M. Johnson, sub-assistant.	From Pajaro river, bay of Monterey, south to town of Monterey, and from Point Año Nuevo north towards San Francisco.

APPENDIX No. 1—Continued.

No. of section of survey.	Limits of sections.	Field and hydrographic parties.	Operations.	Persons conducting operations.	Localities of operations.
X, XI	Western coast of the United States—Continued.	No. 7	Topography	Aug. F. Rodgers, sub-assistant.	Tertiary triangulation and topography from Point Bonita to Duxbury reef. Topography from Point Avisadera to Point St. Matèo, and from north of San Francisco bay to include Duxbury reef.
		8	Hydrography	Lieutenant Commanding Jas. Alden, U. S. Navy, assistant.	Canal de Haro and strait of Rosario, continued. General reconnaissance of coast revised and additions made from San Francisco north. Reconnaissance of Duwamish bay, of Seattle harbor, and of Port Townsend roads. San Francisco entrance completed. Examination of sites for light-houses.
		9	Tidal observations.	Lieutenant W. P. Trowbridge, U. S. Engineers assistant.	Establishment of tidal stations at San Diego, San Pedro, San Luis Obispo, Monterey, Fort Point, Humboldt bay, Port Orford, and Columbia river.

APPENDIX No. 2.

List of army officers on Coast Survey duty March 1, 1854.

Name.	Rank.	Date of attachment.
Thomas J. Cram	Captain topographical engineers	December 7, 1846
Henry Prince	Captain and brevet major 4th infantry	December 10, 1850
Henry W. Benham	Captain engineers	April 1, 1853
Edward O. C. Ord	Captain 3d artillery	December 30, 1852
William R. Palmer	Captain topographical engineers	March 2, 1852
Augustus A. Gibson	Captain 2d artillery	January 17, 1851
James Totten	First lieutenant 2d artillery	December 10, 1850
Edward B. Hunt	First lieutenant engineers	May 5, 1851
John G. Foster	Second lieutenant and brevet captain engineers	March 20, 1852
James Oakes	First lieutenant and brevet captain 2d dragoons	February 7, 1854
Daniel T. Van Buren	First lieutenant 2d artillery	December 2, 1852
Joseph C. Clark, jr.	First lieutenant 4th artillery	January 7, 1854
Augustus H. Seward	First lieutenant 5th infantry	December 8, 1851
William P. Trowbridge	Second lieutenant engineers	April 18, 1851
James P Roy	Second lieutenant 2d infantry	October 7, 1853
Andrew W. Evans	Brevet second lieutenant 7th infantry	November 10, 1852

APPENDIX No. 2 *bis.*

List of army officers on Coast Survey duty September 1, 1854.

Name.	Rank.	Date of attachment.
Thomas J. Cram	Captain topographical engineers	December 7, 1846
Henry Prince	Captain and brevet major 4th infantry	December 10, 1850
Henry W Benham	Captain engineers	April 1, 1853
Edward O. C. Ord	Captain 3d artillery	December 30, 1852
William R. Palmer	Captain topographical engineers	March 2, 1852
Augustus A. Gibson	Captain 2d artillery	January 17, 1851
James Totten	First lieutenant 2d artillery	December 10, 1850
Edward B. Hunt	First lieutenant engineers	May 5, 1851
Daniel T. Van Buren	First lieutenant 2d artillery	December 2, 1852
Joseph C. Clark, jr	First lieutenant 4th artillery	January 7, 1854
Augustus H. Seward	First lieutenant 5th infantry	December 8, 1851
William P. Trowbridge	Second lieutenant engineers	April 18, 1851
James P. Roy	Second lieutenant 2d infantry	October 7, 1853
Andrew W. Evans	Brevet second lieutenant 7th infantry	November 10, 1852

APPENDIX No. 3.

List of navy officers on Coast Survey duty March 1, 1854.

Vessel.	Locality of service.	Name.	Rank.	Date of attachment.
Schooner John Y. Mason.	Section III	R. Wainwright	Lieutenant commanding	January 31, 1848
		S. D. Trenchard	Lieutenant	March 1, 1853
		John B. Stewart	Acting master	November 15, 1852
		Gustavus Harrison	Passed midshipman	July 29, 1853
Steamer Legaré and schooner Bouncer.	Section V	J. N. Maffitt	Lieutenant commanding	May 9, 1843
		A. C. Rhind	Lieutenant	June 20, 1845
		J. P. Jones	Acting master	June 28, 1853
		Wm. D. Whiting	Passed midshipman	July 30, 1853
		Hunter Davidson	do do	January 17, 1852
Steamer Corwin, and tender.	Section VI	T. A Craven	Lieutenant commanding	November 27, 1850
		B. N. Westcott	Lieutenant	April 3, 1852
		J. C. Febeger	do	December 3, 1851
		Edward Renshaw	Acting master	June 3, 1853
		Thomas C. Eaton	do do	July 23, 1852
		T. Le P. Cronmiller	Assistant surgeon	November 28, 1853
Schooner Crawford	Section VII	O. H. Berryman	Lieutenant commanding	December 8, 1853
		Earl English	Acting master	December 21, 1853
		J. G. Maxwell	Midshipman	December 27, 1853
		Henry Erben, jr	do	December 21, 1853
		W. H. Ward	do	January 3, 1854
		R. B. Tunstall	Assistant surgeon	December 21, 1853
Steamer Walker	Section VIII	B. F. Sands	Lieutenant commanding	May 14, 1850
		S. S. Bassett	Acting master	March 17, 1849
		R. C. Duval	Passed midshipman	November 17, 1852
		J. A. Seawell	do do	December 5, 1853
		C. H. Williamson	Assistant surgeon	December 5, 1853
Schooners Arago and Belle.	Section IX	E. J. De Haven	Lieutenant commanding	November 12, 1853
		John Wilkinson	Lieutenant	November 12, 1852
		L. H. Lyne	Acting master	September 26, 1852
		G. H. King	do do	November 12, 1852
		James F. Huestis	Assistant surgeon	January 4, 1854
Steamer Active and schooner Ewing.	Sections X and XI	James Alden	Lieutenant commanding	May 18, 1849
		Thomas H. Stevens	Lieutenant	February 21, 1851
		Israel C. Wait	do	May 6, 1852
		Joel S. Kennard	do	May 6, 1852
		Richard M. Cuyler	do	June 20, 1845
		A. M. De Bree	Acting master	April 2, 1853
		James Suddards	Assistant surgeon	April 3, 1852
	Office	H. S. Stellwagen	Lieutenant	October 22, 1852
	Office	Thomas B. Huger	do	May 14, 1852

APPENDIX No. 3—Continued.

Vessel.	Locality of service.	Names.	Rank.	Date of attachment.
	Office	Foxhall A. Parker	Lieutenant	March 31, 1853
	Office	John J. Almy	....do	March 12, 1851
	Office	M. C. Perry	....do	January 15, 1853
	Office	R. L. Law	Passed midshipman	May 1, 1851
	Office	John T. Walker	....do......do	April 7, 1853
	Office	D. Phenix	....do......do	April 7, 1853
	Office	M. Woodhull	Lieutenant	May 30, 1848
	Office	John Rutledge	....do	May 3, 1852
	Office	S. R. Franklin	Passed midshipman	April 2, 1853
	Office	Jos. B. Smith	....do......do	August 4, 1852
	Office	A. N. Smith	Lieutenant	November 8, 1853
	Office	J. B. McCauley	Passed midshipman	October 16, 1850
	Office	A. G. Pendleton	Professor of Mathematics	May 8, 1848

APPENDIX No. 3 *bis*.

List of navy officers on Coast Survey duty September 1, 1854.

Vessel.	Locality of service.	Name.	Rank.	Date of attachment.
Steamer Bibb	Section I	H. S. Stellwagen	Lieutenant commanding	October 22, 1852
		E. C. Stout	Acting master	June 7, 1854
		S. R. Franklin	Passed midshipman	April 2, 1853
		W. T. Truxtun	....do......do	July 19, 1854
		W. K. Mayo	....do......do	July 9, 1853
		H. M. Garland	Midshipman	June 13, 1854
Schooners Gallatin & Madison.	Section I	Maxwell Woodhull	Lieutenant commanding	May 30, 1848
		John Rutledge	Lieutenant	May 3, 1852
		Jos. B. Smith	Acting master	August 4, 1852
		S. B. Luce	......do	May 18, 1854
		Oscar F. Johnson	Passed midshipman	May 18, 1854
		W. McN. Armstrong	Midshipman	May 18, 1854
Schooner Nautilus	Section II	Richard Wainwright	Lieutenant commanding	January 31, 1848
		S. D. Trenchard	Lieutenant	March 1, 1853
		J. B. Stewart	Acting master	November 15, 1852
		G. Harrison	Passed midshipman	July 29, 1853
		A. Pendergrast	....do......do	July 20, 1854
Schr. John Y. Mason	Section III	J. N. Maffitt	Lieutenant commanding	May 9, 1843
		J. P. Jones	Acting master	June 28, 1852
		H. Davidson	Passed midshipman	January 17, 1852
Steamer Hetzel and schooner Graham.	Section III	J. J. Almy	Lieutenant commanding	March 12, 1851
		M. C. Perry	Lieutenant	January 15, 1853
		R. L. Law	Acting master	May 1, 1851
		John T. Walker	......do	April 7, 1853
		Dawson Phenix	Passed midshipman	April 7, 1853
		James C. Walker	Midshipman	April 22, 1854
		W. G. Dozier	....do	May 10, 1854
		Edward Shippen	Assistant surgeon	April 22, 1854
Steamer Corwin	....	T. A. Craven	Lieutenant commanding	November 27, 1850
		B. N. Westcott	Lieutenant	April 3, 1852
		J. C. Febiger	....do	December 3, 1851
		E. Renshaw	Acting master	June 3, 1853
		Thomas C. Eaton	Passed midshipman	July 23, 1852
		George E. Belknap	....do......do	June 27, 1854
		Trevett Abbott	....do......do	June 27, 1854
		T. Le P. Cronmiller	Assistant surgeon	November 28, 1853
Steamer Active and Schooner Ewing.	Sections X and XI.	James Alden	Lieutenant commanding	May 18, 1849
		Thomas H. Stevens	Lieutenant	February 21, 1851
		J. C. Wait	....do	May 6, 1852
		J. S. Kennard	....do	May 6, 1852
		R. M. Cuyler	....do	June 20, 1845
		A. M. De Bree	Acting master	April 2, 1853
		Ed. E. Stone	Passed midshipman	March 29, 1854
		P. C. Johnson	....do......do	July 20, 1854

APPENDIX No. 3 *bis*—Continued.

Vessel.	Locality of service.	Name.	Rank.	Date of attachment.
Steamer Active and Schooner Ewing.	Sections X and XI.	James Suddards	Assistant surgeon	April 3, 1852
	Office	B. F. Sands	Lieutenant	May 14, 1850
	Office	S. S. Bassett	Passed midshipman	March 17, 1849
	Office	R. C. Duval	....do......do	November 17, 1852
	Office	Jos. A. Seawell	....do......do	December 5, 1853
	Office	O. H. Berryman	Lieutenant	December 8, 1853
	Office	Earl English	Passed midshipman	December 21, 1853
	Office	E. J. De Haven	Lieutenant	November 12, 1853
	Office	L. H. Lyne	Passed midshipman	September 26, 1852
	Office	W. D. Whiting	....do......do	July 30, 1853
	Office	A. G. Pendleton	Professor of Mathematics	May 8, 1848

APPENDIX No. 4.

List of assistant engineers United States Navy, on Coast Survey duty March 1, 1854.

Vessel.	Name.	Rank.	Date of attachment.
Steamer Corwin	S. H. Houston	Second assistant engineer	May 11, 1853
	J C. Hull	Third assistant engineer	May 14, 1852
	C. Lindsley	......do......do	November 28, 1853
	G. W. Plympton	......do......do	November 28, 1853
Steamer Legaré	C. W. Geddes	First assistant engineer	May 19, 1853
	F. G. Sumwalt	Third assistant engineer	November 17, 1853
	H. B. Nones, jr	......do......do	December 3, 1853
Steamer Walker	A. Lawton	First assistant engineer	October 22, 1853
	A. Broadnix	Second assistant engineer	December 5, 1853
	James M. Harris	Third assistant engineer	December 5, 1853
Steamer Active	N. C. Davis	First assistant engineer	February 22, 1853
Steamer Hetzel	W. C. Wheeler	Second assistant engineer	September 7, 1853
Steamer Bibb	E. S. De Luce	First assistant engineer	June 4, 1853

APPENDIX No. 4 *bis*.

List of assistant engineers United States Navy, on Coast Survey duty September 1, 1854.

Vessel.	Name.	Rank.	Date of attachment.
Steamer Bibb	James M. Adams	First assistant engineer	June 7, 1854
	R. M. Bartleman	Third assistant engineer	June 8, 1854
	Charles Schroeder	......do......do	June 7, 1854
Steamer Hetzel	W. C. Wheeler	Second assistant engineer	September 7, 1853
	George W. City	Third assistant engineer	April 17, 1854
Steamer Corwin	Daniel T. Mapes	Second assistant engineer	June 27, 1854
	George W. Plympton	Third assistant engineer	November 28, 1853
	James F. Lamdin	......do......do	June 30, 1854
Steamer Active	N. C. Davis	First assistant engineer	February 22, 1853
Steamer Walker	A. Lawton	......do......do	October 22, 1853

APPENDIX No. 5.

List of information furnished by Coast Survey under authority of the Treasury Department.

Date.		To whom communicated.	Information communicated.
1853.			
Oct.	22	Lieut. G. G. Meade, topographical engineers	Tracing of Rebecca shoal, Florida Keys.
Nov.	12	Light-house Board	Tracing of Alden's Rock, Portland harbor, Maine.
		Do	Tracing of Deep Hole Rock, Mass.
	12	General H. Cadwallader	Tracing of Gunpowder and Back rivers, Maryland.
	17	Light-house Board	Tracing of Minot's Ledge, Mass.
	18	Navy Department	Tracing of Key West hydrography, Florida.
	22	Light-house Board	Tracing of Alden's reconnaissance of Western coast.
	23	Do	Tracing of positions of life-boats, coast of Maine.
	26	Do	Tracing of Pascagoula river, Mississippi sound.
Dec.	1	Land Office	Tracing of Boca Chica Key, Florida.
	12	Light-house Board	Tracing of York harbor, Maine.
	15	Do	Tracing of entrance to Timballier bay, Louisiana.
1854.			
Jan.	6	Do	Tracing of Apalachicola bay and vicinity, Florida.
	12	Bureau of topographical engineers	Tracing of outlines of general map of the United States.
	13	Hon. D. L. Yulee	Distances between Atlantic seaports of Europe and the United States.
	31	G. W. Blunt, esq	Tracing of Lieut. Comg. McArthur's chart of Chesapeake bay.
		Do	Tracing of Little Choptank river, Maryland.
Feb.	7	Do	Tracing of Lieut. Comg. Almy's survey of the lower part of Chesapeake bay.
		Do	Tracing of Big Choptank river and Hungerford's creek, Maryland.
	9	Hon. J. Smith Hollins	Tracing of Patapsco river, Maryland.
	13	G. P. Worcester, esq	Tracing of Baltimore city and vicinity.
	24	G. W. Blunt, esq	Tracing of seacoast of Virginia to Smith's island.
March	1	Capt. D. P. Woodbury, corps of engineers	Tracing of Cape Fear river, N. C.
	2	Board of engineers on James river improvement	Tracing of James river, below Richmond—three sheets.
	2	Light-house Board	Tracing of Pungoteague creek, Chesapeake bay.
April	11	H. F. Walling, esq	Tracing of northwest shore of Massachusetts bay, Nahant, Salem harbor, Cape Ann, and entrance to Merrimack river, Massachusetts.
	11	Hon. J. A. Bayard	Tracing of Dona and Mahon rivers, Delaware bay.
	11	Navy Department	Tracing of Portland harbor, Maine.
May	1	Dr. A. Randall	Tracing of Punta de los Reyes, California.
		Do	Tracing of Drake's bay, California.
	19	Hon. W. M. Gwin	Tracing of San Francisco city, California.
	19	T. W. McCance, esq	Tracing of James river sheet, from Mayo's bridge down.
	31	G. W. Blunt, esq	Tracing of Martha's Vineyard, Massachusetts.
		Do	Tracing of Old Man and Lone Rock, Mass.
		Do	Tracing of Muskeget channel, Mass.
		Do	Tracing of Wolftrap, Chesapeake bay.
June	12	Navy Department	Tracing and report on Beaufort harbor, North Carolina.
	19	Committee on Charleston harbor	Tracing of Maffitt's channel, from resurvey of 1854. Comparative map of Maffitt's channel—1852 and 1854.
	26	J. D. B. De Bow, esq	Proportion of shore-line between northern and southern States.
	28	G. W. Blunt, esq	Tracing of south shore of Massachusetts, from Hyannis to Nobska light.
		Do	Tracing of Tangier and Watt's island, Chesapeake bay.
	30	Board of Engineers	Tracing of Rappahannock river, Virginia.
	30	Light-house Board	Tracing of mouth of North Edisto river, South Carolina.
	30	Dr. A. Randall	Tracing of Ballenas bay, California—two sheets.
July	1	Light-house Board	Tracing of North and South Island Points, Georgetown harbor, South Carolina.
		Do	Tracing of Maffitt's channel, Charleston harbor, S. C.
		Do	Tracing of Coffin's Patches, Florida reef.
August	1	Capt. D. P. Woodbury, corps of engineers	Tracing of position of buoys, Charleston harbor, S. C.
	5	Thos. Weston, jr., esq	Tracing of Dorchester, Roxbury, Cambridge, and Beverly, Massachusetts.
	10	John Burgwyn, esq.	Tracing of part of Beaufort harbor, North Carolina.
	17	Hon. S. R. Mallory	Tracing of shore-line of Boca Chica, Florida reef
	21	Cowperthwaite, Desilver & Butler	Tracing of reconnaissance of coast of Louisiana

APPENDIX No. 5—Continued.

Date.		To whom communicated.	Information communicated.
1854.			
Aug.	25	G. W. Blunt, esq	Tracing of hydrography from Key Biscayne to Carysfort reef light-house, Florida reef.
Sept.	5	Light-house Board	Tracing of Point Año Nuevo, California.
		Do	Tracing of Santa Cruz, California.
		Do	Tracing of Turtle harbor, California.
	7	W. D. Cooke, esq	Latitude and longitude of points in North Carolina.
	15	Light-house Board	Tracing of Little Choptank river, Maryland.
	15	W. D. Carpenter, esq	Tracing of Hudson river hydrography—1853.
	20	Charles Copley, esq	Tracing of Buzzard's bay, Mass.; Albemarle sound, N. C.; and Chesapeake bay, No. 2.
	26	G. W. Blunt, esq	Tracing of reconnaissance of Wimble shoals.
	30	J. S. Silver, esq	Tracing of coast of New Jersey, from Cape May to Leaming's beach.
	30	Land Office	Tracing of Rockland and adjacent keys, Florida reef.
Oct.	2	Dr. Alex. Wilcocks	Tidal records, Boston harbor.
	7	Commission on Portland harbor	Tracing of Col. Anderson's map of Portland harbor; Coast Survey map, 1853; comparative map of harbor, Colonel Anderson's, and Coast Survey.
Nov.	4	Hon. F. O. J. Smith	Tracing of soundings in Portland harbor, Maine.
	4	A. P. Marshall, esq	Levels and azimuth, Bramhall's Hill, Maine.
	4	Prof. Smith, (Bowdoin.)	Latitude, longitude, and azimuth of Presbyterian church, Brunswick, Maine.
	27	Lieut. C H. A. H. Kennedy, U. S. N.	Magnetic variation and distances between points near the entrance to Chesapeake bay.

APPENDIX No. 6.

List of capes, headlands, islands, harbors, and anchorages on the Western coast of the United States, of which either the geographical positions have been determined, topographical surveys made, or charts or sketches issued, to date of report of 1854.

Names, in geographical order.		Character of work.	Published.
Los Coronados islands	Position determined	Topographical survey	Sketch.
San Diego bay	do	do	do
Point Loma	do	do	do
False bay, near San Diego	do	do	
San Clemente island, anchorage	do	Preliminary survey	do
Santa Catalina island, anchorage	do	do	do
San Nicolas island	do	do	
San Pedro harbor	do	Topographical survey	do
Cuyler's harbor, San Miguel island	do	Preliminary survey	do
Prisoners' harbor, Santa Cruz island	do	do	do
Santa Barbara, anchorage	do	Topographical survey	do
Point Conception and Coxo harbor	do	Preliminary survey	
San Luis Obispo harbor	do	do	
San Simeon island	do	do	
Point Pinos, Bay of Monterey	do	Topographical survey	Preliminary chart.
Pajaro river, Bay of Monterey	do	do	
Sanquel cove, Bay of Monterey	do		
Bay and town of Monterey	do	do	do
Santa Cruz harbor, vicinity of Monterey	do	do	
Point Año Nuevo, vicinity of Monterey	do	do	
Point San Pedro	do	do	
Point Lobos, and southward	do	do	
Point Lobos, and northward	do	do	
Alcatraz and Yerba Buena islands	do	do	Sketch.
Presidio and Fort Point	do	do	
Lime Point and Point Cavallos	do	do	
City of San Francisco, harbor	do	do	Preliminary chart.

APPENDIX No. 6—Continued.

Names, in geographical order.		Character of work.	Published.
Points Bruno and Avisadera	Position determined	Topographical survey	
Point San Mateo and Guano island	do	do	
Contra Costa, Brook's island	do	do	
Contra Costa, San Antonio creek	do	do	
Mare Island straits	do	do	Sketch
San Rafael and Bluff Point	do		
Angel island, Raccoon straits	do	do	
Richardson's bay	do	do	
Points Bonita and Diablo	do	do	
Rocky Point	do	do	
Duxbury reef	do	do	
Point Reyes	do	do	
Tomales bay	do	do	
Haven's anchorage, Point Arena	do	Preliminary survey	
Shelter cove, Point Arena	do	do	Sketch
Mendocino city, Point Arena	do	do	do
Humboldt bay, Point Arena	do	do	do
Trinidad bay, Point Arena	do	do	do
Crescent City harbor	do	do	do
Ewing harbor, or Port Orford	do	Topographical survey	do
Umquah river, anchorage	do	Preliminary survey	do
Point Adams and Sand island	do	Topographical survey	Preliminary chart.
Mouth of Columbia river	do	do	do
Cape Hancock, or Disappointment	do	do	Sketch
Shoal-water bay, anchorage	do	Preliminary survey	do
Point Grenville, anchorage	do		do
Cape Flattery	do	Topographical survey	do
Nee-ah harbor	do	Preliminary survey	Preliminary chart.
False Dungeness, anchorage	do	do	Sketch
Canal de Haro and entrance of Rosario strait.	do	do	do

APPENDIX No. 7.

Results of the Coast Survey at different periods, from 1844 to 1854.

	Previous to 1844.	From 1844 to 1852.	For 1852.	For 1853.	Total from beginning of survey.
Reconnaissance—					
area, in square miles	9,642	30,548	1,706	1,708	43,604
parties, number of			6	5	
Base lines—					
number of	1	5		2	8
preliminary, number of	2	14	4	4	24
length of, in miles	19½	64	4½	18½	106½
Triangulation—					
area, in square miles	9,076	17,294	1,703	3,089	31,162
extent of coast-line, in miles	310	976	224	154	1,664
extent of shore-line, in miles	3,215	6,427	900	888	11,430
horizontal angle stations, number of	750	1,160	223	224	2,357
points determined, number of	1,183	2,008	446	346	3,983
vertical angle stations, number of	15	71	14	7	107
heights determined, number of	44	244	66	9	363
Astronomical stations—					
azimuth, number of	9	32	6	9	56
latitude, number of	9	44	17	20	90
longitude, number of	1	27	18	21	67
latitude, extra, number of					
longitude, extra, number of			5	5	
Magnetic stations, number of		116	8	13	137
Triangulation parties, number of			18	16	

APPENDIX No. 7—Continued.

	Previous to 1844.	From 1844 to 1852.	For 1852.	For 1853.	Total from beginning of survey.
Astronomical parties, number of	....	....	4	7	....
Magnetic parties, number of	....	....	5	9	....
Topography—					
area in square miles	6, 222	3, 967	601	551	11, 341
length of shore-l ne, in miles	6, 100	7, 033	1, 301	1, 468	15, 902
Topographical parties, number of	....	....	15	14	....
Hydrography—					
area, in square miles	9, 623	20, 950	....	....	....
parties, number of	....	....	9	10	....
soundings, number of	808, 147	1, 852, 009	288, 375	305, 377	3, 253, 908
soundings in Gulf Stream for temperature	....	1, 455	....	....	1, 455
fathoms of line used in same	....	143, 108	....	....	143, 108
tidal stations, number of	108	174	56	100	438
tidal parties, number of	....	....	5	6	....
current parties, number of	....	....	3	3	....
current stations, number of	....	321	21	89	431
specimens of bottom, number of	1, 327	4, 345	252	105	6, 029
Topographical maps, (original,) number of	166	187	29	34	416
Hydrographical maps, (original,) number of	127	172	25	49	373
Reductions and other maps	326	399	174	133	1, 032
Total number of manuscript maps	619	758	228	216	1, 821
Records of triangulation, (original,) number of volumes	97	133	33	64	327
Records, astronomical, (original,) number of volumes	17	149	48	29	243
Records, magnetic, (original,) number of volumes	4	42	7	6	59
Duplicates of the above, number of volumes	27	250	73	76	426
Computations, number of volumes	78	158	72	101	409
Hydrographical books, sounding and angle observations (original,) number of vols.	188	990	206	183	1, 567
Hydrographical books, sounding and angle observations (duplicates) do.	28	70	27	15	140
Hydrographical books, tidal and current observations (original) do.	127	499	139	123	888
Hydrographical books, tidal and current observations (duplicates) do.	....	599	132	114	845
Hydrographical books, tidal reductions, number of volumes	....	220	26	6	252
Total records, number of volumes	566	3, 110	763	717	5, 156
Library, number of volumes	....	1, 673	171	273	2, 117
Engraved plates of maps, number of	5	40	3	4	52
Engraved plates electrotyped, number of	....	55	23	47	125
Published maps, number of	....	37	5	5	47
Printed sheets of maps distributed, number of	....	15, 501	5, 799	8, 042	29, 342
Printed sheets of maps, sale-agents, number of	....	28, 077	6, 866	4, 375	39, 318
Total number of printed sheets	....	57, 001	31, 818	24, 076	112, 895
Instruments, cost of	....	$167, 094	$3, 835	$5, 296	$176, 225

APPENDIX No. 8.

General list of Coast Survey discoveries and developments to 1853 *inclusive, compiled by Lieutenant E. B. Hunt.*

As the operations of the Survey advance along the coast, important facts before unknown are constantly brought to light. Many facilities for, and dangers to, navigation are thus discovered, which had been before wholly unknown, and those before but imperfectly known are developed by accurate surveys. Many such developments and discoveries occur in the geodetic and topographical operations, some of which are of no slight value; but those which are embraced in the hydrographic work are often of vital importance to commerce and navigation. The following list presents some of the most important items of this nature, and may collectively be regarded as exhibiting one of the most valuable results of the Survey. In fact, each sheet which gives shore-line and hydrography with increased accuracy has somewhat of discovery or development to claim; but in this list only those cases are included in which a specific benefit has been conferred on navigation, either by unfolding some new facility, disclosing some serious danger, or indicating some important change of configuration. The arrangement is geographical, and in the order of sections.

1. A rock not on any chart, in the inner harbor of Gloucester, Mass.—discovered 1853.

2. A bank ninety miles eastward of Boston, with about thirty-six fathoms water—probably a knoll connected with Cashe's ledge, but with deep water between it and the ledge—1853.

3. Boston harbor: Broad Sound channel thoroughly surveyed, and marks recommended—1848.

4. Nantucket shoals: Davis' New South shoal, discovered in 1846, six miles south of the old Nantucket South shoals, in the track of all vessels between New York and Europe, or running along the coast from the Eastern to the Southern States, or South America.

5. Ditto: Two new shoals north and east of Nantucket—discovered in 1847.

6. Ditto: Six new shoals near Nantucket, the outermost one 14½ miles from land, and with only ten feet water—discovered in 1848.

7. Ditto. McBlair's shoals, off Nantucket—discovered in 1849.

8. Ditto: Davis' Bank—discovered in 1848, and survey finished in 1851.

9. Ditto: Fishing Rip, a large shoal extending north and south about ten miles to the eastward of Davis' Bank and thirty from Nantucket, with four and a half fathoms—surveyed in 1852.

10. Ditto: A ridge connecting Davis' New South shoal and Davis' Bank—found in 1853.

11. Ditto: A small bank or knoll, with but five fathoms on it, about five miles east of Great Rip, with twelve fathoms between it and Davis' Bank and Fishing Rip, the water gradually deepening outside of it to the northward and eastward, beyond the limits of the series of shoals.

12. Contraction of the inlet at the north end of Monomoy island, and opening of new entrance to Chatham harbor—1853.

12 *bis*. Muskeget channel—surveyed by Lieut. C. H. Davis in 1848, and Lieut. C. H. McBlair in 1850.

13. Numerous rocks in Martha's Vineyard sound, Long Island sound, and the various bays and harbors connected with them.

14. Gedney's channel into New York bay, having two feet more water than the old channels. Had the true depth of this channel (which is seen, by comparing old and new charts, to have then probably existed) been known in 1778, the French fleet under Count D'Estang would have passed into the bay and taken the assembled British vessels.

15. Sandy Hook; its remarkable increase out across the main ship-channel has been traced from the surveys of the topographical engineers and others, and by several successive special surveys.

15 *bis*. Increase of depth in Buttermilk channel, ascertained and made known in 1848, by survey of Lieutenant D. D. Porter.

16. Delaware bay: Blake's channel at the entrance discovered in 1844—open when the eastern channel is closed by the ice. This discovery has served to develop, strikingly, the resources of that portion of Delaware.

17. Blunt's channel in Delaware bay.

18. Changes in the Delaware near the Pea Patch.

19. The true extent and position of the dangerous shoals near Chincoteague inlet, Virginia—1852.

20. Metompkin inlet, Virginia, shoaling from eleven to eight feet in the channel during 1852.

21. Two channels into Wachapreague inlet, Virginia—one from the northward and the other from the eastward—both with seven feet water at low tide—1852.

22. A shoal half a mile in extent, not put down on any chart, 5½ miles east from the north end of Paramore's island, Virginia: it has but four fathoms water on it, and has nine fathoms around it—1852.

23. Great Machipungo inlet, Va.; found to have a fine wide channel, with eleven feet water on the bar at low tide and fourteen at high; good anchorage inside in from two to eight fathoms: the best harbor between the Chesapeake and Deleware entrances—1852.

24. Two shoals near the entrance to the Chesapeake—one 4¾ nautical miles S. E. by E. from Smith's island light-house, with seventeen feet upon it; and the other E. by S. nearly, 7¾ miles from the same light, with nineteen and a half feet upon it—1853.

25. Only three feet water upon the "Inner Middle," the shoal part of the Middle Ground west of the "North Channel," at the Chesapeake entrance—1852.

26. A twenty-five fathom hole two and a half miles west-southwest from Tazewell triangulation point, eastern shore of the Chesapeake; all other charts give not more than sixteen fathoms in this vicinity.

27. A shoal at the mouth of the Great and Little Choptank, in Chesapeake bay—1848.

28. Deeper water found on Diamond shoal, and a dangerous nine-feet shoal off Cape Hatteras—1850.

29. A new channel, with fourteen feet water, into Hatteras inlet, formed during the year 1852, which is better and straighter than the old channel.

30. The well-ascertained influence of prevailing winds in the movement of the bars at Cape Fear and New Inlet entrances, and the gradual shoaling of the main bar; the latter fact being of great importance to the extensive commerce seeking this harbor—1853.

31. Frying-Pan shoals, off Cape Fear, N. C. A channel of 2½ fathoms, upwards of a mile wide, distant 11 nautical miles from Bald Head light-house, across the Frying-Pan shoals. A channel extending from 3 to 4 miles from the point of Cape Fear to 8 to 8½ from it, with sufficient water at low tide to allow vessels drawing 9 or 10 feet water to cross safely. A channel at the distance of 14 nautical miles from Bald Head light-house, one mile wide, with 3½ to 7 fathoms water on it. The Frying-Pan shoals extend 20 nautical miles from Bald Head light-house, and 16, 17, and 18 feet water is found 17 and 18 nautical miles out from the light.—1851.

32. Shoaling of Cape Fear River bar thoroughly examined for purposes of improvement—1852.

33. Changes at the entrance of Winyah bay, Georgetown harbor, and the washing away of Light-house Point, at the same entrance—1853.

34. Maffitt's new channel, Charleston harbor, with the same depth of water as the ship channel—1850.

35. Changes in the channels at the entrance of Charleston harbor—1852.

36. The remarkable discovery of continuous deep-sea soundings off Charleston, and of soundings in the depth of between four and five hundred fathoms beyond the Gulf stream—1853.

37. The discovery of cold water at the bottom of the sea below the Gulf Stream, along the coasts of North and South Carolina, Georgia, and Florida—1853.

38. The discovery of the cold wall, alternate warm and cold bands, and various other features of the Gulf Stream, especially such as concern its superficial and deep temperatures on sections, and its distribution relative to the shore and bottom.

39. Various facts relative to the distribution of minute shells on the ocean-bottom, of probable use to navigators for recognising their positions.

40. Hetzel shoal, off Cape Canaveral, Florida—1850.

41. A new passage, with three fathoms water, through Florida reef to Legaré harbor, under Triumph reef, (lat. 25° 30′, long. 80° 03′ W.,) which, if properly buoyed, will be valuable as a harbor of refuge.

42. A new channel into Key West harbor—1850.

42. Isaac shoal, near Rebecca shoal, Florida reef; not laid down on any chart—1852.

44. Channel, No. 4, a northwest entrance into Cedar Keys bay—1852.

45. Mobile Bay Entrance bar; in 1822 only 17 feet at low water could be carried over it; in 1841 it was 19, and in 1847 it was 20¾ feet, as shown by successive surveys—1847.

46. The diminution, almost closing, of the passage between Dauphine and Pelican islands, at the entrance of Mobile bay—1853.

47. Horn Island channel, on the coast of Mississippi.

48. The removal of the East Spit of Petit Bois island in the hurricane of 1852, opening a new communication between the gulf and Mississippi sound, and the rendering of Horn Island Pass more easy of access by the removal of knolls—1853.

49. The accurate determination of Ship shoal, off the coast of Louisiana, in connexion with the site for a light-house—1853.

50. The changes at Aransas Pass, Texas, as bearing on the question of a light-house site—1853.

51. The determination of the position and soundings on Cortez Bank, near the island of San Clemente, coast of California—1853.

52. A shoal inside of Ballast Point, San Diego bay, with twelve and a half feet of water: not laid down on any chart—1852.

53. Changes in the channels of entrance of Humboldt bay or harbor, California—1852 and 1853.

54. The depth of water on the bars at the entrance of Rogue river and Umquah river, Oregon—1853.

55. South channel, Columbia river, surveyed and made available to commerce—1851. Changes of channels, their southward tendency, and a new three-fathom channel from Point Hancock, due west to open water, Columbia entrance—1852. Further changes—1853.

56. Various surveys and charts of small harbors on the Pacific, and a continuous reconnaissance of the entire western coast and islands adjacent, a great part of which was very imperfectly known.

Additional list for 1854.

57. Determination of the dimensions of Alden's Rock, near Cape Elizabeth, Maine.

58. A bank, (Stellwagen's Bank,) with ten and a half to fourteen and a half fathoms of water on it, at the entrance to Massachusetts bay, and serving as an important mark for approaching Boston and other harbors.

59. A dangerous sunken ledge (Davis' ledge) to the eastward and in the neighborhood of Minot's ledge.

60. Several rocks in the fair channel-way in Boston harbor entrance.

61. The tidal currents of Nantucket shoals and the approaches.

62. The tidal currents of Long Island sound.

63. The changes in New York harbor, near the city, between 1845 and 1854.

64. The general permanence of the Bodkin channel and shoals in its vicinity, at the entrance of the Patapsco river—between 1844 and 1854.

65. A shoal (New Point shoal) in Chesapeake bay, with sixteen feet water on it, southeast from New Point Comfort light-house, off Mobjack bay.

66. A reconnaissance of the Wimble shoals near Nag's Head, coast of North Carolina.

67. The general permanence in depth on the bar of Beaufort, N. C., with the change of position of the channel.

68. The changes in Maffitt's channel, Charleston harbor, S. C., from 1852 to 1854.

69. A harbor of refuge (Turtle harbor) to the northward and westward of Carysfort light-house, Florida reef, with a depth of water of twenty-six feet at the entrance.

70. A safe rule for crossing the Florida reef near Indian key.

71. Co-tidal lines for the Atlantic coast of the United States.

72. An increase of depth of water on the bar at Pass Fourchon, Louisiana.

73. A shoal at the entrance to the Straits of Rosario, Washington Territory, giving good holding-ground in thirty-three feet.

74. Belle Rock, in the middle of Rosario strait, Washington Territory, visible only at extreme low tides.

75. Entrance Rock, at the entrance of Rosario strait.

76. Unit Rock, in the Canal de Haro, Washington Territory.

77. A five-fathom shoal in the Strait of Juan de Fuca, between Canal de Haro and Rosario strait.

78. The non-existence of two islands at northern entrance of Canal de Haro laid down on charts.

79. The non-existence of San Juan island, usually laid among the Santa Barbara group.

80. Tides of San Diego, San Francisco, and Astoria.

APPENDIX No. 9.

Letter from the Superintendent to the Secretary of the Treasury communicating the discovery, by Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, of an important bank at the entrance to Massachusetts bay.

COAST SURVEY STATION, NEAR CAMDEN, MAINE, *Nov.* 20, 1854.

SIR: I have the great gratification to announce to you the discovery, by Lieut. Comg. H. S. Stellwagen, in the entrance to Massachusetts bay, of a bank, which must be of great importance to navigators as a guiding-mark. The least water on the bank is ten and a half fathoms at six and a half nautical miles N. 30½° W. (true) from Race Point light, Cape Cod. It lies generally outside of a line from Race Point light to Thatcher's Island light, Cape Ann; is seventeen nautical miles in length, five miles at its greatest breadth, two and a half at its least, and three miles in average breadth.

Its direction, by compass, is nearly N. by W. and S. by E. The north end of the bank is in the latitude of Nahant nearly, and the south end in that of a point five miles south of Scituate light: so that it lies in the direct approach from the southward to Boston, and being at a convenient depth for sounding while crossing it, is perfectly safe. It will serve as an excellent mark, in foggy or stormy weather, to determine a vessel's position. From ten and a half fathoms at six and a half nautical miles from Cape Race light, the bank deepens, on the average, but very slowly, reaching thirteen fathoms at nine and eleven miles, fourteen fathoms at thirteen and a half and fourteen miles, and fourteen and a half fathoms at twenty miles. It then deepens more rapidly to twenty fathoms, and then quite rapidly from this to thirty and thirty-five fathoms. The outer side of the bank slopes off gradually, and the inner quite abruptly, as a general rule.

Lieut. Comg. Stellwagen remarks, in his report: "I consider the promulgation of this discovery a very essential thing to navigators, and that the knowledge of it will highly benefit commanders of vessels and the great commercial interest of the city of Boston, as an invaluable aid to vessels bound in during thick weather, by day or night. By it they can not only ascertain their distance to the *eastward* of the coast, but, by attention to the lead after passing inside, a good idea of the latitude may also be obtained. Thus, three or four miles to westward of the northern half of the shoal, the water deepens generally to fifty fathoms, while at the same distance inside of the southern half, the soundings diminish gradually from forty-five fathoms, in latitude 42° 15′ north, to thirty-five fathoms, all the way across to the main land."

A sketch will immediately be prepared at the Coast Survey office, so as to show these and other peculiarities of the bank, and it will at once be published.

I have carefully examined the claims to discovery of this bank by Lieut. Comg. Stellwagen, and sifted the evidence by charts, and by the information of pilots, fishermen, and others. These I shall submit with my annual report, observing, in the mean time, that I consider it fully substantiated. The development of this bank, and the pointing out of its usefulness would, of themselves, give a credit little short of a discovery; but I shall show that a full discovery has been made. Stellwagen's Bank will rank in importance with Gedney's channel, at the entrance of New York, and Davis' shoal, on the highway to that mart from Europe and the eastern States, and will add another proof that important discoveries and developments are to be made by the Coast Survey, even in what may be called the beaten tracks of commerce and navigation.

I would respectfully request authority to publish a notice and sketch of this discovery.

Very respectfully, yours,

A. D. BACHE,
Superintendent Coast Survey.

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 10.

Letter to the Secretary of the Treasury communicating the positions of three dangerous rocks in the channel-way of Boston harbor, and ranges for avoiding them, ascertained by Commander C. H. Davis, U. S. N., and reported to the Superintendent.

COAST SURVEY STATION, NEAR CAMDEN, MAINE,
November 16, 1854.

SIR: Through the courtesy of Commander Charles H. Davis, U. S. N., late a hydrographic chief in the Coast Survey, I have been furnished the positions of three very important and dangerous rocks in Boston harbor, situated in the fair channel-way, inside of Boston light. Commander Davis acknowledges obligations to Mr. Alfred Nash, commissioned pilot of Boston harbor, for valuable services in this connection.

These rocks were recently discovered by vessels striking on them while in the charge of able pilots, and numbered 1, 2, 3, from the light-house up. They may be *approximately* laid down on the chart as follows:

1. Distant seven hundred yards from Boston light, on the bearing W. 54½° S.

2. Distant seventeen hundred and seventy yards from Boston light, on the bearing W. 24¼° S., which will be about two hundred and forty yards from the new beacon on the spit, in a south and east direction.

3. Distant two thousand three hundred and forty-three yards from Boston light, on the bearing W. 14¼° S., which will be about one hundred and seventeen yards beyond and above the old beacon on the spit, in a south and west direction.

These bearings are true.

The first rock may have on it as little as .... 12 feet.
The second......do.........do.........do... 15 "
The third ....do.........do.........do... 17 "

Ranges for avoiding the rocks.

1. The new beacon on the spit, kept open to the north with the hotel on Long Island, leads clear to the south of the first rock.

2. Shutting in entirely the hotel on Long Island with the north part of George's island, leads clear to the south of the second rock.

3. Nix's Mate on the northern edge, or at furthest the centre of Bunker Hill monument, (but not on or beyond the southern edge of it,) leads clear to the south of the third rock.

If Bunker Hill monument is not visible, then Deer Island beacon, kept on the north end of Apple island, while passing the range of the old beacon on the spit, on the little head of the Great Brewster, will answer the same purpose.

I would respectfully request authority to publish the foregoing for the benefit of navigators.

Very respectfully, yours,

A. D. BACHE,
Superintendent United States Coast Survey.

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 11.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, communicating notice by Commander Charles H. Davis, U. S. N., of a dangerous sunken ledge in the vicinity of Minot's, approaches to Boston bay.

COAST SURVEY STATION, NEAR CAMDEN, MAINE,
August 28, 1854.

SIR: By the kindness of Commander Charles H. Davis, U. S. N., the officer who executed the hydrography of Boston harbor and its approaches, the Coast Survey has been enabled recently to determine the position of a very dangerous sunken ledge in the neighborhood of Minot's ledges, approaches to Boston bay. This sunken ledge is very little known, and no notice of it has yet been published. It has only ten feet of water on it at low water, spring tides.

The position may be determined by the following magnetic bearings from it:

The light-boat bears NW. by W. ¾ W.

Scituate light bears S. by E.

Minot's Rock, (outer Minot's,) W. by N. ¾ N.

The rule for avoiding this and all similar dangers in this vicinity is, *not to pass to the southward of the light-boat*, where strangers have no excuse for going at any time.

I would respectfully request authority to give the usual public notice of the foregoing.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 12.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, communicating the discovery of "New Point Shoal," and description of York Spit, Chesapeake bay, by Lieut. Comg. J. J. Almy, U. S. N., assistant in the Coast Survey.

COAST SURVEY OFFICE, *July* 15, 1854.

SIR: In a recent communication Lieut. Comg. J. J. Almy, U. S. N., assistant in the Coast Survey, reports, in the prosecution of the hydrography of the Chesapeake off the entrance of Mobjack bay, the discovery of a shoal with sixteen feet of water on it, southeast from New Point Comfort light-house, which he proposes to call "*New Point Shoal.*"

The following extracts from his letter give the particulars of his discovery, and also a description of *York Spit,* which will be useful to navigators:

"While prosecuting soundings to the southward and eastward of New Point Comfort light-house, I discovered a shoal with eighteen, seventeen, and sixteen feet of water upon it. This is the only detached shoal, if I may except the 'Inner Middle,' with which I have met anywhere below Windmill Point, or below the widest part of Chesapeake bay. The shoal is three-quarters of a mile long and a third of a mile wide, extending in an east-northeast and west-southwest direction; and the sixteen-feet shoal part lies due southeast from New Point Comfort light-house, a distance of four nautical miles from it. There are five and three-quarters and six fathoms between this shoal and the light-house. The best charts have six fathoms where the shoal lies. I propose to call it '*New Point Shoal,*' as an appropriate name by which navigators could easily call to mind its locality.

"Since I have discovered and mentioned it to people in this vicinity, one of the old residents remembers that some fifteen or twenty years ago a deeply laden ship struck and thumped hard in that locality.

"York Spit is, as you know, one of the greatest dangers to navigators in this part of Chesapeake bay. It is a narrow spit, or bar, lying between the entrance into Mobjack bay and the entrance into York river, varying in width from a quarter to half a mile, and extending out from the land six and a half nautical miles, equal to seven and a half statute miles, where it commences to deepen beyond three fathoms. At a distance of six nautical miles from the land there are, as I found, only fourteen feet of water."

I would respectfully request authority to publish the foregoing.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 13.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, communicating results from a hydrographic reconnaissance of Wimble shoals, coast of North Carolina, made by the party of Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey.

COAST SURVEY STATION, NEAR CAMDEN, MAINE,
September 22, 1854.

SIR: A hydrographic survey of Wimble shoals, on the coast of North Carolina, included in my instructions to Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, has been executed in part by that officer, and reported upon. The prosecution of this desirable work in the present season was, however, prevented by the ravages of cholera on board his vessel, and the following extracts from his report of reconnaissance are communicated in advance of the complete survey, for the benefit of navigators.

"The Wimble shoals consist of three ridges, parallel to the coast of North Carolina, lying east-southeast from the northern part of the woodlands on Chicomicomico, and distant from two to four statute miles from the beach. The soundings are very irregular, changing sometimes two and a half fathoms in a cast of the lead, with coarse sand, gravel, and shells, on the shoals, and outside, in thirteen fathoms, soft black mud.

"I have not in this season struck the shoalest water, as, in September, 1852, crossing in the Corwin, we had one cast of *three fathoms*, with five and seven fathoms before and after it.

"Vessels of considerable draught should not approach the land here within four miles; there is generally a strong current setting towards the shore, and the water shoals very suddenly.

"I have already stated to you the circumstances which made it impossible to continue the work; but so far as it goes, it is reliable, and may serve the present interests of navigation on the coast."

I would respectfully request authority to publish the foregoing.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 14.

Report of Lieut. Comg. J. N. Maffitt, U. S. N., assistant in the Coast Survey, on Beaufort harbor, North Carolina, communicated, by request, to the honorable Secretary of the Navy June 12, 1854.

The entrance to the harbor of Beaufort, North Carolina, is seven miles WNW. from Cape Lookout light-house, and easy of access in all winds excepting those from the west and northwest. The bar has, at present, fifteen and a half feet at mean low water.

The anchorage, from abreast of Fort Macon wharf to a point a mile and three-quarters westward, is safe, and completely protected from all winds.

The direction of the channel has changed materially from time to time. According to an old chart, (no authority,) it was SSW., with sixteen feet.

In 1820	according to Kearney	it was N. and S.	with 13	feet.	
1830	do	(Army) it was N. and S.	with 18	"	
1839	do	Lieut. Glynn it was S. 21° 30′ E.	with 15	"	spring tide.
1850	do	Coast Survey it was S. 52° 15′ E.	with 17	"	m. l. w.
1854	do	Coast Survey it was S. 52° 15′ E.	with 15½	"	"

The bar of Beaufort is composed of coarse and fine marine sand, mixed with dead shells; and, like all southern sand-bars, it is subject to the extraneous influences of sea and current. During the last thirty years, this bar has varied slightly in depth, but materially in direction. From the best evidence which could be obtained—both positive and traditionary—I have concluded that the normal depth upon the bar at mean low water is sixteen feet. This deduction is based upon the following evidence:

Wimble's chart, published in 1737, (one hundred and seventeen years ago,) gives eighteen feet as the depth on the bar at low tide.

It is also stated, on good authority, that Lawson's chart, published in 1718, coincides with Wimble's in the depth at low water.

In evidence of the continued excellent depth of water on this bar, it may not be out of place to state that, in the year 1760, the colonial legislature granted to a company a charter authorizing the connexion of Beaufort with Neuse river by means of a ship-canal; and as Ocracoke bar (the natural outlet to the Neuse river) had then twelve feet at low water, the inference is, that the channel had not deviated in depth since the survey of Wimble.

It is a well-attested fact that, during the war of the Revolution, an English cruiser, drawing twenty-two feet, entered the harbor of Beaufort, and was conducted out again by a resident pilot, who stated that "she crossed the bar with an ordinary high tide, but struck lightly several times."

In the years 1811, 1813, and 1815, serious changes, as to depth and direction, occurred upon this bar, which were attributed to the heavy southwest gales of those years—that of 1815 being one of the most violent and disastrous ever known upon the coast. Shackelford's Point was much affected by the sea, and the site of old Fort Hampton entirely destroyed. The bar was injured so that but twelve feet could be brought over it at low water.

After the year 1815 the channel-way gradually changed its direction more to the southward; the depth of water also steadily increased until 1830, when a depth of eighteen feet at low water was reported by officers of the army.

In the year 1838 the ship Napoleon, bound for Liverpool with naval stores, crossed the bar with a draught of seventeen and a half feet. In 1839 the bar was surveyed by order of the Hon. J. K. Paulding, Secretary of the Navy, and "fifteen feet water at the lowest observed tides," reported by Lieut. Glynn, the officer in charge of the survey.

In 1850 the bar was sounded out under my direction, and seventeen feet found upon it at mean low water. My present survey gives fifteen and a half feet at mean low water. The differences noticed in the depth are attributable to local causes of a transient character, not permanently affecting the general capacity of the bar.

Point Macon has been successfully protected from the encroachment of the sea by a system of jettees, and Shackelford's Point requires a like expedient, as in every gale from the southward, portions of it are washed away. The Coast Survey shore-lines of 1851 and 1854 differ materially, showing a large decrease of the point, the effect of which is undoubtedly injurious, not only upon the direction of the channel, but also as affecting the depth of water on the bar. If this salient point, which governs so materially the ebb and flood, was protected from abrasion by the sea, the channel would probably be more fixed in its character.

A marked evidence of the value of this harbor is derived from information furnished by the Treasury Department, to the effect, that though in 1810 the gross revenue accruing to government through the custom-house at Beaufort was but $522, in 1813 it suddenly increased to $105,214, and throughout the war it continued the like large returns to the treasury.

The geographical position of Beaufort is favorable, not only for purposes of commerce, but as affording protection during northeast and eastwardly storms. Cape Lookout affords a natural breakwater in gales from those points, with excellent and well-protected anchorage under the land, the light-house bearing east.

The harbor.—The harbor of Beaufort may be regarded as extending from Macon Point westward to the entrance of Bogue sound abreast of Shepherd's Point. It is bounded on the south by marsh-lands belonging to the Fort Macon property and the Literary Society of the State; on the north by sand-banks, bare at low water, and marsh-land, also the property of the Literary Society. The average width of the harbor is three hundred yards, exclusive of the mouth of Newport river, which also affords excellent anchorage as far as the flats. The channel here is two hundred and eighty yards wide.

The marsh-land traversed by Fishing creek bordering upon the government property has deep water along its margin, on which wharves could be built at small expense. There are several good localities adjacent to Shepherd's Point for wharves, which would not involve extraordinary outlay.

In the event of the contemplated railroad terminating at this port, all the marsh-lands mentioned must become important for the necessities of commerce. My opinion strongly inclines to their selection for government purposes, as the water is bold from Fishing creek westward, and the sand-hills by the seashore offer the most healthy sites for dwelling-houses. This selection is based upon the presumption that government designs to establish at this port only a depot for the collection of naval stores and fuel for the use of the second-class steamers, which would always find this a convenient harbor for a re-supply of coal when cruising off the coast. The actual bar is but three hundred and seven yards wide, passing rapidly from three and a quarter to three and a half fathoms (over fifteen and a half feet at mean low water.)

The normal depth of water on the bar I have assumed as sixteen feet at mean low water, which at high water will allow sloops-of-war and second-class steamers to enter without difficulty, while brigs, schooners, and third-class steamers could come in at any stage of the tide.

Harbors with such facilities, on this part of the coast, are too valuable to be neglected by the government. Many of our coasting-schooners use this port constantly as a harbor of refuge, and the establishment of lights and buoys by the general government, to afford additional facilities for ingress and egress, would be fully warranted by the importance of this coasting trade.

On several occasions during the month of March, 1854, I have seen from seventeen to twenty vessels with valuable cargoes anchored in this port for safety from the gales.

The establishment of a railroad depot at this place, as an outlet for the mineral wealth and agricultural resources of the interior and western parts of the State, would no doubt cause the port to grow rapidly in commercial impoɪtance.

The facilities are great for inland navigation—with Pamplico by means of Core sound, and also with the rich county of Onslow by the way of Bogue sound, the navigation of which could be improved without very great expenditure of means. Naval stores in abundance could be shipped here; coal and copper obtained by railroad from Chatham county, live oak from Onslow, and white oak and other timber from the adjacent country. It is certain that encouragement and increased facilities would very soon make this an important southern port. The salubrity of the place is such as to render it a rendezvous during the summer months.

I incline strongly to the opinion that jettees would save Point Shackelford, and if extended, (as the land formed) would have a tendency to improve the depth of water on the bar. This point, well secured or *prolonged*, would change the current, and no doubt the bar-channel, more to the southward or at right-angles to the coast. The result would be to force the bar promptly seaward into deep water, instead of following the coast-in shoal.

Where artificial means are to be resorted to, with reference to sand-bar improvements, I am impressed with the conviction that if the current *can* be governed, means should be applied to force the bar seaward *into deep water at right-angles to the coast.* Charleston main ship-channel loses all benefit of the ebb current by its general diffusion before it reaches the desired point. If all the ebb could be forced out *east*, that bar would have twice its present capacity.

This opinion is, of course, based upon the theory that the more contracted the outlet for a body of water, the greater will be the velocity of the current or scouring influence by which the bar is deepened, or at least kept at its uniform depth.

The channels connecting Beaufort and Lenoxville with the main harbor are intricate; that leading into the former has but six feet at mean low water. The channel around Shackelford's Point, leading up to the latter, has eleven feet at mean low water. It is narrow, and subject to constant changes. Passing Shepherd's Point the channel has four fathoms.

Eleven feet, at mean low water, can be carried up to Gallant Point; ten feet, at mean low water, abreast of Carolina City.

The channel by Bird island, though more permanent, is tortuous, and affords but nine feet at low water.

Respectfully yours,

J. N. MAFFITT, U. S. N.,
Assistant in the U. S. Coast Survey.

Prof. A. D. BACHE,
Superintendent of Coast Survey.

APPENDIX No. 15.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, communicating the discovery of a harbor of refuge near Carysfort reef, coast of Florida, by Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey.

COAST SURVEY STATION, NEAR CAMDEN, ME.,
September 27, 1854.

SIR: The following extract from the season's report of Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, is communicated as of immediate interest to navigators on the Florida coast:

"An excellent harbor was discovered by my party four and a half miles to the northward and westward of Carysfort light-house, so easy of access that it may become an important harbor of refuge, if properly marked by a beacon and buoys. The depth of water at the entrance to the channel is twenty-six feet, and the light-house, from its proximity, assists in guiding to the anchorage, which is soft clay, and known to only a few persons.

"I propose to call this *Turtle harbor*, as being near to the reef of that name."

A sketch of the harbor and locality will be published with my report of the present season. (See Sketch F, No. 3.)

The recommendation in regard to the beacon and buoys has been already transmitted to the Light-house Board.

I would respectfully request authority to publish the foregoing.

Very respectfully, yours, &c.,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 16.

Letter from the Superintendent to the Secretary of the Treasury, in relation to a safe and convenient passage across the Florida reef at Indian Key, communicated by Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey.

NEW YORK, *December* 5, 1854.

SIR: The following extracts from a letter of Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, relative to a safe and convenient passage across the Florida reef, at Indian key, are communicated as being of immediate interest to navigators:

"Of all the Florida keys, *Indian key* may be the most readily distinguished. It is a wrecking station, and contains five or six houses, which give it the appearance of a settlement; but, with the exception of a few tall cocoanut trees, the island is destitute of all vegetation."

"With Indian key bearing from N. to NW. by N., vessels may run for it, crossing the reef in four fathoms, and gradually shoaling to three fathoms when within a mile and a half of the key, where they may anchor safely."

I would respectfully request authority to publish the foregoing.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 17.

Letter to the Secretary of the Treasury, communicating the discovery of a three-fathom shoal near the entrance to Garden Key channel, Tortugas, reported by Lieut. H. G. Wright to the Chief Engineer, and referred to the Superintendent.

COAST SURVEY STATION, NEAR CAMDEN, ME.,
October 27, 1854.

SIR: I am indebted to the Chief Engineer, Gen. Totten, for an extract from a letter of Lieut. H. G. Wright, of the corps of engineers, communicating the existence of a shoal spot, not upon the chart nor generally known to wreckers or fishermen, in Garden Key channel, the light-house bearing south. This shoal has scant three fathoms of water on it, while there are six and a half and seven fathoms on each side of it.

The hydrography of the Coast Survey has not yet included this channel.

I would respectfully request authority to publish the foregoing for the use of navigation.

Very respectfully,

A. D. BACHE, *Superintendent.*

Hon. P. G. WASHINGTON,
Acting Secretary of the Treasury.

APPENDIX No. 18.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, in relation to the alleged existence of a shoal of twenty fathoms in latitude 27° north, longitude 89° west of Greenwich.

COAST SURVEY OFFICE, *May* 6, 1854.

SIR: My attention was called by George W. Blunt, esq., of New York, to the supposed existence of a shoal nearly south of the Belize, in latitude 27° north.

This has been searched for under my instructions, by Lieut. Comg. B. F. Sands, U. S. N., assistant in the Coast Survey, who reports that, after a careful examination in the position indicated and its vicinity, no bottom was found in from 100 to 145 fathoms.

I would respectfully request authority to publish the foregoing.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 19.

Letter from the Superintendent of the Coast Survey to the Commissioner of the General Land Office, communicating the results of the survey of Florida keys, in the vicinity of Key West and Spanish harbor.

COAST SURVEY OFFICE, *July* 13, 1854.

SIR: I have the honor to acknowledge the receipt of your letter of July 6, requesting to know the progress made in the survey of the Florida keys.

1. On the passage of the appropriation in March, 1853, I made immediate arrangements, anticipating the beginning of the fiscal year, and sent a party to the keys east of Key West for triangulation and topography. The result was a survey of Boca Chica key and its connection with Key West and the adjacent keys. The map of this survey showing the character of the key, the amount of woods, ponds, &c., &c., was transmitted to you on the 15th of December, 1853, with extracts from the reports of the assistants making the survey. An extract from the report of Sub-Assistant R. M. Bache is appended to this letter, marked [M.]

2. I then proposed a method of numbering the sections of the keys, so that they might be sold as the survey advanced, if you deemed it proper. This, on conference with you, was deemed satisfactory, and I have acted upon it in the subsequent surveys.

The system of marking and numbering enables you, by differences of latitude and longitude, obtained geodetically, to connect all the keys together, and with the main, when the work is so far advanced.

It is very simple and explicit, and, with the modifications suggested by your office, seems to me to meet all the wants of the government and of the buyer of the land. The marks are easily replaced, if by accident obliterated, and the divisions are easily understood. I append a note of this system, [N.]

3. During the past year the triangulation has extended beyond the topography, which includes the following named keys. The map of these is in preparation, and will be sent to your office in a few weeks. They are—East Harbor Keys, West Harbor Keys, Cayo Agua, Desolation, Hawk, Middle, Eagle Nest, Snake, Rockland, East Rockland, Big Coppitt, Half-Moon, Shark, Attava, Gieger's Key, South Saddle Hill, Round, Wall, Bird, and Pelican Keys.

The particulars in regard to these keys will be found explicitly stated in the report of J. Hull Adams, esq., hereto annexed and marked [O.]

4. We have, besides these surveys, topographical maps of the keys from Cape Florida to near Carysfort reef, at the disposal of your office, and of surveys in the vicinity of Bahia Honda. A description of the keys surveyed during the past year will be found in the report of S. A. Wainwright, esq.; a copy of which is herewith enclosed, [P.]

5. All the necessary arrangements are made for prosecuting this work vigorously during the next season, the triangulation being in advance of the topography.

6. As far as depends upon marking and maps, the Boca Chica key affords the means of securing the necessary general legislation for the sale of the keys.

Yours, respectfully,

A. D. BACHE, *Superintendent.*

JOHN WILSON, Esq.,
Commissioner of General Land Office.

[M.]

* * * * * * *

In making the survey of Boca Chica, and laying it out in quarter-sections, I adopted the following plan:

A number of posts, painted black and marked U.S.C.S., were used for the marking of the points along the shore. These posts were of the following dimensions, which were found to be sufficient, except in two cases, where the water of Pelot's creek was so deep that ordinary flag-poles were used.

Length of post, two and three-quarters feet; thickness of post, three inches.

In addition to the painting of U.S.C.S. on the posts, they were numbered, and also marked with the letters P. or M., to signify parallel or meridian. Of course, these letters P. and M. were marked on the spot, as it was impossible to know whether a parallel or meridian post would be necessary, unless the shore was very regular.

The advantage of numbering and lettering the posts P. and M. is very great; for if the person who runs out the lines finds a post on one side of an island numbered, he will see, by reference to the map, where the line comes out on the other side, by the number there; whereas he could not do this without the numbering, unless by finding some of the posts, and comparing their positions with the topography. The lettering gives him the direction to run, even without the map.

I understand that the surveys of land in Florida are made using the magnetic north. This was not done on Boca Chica, as I had not the variation.

On commencing the survey of Boca Chica, I saw that there would be great inaccuracy in the work if the quarter-miles were laid off with the dividers one from the other as the work proceeded, so that the work was commenced by making a projection of squares of a quarter of a mile in area on the map; and, in making the survey, all that was necessary was to sight from the position of the table to the spot where the post was to be placed, and to chain the line.

The only change to be made in the surveys of the other keys would be to make the projection of squares by the magnetic north.

Of course, the posts and poles used for marking points must differ on other keys, as the bottom is sometimes very soft, and would require long poles in those places where it would be necessary to place the mark in the water.

* * * * * * * *

Yours, respectfully,

R. M. BACHE,
Sub-Assistant U. S. Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

[N.]

1. To take some triangulation point on Key West as a starting-point, and reckon the differences of latitude and longitude from it. The centre of Sand Key light-house is adopted for the purpose.

2. To number the keys and islands according to convenience and order of sale, and also to give their names, thus:

No. 1. Boca Chica, between parallels —— and —— north of Sand Key light, and meridians —— and —— east of ditto.

Minutes and decimals of a minute to be stated.

3. On sketch-map, to show the point from which the differences of latitude and longitude are reckoned, and the relation of the islands and keys to each other and to the main.

4. The points, north, south, east, and west, to be reckoned by the true meridian.

The variation of the compass, at the time of the survey, to be written on the map sections, to refer hereafter to geographical miles, sixty to a degree at the equator, or minutes of latitude, nearly, unless otherwise stated.

5. Divisions to be made into sections and quarter-sections, and to be numbered, beginning south and west, and going on northward and towards the east.

The numbers of the sections to be written on the map in the spaces, and, in an explanation, reference to be made to the marks.

Important lines only to be run out. Areas to be stated.

To estimate roughly surface of shallow ponds not navigable, so as to subtract, if necessary, from area of land.

[O.]

JUNE 29, 1854.

SIR: In pursuance of your instructions, I repaired to Key West; and, having hired a suitable vessel, I anchored her inside of the Harbor keys, about ten miles northward and westward of Key West. This is considered a good refuge for vessels drawing not more than six feet.

I commenced the topographical work at West Harbor key, which is about half a mile in length. Being elevated, its soil is the best in this vicinity, sustaining a growth of button-wood and sea-grape, with but little mangrove.

The group south and east of this comprises Kayo Agua, Desolation keys, Middle key, and Hawk key. These are much broken up by channels in every direction. Kayo Agua—a half-mile long and a quarter in breadth—is the largest; but at ordinary high water, most of the group are overflowed. They are all covered with mangrove, surrounded by mud-flats, making the approach very inconvenient, and together comprise an area of about four square miles.

A mile eastward of these lies a group called East Harbor keys, which may be regarded as *one*, intersected by numerous deep passages throughout its length of two and a half miles. In breadth it varies from a quarter to half a mile, and bears a dense growth of mangrove.

Eagle's Nest, to the southward, is about half a mile in length, and has some firm ground. The next in order is called Snake key, a mile in length, of coral formation, and overgrown with brush and mangrove. Westward of this lie three very small and unimportant keys. A group to the southward comprises Rockland key, a mile in length, of hard coral, covered with rough grass and low bushes, and at its southern extremity thick mangrove; East Rockland and Big Coppitt, or Coppice, of the same size, but very much cut up with channels, and generally covered with water at spring tides. The northern half of the last named, however, has a good soil sustaining a growth of iron-wood, button-wood, and sea-grape, and is similar in character, but of better quality than the southern part of East Rockland. There is a house and small plantation on Big Coppitt.

On the north side of these lie Half-Moon keys, Shark key, and O'Hara key; and, further distant, Wall key; all narrow, unimportant strips, generally less than a mile in length, and covered with grass or mangrove.

Geiger's key, east of Boca Chica, is separated from it by Pelot's creek. This key is two miles long, and has some good land, bearing a growth of iron-wood and button-wood throughout. Just south of its eastern extremity is South Saddle Hill, which is important as being the first land seen by vessels approaching this part of the coast. The southwest half abounds with very tall mangroves, which give it the appearance of a *hill*, but these are bordered by button-wood and sea-grape; the other half bears a lower growth, and is not important. This key is three-fourths of a mile in length, and two smaller keys to the north of it bear the same name.

Two strips adjoining those just noticed are called Bird key and Pelican key, both unimportant except for their fuel, of which a scarcity already begins to be felt at Key West.

The keys are all surrounded by extensive flats of deep mud.

The difficulty of determining the land-marks at the intersection of the meridional and parallel lines with the shore was sometimes very great, and consumed much time; but I was enabled to get them all, as well as the intersections of the quarter-section lines, and have planted numbered stakes at each.

I have the honor to be, very respectfully, your obedient servant,

HULL ADAMS.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey, Washington.

[P.]

Bahia Honda, or Spanish harbor, to the south of it, is surrounded by keys more stable in character than those near Old Rhodes harbor.

Spanish key, on which my base was measured, is a large dry marsh bordered by cocoanut, palmetto, and small oak woods. An arm of the sea makes into it, and, by an unusual swell from the ocean, parts of it may possibly be overflowed, but during the time occupied in the operation referred to above it was quite dry.

Pine key is very similar to that just described, with large pines, however, on the waterside, and more abundant undergrowth.

All the keys in Spanish harbor are of coral formation, covered by two feet or more of soil. No depth of water occurs within from fifty to one hundred yards from the shore, which is in all cases fringed with bushes; beyond this distance the bottom is composed of sharp coral rocks.

It is difficult to determine whether these keys are increasing or diminishing in size; but from my own observation, made during a short stay, I incline to the latter view, from finding at the water-edge large trees, which certainly must have grown in a more fertile position.

From Bahia Honda the distance to Old Rhodes harbor is about a hundred and twenty miles. Most of the small keys in this last named vicinity are covered with a thick growth of mangrove, and have generally very abrupt banks, with either deep water over soft, muddy bottom in the passages between them, or scarcely any at all. They appear to be low and swampy in the interior, evidently corresponding in contour with the well known peculiarity of the coral formation beneath.

Old Rhodes key is more stable in character and more considerable in size than either of those just alluded to.

Key Largo North appears to be a dry marsh, bordered with pines. This is, perhaps, the largest of the whole range. A little to the eastward of its northern extremity is Angle-fish key, three-fourths of a mile long, with a margin of small trees; and directly north of that Palo Alto key, about a mile in length, and covered with almost impenetrable bushes. Neither of these will average more than a fourth of a mile in breadth, and, like all the small keys, both in this vicinity and at Spanish harbor, are of little value.

APPENDIX No. 20.

Extracts from the report of F. H. Gerdes, esq., assistant United States Coast Survey, on the reconnaissance of the coast of Louisiana in 1854.

From the entrance to Atchafalaya bay, which is marked by a beacon and light-boat, (between Marsh island and Point au Fer,) in latitude 29° 25′ north, and longitude 3° 32′ west of Mobile, the water extends in a northwesterly direction, forming two other bays continuous with it, but partly separated by points of land projecting towards the island. These are named respectively Côte blanche, which lies entirely behind Marsh island, and Vermilion bay. The last mentioned has an outlet to the Gulf, between the western end of the island (on which there is a light-house) and the low marsh of Chenière au Tigre. This is called the Southwest Pass.

The navigation of these bays, but chiefly of the Atchafalaya, is very important, and is daily increasing, as nearly all the produce of Bayou Teshe and Atchafalaya river passes through it. Vessels of the larger class use an outside anchorage near the light-boat, at the entrance, where they find ten and eleven feet water, and discharge and take in cargo by lighters. The channel inside and above the barrel-stake has fully eight feet, but is very crooked and intersected by numerous oyster-reefs or bars, for the most part parallel to each other. A very able report, made by Captain Field, who surveyed the bay and river for the New Orleans and Opelousas Railroad Company, states that these bars might be cut through at comparatively small expense, thus increasing the depth to ten feet, and shortening the passage from the entrance to the mouth of the river fully one-half.

West of Vermilion bay the low, marshy coast of Louisiana stretches with but little variety of natural feature throughout a distance of about a hundred miles to the Sabine, the boundary of Texas.

About six miles westward of the Southwest Pass occurs the thickly-wooded hammock of Chenière au Tigre, of from three to five miles in extent, and on which there is some solid soil, and perhaps ten miles northwest of it another called *Pecan island*. This is quite narrow, but extends parallel with the coast-line in a direction nearly east and west about fifteen miles, and projects several branches into the marsh from its northern side. It is said to be entirely covered with a growth of superior *live-oak*, but is so extremely difficult of access that very little is certainly known concerning it. The facts stated in connexion with the supposed value of this hammock, seem to be worth investigation. It lies about ten miles north of the mouths of Freshwater and Big and Little Constance creeks.

The next feature presented by the shore of the Gulf, is the very shallow mouth of Bayou Mermenton. The bayou extending in a northeasterly direction is soon lost in the impenetrable swamp, but reappears some forty miles higher up in the country.

Twenty miles west of this, and perhaps forty east of the Sabine, Lake Calcasieu, twelve miles long and about five wide, finds its outlet to the Gulf between wooded hammocks and through some tillable land; and a few miles further on, Mud lake, smaller than the one before mentioned, and lying much nearer to the margin of the coast. The Sabine river and lake are inserted in the sketch of reconnaissance from the astronomical determinations and surveys of Major Graham, United States topographical engineers, and some of the details of the interior east of Lake Calcasieu were determined from the State surveys of Louisiana. The marshes between it and Vermilion bay are reported to be impenetrable.

While temporary repairs of the schooner Gerdes were in progress, I made a special reconnaissance of Fourchon Pass, the principal outlet of Bayou Lafourche. The bulk of the staple produce of that vicinity has been heretofore taken through the bayou to Donaldsonville, on the Mississippi river, and thence down to New Orleans; but, besides other advantages, the distance to the same point will be lessened by using the pass as an outlet to the Gulf navigation. The water on the bar has *doubled in depth within two years*, and is believed to be still increasing. According to my soundings, eight feet can be brought in a straight line to the Gulf without any difficulty. A light-house, or some other distinguishing mark, on the sand-hill which bounds the east side of the pass, would increase the facilities for navigation.

Within the last ten years the resources of the lower parts of Louisiana have been rapidly developing, trade has increased accordingly, and the coast-line in consequence has been better known. Clearings which a few years since stopped within sixty miles of the Gulf, can now be traced to the very edge of the marshes in the vicinity of the Atchafalaya, Teshe, and other streams. The New Orleans and Texas railroad passes through the most fertile land, and will probably in a short time double the commerce and enterprise of this part of the State. As an additional link to the great chain from the north, this road presents another feature of special importance in the contemplated connection between New Orleans and Galveston, by the finished road as far as Berwyck on the Atchafalaya, and thence by a line of steamers. The project now referred to, besides avoiding the only dangerous part of the passage by the Gulf, would lessen the distance between the two points about a hundred and thirty miles. Its practicability, however, must depend in part upon the result of a hydrographic survey of Atchafalaya bay and river, but there is reason for believing that the issue will be found favorable to the interests and convenience of the travelling community.

APPENDIX No. 21.

Extracts from report of Assistant W. E. Greenwell on the general features and peculiarities of the coast of lower Texas, with suggestions in regard to facilities for navigation.

The country between Brazos St. Iago and the Rio Grande is mostly a level prairie of alluvial soil—a vast grazing plain, upon which thousands of cattle find subsistence the whole year round. Rising abruptly on this plain are islands, or "montes," as they are called, varying from fifteen to forty feet in height—curious features in themselves, since they all differ, both in soil and vegetation, from the level below. Upon these grows, in all its perfection, the mezquite, intermixed with a species of ebony and lignumvitæ, perhaps the best fuel in the world.

The Rio Grande is a narrow, tortuous stream, with an average width of not over four hundred feet. It is navigable for steamboats of light draught as far up as Roma, three hundred and thirty miles from its mouth, but impracticable for any other kind of vessels.

The bar is a shifting quicksand, with an average depth of from four to six feet, and is impracticable for sailing-vessels unless in tow of a steamer.

Artificial constructions, similar in character to the railroad now in progress of construction between Brownsville and Point Isabel, will be required to develop the vast agricultural resources of the valley of the Rio Grande.

The harbor of the Brazos St. Iago is the only one on the coast of Texas south of Aransas Pass. Through it the products of the Rio Grande find egress, and merchandise of all classes, machinery, agricultural implements, &c., &c., find way to lower Texas and Mexico. The exports from this region of our country, passing over the bar, consist of hides, wool, and specie.

The total number of arrivals and departures within the last five years are stated as follows:

Sailing-vessels entered..........408—Cleared..........	406
Steamers..........do..........150......do..........	143
Total tonnage......do..........78,299......do..........	77,033
Fifty thousand hides are exported yearly, valued at..........	$125,000
Wool in the same period..........	25,000
Specie the past year (reported)..........	1,904,951

Like that at the mouth of the Rio Grande, the Brazos bar is shifting; and, as a general thing, more water can be carried over it in winter than during the summer months. I crossed in November with nine feet, but found only seven on coming out in May. This variation in depth appears to be due to the prevalence of northers in winter. These bank up, as it were, the water in Laguna del Madre, which, rushing out with increased velocity over the bar, carries seaward the loose quicksand of which it is composed.

The highest tides in the harbor are coincident with northers; and while at maximum inside, filling the lagoons and overflowing the lowlands adjacent, the shores of the Gulf outside are often bare. During the summer the wind is almost exclusively from the southeast, and the rise and fall of the tide more regular.

My impression is, that from ten to twelve feet of water might be kept on the Brazos bar (which is merely a ridge of loose sand) by a system of dredging, similar to that going on at the mouth of the Mississippi.

From Paso Caballo to the Brazos St. Iago—a distance of one hundred and fifty miles—there is no distinguishing feature whatever along the coast. Vessels bound down, during the winter months, try to make the land of Padre island from ten to twelve miles north of the Brazos, to which the light at Point Isabel is the only leading mark. In the event of being blown off by the northers, which succeed each other at intervals of from four to six days, and blow with a violence rarely known in higher latitudes, navigators must rely entirely upon the sextant to know their whereabouts. The land offers no facilities of recognition, and the character of the bottom is yet so little known as to be no guide whatever. In the absence of a light-house, large wooden structures, at regular intervals along the coast of Padre island, would give essential aid to vessels.

A case within my own knowledge—showing the peculiarity of northers in reference to this part of the coast—occurred during the past winter, in which a vessel was off the bar twenty-nine days before she was able to get in.

Upon examining charts of this part of the Gulf coast, and comparing them in respect to outline with reliable local information, it appears that, about twelve miles south of the Rio Grande, the shore takes a southwesterly direction for almost twenty-five miles, or as far down as the San Fernando. This is an important fact, which is not furnished by any published chart which I have yet examined. The curve in the shore gives a lee, subject, of course, to the heavy rollers from the Gulf, but safe from the break of the swell. A few to whom this fact is known have, in great stress of weather, found shelter here; and in one instance a small schooner, though in a crippled condition, after riding out a violent norther, actually landed her passengers during its height.

My duties did not admit of my visiting this part of the coast in person, but doubtless an examination of the facts communicated might prove not only of benefit to the coasting trade of lower Texas, but of great consequence to commerce at large.

Very respectfully,

W. E. GREENWELL,
Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 22.

Extracts from the report of Sub-Assistant W. M. Johnson in reference to the features of the country between Pajaro and Salinas rivers, California.

CAMP, *September* 30, 1854.

SIR: * * * * The country between the Pagaro and Salinas rivers is in all respects similar in its formation to that from Point Año Nuevo to the Pagaro, which was surveyed and reported upon by Mr. Harrison.

Extending from the mouth of the Pajaro to the Salinas river is a range of low sand-hills, between which and the older formation lie several ponds, which mark the former bed of the Pajaro. It evidently at one time found its way to the ocean through this channel; but, by an accumulation of its water through the winter months, it burst the narrow strip of beach which separated it from the sea, and thus formed for itself a new and more direct outlet. This new mouth, if we may so call it, is frequently closed by the sand thrown up during the prevalence of southeast gales. This part of the country is peculiarly adapted to grazing, since fresh water is plenty; and the fogs that prevail during the summer months afford sufficient moisture to nourish and keep alive the grasses during the dry season.

The valley of the Salinas is watered through its whole extent by the river of the same name; and near the coast several sloughs take their rise and empty into the river near its mouth. Neither the river nor the sloughs are navigable but for a short distance, and only for vessels of light draught. In summer the Salinas is an insignificant stream, fordable, but for the quicksands, at any point three miles from its mouth. In winter it is a rushing torrent, that destroys large tracts of fertile country by overflowing its banks, and depositing on the low lands sand and gravel frequently to the depth of two and a half feet.

On the Salinas there are evidences of frequent changes in the beds of streams. These were carefully surveyed and represented as they now appear. In some of the old beds we still find marsh, while others can be traced only by slight depressions in the plain. The river frequently, during winter, forms for itself a new outlet. This was the case in the winter preceding the last, and many persons regard the pôint referred to as the mouth of the Salinas.

South of the Salinas the character of the country undergoes a striking change; the soil is a loose, dry sand, that produces sparingly but the coarsest grasses; and, in the distance of twelve miles, water fit for use can be found in only one locality, by digging on the margin of one of the salt-water ponds.

I have the honor to be, very respectfully, your obedient servant,

W. M. JOHNSON.

Prof. A. D. BACHE,
Superintendent of Coast Survey.

APPENDIX No. 23.

Table showing the depths which can be carried into some of the principal harbors, bays, &c., on the coast of the United States. [Withdrawn for revision. See conclusion of Appendix.]

APPENDIX No. 24.

Communication from Lieut. Comg. J. J. Almy, U. S. N., assistant in the Coast Survey, in relation to the commerce of Chesapeake bay.

U. S. COAST SURVEY STEAMER HETZEL,
Old Point Comfort, Virginia, October 5, 1854.

DEAR SIR: In conversations with you relative to the survey of the Chesapeake and its tributaries, I recollect to have spoken more than once of the *extensive* and still *increasing* commerce of Chesapeake bay.

While at anchor lately in the vicinity of the capes, taking current observations, I found opportunity to count the number of vessels which passed the capes, outward-bound, in the course of several days.

September 18.—Seventy-five sail of different classes passed the capes and went to sea, about one-third of them being square-rigged vessels. This is about the average.

September 19.—Five ships, four barks, fifteen brigs, and twenty-eight schooners, making a total of fifty-two sail, went to sea.

September 24.—Eighty-six sail passed the capes outward-bound, about one-third of them being sqare-rigged vessels.

Commerce having an important bearing upon the Coast Survey and its usefulness, it occurred to me that you would regard statistics of this nature with the degree of interest which warrants this communication.

I am, sir, very respectfully, your obedient servant,

JOHN J. ALMY,
Lieut. U. S. N., Assistant in Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 25.

Extracts from letter of Lieut. Comg. O. H. Berryman, U. S. N., assistant in the Coast Survey, in relation to the entrance and anchorages at Tampa bay.

* * * For reasons mentioned in my report, I have been unable to make the desired reconnaissance of Tampa bay; but, from my own previous observation

and information derived from pilots and others, I am enabled to give the following information, which I hope may be of present service.

The entrance to the bay of Espiritu Santo is over a hard sand-bar, two and a half miles from the light-house, having on it about twenty feet at ordinary low tides. The course in is E. by S. by compass, with the light-house on that bearing until over the bar, when from four to sixteen fathoms can be had, the last-named off the north end of Egmont key within a hundred and fifty yards of the shore; continuing up the channel, five, four, three, and two and a half fathoms, will be found within about three miles of Gadsden Point. Beyond this the channel becomes tortuous, but ten feet water may be found within a mile of Ballast Point.

West of the anchorage off Gadsden Point is good anchorage for several miles, in from four to five fathoms water, and four may be found at two miles from the land, but fifteen feet must be crossed in order to reach this anchorage.

Ten feet water may be carried to old Tampa, close to the shore.

At Piney Point, the south end of a peninsula forming the western boundary of old Tampa bay, fifteen feet water is found within two miles of the shore, and within four miles an excellent anchorage for a fleet of large ships. This is nearer the entrance of Espiritu Santo bay than either of the points previously mentioned.

The mouth of the Little Manitee, on the opposite side of the bay, can be approached within two miles with three and a half fathoms, but the coast is low and marshy and intersected by numerous lagoons.

My own observations were made casually, and nothing is here stated as the result of a formal reconnaissance.

I am, very respectfully, your obedient servant,

O. H. BERRYMAN,

Lieut. U. S. N., Assistant in Coast Survey.

Prof. A. D. BACHE, *Superintendent.*

APPENDIX No. 26.

Letter from Lieut. Comg. O. H. Berryman, U. S. N., assistant in the Coast Survey, in relation to the commercial facilities of Cedar Keys, western side of the Peninsula of Florida.

SEPTEMBER 13, 1854.

SIR: I have the honor to communicate the following information concerning the commercial facilities of Cedar keys, as developed by the recent survey made by the party under my charge.

The depth which can be carried in from sea by the several channels at low water is about ten feet, but at high water nearly twelve may be found with ordinary tides, and the approaches are easy both for ingress and egress.

The extent of anchorage in the harbor on the Depot key side is a little less than a mile long by about two hundred yards broad; and though No. 4 channel has a greater extent of anchorage, with a little deeper water, its seaward approach to the bar is such as to render the other in that respect preferable. Opposite Depot, and near May key, still more extensive anchorage may be reached with ten feet by passing around a narrow sand-bank, which separates it from Depot anchorage.

About fifteen feet may be had in these last described anchorages, and all of them are secure. The best, in my opinion, is the anchorage southeast of Sea-Horse key, vessels having there more room to run cable than in either of the others.

The general depth of water in the harbors is about fourteen feet, but it is proper to remark that heavy gales from northeast or east reduce all the depths mentioned several feet.

The character of the bottom for holding cannot be called good, yet it is sufficiently so for vessels with proper anchors and cables in *all* winds or gales, excepting the violent hurricanes which sometimes visit these keys. These are the occasion also of extraordinary tides, which, I am informed, overflow nearly all the low islands.

All ports in this angle of the Gulf suffer from a rise of water in *heavy* southwest gales. The height of the land on May key, as estimated by the eye, is perhaps about twenty-five feet.

Piers of wood may be carried to the deepest water conveniently.

So far as my experience has extended, the localities of Cedar keys are not liable to fogs. The best approach to them for vessels of light draught is from the west, on the parallel of 28° 56′ north latitude. Passing the end of the reef in four or five fathoms water, the light-house and Sea-Horse key may be seen bearing N. 33° E., true.

I am, very respectfully, your obedient servant,

O. H. BERRYMAN,
Lieut. U. S. Navy and Assistant in Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 27.

Letter from Assistant F. H. Gerdes, in relation to the commercial facilities and resources of Cedar Keys, west coast of Florida.

OCTOBER 7, 1854.

DEAR SIR: In answer to your letter regarding the commercial facilities of Cedar keys, Florida, I am able to communicate the following information:

The depth carried from sea into the *Sea Horse*, or main channel, is fully ten feet at low, and twelve at high water, ordinary tides, and the keys are easy of ingress or egress.

The anchorage at Atcena Otee (*Depot key*) is about a mile long, and from two hundred to three hundred yards wide, and is separated from a larger one at May key by a narrow *sand-bar*, which, however, may be passed around with ten feet of water. In both anchorages the depth is fifteen or sixteen feet at low tide, and the holding-ground is good, though not comparable with soft bottom; it is equal to any in the vicinity. The anchorage at channel No. 4, is more extensive than either of the others; but its entrance may not be so good as that of the main channel. All the anchorages are perfectly secure and land-locked.

Vessels provided with good anchors and chains may here ride out any gale, from whatever quarter it may blow; but violent hurricanes occur here as at other points on the Gulf.

Wooden piers can be conveniently carried out to the deepest parts of the channels.

The highest land on May key is, I think, thirty-three feet above high-water mark. During several successive seasons that I have been employed in the neighborhood of Cedar keys, fogs have occurred but rarely, and then were only of short duration.

Heavy gales, as a matter of course, influence the rise and fall of the tide; but, owing to the location, probably not to such an extent here as at other places in the vicinity, which are more locked up from the north. The highest tide within the last fifteen years rose, I believe, eleven feet at Depot key, and overflowed only the lower part of that island.

The harbor of Cedar keys compares to advantage with others in the immediate vicinity, and its position in respect to the Suwanee, Crystal, and adjacent rivers, is highly favorable to the development of their important local resources. The valleys of these rivers are covered with extensive forests of pine and cedar; and owing to the ample facilities for reaching the Gulf, lumber has already become an article of export from Depot key, as well as cotton, sugar, and tobacco.

Fish, oysters, green turtle, and many kinds of game abound here, and the climate is as healthy and pleasant as any in the United States.

A weekly mail across the peninsula keeps the Cedar keys in communication with the Atlantic coast.

Respectfully, your most obedient servant,

F. H. GERDES,
Assistant U. S. Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 28.

Statement of the commerce of Humboldt bay, California, communicated by Assistant George Davidson, from July 1, 1853, *to May* 31, 1854.

Time.	Vessels arrived in the bay.						Tonnage.			Merchandise brought up.	Passengers brought up.	Average passage.	Lumber shipped from the bay.
1853–1854.	Months.	Steamers.	Barques.	Brigs.	Schooners.	Total.	Greatest.	Least.	Average.				
										Tons.		*Days.*	
July 1 to September 30	3	2	5	14	19	40	540	71	144	997	67	13	6,670,000
October 1 to December 31	3	1	6	8	18	33	450	91	157	676	155	14½	3,576,000
January 1 to March 31	3	....	8	21	20	49	399	91	174	725	186	12	6,303,000
April 1 to May 31	2	3	1	6	11	21	288	103	171	691	154	9	2,383,000
Total	11	6	20	49	68	143	22,660			3,089	562	......	18,932,000
Monthly average	....	....	....	....	....	13	2,005			281	51	......	1,721,100

"Many of the vessels trading to this bay are ill adapted to contend against the summer winds; some will beat up in six days, whilst others require three or four times that number. With vessels adapted to the trade, the average time from San Francisco to Humboldt bay should not exceed eight days, while the downward passage would average about four.

"The number of passengers reported gives only a diminutive idea of the number who arrive, inasmuch as there are many other inlets for immigration.

"The average tonnage has regularly increased, and there has been a decrease in the length of the average passage to windward.

"No account has been kept of the number of passengers who have left in the vessels."

APPENDIX No. 29.

Extracts from the reports of Assistant G. A. Fairfield and Sub-Assistant Henry Mitchell on the tidal observations made on the south shore of Massachusetts, and in Nantucket and Vineyard sounds.

WALTHAM, MASSACHUSETTS, *November* 4, 1854.

DEAR SIR: I submit the following report of my work in Vineyard sound during the past season:

On receiving your instructions, I proceeded to Nantucket and consulted with Mr. Mitchell, who had been for some time engaged in observing in that vicinity.

* * * * * * *

A self-registering gauge, forwarded from the office, was put up on the wharf at Wood's Hole; but, in consequence of a derangement which could not be perceived at the outset, the record could not be regarded as reliable.

Gauges were kept in operation simultaneously for six weeks at Nobska, Point Gammon, and Monomoy. I have found, by the resulting observations, that the tide which flows in by Monomoy from the ocean, meets with very little interruption until after it passes Point Gammon. A remarkable difference, however, was found between Nobska and Point Gammon; and, in order to mark its precise locality, a gauge was erected at Davis's Neck, about five miles from Nobska; but a week's observations showed very little difference between that point and Point Gammon. The conclusion seems to be warranted, that the whole difference is distributed between Davis' Neck and Nobska.

The tides in the vicinity are very much affected by the wind. At one period, a rise and fall of not more than an inch or two occurred successively for several days.

On the 21st of October my observations were closed, the records being placed, by your direction, in the care of Mr. Mitchell.

Yours, very respectfully,
G. A. FAIRFIELD,
Assistant U. S. Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

Report of Sub-Assistant Henry Mitchell.

The following is an abstract of various reports made from time to time relative to the progress of the tidal party under my charge and your immediate direction, from the early part of July until the middle of October of the present year:

In the instructions received, a system of observations was laid down, with a view to determine the progress of the tide-wave from the open sea, and through the Vineyard and Nantucket sounds, and various openings into them. In order to effect this, simultaneous observations were necessary at different localities along the outer and inner coast, in connection with the careful examination of tides passing through the avenues leading to the sounds. The portions of this field of operation intrusted to my direction were the south sides of Nantucket and Martha's Vineyard islands, the southern shores of Nantucket and Vineyard sounds from Great Point to Gay Head, and the east and west sides of Muskegat channel.

Permanent tidal stations were first established at Nantucket harbor, West Chop, and Wood's Hole, and to these were to be referred the results obtained at various local stations, as directed in your instructions.

At the outset many difficulties were encountered in attempts to construct tide-gauges capable of withstanding the force of the currents and breakers at the outside stations; but after repeated failures of the most discouraging kind, I am pleased to say our experiments terminated in complete success. By the method which I shall presently mention in detail, we have since been enabled to carry on the outside series with comparative ease. The failures just referred to are perhaps not without interest in the present connection, as exhibiting the effect of strong currents and heavy seas. Our first attempt was made at Siasconsett, with an iron tube armed at the lower end with an augur, which was screwed firmly into the sand just without the breakers and in two fathoms water; but this, though opposing a very small surface, was immediately deflected from its upright position by the strong ebb current. After readjusting the pipe perpendicular to the surface, it was carefully wound with one thousand pounds weight of chain-cable arranged in the form of a pyramid; but this expedient failed to secure the permanence of the gauge, as the current, by undermining, very soon overturned the structure. The next trial was the substitution for the last-mentioned structure, of a tripod of iron bars attached to three heavy anchors, and this also failed in resisting the force of the sea. By great exertion the apparatus was then taken up and a fourth anchor procured, through the ring of which the pipe was passed, and while the anchor was suspended between two surf-boats, the pipe was again screwed into the sand in its first position. The anchor was then lowered carefully to the bottom, with its flukes in the direction of the strongest current, and the tripod was finally fastened to the gauge. A sucession of violent gales, since experienced, has left this structure entirely unharmed.

The outside series thus commenced has been carried on at four stations, viz: Siasconsett, Weweeder, Smith's Point, and Wasque. A tripod of oak piles, shod with iron, was successfully used to support the gauge at the last-named station, which is not subjected to strong currents, and somewhat protected from the force of the sea by a bar.

Much difficulty was experienced in preventing the registry of long swells, which would cause the float to rise and fall. A very small stream of water only was allowed to enter the gauge-tube, and that at a distance below the surface. It was, however, sometimes impossible to determine the exact flow of water necessary for a reliable observation, as in the open sea, species of primary waves occur not unlike the great tide-wave; and these traversing the ocean slowly, may easily be confounded with it.

The tidal station at Smith's Point is some distance from the inhabited part of the island of Nantucket, and very much exposed to the sea. This was occupied by Mr. Gustavus Würdemann; and perhaps none but a thoroughly experienced observer, inured to the consequent privations, could have maintained, as he has, the perseverance and courage requisite for its proper management.

The stations Wasque and Smith's Point were used in the investigation of the tides of Muskegat channel, simultaneous observations being made at Tuckernuck on the east and Cape Poge and Choppaquiddick on the west shore. The tides on the western shore of Muskegat channel are so inconsiderable and irregular, that little hope was entertained at the outset of obtaining reliable results; but through the indefatigable efforts of Mr. Nes, the observer, a correct view will be furnished of at least a few of the phenomena of the tides of that locality.

Mr. Fendall's long and excellent series at Tuckernuck, with that of Brant Point, and a few weeks' work at Great Point, completed the system proposed for the south side of Nantucket sound.

In the Vineyard sound, commencing at Gay Head, the tides were studied at Menamsha, Cedar Tree, Chappaquonsett, outside West Chop, and West Chop light-house. At the last two stations remarkable tidal phenomena were presented, which seemed to require the attention of the most intelligent and experienced observers. Mr. Würdemann and Mr. Fendall were therefore called upon, and the results of their observations will attest the faithful discharge of the duties thus assigned.

The results obtained throughout, it is hoped may throw some light upon the problems proposed for solution; but it is quite certain that they suggest a number of important and interesting questions yet to be answered.

Very respectfully, yours,

HENRY MITCHELL,
Sub-Assistant in Coast Survey.

Prof. A. D. BACHE, *Superintendent.*

APPENDIX No. 30.

Report to the Superintendent of the Coast Survey on tidal and magnetic observations of the Western coast of the United States, by Lieut. W. P. Trowbridge, Corps of Engineers, assistant in the Coast Survey.

SAN FRANCISCO, CALIFORNIA, *September* 6, 1854.

DEAR SIR: I have the honor to report to you, according to your instructions, the progress of the tidal and other observations under my charge on this coast up to the present time.

Your original instructions, received at Washington in March, 1853, were so full and comprehensive, that I have but little to report, except the progress I have made in executing them. They required, mainly, complete sets of observations at certain points for the determination of the progress of the tide-wave, and special observations for the phenomena of harbor-tides; and also, as far as practicable, investigations and comparisons of results of observation with theory. I have found that the administration of the affairs of an extended system of observations, together with almost constant field-work, has prevented my making, heretofore, any complete or systematic computations; and the expense of hiring computers is so great, that I am obliged to forego the pleasure of regularly working up my results. They are transmitted to you regularly, however, and will, I trust, enable you to determine those questions which you are so anxious to solve.

It has been a source of much regret that I could not have devoted more time to preparations for my new duties before leaving Washington; for, as I anticipated, experience here is costly, both in time and money. It seems a very simple task to make correct tidal observations; but, in all my experience, I have found no observations which require such contant care and attention.

The self-registering tide-gauge is, I think, the only proper means of determining the rise and fall of the water, and even this machine requires more care and attention than has usually been bestowed upon it. To make equally good observations with the ordinary staff-gauge, requires at least three observers, and, of course, the expense must be much greater.

As tidal observations must be intrusted to the care of observers who cannot be supposed to appreciate fully their importance, I have been quite anxious to secure the services of such as would record faithfully their observations; and it is with pleasure that I can report that, with one exception, they have discharged their duties to my entire satisfaction. I may mention particularly Mr. T. A. Szabo, Corporal James Wayne, Andrew Cassidy, and James A. Black.

Mr. Szabo, in addition to his duties as an observer, has assisted me in my own operations. Corporal Wayne has had sole charge of the self-registering tide-gauge at Astoria, and communicates with me fully every month. I would respectfully recommend him to your notice, also, as an accurate computer. He has investigated, to a certain extent, the observations at Astoria, and his results are worthy of much credit.

Andrew Cassidy has had charge of the observations at San Diego since September 22, 1853, and deserves much credit for his zeal and attention in the discharge of his duties.

J. A. Black has assisted me in setting up most of the gauges, besides taking part in the observations.

Nine prominent stations have been occupied as tidal stations on the coast, and four magnetic stations. (See Sketch J—K, stations marked T.)

The accompanying table will show the names of the tidal stations, and the interval during which the observations were continued. The observations have been kept up for at least two months at each station, and in some instances for three or four lunations. The gauges at San Diego, San Francisco, and the Columbia river are permanent, and have been in operation since July 1, 1853. From January 13th to March 20, 1854, observations were made simultaneously at five stations, viz: at the three permanent stations, and those of San Pedro and San Luis Obispo. From April 13th to June 15th they were simultaneous at four, and from July 21st to the present time at five, the intermediate stations being changed every two months.

The observations have been conducted with much care, and will, I trust, afford all the necessary data for determining the progress of the tide-wave.

My report of January gave an account of my operations up to that period. I was then stationed with my party at the port of San Luis Obispo. The observations at this station were finished about the 20th of March, and the gauge transferred to the Bay of Monterey about the 1st of April.

Of the tidal observations at San Luis Obispo I have only to say, that they fully came up to my expectations. They were made by three observers, under my immediate direction. The station was well situated for getting the full force of the sea-tide, uninfluenced by local causes.

The observations in the Bay of Monterey were commenced on the 13th of April, and finished on the 15th of June. The gauge, a self-registering one, was placed upon a firm structure, built at the end of the custom-house wharf. The curve of rise and fall was unbroken, except at the end of the sheets. The time was determined by astronomical observation.

The usual magnetic observations for declination, intensity, and dip were made at Monterey, and also observations for time with the transit, with a view to observe the solar eclipse of May 26th, but cloudy weather unfortunately prevented any observations on that important phenomenon.

After finishing the observations at Monterey, I transported my party to San Francisco, and made immediate preparations for establishing observations on the northern coast. On consulting with Assistant George Davidson, I learned that it would be impossible to get nearer to Cape Mendocino than Humboldt bay, and accordingly sent J. A. Black to that point, with two assistants, with full and detailed instructions to make a series of staff observations at the entrance of the harbor. I have the pleasure to transmit to you the results of his first month's observations—from July 21st to August 21st. The curve of rise and fall constructed from these observations is quite equal to those of the self-registering gauges in point of accuracy. The observations are made with a floating staff, divided into feet and tenths, and read by a fixed index, the higher numbers corresponding to high tides. The time is kept by a chronometer, regulated and set in San Francisco to Humboldt time. I have every reason to be gratified with these observations, and hope they may prove useful.

By the same steamer that carried Mr. Black to Humboldt, Mr. Szabo took passage for Port Orford, for the purpose of establishing at that point a self-registering gauge. He succeeded in erecting a structure for the gauge among the rocks at the point designated on the accompanying chart of that place. His observations were commenced on July 25th, and continue at the present time. The first sheet I transmit herewith; it shows an uninterrupted curve of rise and fall for the month.

I am indebted to Dr. Milhaw and Lieut. Kautz, of the U. S. army, stationed at Port Orford, for their kindness in facilitating Mr. Szabo's operations.

The usual daily meteorological observations are made at each tidal station in connection with the tidal observations. Much care was taken in instructing the observers in the use of the meteorological instruments, and the necessity of accuracy and faithfulness fully impressed upon them.

The observations at Port Orford and Humboldt will be continued through three lunations, after which it is my intention to occupy Bodega as a tidal and magnetic station.

The observations at Astoria are progressing favorably under the excellent care of Corporal Wayne. The observations at San Diego continue uninterrupted. With the exception of one or two months, during which I could not communicate with the observer, the observations have been as good as I could wish. The interruption of the observations was caused by a piece of kelp getting into the aperture in the bottom of the float-box. This was not noticed by the observer until his attention was called to the irregularities of the curve. It was then promptly remedied, and no interruption has occurred since.

I have already informed you of the change in the position of the gauge in San Francisco bay, from North Beach to Fort Point, and of the substitution of a new machine with a scale of one-twelfth for the old one. This change has relieved me from the anxiety with which I was formerly obliged to watch the observations here. The gauge at Fort Point has been running two months without a single interruption. This gauge is now in charge of Sergeant H. E. Uhrlandt, who joined me, according to your instructions, about the 1st of July. Sergeant Uhrlandt renders me valuable assistance in my office duties, besides conducting these observations.

Magnetic observations.—Magnetic observations have been made at four stations, for determining the declination, intensity, and dip, at each station. The observations were made with Barrow's dip-circle, and the portable declinometer. The stations at which these observations were made were San Diego, San Pedro, San Luis Obispo, and Monterey.

The observations at San Diego for dip consist of three sets on different days, each set of observations consisting of twenty-four partial results.

The observations for absolute declination rest upon one set of observations on the north star, after having determined several times the zero of the magnet scale. The time was determined by a transit, and I put confidence in the result: the intensity, by one set of experiments of vibration and one of deflection. Want of time prevented my repeating the observations.

At San Pedro three similar sets of observations were made for dip; and for absolute declination several sets of observations on the north star in connection with a mark: for intensity, two sets of vibration experiments and one of deflection. An equal number of observations were made at San Luis Obispo and Monterey, for the determination of the same elements of the magnetic force.

It is my intention to make magnetic observations at Presidio and Bodega before the rainy season commences, if possible.

On the accompanying coast-charts I have marked the general localities of the stations which have been occupied, and also the local position of the gauges. In the records of each station which have been transmitted, will be found particular descriptions of the different gauges. (See Sketch J—K, Western coast, where the stations are marked T.)

Wherever staff observations have been made, the same method has been used of a floating staff enclosed in a box, the staff being divided into feet and tenths and read by a fixed index, high numbers corresponding to high tides.

I have superintended personally the erection of all the gauges except those of Humboldt and Port Orford, and have given each observer detailed written instructions with regard to his duties.

The observers communicate with me monthly, or oftener, giving an account of the condition of their work. At the end of each month the observations for that month are transmitted to me, and the results of the observations determined and put in a tabular form. The original observations, with copies of the tables, are then transmitted to the office.

I sincerely hope they have proved satisfactory, though I hardly dare hope that the results will meet your expectations; if they do, I shall feel abundantly rewarded for my anxiety in conducting them.

Very respectfully, your obedient servant,

W. P. TROWBRIDGE,
U. S. Engineers, Assistant in Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey, Washington, D. C.

Stations occupied for tidal observations on the Western coast, during 1853–'54.

Name of station.	Latitude.			Longitude.						Duration of observations.		Kind of gauge observed with.
				Time.			Arc.			From—	To—	
	°	′	″	*h.*	*m.*	*s.*	°	′	″			
San Diego	32	41	58	7	48	53.7	117	13	25	July 6, 1853	Sep. 20, 1853	Staff-gauge.
										Sep. 22, 1853	Aug. 31, 1854	Self-regis'g gauge.
San Pedro	33	43	19.6	7	53	4.2	118	16	3	Nov. 15, 1853	Mar. 23, 1854	Do.
San Luis Obispo	35	10	37.5	8	2	54	120	43	31	Jan. 13, 1854	Mar. 11, 1854	Staff-gauge.
Monterey	36	37	59	8	7	37	121	54	25	Apr. 13, 1854	June 15, 1854	Self-regis'g gauge.
San Francisco bay	37	47	35	8	9	45	122	26	15	June 14, 1853	Aug. 31, 1854	Do.
Humboldt bay	40	44		8	16		124	9		July 21, 1854	Aug. 21, 1854	Staff-gauge.
Port Orford	42	44	21	8	17	55	124	28		July 25, 1854	Aug. 21, 1854	Self-regis'g gauge.
Columbia river	46	16		8	15	17	123	49		July 11, 1853	Aug. 31, 1854	Do.
Cape Disappointment	46	16		....	....	....	....	....	....	July 15, 1853	Aug. 25, 1853 (Nearly.)	Staff-gauge.

APPENDIX No. 31.

Reports of the Chiefs of Divisions to Capt. H. W. Benham, Corps of Engineers, assistant in charge of the office, showing the details of work executed in each Division.

REPORT OF MR. CHARLES A. SCHOTT, ACTING IN CHARGE OF THE COMPUTING DIVISION.

COAST SURVEY OFFICE, *October* 25, 1854.

The annual report of this division for the year ending November 1, 1854, is herewith respectfully submitted.

The charge of the computing division has been continued with Assistant J. E. Hilgard, and, in his absence, with myself. Mr. Hilgard having been engaged on field or special duties for the greater part of the year, I have been acting as chief of the division for nearly ten months.

The organization and distribution of work has remained nearly as last year, it having proved very efficient. In addition to the duties of the computing division, as already stated in the Superintendent's annual report for 1853, that of adjusting the various geodetic and astronomical operations, and of satisfying the required conditions by the application of the method of least squares is becoming of greater importance. This results from the general plan of conducting the operations simultaneously in the several sections, thus affording, besides the checks in each when compared, independent checks and a measure of the accuracy.

The amount of work performed—the detail of which is appended to this report—appears to exceed that of last year, owing to the greater familiarity of the computers with the kind of work assigned to them. It was not neglected, however, to change occasionally the nature of the work, to insure to each computer a more general acquaintance with all the operations. The project of work, as approved, has been adhered to as closely as circumstances would permit, and the revision and adjustment of former operations has been brought up as far as desirable. The current field-work of the year was attended to without delay, and calls for results or information were promptly answered.

The duty at the magnetic observatory was assigned to the chief of the division; and after Mr. Hilgard had resumed his field-operations in December last, the perfection of the chemical and mechanical process of the self-registering declinometer, the only instrument that has as yet been received, was left as a part of my duty, in which I was assisted by Mr. Hoover, and occasionally by Mr. Main. A continuous photographic trace was brought out for a week before and a week after the solar eclipse in May last, during which, also, a set of meteorological observations were made by Messrs. Main, Hoover, Wiessner, and myself.

The distribution of the different classes of computations among the computers has been as follows: The computations for latitude and azimuth were made by Mr. E. Nulty; the reduction of transits and of chronometric differences of longitude, of astronomical revisions in general, and revisions of magnetic results, by Mr. J. Main. The reduction of triangulations were made by Assistant Werner; their revision and adjustment, generally, by Mr. G. Rumpf, who had also in charge the register of geographical positions. Reductions of longitudes by moon-culminations and miscellaneous astronomical and geodetic operations were performed by Mr. J. Wiessner. Mr. J. T. Hoover acted as clerk to the division, and assisted in miscellaneous computations. The other members of the division have generally been working under the direction of some one of the above computers.

When not in charge of the division, I have been engaged on special duty, and for a month and a half on hydrographic investigations or discussions by special direction of the Superintendent, or by calls from the assistant in charge. Revisions, reports, and discussions on astronomical, geodetic, or magnetic work in general, have formed a part of my duty.

The gentlemen at present connected with the division have shown the same interest and prompt attendance on their respective duties as noticed in last year's report.

The detail of the occupation of the several computers during the year ending November 1, 1854, is appended.

Mr. Charles A. Schott was in charge of the computing division for nearly ten months. Among a number of reports submitted by him to the Superintendent and assistant in charge of the office, the following may be specially noticed:

On the mean temperature of the air for each of the four seasons at five places on the Atlantic coast; on the temperature of the surface of the earth and at different depths; on the azimuth Cape Henlopen and Townbank, Section II; on the adjustment, by the method of least squares, of the seaboard triangulation from the base Davis-Quilling, Section III, north to Cape Henlopen and south to Cape Charles; on catalogue errors in north polar distances of stars, deduced from observations with the zenith telescope; on the longitude of Telegraph Hill, Section X, from moon culminations; on the latitude of Agamenticus, Section I, from observations with zenith telescope; and on side equations. He has also reduced magnetic intensities observed at Cape Florida and Sand key, Section VI, and prepared astronomical and geodetic forms of record and reduction for the Congress map.

The observations for changes of magnetic declination by the photographic self-registering instrument were continued at intervals from December till June, and the chemical and mechanical process improved. A continuous trace was brought out, showing the changes of declination during a fortnight in May last, at the time of the solar eclipse. Mr. Schott has also devoted a large portion of his time to investigations of currents, and submitted, among other reports, the following: 1st, on our knowledge of the Gulf Stream prior to Coast Survey investigations; 2d, on currents in St. John's river and Fort St. George inlet, Section VI; 3d, on currents near Ship shoal, Louisiana, Section VIII; 4th, on tidal currents of the Nantucket shoals, including several papers; 5th, on tidal currents in Muskeget channel and approaches, and also upon the currents in Salem harbor.

Mr. Eugene Nulty has computed the azimuth at Mount Rose, Section II; the chronometric difference of longitude between Pascagoula, Section VIII, and Dollar Point, Section IX; the azimuths at Sebattis, Section I, and at Davis, Section III. He has also reduced the latitudes determined by Assistant Davidson on his fourth chronometric trip in Sections X and XI, and computed the latitudes of Washington city, Hilgard's observatory; of a station near the mouth of the Rio Grande, Section IX; of Allston, Section V; of Humboldt, Section XI; and the azimuth of Allston. The magnetical observations at five stations, Sections IX and X, were also reduced.

Assistant Theodore W. Werner has made the reduction of the following triangulations: Near Key West, 1853; of Rappahannock river, 1853, Section III; of the Canal de Haro and Rosario straits, Section XI, 1853; of Hudson river, Section II, 1853; of James river, Section III, 1854; of San Francisco bay, Section X, 1854; near Norfolk, Section III, 1853; of Bogue sound, North Carolina, 1854. He has also computed rectangular co-ordinates of the Bahia Honda triangulation, 1853; reduced the Sinepuxent base, Section III; made abstracts of horizontal angles at Mount Blue, and the primary stations, in Section IV; computed positions near New York determined by Assistant Blunt in 1854; and adjusted the Savannah River triangulation, 1852, 1853, 1854, together with that of Calibogue sound.

Mr. G. Rumpf has kept the registers of geographical positions, and prepared them for publication in the Superintendent's report of 1853; has indexed and labelled the astronomical and geodetic records previous to 1844, and revised the triangulations on the Florida reef, the horizontal angles of primary triangulation of Section IV, and solved the conditional equations of Mount Blue, Section I. He has completed the revision of the secondary triangulation of the Upper Chesapeake, and adjusted, by the method of least squares, the seaboard triangulation north and south of Davis-Quilling, Section III; computed geographical positions near Key West and near Brooklyn, Section II; made a reduction of observations south of Cape Henry, Section III, 1854; Cape Fear River triangulation, Section IV, 1852–53; and of Savannah river, 1851. He has also made miscellaneous computations for the use of the office; revised the azimuth computations of Townbank and Cape Henlopen, Section II; and directed the computations made by Messrs. J. E. Nulty, H. Pyne, D. A. Burr, and J. H. Toomer.

Mr. James Main has revised the computations for azimuth at Mount Rose, Section II; has put the magnetic term day-observations into curves; reduced the longitudes from chronometer transportations of Bodega bay, Haven's anchorage, Mendocino city, Shelter cove, Bucksport, Trinidad bay, Crescent City, Port Orford, Umquah river, Astor Point, and Lummi island, Sections X and XI; and revised finally the reductions of magnetic declination, dip, and intensity, in all the sections. Some miscellaneous computations were also made for the use of the office.

Mr. John E. Nulty reduced mean to apparent places of stars for latitude reductions; assisted Mr. Rumpf in making out abstracts of horizontal angles of stations north of Davis, Section III, and on the Chesapeake, upper part. He computed, under Mr. Rumpf's direction, the triangulation of the Canal de Haro and Rosario straits, and performed other miscellaneous work. His services were discontinued on July 1st.

Mr. J. Wiessner has extended the projection tables to answer for the extent of the United States; revised horizontal angles at Sebattis, and computed triangles north of it; computed the latitude of Washington city, Hilgard's observatory, and approximately those observed by Assistant Davidson in Sections X and XI; and revised the latitude of Aagamenticus, Z. S. and Z. T., and computed the same from prime vertical observations. He has reduced transits at Allston, Section IV, and at a station near the mouth of the Rio Grande, Section IX; and reduced moon culminations at Cape Florida and mouth of Rio Grande, 1853; computed rectangular co-ordinates of the Rappahannock River triangulation, 1853, and checked a portion of the adjustment of the seacoast triangulation, Section III. He has, besides, performed some miscellaneous astronomical and geodetic computations.

Mr. John T. Hoover has performed the clerical duty of the computing division, and made miscellaneous computations, conversions of measures, and reduction of places of stars for the Humboldt latitude, Section XI. He assisted regularly at the magnetic observatory.

Mr. D. A. Burr joined the division as a computer July 1, 1854, and made some miscellaneous computations under Mr. Rumpf's direction. He was transferred to Assistant Pourtales August 21st for special duty in reference to river tides, and reported again for duty in this division October 23d.

Mr. J. H. Toomer joined the computing division August 8, 1854; has been engaged on miscellaneous computations under Assistant Hilgard's immediate direction, and reduced the triangulation at the mouth of the Rio Grande, Section IX, 1854.

The following gentlemen have been connected temporarily with the division: H. S. Duval and Mr. Wagner, for about one month each; H. Pyne, for three months; and Messrs. Breckenridge and Jardella, for three weeks each; and Mr. Burr, previous to his joining the division, for three months; all these receiving instruction or assisting the computers.

Mr. McL. Tilton was added to the computing division October 1, 1854. Previously he was studying and acted as copyist.

Duplicating and miscellaneous copying by R. Freeman; miscellaneous computations, under the immediate direction of Assistant Hilgard, by A. S. Clements.

The division has also furnished the following information:

A list of geographical positions to Commissioner Woodman, relating to the survey of the State of New Hampshire.

A list of moon culminations to Major W. H. Emory, for the use of the Mexican boundary survey.

A list of geographical positions near Washington, D. C., to Mr. French.

A list of moon culminations to Lieut. J. M. Gilliss for the use of the United States astronomical Expedition to Chili.

REPORT OF OFFICE-WORK EXECUTED IN THE TIDAL DIVISION IN CHARGE OF ASSISTANT L. F. POURTALES.

Since the date of my last annual report, the organization of this division of the office has undergone no material change. The duties performed have been of two kinds:

1st. The reducing of observations as they are received from the observers. This is done as far as possible immediately after their receipt, so that defects may be soon detected and remedied, and also in order that tide-tables may be prepared at short notice whenever wanted.

2d. The discussion of observations extended over long periods, or made at stations presenting remarkable peculiarities, their comparison with theory and the formation of tables to be used in the prediction of tides. The most important piece of work coming under this head, is the discussion of the tides observed at Boston dry-dock since 1847. The results will not only enable us to predict the tides at Boston with considerable accuracy, but will also reduce greatly the labor of obtaining complete tidal data for any other place in the northern part of the Atlantic coast.

The observations on which this discussion is based, prove to have been taken very faithfully, and reflect great credit on Mr. Isaac Williams, the observer.

Another very important discussion in progress coming under this head, is the one relating to the tides of the Gulf of Mexico.

The series of observations being now complete, or nearly so, the work will probably be pushed to a successful termination in the course of the coming year.

Approximate results were worked out from the observations of tides on the Western coast as soon as the number of observations seemed to warrant it. They were communicated by the Superintendent to the American Association for the Advancement of Science, at its meeting in this city in May last.

The computations relating to a first approximation towards the determination of the co-tidal lines on the Atlantic coast were also performed in this division, from forms furnished by the Superintendent, who communicated a paper on that subject to the same body on the above occasion.

The work named under the first head was performed by Messrs. Hawley, Nes, Fendall, Montgomery, Bagwell, Parrish, Bassett, Duval, Baker, and Blanchard; the discussion classed under the second head by Messrs. Mitchell, Heaton, Avery, Kincheloe, and Burr.

Mr. H. Mitchell began in December to discuss the observations taken at Boston dry-dock during a period of six and a half years, Sir W. Lubbock's discussions of the tides of London and Liverpool being taken as a model. He was enaged on that work almost continually until he left for the field, on the 6th of July. He was in charge of the division during my absence in the field in May and June.

Mr. H. Heaton has chiefly been engaged in the computations for the discussions of the tides of the Gulf of Mexico, and particularly of the observations made during two years at Galveston, Texas. These computations were made under the immediate direction of the Superintendent. He has also made a part of the computations relating to the determination of the co-tidal lines, and other miscellaneous work at different times.

Mr. R. S. Avery joined the office on the 17th of October, 1853; and, after having become familiar with the subject by making some of the simple reductions of tides, he took up, jointly with Mr. Mitchell, the discussion of the Boston tides, on which he is still engaged. The results already obtained have proved him to be a careful and accurate computer.

Mr. J. Kincheloe joined the office July 22, and was assigned to aid Mr. Avery in the discussion of the Boston tides, in which duty he has shown assiduity and usefulness.

Mr. D. A. Burr was temporarily ordered to join this division from the computing division, to which he belongs, in order to treat a set of observations made at Curl's Neck, in the James river, after Airy's method of discussing river tides. He began August 19, and finished October 23, and has shown assiduity and considerable skill for so young a computer.

Mr. P. R. Hawley has been engaged, during the whole year, in reading off the observations of tides recorded by the self-registering tide-gauges, and in making first and second reductions of the same.

Mr. C. Fendall was attached to this division until July 15, when he joined Mr. Mitchell's party in the field. He was chiefly engaged in reducing the observations made on the ordinary tide-gauges, in preparing tide-tables, and in other miscellaneous duties. He has also made a number of diagrams illustrating the tides of the Western coast, and the distribution of temperatures in the Gulf Stream.

Mr. F. F. Nes was engaged, until February 8, in making reductions of observations made with ordinary tide-gauges, in completing former computations which had not been made according to the plan now adopted, and in other miscellaneous duties. He was then attached to a field party.

Mr. G. C. Blanchard reported July 15, and has been engaged in ordinary first and second reductions, and in copying.

Messrs. Montgomery, Bagwell, Parrish, Bassett, Duval, and Baker, were only attached temporarily to this division for short periods of time, intervening between their return from, and departures for, field duty. They were occupied on various computations connected with the tides.

In concluding, I would remark that, with very few exceptions, the computers in this division have taken great interest in the results of their work—a cause always productive of zeal and an ambition to be correct. Special mention is due, in this respect, to Messrs. Mitchell, Avery, and Heaton.

Respectfully submitted:

L. F. POURTALES,
Assistant U. S. Coast Survey, in charge of Tidal Division.

REPORT OF CAPTAIN A. A. GIBSON, U. S. A., IN CHARGE OF THE DRAWING DIVISION.

COAST SURVEY OFFICE,
November 30, 1854.

In presenting the following report of the drawing division for the year which has just closed, I respectfully refer to a statement of work accomplished, showing the specific duties performed by each draughtsman, and a list of maps and sketches completed or in progress.

The force, numerically, has not been greater than heretofore, and may be considered the minimum, under the present requirements of the division. With another first class draughtsman, and with the rapid improvement of the less experienced, I confidently believe that the force will soon be adequate to meet all demands existing or to come. The work executed on contract has been limited; but not so much from want of material to give out, as from the difficulty of engaging proper draughtsmen.

No material changes in the organization of the division have been made; nor have I discovered the necessity of proposing any amendments to the rules and regulations by which it is governed.

It is worthy of note how interesting the work of this division is becoming, from the magnitude of the results of the survey, and how, from the apparently chaotic mass in which they are first presented, art moulds them into expressive form. The reductions of the first order are no less distinguished for their exquisite finish, than for their extreme accuracy; they are models for the engraver, which, to reproduce, would be the highest attainment of his skill. Nor is this approach to perfection more necessary for the accurate representation of minute details of topography on the scale of coast charts, than to enable the engraver to copy them truthfully, and without confusion.

I can hardly speak in exaggerated terms of the fidelity with which the more experienced draughtsmen execute their work. By long practice they have acquired wonderful facility in detecting the faults of original work, and ingenious methods of rectifying them when the case admits. A reduction to $\frac{1}{80000}$, containing errors exceeding sixty feet, is rejected. Considering the extreme tests to which the surveys are here subjected, the hindrances to reduction arising from their imperfections have been comparatively slight. The most general source of error is the shrinkage of the paper. To meet this difficulty, every sheet furnished to the plane-table and hydrographic parties is prepared in this division, the trigonometrical points being plotted, and parallels projected, only when the atmosphere is favorable. The verification immediately follows, to make certain that at some one moment the measurements are true; then, whatever distortion by use or exposure the sheet may subsequently undergo, the draughtsmen possess the means of restoring upon their reductions the true relation of the topography to the trigonometrical determinations.

The experiment of using backed paper appears to have given to the field-parties universal satisfaction, but it has not been found the best method for reductions stretched on boards.

The most popular method of reducing is by "squares," constructed upon some line connecting trigonometrical points. The camera is seldom used for any but hydrographic reductions. The pantograph has not been introduced. A successful trial was made of it, but under such disadvantages as to render its economy doubtful without some device for more readily applying this instrument to separate sheets. Of its economy and relief to the eye there is no question.

The expansion of the survey has made the subject of projects almost an exclusive branch. The Atlantic coast is now so nearly defined as to require the immediate study of prospective charts—and you are acquainted with the fact that it has already received considerable attention. In this I have received valuable assistance from Mr. W. P. Schulz, who was recently relieved from clerical duties for a better application of his services to the miscellanies of the division, which have largely multiplied in the past year.

During the summer I made views of the approaches to Salem and Gloucester harbors, and of the city of Petersburg, Va.

The improvement of the less experienced draughtsmen has been flattering; it is evidently the result of an earnest desire to excel, and of the example of those more proficient. With gratification I recur to the evidences of a uniform disposition in each and all to discharge their duties promptly and well.

Statement of work accomplished in the Drawing Division during the year ending November, 1854, in the order of draughtsmen.

1. W. M. C. Fairfax, assistant, has been engaged on the topography of Eastern series, No. 3, $\frac{1}{80000}$; Long Island sound, No. 1, $\frac{1}{80000}$; Chesapeake bay, No. 1, $\frac{1}{80000}$; Mississippi sound, No. 1, $\frac{1}{80000}$; the reconnaissance south of Cape Fear, $\frac{1}{400000}$; and Boston harbor, $\frac{1}{20000}$.

2. M. J. McClery, assistant, has been engaged on the topography of Chesapeake bay, Nos. 2 and 3, $\frac{1}{80000}$; and on the general map, $\frac{1}{1500000}$, prepared for Congress.

3. Mr. Joseph Welch has been engaged on the topography of Eastern series, Nos. 2 and 3, $\frac{1}{80000}$; Appomattox river, $\frac{1}{5000}$; and the sketch of Pungoteague creek, $\frac{1}{10000}$.

4. Mr. J. J. Ricketts has been engaged on the hydrography of Key Biscayne, $\frac{1}{20000}$, (original chart;) Florida reefs, No. 1, $\frac{1}{80000}$; and Long Island sound, No. 1, $\frac{1}{80000}$; besides examinations and corrections of other work.

5. Mr. E. Hergesheimer has been engaged on Congress map, $\frac{1}{1500000}$; San Francisco entrance, $\frac{1}{50000}$; Appomattox river, $\frac{1}{5000}$; and Monomoy harbor, $\frac{1}{10000}$. He resigned on the 1st of April.

6. Mr. J. R. P. Mechlin has been engaged on the hydrography of Eastern series, No. 2, $\frac{1}{80000}$; Muskeget channel, $\frac{1}{60000}$; Chesapeake bay, No. 1, $\frac{1}{80000}$; and Charleston harbor, $\frac{1}{500}$; besides executing a large amount of miscellaneous work.

7. Mr. L. D. Williams has been engaged on Congress map, $\frac{1}{1500000}$; Monomoy harbor, $\frac{1}{5000}$; Romer and Flynn's shoals, $\frac{1}{40000}$; Appomattox river, $\frac{1}{5000}$; Beaufort harbor, $\frac{1}{2000}$; Plymouth harbor, $\frac{1}{2000}$; and on verifications, projections, progress sketches, &c.

8. Mr. E. Freyhold has been engaged on Congress map, $\frac{1}{1500000}$; San Luis Pass, $\frac{1}{40000}$; sketches of Western coast, $\frac{1}{\ldots 000}$; hydrography of Portland harbor, $\frac{1}{20000}$; and projections for field-work, &c. He resigned on the 8th of August.

9. Mr. J. R. Key has been engaged on Beaufort harbor, $\frac{1}{20000}$; Appomattox river, $\frac{1}{5000}$; Albemarle sound, $\frac{1}{200000}$; Ship and Sand Shoal inlets, $\frac{1}{40000}$; Pulgas Base, $\frac{1}{40000}$; Santa Cruz, $\frac{1}{40000}$; Point Año Nuevo and Santa Cruz, $\frac{1}{20000}$; comparative map of Maffitt's channel, $\frac{1}{10000}$; comparative map of Portland harbor, $\frac{1}{10000}$; Congress map, $\frac{1}{1500000}$; harbors of Annisquam and Ipswich, $\frac{1}{20000}$; and on progress sketches, tracings, &c.

10. Mr. W. P. Schulz, in connection with clerical duties, has been engaged on projects and miscellaneous work of the division. On the 10th of October he was assigned wholly to the latter description of work.

11. Mr. W. T. Martin joined the division on the 19th of November, 1853, and was assigned as draughtsman to Lieut. Comg. Wilkinson's party in the Coast Survey office. Since the 1st of February, 1854, his duties have been wholly in the division, and applied to the drawing of the apparatus for measuring base-lines; progress sketches; comparative map of the shore-line of part of the city of New York; and the topography of Gloucester harbor, $\frac{1}{20000}$; besides miscellaneous work.

12. Mr. A. Lindenkohl joined the office July 1st, and has been engaged on the reductions of Western coast reconnaissances, Nos. 2 and 3, progress sketches, comparative map of Portland harbor, projections, and other miscellaneous work.

13. Mr. R. S. Lankoronski was taken on trial on the 15th of December, 1853, and voluntarily left the division on the 10th of March. He was employed on sketches and the reduction of Umquah river, $\frac{1}{20000}$.

14. Mr. Frederick Fairfax was taken on trial the 15th of February, and his work was considered as executed on contract until the 1st of September, when he was registered with the draughtsmen. He has been engaged on the sketch of the Rio Grande, $\frac{1}{20000}$; topography of Santa Cruz and Point Año Nuevo, $\frac{1}{40000}$; comparative maps of Portland harbor, and Maffitt's channel, and York river, $\frac{1}{20000}$.

15. Mr. F. Boucher joined the office the 8th of August. He has been engaged chiefly on progress sketches.

16. Mr. B. Hooe, jr., has been employed on tracings.

17. Mr. R. L. Eastman joined the office on the 5th of June, and was engaged in tracing and other miscellaneous work until the 10th of October, when he was transferred to Lieut. Comg. Berryman's party.

18. Artificers Campbell and McEnery have been employed on tracings and copying. The former has also been in charge of the register of foreign maps. The latter was discharged on the 1st of July from the military service, and consequently from Coast Survey duty.

Mr. G. A. Porterfield relieved Mr. W. P. Schulz of the clerical duties of the office on the 10th of October.

List of Maps and Sketches completed or in progress during the year ending November 1, 1854, *arranged in order of sections.*

Name.	Scale.	Description.	Remarks.
SECTION I.			
Progress sketch, A	$\frac{1}{600000}$	....	Completed.
Do ......A, *bis*	$\frac{1}{400000}$	....	Do.
Reconnaissance of Eggemoggin Reach	$\frac{1}{20000}$	Light-house sketch	Do.
Portland harbor	$\frac{1}{20000}$	Preliminary chart	Do.
Do	$\frac{1}{20000}$	Comparative map	Do.
Do	$\frac{1}{10000}$	........do........	Do.
Wood island and vicinity.			
York River and Cape Neddick harbors	$\frac{1}{20000}$	Light-house sketch	Do.
Annisquam and Ipswich harbors	$\frac{1}{20000}$	Preliminary chart	Do.
Gloucester harbor	$\frac{1}{20000}$	........do........	Do.
Stellwagen's Bank	$\frac{1}{400000}$	........do........	Do.
Plymouth harbor	$\frac{1}{20000}$	........do........	Do.
Eastern series, No. 3	$\frac{1}{80000}$	Finished map	Topography nearly completed; hydrography in progress.
Do.....No. 2	$\frac{1}{80000}$	........do........	Topography completed; hydrography nearly completed.
Monomoy harbor	$\frac{1}{40000}$	........do........	Completed.
Bass River harbor	$\frac{1}{40000}$	Preliminary chart	Do.
Muskeget channel	$\frac{1}{60000}$	Finished map	Do.
Nantucket shoals	$\frac{1}{200000}$	Preliminary chart	Do.
Tidal currents of Nantucket shoals	$\frac{1}{300000}$	Sketch	Do.
SECTION II.			
Progress sketch, B	$\frac{1}{800000}$	....	Completed.
Tidal currents, Long Island sound	$\frac{1}{800000}$	Sketch	Do.
Long Island sound, No. 1	$\frac{1}{80000}$	Finished map	Do.
Part of Manhattan island	$\frac{1}{8000}$	Comparative map.	
SECTION III.			
Progress sketch, C	$\frac{1}{400000}$	....	Completed.
Chesapeake bay	$\frac{1}{400000}$	Preliminary chart	In progress.
Sea-coast of Virginia, No. 2	$\frac{1}{200000}$	........do........	Completed.
Ship and Sand Shoal inlets	$\frac{1}{40000}$	........do........	Do.
Chesapeake bay, No. 6	$\frac{1}{80000}$	Finished map	In progress.
James River entrance	$\frac{1}{80000}$	Preliminary chart	Dₒ.
James river, from Richmond to Harrison's bar	$\frac{1}{80000}$	........do........	Do.
Appomattox river, from Petersburg to City Point	$\frac{1}{5000}$	Finished map	Completed.
Rappahannock river, from Fredericksburg to Port Royal	....	Preliminary chart	In progress.
Chesapeake bay, No. 5	$\frac{1}{80000}$	Finished map	Do.
Do.......No. 4	$\frac{1}{80000}$	........do........	Do.
Do.......No. 3	$\frac{1}{80000}$	........do........	Topography nearly completed; hydrography in progress.
Do.......No. 2	$\frac{1}{80000}$	........do........	Nearly completed.
Do.......No. 1	$\frac{1}{80000}$	........do........	Completed.
SECTION IV.			
Progress sketch, D	$\frac{1}{600000}$	....	Completed.
Do......No. 2	$\frac{1}{400000}$	....	Do.
Albemarle sound	$\frac{1}{200000}$	Preliminary chart	Do.
Reconnaissance of Wimble shoals	$\frac{1}{50000}$	Sketch	Do.
Beaufort harbor	$\frac{1}{20000}$	Preliminary chart	Do.
Cape Fear river	$\frac{1}{30000}$	Finished map	In progress.
Gulf Stream chart	$\frac{1}{5000000}$	Sketch	Completed.
Gulf Stream diagrams of observations	....	Sketch	Ðo.
Co-tidal lines of the Atlantic coast	$\frac{1}{10000000}$	Sketch	Do.

List of Maps and Sketches—Continued.

Name.	Scale.	Description.	Remarks.
SECTION V.			
Progress sketch, E	$\frac{1}{400000}$		Completed.
Do......No. 2, (Savannah river)	$\frac{1}{200000}$		Do.
Winyah bay and Georgetown harbor	$\frac{1}{40000}$	Preliminary chart	Do.
Winyah bay and Georgetown harbor, and Cape Roman shoals	$\frac{1}{100000}$	Preliminary survey	In progress.
Charleston harbor, enlargement of	$\frac{1}{30000}$	Finished map	Do.
Maffitt's channel	$\frac{1}{50000}$	Comparative chart	Completed.
SECTION VI.			
Progress sketch, F	$\frac{1}{1200000}$		Completed.
Do.......No. 2, (Florida reefs)	$\frac{1}{400000}$		Do.
Key Biscayne and vicinity	$\frac{1}{20000}$	Original chart	Do.
Florida reefs, No. 1	$\frac{1}{80000}$	Finished map	Topography in progress; hydrography nearly completed.
Turtle harbor	$\frac{1}{40000}$	Light-house sketch	Completed.
Coffin's Patches	$\frac{1}{20000}$	........do	Do.
Cedar Keys and vicinity	$\frac{1}{50000}$	Preliminary chart	In progress.
SECTION VII.			
Progress sketch, G	$\frac{1}{600000}$		Completed.
SECTION VIII.			
Progress sketch, H	$\frac{1}{600000}$		Completed.
Mobile bay, No. 1	$\frac{1}{60000}$	Finished map	Nearly completed.
Mississippi sound, No. 2	$\frac{1}{80000}$	........do	Topography completed; hydrography nearly completed.
Pass Fourchon	$\frac{1}{10000}$	Reconnaissance	Completed.
SECTION IX.			
Progress sketch, I	$\frac{1}{600000}$		Completed.
Rio Bravo del Norte	$\frac{1}{20000}$	Preliminary chart	Do.
SECTIONS X and XI.			
Progress sketch, J and K	$\frac{1}{4000000}$		Completed.
Santa Cruz and Point Año Nuevo harbors	$\frac{1}{40000}$	Preliminary chart	Do.
Entrance to San Francisco bay	$\frac{1}{50000}$	Finished map	In progress.
Pulgas base	$\frac{1}{40000}$	Sketch	Completed.
Alden's reconnaissance, No. 2, from San Francisco entrance to Umquah river	$\frac{1}{1200000}$	Sketch	Do.
Shelter cove, Mendocino City and Crescent City harbors, and Port Orford or Ewing harbor	$\frac{1}{20000}$	Preliminary chart	Do.
Umquah River entrance	$\frac{1}{20000}$	........do	Do.
Alden's reconnaissance, No. 3, from Umquah river to the 49th parallel	$\frac{1}{1200000}$	Sketch	Do.
Grenville harbor	$\frac{1}{20000}$	Preliminary survey	Do.
Tidal diagrams: San Diego, San Francisco, and Astoria			Do.
Drawings of base measuring apparatus			Do.
Mitchell's tide-gauge			Do.
Plan of Lieut. Comg. Craven's sounding apparatus			Do.
Do......do......do...current indicator			Do.

REPORT OF LIEUT J. C. CLARK, U. S. A., IN CHARGE OF THE ENGRAVING DIVISION.

This division remained under the charge of E. B. Hunt, lieutenant engineers U. S. A., from the date of last report until February 13th, when he was relieved by Brevet Captain James Oakes, 2d dragoons U. S. A., who continued in charge until April 1st, when he was relieved by myself, with whom the charge has continued until the present time.

Several important charts have been brought near to completion during the year, which are expected to be finished about the last of December, viz: Newburyport harbor, Salem harbor, Long Island sound, Nos. 1, 2, and 3; Charleston harbor, Key West harbor, $\frac{1}{50000}$; Mobile bay, No. 1, and Alden's reconnaissance Western coast, No. 2.

The two charts—Wellfleet harbor and Galveston Bay entrance—reported finished in last report, have had important additions and corrections applied to them during the year.

The following-named principal charts have been well advanced during the year, viz: Boston harbor, Muskeget channel, south side Long Island No. 2, Albemarle sound No. 2, and Mobile bay No. 2.

Four have also been commenced during the year, viz: Portsmouth harbor, Monomoy harbor, Chesapeake bay No. 2, and Beaufort harbor, North Carolina; two of which, Portsmouth and Monomoy harbors, have made considerable progress; and the hydrographic portion of the chart of Beaufort harbor, North Carolina, is expected to be ready for publication in December.

New editions of the following charts, consequent upon important additions and corrections, have been completed for the superintendent's annual report of 1853, since the date of last report from this division, viz: Davis' shoals, Cape Fear river and New inlet, North Edisto river, Horn Island Pass, Aransas Pass, San Diego entrance, and reconnaissance of Western coast No. 1.

The following sketches and preliminary charts, previously commenced for the Superintendent's report of 1853, have been completed since the date of last report, viz: Sow and Pigs reef, Romer and Flynn's shoals, Wachapreague, Machipongo, and Metomkin inlets, Cape Charles and vicinity, Cherrystone inlet, Pungoteague creek, St. John's River entrance, Middle or Main and West entrances St. George's sound, San Luis Pass, and Cortez Banks. And the following sketches, &c., for the same report, have been wholly engraved during the year, viz: Alden's Rock, Minot's Ledge, Seacoast Virginia No. 2, (upper part;) Gulf Stream explorations, No. 1; Gulf Stream explorations, No. 2, (diagrams;) Tidal diagrams Key West, Pascagoula river, Ship Island shoals, Sabine Pass, and Tidal diagrams Rincon Point.

The following sketches, &c., intended for the Superintendent's annual report of 1854, have been wholly engraved during the year, viz: Tidal currents Long Island sound, Ship and Sand Shoal inlets, Co-tidal lines Atlantic coast, Gulf Stream explorations, 1854, (diagrams;) Pulgas base, Tidal diagrams Rincon Point, San Diego, and Astoria, and Base apparatus. And the following sketches, intended for the same report, have been commenced during the year, and are in progress, viz: Seacoast Virginia, No. 2, (lower part;) Gulf Stream explorations, 1854; Turtle harbor, Florida reefs; Rio Bravo del Norte, Santa Cruz, and Año Nuevo harbors; Reconnaissance Western coast, No. 2; Port Orford or Ewing harbor, Mendocino City, and Crescent City harbors; and Shelter cove and Umquah river.

Additions to charts, showing the progress of the survey in the several sections, have been engraved, and corrections and additions, made necessary by natural and artificial changes on the coast, have been applied to charts previously published.

Four engravers—Messrs. F. Dankworth, John Knight, A. Rollé, and J. Young—have been employed in the office during the entire year on important topography and hydrography; and four apprentices—J. J. Knight, R. F. Bartle, S. V. Bradley, and F. W. Benner—on the preliminary charts and sketches. Four engravers—Messrs. S. Siebert, William Smith, H. Knight, and J. V. N. Throop—have been employed in the office during part of the year, on important topography and hydrography; and three apprentices—H. C. Evans, J. S. Pettit, and C. F. Smith—on the preliminary charts and sketches. Messrs. E. F. Woodward and E. Yeager, of Philadelphia, have been employed on contract during a large portion of the year, on hydrography and lettering, and Mr. G. McCoy, of New York, on topography and views, since September 26th.

Portions of several charts have also been engraved on contract, out of the office, by other engravers.

I herewith give a general summary of the work done upon several of the most important plates.

Boston harbor.—A large portion of the sand below low-water line has been engraved by Mr. Rollé. He has also engraved a portion of the topography previously omitted. Mr. John Knight has engraved a large portion of the general lettering and additional soundings.

Salem harbor.—All the woods, marsh, and fields, and a large portion of the hills, have been engraved by Mr. Dankworth, finishing the topography. The sailing directions and lines, title, and a portion of the general lettering, have been engraved by Mr. John Knight. A portion of the sand below low-water line has been engraved by Mr. Henry Knight.

Newburyport harbor.—The views, fields, and grass have been engraved by Mr. Young; a portion of the sand, by Mr. Evans; and additions to the topography, by Mr. Henry Knight.

Monomoy.—The soundings and bottoms have been engraved by Mr. Wm. Smith, and nearly all the topography by Mr. Evans.

Long Island sound, No. 1.—The sailing directions have been completed by Mr. John Knight, and the northern shore of the sound has been sanded to the eighteen-foot curve by Mr. Rollé.

South side Long Island, No. 2.—The hills have been engraved by Mr. Siebert, and a portion of the sand by Mr. Rollé.

Albemarle sound, No. 2.—A large portion of the topography has been engraved by Mr. Young.

Charleston harbor.—Nearly the entire sand below low-water line has been engraved by Mr. Dankworth. The general lettering and that of the tables, except the current table, has been engraved by Mr. John Knight, Mr. Yeager, and Mr. Wm. Smith.

Key West harbor and its approaches, $\frac{1}{50000}$.—The sand below the six-foot curve has been engraved by Mr. Woodward. The topography of the chart and the sanding of the sub-sketch have been engraved by Mr. Henry Knight. The sailing directions and notes have been engraved by Mr. Yeager.

Mobile bay No. 1, $\frac{1}{80000}$.—Mr. Henry Knight has engraved the sand between low-water line and the twelve-foot curve. Mr. Siebert finished the engraving of the topography.

I respectfully call your attention to the accompanying lists of maps engraved, preliminary charts and sketches engraved, maps engraving, plates unfinished at the date of last report, plates commenced during the year, and plates finished during the year.

List of Coast Survey maps, preliminary charts and sketches, engraved and engraving.

1. List of maps and charts engraved.

No. 1.	Richmond's island	1-20,000
2.	Wellfleet harbor	1-50,000
3.	Nantucket harbor	1-20,000
4.	Hyannis harbor	1-30,000
5.	Harbor of Edgartown	1-20,000
6.	Harbors of Holmes' Hole and Tarpaulin cove	1-20,000
7.	Harbor of New Bedford	1-40,000
8.	General chart of the coast from Gay Head to Cape Henlopen	1-400,000
9.	Fisher's Island sound	1-40,000
10.	Harbor of New London	1-20,000
11.	Mouth of Connecticut river	1-20,000
12.	Harbor of New Haven—new edition, 1852	1-30,000
13.	Harbors of Black Rock and Bridgeport	1-20,000
14.	Harbors of Sheffield and Cawkin's islands	1-20,000
15.	Huntington bay	1-30,000
16.	Oyster bay or Syosset harbor	1-30,000
17.	Harbors of Captain's islands, East and West	1-20,000
18.	Hart and City islands and Sachem's Head harbor 1-20,000,	1-10,000
19.	Hell Gate	1-5000
20.	New York bay and harbor and the environs—sheet No. 1	
21.	Do do do do No. 2	
22.	Do do do do No. 3	
23.	Do do do do No. 4	1-30,000
24.	Do do do do No. 5	
25.	Do do do do No. 6	

No. 26.	New York bay and harbor and the environs	1–80,000
27.	Western part of south coast of Long Island	1–80,000
28.	Little Egg Habor	1–30,000
29.	Delaware bay and river—sheet No. 1	1–80,000
30.	Do..........do..........No. 2	
31.	Do..........do..........No. 3	
32.	Seacoast of Delaware, Maryland, and part of Virginia	1–200,000
33.	Harbor of Annapolis and Severn river	1–60,000
34.	Mouth of Chester river	1–40,000
35.	Pasquotank river	1–60,000
36.	Mobile bay entrance	1–40,000
37.	Cat and Ship Islands harbors	1–40,000
38.	Galveston bay entrance	1–40,000

2. List of preliminary charts and sketches engraved.

No. 1.	Alden's rock	1–1,000
2.	Current chart, Boston harbor	1–100,000
3.	Minot's ledge	1–10,000
4.	Davis' shoal and other dangers—new edition	1–200,000
5.	Sow and Pigs reef	1–240, 1–20,000
6.	Tidal currents, Long Island sound	1–800,000
7.	Buttermilk channel	1–5,000
8.	Beacon ranges, New York harbor	1–40,000
9.	Romer shoal and Flynn's knoll	1–40,000
10.	Changes in Sandy Hook	1–10,000, 1–40,000
11.	Chincoteague inlet	1–40,000
12.	Seacoast Virginia, No. 2, (upper part)	1–200,000
13.	Wachapreague, Machipongo, and Metomkin inlets	1–40,000
14.	Ship and Sand Shoal inlets	1–40,000
15.	Entrance to Chesapeake bay	1–100,000
16.	Cape Charles and vicinity	1–80,000
17.	Cherrystone inlet	1–40,000
18.	Pungoteague creek	1–40,000
19.	Fishing or Donoho's battery	1–80,000
20.	Hatteras shoals	1–20,000
21.	Cape Hatteras	1–20,000
22.	Hatteras inlet—4th edition	1–20,000
23.	Ocracoke inlet	1–40,000
24.	Beaufort harbor	1–20,000
25.	New River and bar	1–15,000
26.	Frying Pan shoals	1–120,000
27.	Cape Fear river and New inlet	1–40,000
28.	Gulf Stream explorations, 1853	1–5,000,000
29.	Diagrams—Gulf Stream explorations, 1853.	
30.	Diagrams—Gulf Stream explorations, 1854.	
31.	Co-tidal lines, Atlantic coast	1–10,000,000, 1–1,500,000
32.	Cape Roman shoals	1–100,000
33.	Bull's bay	1–40,000
34.	N. Edisto river—new edition	1–50,000
35.	Savannah river entrance	1–30,000
36.	Savannah city, Front and Back rivers	1–20,000
37.	St. Andrew's shoal	1–60,000
38.	St. John's river entrance	1–25,000
39.	Musquito inlet	1–40,000
40.	Cape Cañaveral	1–60,000
41.	Key West—2d edition	1–100,000
42–48.	Key West tidal diagrams.	
49.	Rebecca shoals	1–600,000
50.	Western coast, Florida	1–1,200,000
51.	Reconnaissance, vicinity of Cedar Keys	1–300,000
52.	Channel No. 4, Cedar Keys	1–30,000
53.	Florida sketch.	
54.	St. Mark's bar and channel	1–40,000
55.	Middle or Main and Western entrances St. George's sound	1–80,000
56.	Entrance to Mobile bay	1–10,000
57.	Mobile bay—2d edition	1–200,000
58.	Horn Island Pass and Grand bay	1–300,000
59.	Horn Island Pass—new edition	1–40,000
60.	Pascagoula river	1–20,000
61–70.	Cat Island tidal diagrams.	
71.	Pass Christian	1–40,000
72.	Delta of Mississippi	1–60,000
73.	Barataria bay entrance	1–30,000
74.	Timballier bay entrance	1–20,000
75.	Isle Dernière or Ship Island shoals	1–80,000

No. 76.	Entrance to Sabine river	1–40,000
77.	Entrance to Galveston bay	1–40,000
78.	Galveston bay—2d edition	1–200,000
79.	San Luis Pass	1–20,000
80.	Aransas Pass—2d edition, enlarged	1–30,000
81.	Alden's reconnaissance of Western coast from San Francisco to San Diego—new edition	1–1,200,000
82.	Cortez Bank	1–10,000, 1–1,200,000
83.	San Diego entrance—new edition	1–15,000, 1–25,000
84.	Catalina harbor	1–15,000
85.	Prisoner's harbor, Cuyler's harbor, and northwest anchorage San Clemente island	1–20,000
86.	Santa Barbara	1–20,000
87.	San Simeon, Santa Cruz, San Luis Obispo, and Coxo	1–20,000, 1–40,000
88.	Point Conception	1–40,000
89.	Point Pinos	1–20,000
90.	Monterey harbor	1–40,000
91.	San Pedro	1–20,000
92.	San Francisco bay entrance	1–400,000
93.	San Francisco city—3d edition	1–10,000
94.	Tidal diagrams, Rincon Point.	
95.	Pulgas base	1–40,000, 1–400,000
96.	Mare Island straits	1–30,000
97.	McArthur's reconnaissance of Western coast from Monterey to mouth of Columbia river—sheet No. 1, 3d edition.	
98.	McArthur's reconnaissance of Western coast from Monterey to mouth of Columbia river—sheet No. 2, 3d edition.	
99.	McArthur's reconnaissance of Western coast from Monterey to mouth of Columbia river—sheet No. 3, 3d edition.	
100.	Humboldt bay	1–30,000
101.	Trinidad bay	1–20,000
102.	Mouth of Columbia river—2d edition	1–40,000
103.	Do ... do	1–200,000
104.	Cape Hancock or Disappointment	1–20,000
105.	Shoalwater bay	1–80,000
106.	Tidal diagrams, Rincon Point, San Diego, and Astoria.	
107.	Alden's reconnaissance Western coast from Gray's harbor to Admiralty inlet	1–600,000
108.	Cape Flattery and Nee-ah harbor	1–40,000
109.	False Dungeness harbor	1–30,000
110.	Base apparatus.	
111.	Self-registering tide-gauge.	
112–125.	Progress sketches.	

3. List of maps and charts engraving.

No. 1.	Portsmouth harbor	1–20,000
2.	Newburyport harbor	1–20,000
3.	Salem harbor	1–25,000
4.	Boston harbor	1–40,000
5.	Monomoy harbor	1–40,000
6.	Muskeget channel	1–60,000
7.	Eastern series, from Point Judith eastward—three sheets	1–80,000
8.	Long Island sound—sheet No. 1 (additions)	1–80,000
9.	Do ... do ... do .. No. 2 (additions)	1–80,000
10.	Do ... do ... do .. No. 3	1–80,000
11.	South side Long Island—sheet No. 2	1–80,000
12.	Do ... do ... do .. No. 3	1–80,000
13.	Seacoast of Virginia, No. 2, (lower part)	1–200,000
14.	Chesapeake bay, No. 1	1–80,000
15.	Do ... No. 2	1–80,000
16.	Patapsco river	1–60,000
17.	Gulf Stream explorations, 1854	1–5,000,000
18.	Albemarle sound	1–200,000
19.	Albemarle sound—sheet No. 1	1–80,000
20.	Do ... do .. No. 2	1–80,000
21.	Beaufort harbor, North Carolina	1–30,000
22.	Charleston harbor	1–30,000
23.	Turtle harbor, Florida reefs	1–40,000
24.	Key West harbor and its approaches	1–50,000
25.	Mobile bay—sheet No. 1	1–80,000
26.	Do ... do .. No. 2	1–80,000
27.	Rio Bravo del Norte	1–20,000
28.	Santa Cruz and Año Nuevo harbors	1–40,000, 1–1,200,000
29.	Alden's reconnaissance Western coast, No. 2	1–1,200,000
30.	Shelter Cove, Mendocino City, and Crescent City harbors, and Port Orford or Ewing harbor	1–20,000
31.	Umquah river	1–20,000

Of the above, Nos. 13, 17, 23, 27, 28, 29, 30, and 31 will be included in the Superintendent's annual report for 1854.

List of plates unfinished at the date of last report.

No. 1.	Newburyport harbor	1-20, 000
2.	Salem harbor	1-25, 000
3.	Boston harbor	1-40, 000
4.	Sow and Pigs reef	1-240, 1-20, 000
5.	Eastern series, from Point Judith eastward—three sheets	1-80, 000
6.	Long Island sound, No. 1, (additions)	1-80, 000
7.	Do......do...No. 2, (additions)	1-80, 000
8.	Do......do...No. 3	1-80, 000
9.	South side Long Island, No. 2	1-80, 000
10.	Do.........do....No. 3	1-80, 000
11.	Romer shoal and Flynn's knoll	1-40, 000
12.	Chesapeake bay, No. 1	1-80, 000
13.	Patapsco river	1-60, 000
14.	Wachapreague, Machipongo, and Metomkin inlets	1-40, 000
15.	Cape Charles and vicinity	1-80, 000
16.	Cherrystone inlet	1-40, 000
17.	Pungoteague creek	1-40, 000
18.	Albemarle sound, No. 2	1-80, 000
19.	Charleston harbor	1-30, 000
20.	St. John's river entrance	1-25, 000
21.	Key West harbor and its approaches	1-50, 000
22.	Middle or main and west entrances St. George's sound	1-80, 000
23.	Mobile bay, No. 1	1-80, 000
24.	Do....No. 2	1-80, 000
25.	San Luis Pass	1-20, 000
26.	Cortez Banks	1-10, 000, 1-1, 200, 000

Of the above, Nos. 4, 11, 14, 15, 16, 17, 20, 22, 25, and 26 were included in the Superintendent's report for 1853.

List of plates commenced during the year.

No. 1.	Alden's rock	1-1, 000
2.	Portsmouth harbor	1-20, 000
3.	Minot's Ledge	1-10, 000
4.	Monomoy harbor	1-40, 000
5.	Currents Long Island sound	1-800, 000
6.	Seacoast Virginia, No. 2, (upper part)	1-200, 000
7.	Do........do.... (lower part)	1-200, 000
8.	Ship and Sand Shoal inlets	1-40, 000
9.	Chesapeake bay, No. 2	1-80, 000
10.	Gulf Stream explorations, No. 1, 1853	1-5, 000, 000
11.	Do..........do......No. 2, (diagrams.)	
12.	Do..........do......1854	1-5, 000, 000
13.	Do..........do......1854, (diagrams.)	
14.	Co-tidal lines, Atlantic coast	1-10, 000, 000, 1-1, 500, 000
15.	Beaufort harbor, North Carolina	1-30, 000
16.	Florida sketch.	
17.	Turtle harbor, Florida reefs	1-40, 000
18-24.	Tidal diagrams, Key West.	
25.	Pascagoula river	1-20, 000
26.	Ship Island shoal	1-80, 000
27.	Sabine Pass	1-40, 000
28.	Rio Bravo del Norte	1-20, 000
29.	Santa Cruz and Año Nuevo	1-40, 000, 1-1, 200, 000
30.	Alden's reconnaissance Western coast, No. 2	1-1, 200, 000
31.	Pulgas base	1-40, 000, 1-400, 000
32.	Tidal diagrams, Rincon Point.	
33.	Tidal diagrams, Rincon Point, San Diego, and Astoria.	
34.	Shelter cove, Mendocino, and Crescent City harbors, and Port Orford or Ewing harbor	1-20, 000
35.	Umquah river	1-20, 000
36.	Base apparatus.	

Of the above, Nos. 1, 3, 6, 10, 11, 18 to 24, 25, 26, 27, and 32, were included in the Superintendent's annual report for 1853, and Nos. 5, 7, 8, 12, 13, 14, 17, 28, 29, 30, 31, 33, 34, 35, and 36 will be included in the Superintendent's annual report for 1854.

List of plates finished during the year.

No. 1.	Alden's rock	1-1, 000
2.	Minot's Ledge	1-10, 000
3.	Wellfleet harbor	1-50, 000
4.	Davis' shoal and other dangers, (new edition)	1, 200, 000
5.	Sow and Pigs reef	1-240, 1-20, 000
6.	Tidal currents Long Island sound	1-800, 000
7.	Romer shoal and Flynn's knoll	1, 40, 000

No. 8.	Seacoast of Virginia, No. 2, (upper part)	1-200,000
9.	Wachapreague, Machipongo, and Metomkin inlets	1-40,000
10.	Ship and Sand Shoal inlets	1-40,000
11.	Cape Charles and vicinity	1-80,000
12.	Cherrystone inlet	1-40,000
13.	Pungoteague creek	1-40,000
14.	Cape Fear river and New inlet—new edition	1-40,000
15.	Gulf Stream explorations, No. 1, 1853	1-5,000,000
16.	Do..........do.....No. 2, (diagrams.)	
17.	Do..........do.....1854, (diagrams.)	
18.	Co-tidal lines, Atlantic coast	1-10,000,000, 1-1,500,000
19.	North Edisto river—new edition	1-50,000
20.	St. John's river entrance	1-25,000
21-27.	Tidal diagrams, Key West.	
28.	Florida sketch.	
29.	Middle or main and western entrances St. George's sound	1-80,000
30.	Horn Island Pass—new edition	1-40,000
31.	Pascagoula river	1-20,000
32.	Ship Island shoal	1-80,000
33.	Sabine Pass	1-40,000
34.	Galveston bay entrance	1-40,000
35.	San Luis Pass	1-20,000
36.	Aransas Pass	1-30,000
37.	Alden's reconnaissance Western coast, San Francisco to San Diego—new edition	1-1,200,000
38.	Cortez Banks	1-10,000, 1-1,200,000
39.	San Diego entrance	1-150,000, 1-25,000
40.	Tidal diagrams, Rincon Point.	
41.	Pulgas base	1-40,000, 1-400,000
42.	Tidal diagrams of Rincon Point, San Diego, and Astoria.	
43.	Base apparatus.	
44-57.	Progress sketches.	

Of the above, Nos. 1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 19, 20, 21 to 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 44 to 57, were included in the Superintendent's report for 1853, and Nos. 6, 10, 17, 18, 41, 42, 43, 44 to 57, will be included in the Superintendent's report for 1854.

REPORT OF MR. GEORGE MATHIOT, IN CHARGE OF THE ELECTROTYPE DIVISION.

COAST SURVEY OFFICE, *Washington, November* 1, 1854.

During the past year I have made eighty plates by the electrotype process. Thirty-five of the plates were alto or mould plates; forty-two were basso or printing plates; and three were blank plates for engraving. Appended is a table of the plates.

One plate was extended by the electrotype process, ("Sketch E, in Section V,") being enlarged in one direction.

I have also, by the electrotype process, gold-plated seven deep-sea thermometers, and parts of several others.

Assistance has been rendered the computing division in the application of photography to the registration of magnetic variations.

During the past summer, as opportunity would permit, without interfering with the electrotype work, I have made a number of experiments on the natural-engraving processes proposed by DONNÉ, GROVE, GAUDIN, TALBOT, and NIEPCE, with a view of obtaining by chemical means, and directly from the original drawings of the survey, copper-plates ready for printing maps, without the long and tedious process of the mechanical artist.

So far, I have not *determined* that I shall obtain a chemiglyphic process; yet I have been much encouraged by my experiments, and have strong hopes of being able to substitute this process for a considerable portion of the engraving, if not to make a complete map.

My examination has not yet extended to the processes of Niepce and Talbot, except that I have determined that their processes can be worked on copper, which is much more economical than steel, as the plates of copper can be prepared by the electrotype process of perfect surface, while expensive manual labor only can furnish those of steel.

M. Donné proposed to etch a daguerreotype with nitric acid. The chemical difference between the "lights" and "shades" of the daguerreotype appears to be sufficient to determine the action of the acid to the dark parts, which are supposed to be silver, while the lights are mercury. I found this process extremely uncertain. In twenty carefully-conducted experiments I succeeded but once in getting definite markings, and this on a portion only of the plate experimented on; hence, I conclude the process is not likely ever to be turned to account.

Professor Grove proposed to engrave the daguerreotype by electro-etching it, making it the positive electrode in a strong bath of chlorohydric acid. This process gives engraving of great beauty, but, unfortunately, of very great delicacy. I made over a hundred trials of this process, and, although I generally obtained a beautiful engraving, yet in only two instances did I obtain lines of sufficient depth to print from, and then the quantity of ink which could be held in the line was only sufficient to give a mere stain on the paper, instead of a well-defined black line.

M. Gaudin proposed to conduct the process of M. Donné on a plate of steel, covered with a film of silver to enable it to receive the daguerrian image. This was designed for producing the graving on a more durable material than silver. But M. Gaudin does not state whether he designed merely to communicate a silver character to the surface of the steel, to enable it to be used as a daguerrian plate, or whether he designed such a coating, that while it might be eaten through in the shades, to expose the easily-oxidable steel, the lights would be protected by the silver film. If the former were his design, I must conclude, from my experiments, that it is impossible, because an indefinitely thin coating of noble metal over an oxidable one determines the formation of multitudes of small galvanic circles on the surface.

I have long had the idea of silvering a copperplate just sufficiently thick to defend the copper from such chemical action as would corrode it, and of then eating through this film by the process of Professor Grove, and afterwards well biting the copper in the bared parts. This I have great expectation of determining to be a practicable method of producing a chemiglyphic line-engraving; but the essential idea of this is probably due to M. Gaudin instead of myself.

The thickness of the film of silver required for the protection of the base metal I have found to be quite considerable; and this, combined with the very slight depth to which the silver can be etched, make the problem of obtaining an engraved plate by the method I propose one of great delicacy. Unfortunately, the requisite thickness of the film is nearly equal to the greatest depth of bite that can be obtained; and hence we may have a good Grove's etching on the film, yet the base metal only partially denuded; and then, if we attempt to enter the lines into the base metal, the result will be extremely irregular and partial.

Again, if the film of silver is not quite sufficient in thickness, the lights of the daguerreotype will be attacked, and the shades blurred by the spread of the lines. The problem depends, therefore, on getting a good protecting film, and then a good biting *through* this film. If the thickness of the film was not, unfortunately, so nearly equal to the depth to which the silver can be etched, I think the making of an engraved plate by chemical means would be comparatively easy.

A copper-plate should have the surface prepared very perfectly. It is then to be electroplated to the weight of one-eighth of a grain to the square inch; but this thickness is not yet well determined. The plate, after being washed in distilled water and dried, is to be slightly buffed, and the daguerreotype taken in the usual manner. Professor Grove recommended chlorohydric acid as the electrolyte for etching; but, in acting on a plate of base metal merely infilmed with the silver, we evidently should select an electrolyte which will not be liable to act on the base metal. Of the various electrolytes I tried, I found chloride of sodium the best; this seems to free the generated chloride of silver more readily than chlorohydric acid, is without much action on the copper base, and has the very great advantage of being free from poisonous qualities or disagreeable exhalations.

The object of the biting process so far has been only to remove the silver from the parts where we want the copper to be bitten in deep lines; but this process evidently cannot be continued till the copper has been bitten sufficiently deep, for it acts on the silver as well as the copper. Hence, the first biting should be continued only long enough to work through the silver film; here there is a liability of spoiling the work in the beginning by overdoing the first biting, which will infallibly remove the silver from the lights in some places, and give the whole plate a blurred or mezzotinted appearance. I can give no directions for the time of the biting through the film; practice and dexterous manipulation, as in the daguerreotype process, are the only helps here.

After the plate has been bitten through the film, it should be washed by immersing in water, and dried over a current of heated air. If, on examination, there appear no marked defects, the process of entering the lines into the copper may be gone on with. For this purpose I have used perchloride of iron, persulphate of iron, and also nitrate of silver. I have not determined which of these is the best, but so far I have a preference for the perchloride of iron. The perchloride may be added to water until it has a lemon-yellow color. The plate is to be immersed in a horizontal position with the face up in the solvent, and a soft camel's hair pencil swept gently over it from time to time. In the course of thirty minutes, or less, the action of the perchloride will have thrown up the chloride of silver, so that the brush can sweep it away, and the bright copper will then appear in the bottoms of the lines. The plate may then be washed and dried, and if, on inspection, it should not be thought deep enough to hold the ink for printing, it may be returned to the bath of perchloride for a short time.

I have not yet obtained a plate which has not been much corroded in the lights; and this corroding in the light has caused me to discontinue the second biting, before the depth of the lines has been sufficient to hold the full quantity of ink required to give a clear black print. When nitrate of silver is used for the second biting, the tendency to open the pores of the film is not so great as when the iron salts are used; but this solvent has a very great tendency to deposite the reduced silver in the fine lines, and this even closes the pores of the film; but, for coarse lines, I have thought that it made a cleaner plate than the iron salts.

I have sought to obtain a third biting, by filling the lines obtained by the second biting with some non-conducting substance, and then heavily silvering or gilding the lights, dissolving out the non-conducting substance from the lines, and again biting; but every experiment I have made in this direction has failed, for the following reasons: the only salts of silver and gold which can be successfully used for electro-deposition are alkaline; the alkali, acting on the oil, gum, resin, wax, or other hydro-carbon which fills the line, dissolves it before the lights are sufficiently coated. Again, when the non-conducting film in the lines is very thin, it is ruptured by the affinity which the negative element of the electrolyte has for the copper. I find that asphaltum is not very readily acted on by the alkaline salts of the noble metals, but I have not yet succeeded in working this substance into the lines.

I took an alto by the electrotype process from a plate, after the first biting, and gave the alto a good coat of gold, and ground down the raised lines with a soft piece of charcoal, so as to cut through the gilding and expose the copper. The plate was then bitten with the perchloride of iron. All the fine lines, as the hair-strokes of the letters and figures, were destroyed, but a good solid cutting of the coarser parts was obtained.

In putting on the silver, I judged of the thickness and weight by making the current which reduced the silver pass through a voltameter in the same circuit, and carefully noting the volume of hydrogen evolved, and referring to the respective equivalents and specific gravities. This is a rather laborious process, but it is probably the only one by which small quantities of electro-deposited metal can be measured.

In conclusion, I would remark that not much should be expected from experiments conducted only at odd hours during a couple of months; and though a useful result has not yet been obtained, still the products are very encouraging, and, thus far, more satisfactory than might reasonably be expected from the short time devoted to the examination.

Table of Electrotypes.

Name of the chart.	Number of altos.	Number of bassos.
New York, $\frac{1}{30000}$, in six sheets	5	
Monterey harbor		1
New Bedford		1
Mobile bay		1
Fisher's Island sound		1
Diagram plate for Key West tides	4	8
Key West harbor	1	1
New river and bar	1	1
Mouth of Chester river		2

Table of Electrotypes—Continued.

Name of the chart.	Number of altos.	Number of bassos.
Delta of the Mississippi	1	1
Seacoast of Maryland, Delaware, and Virginia	1	1
Reconnaissance—vicinity of Cedar Keys	1	
Galveston bay	1	1
San Luis Obispo, &c	1	1
Trinidad bay	1	
Horn Island Pass	1	1
San Diego	1	1
Western coast reconnaissance, (McArthur)	2	3
Mouth of Connecticut river	1	1
Sketch E, Section V	1	1
Large plate of squares for curves	1	1
Alden's reconnaissance Western coast, (Gray's harbor, &c.)	2	2
Shoalwater bay	1	1
Cape Flattery	1	2
Cuyler's harbor	1	1
False Dungeness	1	1
Black Rock and Bridgeport	....	1
Davis' South shoals	1	1
Captain's islands, East and West	....	1
Frying Pan shoals	1	1
North Edisto	1	1
Little Egg harbor	....	1
Wellfleet harbor	1	1
	35	42

REPORT OF MR. S. D. O'BRIEN, IN CHARGE OF THE PRINTING DIVISION.

Since the first of November, 1853, there have been printed the following plates:

Section 1.	Number of impressions.
New Bedford harbor	350
Nantucket harbor	450
Harbors of Holmes' Hole and Tarpaulin cove	450
Edgartown harbor	400
Hyannis harbor	500
Richmond's island	380
Wellfleet harbor	1,280
Davis' South shoal	827
Boston harbor currents	100

Section 2.

Hell Gate	400
New York bay and harbor, $\frac{1}{80000}$	400
General chart of the coast from Gayhead to Cape Henlopen	730
South side of Long Island, No. 1	200
Harbor of New London	666
Hart and City islands, and Sachem's Head harbor	350
New Haven harbor	350
Black Rock and Bridgeport harbors	500
Fisher's Island sound	380
Oyster bay or Syosset harbor	350

Huntington bay	500
Captain's islands, East and West	380
Mouth of Connecticut river	1,690
Romer shoal and Flynn's knoll	50
Little Egg Harbor	350
Delaware bay and river, (3 sheets)	1,200

SECTION 3.

Seacoast of Delaware, Maryland, and part of Virginia	350
Harbor of Annapolis	350
Mouth of Chester river	350
Chincoteague inlet	60
Entrance to Chesapeake bay	140

SECTION 4.

New river and bar	550
Beaufort harbor	600
Pasquotank river	577
Hatteras inlet	700
Ocracoke inlet	545
Fryingpan shoals	725
Fishing or Donoho's battery	100

SECTION 5.

Savannah city, Front and Back rivers	650
Savannah entrance	300
North Edisto river	677
Bull's bay	70

SECTION 6.

Cape Canaveral	226
St. Mark's bar and channel	275
Reconnaissance in vicinity of Cedar keys	500
Channel No. 4, Cedar keys	359
Key West	380
Rebecca shoal	100
Florida sketch	155

SECTION 7.

St. Andrew's shoal	125

SECTION 8.

Mobile bay	725
Entrance to Mobile bay	380
Cat and Ship Island harbors	350
Pass Christian	100
Horn Island Pass	380
Delta of the Mississippi	430

SECTION 9.

Aransas Pass	270
Galveston bay	380

SECTIONS 10 AND 11.

Monterey harbor	530
Catalina harbor	350
False Dungeness	2,005
San Pedro	850
Mare Island straits	550
Cape Hancock	200
Point Pinos	150
Shoal-water bay	1,725
Reconnaissance from Gray's harbor to Admiralty inlet	1,325
Cape Flattery	1,772
Santa Barbara	1,205
Point Conception	160
San Diego	1,575
San Francisco city	513
Humboldt bay	750
Trinidad bay	350
McArthur's Western coast reconnaissance	300
San Simeon, Santa Cruz, &c	650
Alden's reconnaissance from San Diego to San Francisco	1,260
Prisoners' harbor, &c	300
Sketches for annual report	2,990
Tide and current diagrams, (blanks)	1,636
Circular protractors	40
Proofs of finished and unfinished plates, and quarterly proofs	2,350
Total	48,298

REPORT OF MR. V. E. KING, IN CHARGE OF THE DIVISION FOR PUBLISHING, DISTRIBUTING, AND SALE OF MAPS.

At the date of my last report, November 15, 1853, forty-seven sheets of Coast Survey maps had been published. Since then, important additions having been made to the plates of "Wellfleet harbor" and "Galveston entrance," they have been added to the number previously published, which, in addition to Newburyport harbor, Salem harbor, Long Island sound, (in three sheets,) and Charleston harbor, (the last three mentioned expected to be completed by December 31, 1854,) will raise the number published, including Alden's reconnaissance No. 2, to fifty-six maps.

Important additions and corrections having been made to the following preliminary charts, new editions have been published, viz:

Davis' South shoals.
Cape Fear river and New inlet.
North Edisto river.
Horn Island Pass.
Aransas Pass.
San Diego bay.
Reconnaissance Western coast No. 1.

There are at present ready for distribution 380 bound volumes, containing all of the principal and most important maps now published, printed on thin paper. These books are intended to be distributed to members of Congress, prominent officers of the general government, and foreign ministers.

An annual distribution of maps is now being made, by which about nine thousand impressions from new plates will be distributed. The plates are eleven in number, as follows:

1. General chart of the coast from Gay Head to Cape Henlopen, vicinity of New York.
2. Wellfleet harbor, Massachusetts.

3. Mouth of Connecticut river, Connecticut.
4. San Diego bay, California.
5. Bay of Monterey, California.
6. Reconnaissance of the Western coast from San Diego to San Francisco, California.
7. Santa Barbara, California.
8. Reconnaissance from Gray's harbor to Admiralty inlet, Washington Territory.
9. Shoalwater bay, Washington Territory.
10. False Dungeness harbor, Washington Territory.
11. Cape Flattery and Nee-ah harbor, Washington Territory.

Of this number, 900 sheets are being distributed to the several departments in this city, and to the collectors of customs; 450 to foreign governments; 600 to institutions, societies, and officials in England and on the continent of Europe; 850 to institutions, &c., through the Treasury Department; and 6,000 are distributed, through the members of Congress to institutions, societies, &c., in the congressional districts of the several States, each member selecting two institutions to which he desires the maps sent.

List of Coast Survey maps distributed during the year, for sale, use of office, and gratuitously.

Names of charts.	Turned over for sale.	For use of office.	Gratuitously distributed.	Total.
Richmond's island	17	3	42	62
Nantucket harbor	16	9	72	97
Wellfleet harbor	....	....	....	....
Harbor of Edgartown	26	5	72	103
Hyannis harbor	22	1	73	96
Harbors of Holmes' Hole and Tarpaulin cove	11	5	72	88
Harbor of New Bedford	51	3	73	127
General chart of the coast from Gay Head to Cape Henlopen	94	7	92	193
Fisher's Island sound	20	1	56	77
Harbor of New London	29	6	97	132
Mouth of Connecticut river	5	2	51	58
Harbor of New Haven	46	2	94	142
Harbors of Black Rock and Bridgeport	20	1	88	109
Huntington bay	26	1	72	99
Harbors of Sheffield and Cawkin's islands	20	1	47	68
Harbors of Captain's islands, East and West	23	....	38	61
Syosset harbor or Oyster bay	23	1	71	95
Hart and City islands, and Sachem's Head harbor	22	1	75	98
Hell Gate	53	1	79	133
New York bay and harbor—6 sheets	....	1	9	10
New York bay and harbor, $\frac{1}{80000}$	156	3	94	253
Western part of south coast of Long Island	41	2	49	92
Little Egg harbor	20	1	71	92
Delaware bay and river—3 sheets	278	4	81	363
Seacoast of Delaware, Maryland, and part of Virginia	55	3	74	132
Mouth of Chester river	22	1	72	95
Harbor of Annapolis and Severn river	22	2	73	97
Pasquotank river	19	1	76	96
Cat and Ship Island harbors	20	2	86	108
Mobile Bay entrance	22	4	58	84
West coast reconnaissance from Monterey to Columbia river—3 sheets	75	1	60	136
West coast reconnaissance from San Diego to San Francisco	130	6	124	260
San Diego bay	....	....	36	36
Trinidad bay	110	1	84	195
Humboldt bay	110	2	83	195
Monterey harbor	110	....	49	159
Mouth of Columbia river	....	....	....	....
Sketches of Nantucket South shoals	61	4	43	108
Chincoteague inlet	11	....	44	55
Ocracoke inlet	11	2	76	89
Beaufort harbor	16	6	77	99
Frying-pan shoals	21	1	68	90
New river and bar	11	....	75	86
North Edisto river	1	....	45	46

List of Coast Survey maps distributed—Continued.

Names of charts.	Turned over for sale.	For use of office.	Gratuitously distributed.	Total.
Sketches of entrance, Savannah river	11	1	47	59
Savannah city	11	3	77	91
Mobile bay	31	....	93	124
Western coast of Florida	71	1	48	120
Key West	121	....	47	168
St. Mark's bar and channel	61	....	60	121
Delta Mississippi	40	1	26	67
Galveston bay	48	2	56	106
Catalina harbor	116	....	94	210
Prisoners' harbor, &c	116	1	52	169
San Pedro harbor	116	1	82	199
San Simeon, Santa Cruz, &c	116	1	83	200
San Francisco city	10	....	30	40
Santa Barbara	5	1	85	91
Shoalwater bay	....	1	56	57
Cape Flattery and Nee-ah harbor	....	....	....	....
Reconnaissance from Gray's harbor to Admiralty inlet	....	....	....	....
False Dungeness	....	....	....	....
Current chart, Boston harbor	5	....	37	42
Changes of Sandy Hook	11	....	59	70
Entrance, Chesapeake bay	11	....	16	27
Fishing or Donoho's battery	11	....	8	19
Hatteras shoals	21	1	66	88
Hatteras inlet	10	1	70	81
Bull's bay	11	....	65	76
St. Andrew's shoals	21	....	69	90
Mosquito inlet	21	....	68	89
Cape Canaveral	21	....	70	91
Rebecca shoal	21	....	69	90
Reconnaissance, vicinity Cedar Keys	21	....	94	115
Channel No. 4, Cedar Keys	21	....	87	108
Horn Island Pass	21	....	81	102
Pass Christian	21	....	67	88
Aransas Pass	21	....	62	83
Mare Island straits	61	....	102	163
Point Conception	61	....	72	133
Point Pinos	61	....	67	128
Cape Hancock	61	....	47	108
Total	3,232	112	5,083	8,427

There were issued during the year included in the above distribution, twenty-two complete sets of all the maps and sketches published, to universities, institutions, committees of both houses of Congress, and individuals connected with commerce, navigation, &c., throughout the different sections of the Union.

APPENDIX No. 32.

Description of the Congress map, by Lieut. J. C. Tidball, U. S. A., Assistant in Coast Survey.

The Congress map is upon a single sheet about nine feet square, on which is projected, to a scale of $\frac{1}{1500000}$, the entire coast of the United States, exhibiting, by colors and other conventional signs, the progress made in the several operations of the Coast Survey.

The projection used is the polyconic, a method fully explained in Appendix No. 39, Report of Superintendent Coast Survey for 1853.

The central meridian for the Eastern coast is 84° W. from Greenwich. The Western coast being projected separately, has its central meridian 120° W. from Greenwich.

Meridian lines and parallels of latitude are laid down for each degree.

The Eastern coast of the United States is represented in an unbroken line from Passamaquoddy bay, the northeastern limit of Maine, following the various indentations of the shore around the peninsula of Florida to the mouth of the Rio Grande, upon the Gulf of Mexico; and the Western, or Pacific coast, from Frazer's river, near the northwesterly limit of Washington Territory, to San Diego, the southern limit of the United States upon the Pacific.

The northern shore of Cuba and the coasts of Nova Scotia, island of Cape Breton, and a large part of Newfoundland, are likewise laid down, as also the boundaries of the States and the northern lakes.

The general direction and limits of the Gulf Stream are marked out in their proper positions, and the temperature is indicated by shaded bands, increasing in width to the north and east, which are darker in proportion to its greater warmth at different localities, as determined by a system of explorations extending from cape Florida to Cape Cod, and by a series of temperature soundings across the axis of the stream from the following points; Cape Cod, Montauk Point, Sandy Hook, Cape Henlopen, Cape Henry, Cape Hatteras, Cape Fear, Charleston, St. Simons, St. Augustine, and Cape Canaveral.

Diagrams for each of these sections are shown upon the map, in which the curves of different temperatures at the same depths and of the same temperature at different depths are laid down, and also sections representing the form of the bottom of the ocean, which is therein shown to be diversified by mountains and valleys not unlike the earth's surface above water.

Full explanations of these explorations and diagrams are given in the report of the Superintendent of the Coast Survey for 1853 and 1854.

The progress of the various descriptions of work of the survey is shown upon the map by different colors and other conventional signs, which present at a glance the operations in the two grand divisions of the labor—namely, the field and office work; the former of which comprises the topographical and hydrographic reconnaissances, the magnetic and astronomical observations, the primary and secondary triangulations, the topography and hydrography; and the latter, the drawing of topography in progress, drawing of hydrography in progress, engraving of topography in progress, engraving of hydrography in progress, published topography, and published hydrography. The meaning of these colors and signs is explained in the legend upon the map.

The lines and stations where the magnetic telegraph has been used for astronomical observations are marked out, showing the extent to which this great modern invention has been employed for scientific purposes in the ascertaining of longitudes upon the Coast Survey. The map, therefore, as its title indicates, exhibits at one general view the configuration of the coast of the United States, and the limits of the Gulf Stream, the probable limits of soundings, and, by colors, the charts published or in progress; and the extent to which the reconnaissances, triangulation, topography, and hydrography, respectively, are completed or in progress, to November 1, 1854, as compiled from the archives of the Coast Survey and other authorities; and is susceptible of additions and alterations to show the advancement of all these different portions of the work in the successive years.

A table is laid down upon the map, giving, in a condensed form, the statistics of the Coast Survey at periods from 1844 to 1854, showing the total of the work that has been accomplished during that time. A list of Coast Survey charts published, giving the locality, class, scale, and date of publication, is also to be found upon the map. The conventional signs for topographical drawings, used, more or less, upon all the Coast Survey charts, are delineated and explained upon the same sheet; as also scales of shade used in topographical drawings, to represent the different declivities of ground, by which accurate graphic representations of portions of the country bordering upon the coast have been obtained in such manner that their respective elevations and declivities may be judged of by inspection only.

The current-charts, showing the manner of representing, by curves, the direction and velocity of tidal currents in different harbors and sounds, and tidal diagrams, showing the manner of registering the rise and fall of tides by means of curves, are easily understood by inspection.

A tide-table added, gives the rise, fall, and mean duration, &c., of tides at the principal harbors upon the coast.

Numerous specimens of the manner of recording hydrographic observations are given upon the map; and also forms of records and computations of the principal astronomical, magnetic, and geodetic determinations in use by the Coast Survey.

APPENDIX No. 33.

Comparison of the reduction of horizontal angles by the methods of dependent directions and of dependent angular quantities, by the method of least squares.

The inquiry as to the best mode of treating the primary triangulation to obtain its results, has been prosecuted in the computing division, carefully and with much minuteness of detail. The comparison of the early results indicated that the measures of the angles as obtained directly from the average of the successive observations at any station on each of two other stations, including an angle of the triangulation, gave angles which filled the triangles better than those deduced from the process of least squares as employed by Bessel and others. This, as was seen at the time, depended, probably, upon the fact that the stations at which the observations were made were too few in number to give results independent of law, and depending only on probability. The discussion of the observations by adjusting the incidental errors by the application of the method of angular quantities was next made and continued as new stations were occupied, and has now been carried sufficiently far to give a definitive result. A part of the equations of condition (38) were found by Assistant J. E. Hilgard, in charge of the computing division of the Coast Survey Office, and a part (27) by Charles A. Schott, esq., when acting in charge of the division. The discussions extend from the Massachusetts base to the line Mount Independence—Mount Pleasant. (Sketch A *bis.*)

I have thought that it might be of service to present the mode of discussion by least squares, as developed with great plainness, directness, and elegance, by Mr. Schott, (herewith appended, marked S.) This includes the entire question of the determination of those resulting values best satisfying the observations at a given point and the geometrical conditions of a triangulation.

In the ordinary mode of discussing the angles, each angle is supposed to be measured by an observation at its vertex station on the two other stations including it. Each determination so made is considered independent of others, and the mean of several independent determinations is assumed to give the final value of the angle.

As, in the actual measurements in the primary triangulation, the stations upon which observations are made are observed in series, the first of the two more refined methods—that of adjusting directions—would find application in preference to the second—that of adjusting angular spaces. But as the series (especially when numerous signals are observed upon from the one where the measurements are made) are ordinarily broken, any notable difference would be certain to show itself; and it was on this account that the second method received a trial.

A preliminary inquiry, or investigation, was made to determine whether all the observations should be allowed equal weight, or whether they should be classed according to the appearance of the signals used—generally heliotropes. The appearance of the signals had been elaborately noted, and it was therefore easy to decide this question. The comparison of groups of cases when the signal was most satisfactorily seen for steadiness and sharpness, with the opposite, showed that the discrepancy from the mean value of an angle could not be estimated by the condition of the signal, and that lateral refraction made observations which, from the attendant circumstances, seemed good, actually of inferior value to others made under apparently worse conditions. Equal weight was, therefore, given to the individual observations.

I. By treating the observations at each station by the method of dependent directions, the results marked (A) in the following pages were deduced, and by the method of dependent angles, those marked (B.) The stations are referred to in the order required by the equations of condition; their positions will readily be found. (Sketch A *bis.*) The stations at which the observations were made are marked in SMALL CAPITALS, and are regularly numbered.

1. South end of base.

Stations.	Resulting angles.
	° ′ ″
Beacon-pole	0 00 00.000
North end of base	81 00 16.253

2. North end of base.

Stations.	Resulting angles.
	° ′ ″
Great Meadow	0 00 00.000
South end of base	25 16 31.304
Beacon-pole	70 09 30.029

Note.—At these two stations, 1 and 2, the angles were observed with a repeating theodolite, and consequently in accordance with method B.

Stations.			Resulting angles. Method (B.)	Resulting angles. Method (A.)
3. Beacon-pole.	°	′	″	″
Wachusett	0	00	00.000	00.000
Blue	82	05	13.350	13.350
North end of base	105	44	12.812	12.581
Manomet	128	54	18.265	18.260
Great Meadow	156	45	29.976	29.962
South end of base	159	50	58.093	57.820
Copecut	166	12	31.383	31.439
Pocasset	183	40	37.718	37.959
Quaker Hill	193	35	35.967	36.185
McSparran	213	43	41.400	41.618
Spencer	219	09	16.921	16.979
4. Great Meadow.				
Copecut	0	00	00.000	00.000
Pocasset	32	01	27.798	27.778
Quaker Hill	42	12	54.813	55.114
McSparran	61	57	42.482	42.398
Spencer	82	50	10.410	10.490
Beacon-pole	160	29	59.307	59.410
North end of base	219	19	14.107	14.179
Blue	229	39	39.363	39.229
5. Spencer.				
Beacon-pole	0	00	00.000	00.000
Great Meadow	39	56	26.131	26.122
Copecut	76	24	41.938	41.870
Pocasset	90	29	54.553	54.611
Quaker Hill	112	05	19.806	19.644
McSparran	165	11	14.872	14.819
6. Copecut.		′	″	″
Blue	0	00	00.000	00.000
Manomet	64	08	37.827	37.766
Indian	140	03	44.726	44.670
Cuttyhunk	167	11	18.528	18.351
Quaker Hill	231	15	17.696	17.449
Pocasset	239	57	42.840	42.745
Spencer	267	22	32.221	31.929
Beacon-pole	318	01	08.576	08.525
Great Meadow	328	04	06.958	06.702
7. Pocasset.				
Quaker Hill	0	00	00.000	00.000
McSparran	17	56	59.917	59.986
Spencer	62	42	20.216	20.369
Beacon-pole	116	43	49.671	49.686
Great Meadow	141	20	09.288	09.294
(Blue)	151	56	....	24.299
Copecut	201	12	18.672	18.846
8. McSparran.				
Spencer	0	00	00.000	00.000
Beacon-pole	9	23	09.963	10.050
Great Meadow	33	52	44.573	44.518
Pocasset	60	33	20.544	20.487
Quaker Hill	69	07	51.595	51.325
Cuttyhunk	109	31	50.084	49.944

And so on for the rest of the stations, for which the results are given further on.

II. The next part of the present discussion is to test the angles thus found by the geometrical conditions of the triangulation.

The spherical excess in the triangles formed by these stations was computed by the formula—

$$\frac{a\,b.\sin C\,(1 + e^2 \cos 2\,L)}{2\,A^2 \sin 1''}$$

Using a table for $\frac{1 + e^2 \cos 2\,L}{2\,A^2 \sin 1''} = m$

a and b in the formula are the sides, including the angle C; A is the equatorial radius of the earth, e the eccentricity, and L the mean latitude of the station points composing the triangle.

It is unnecessary to give the computations which assume the following simple form, using the triangle formed by Agamenticus, Thompson, and Unkonoonuc, as an example:

Log. Sin C, Agamenticus	1.40431
Log. a, Ag.—Thompson	4.91095
Log. b, Ag.—Unkonoonuc	4.83277
Log. m	9.94531
Excess, 12″.398	1.09334

The following are the computed spherical excesses in the triangles in their order, from the base:

	″
1. Beacon-pole, North End of Base, South End of Base	0.655
2. Great Meadow, Beacon-pole, North End of Base	0.968
3. Spencer, Beacon-pole, Great Meadow	1.846
4. Copecut, Great Meadow, Spencer	1.764
5. Copecut, Beacon-pole, Spencer	3.179
6. Beacon-pole, Copecut, Spencer	3.180
7. Blue, Great Meadow, Beacon-pole	2.090
8. Copecut, Blue, Beacon-pole	4.124
9. Pocasset, Beacon-pole, Spencer	2.273
10. Pocasset, Beacon-pole, Copecut	1.478
11. Pocasset, Great Meadow, Spencer	1.592
12. Pocasset, Great Meadow, Copecut	0.742
13. McSparran, Pocasset, Beacon-pole	3.074
14. McSparran, Spencer, Pocasset	1.271
15. Quaker Hill, Beacon-pole, Spencer	1.881
16. Quaker Hill, Beacon-pole, Copecut	2.521
17. Quaker Hill, Great Meadow, Beacon-pole	1.717
18. Quaker Hill, Pocasset, Beacon-pole	0.928
19. McSparran, Quaker Hill, Beacon-pole	2.352
20. Quaker Hill, Copecut, Spencer	1.222
21. Quaker Hill, Great Meadow, Copecut	1.233
22. Quaker Hill, Great Meadow, Spencer	1.753
23. Quaker Hill, Spencer, Pocasset	0.536
24. McSparran, Spencer, Quaker Hill	0.941
25. Cuttyhunk, McSparran, Quaker Hill	1.417
26. Cuttyhunk, Copecut, Quaker Hill	1.789
27. Indian Hill, Copecut, Cuttyhunk	1.841
28. Manomet, Beacon-pole, Copecut	4.894
29. Manomet, Beacon-pole, Blue	4.874
30. Manomet, Copecut, Blue	5.644
31. Indian Hill, Manomet, Copecut	5.056
32. Shootflying, Manomet, Indian Hill	3.345
33. Copecut, Beacon-pole, McSparran	4.606
34. McSparran, Spencer, Copecut	1.896
35. Cuttyhunk, Copecut, McSparran	3.473
36. Blue, Great Meadow, Copecut	1.604
37. Beacon-pole, Spencer, McSparran	0.470
38. Copecut, Pocasset, Spencer	0.571
39. Thompson, Manomet, Blue	7.416
40. Holt, Thompson, Blue	3.740
41. Unkonoonuc, Thompson, Blue	11.221
42. Unkonoonuc, Holt, Blue	4.812
43. Agamenticus, Thompson, Holt	5.352
44. Agamenticus, Thompson, Unkonoonuc	12.398
45. Agamenticus, Holt, Unkonoonuc	9.714

46.	Patuccawa, Agamenticus, Thompson	6.999
47.	Patuccawa, Agamenticus, Holt	5.762
48.	Patuccawa, Holt, Unkonoonuc	4.595
49.	Ossipee, Agamenticus, Patuccawa	4.342
50.	Mt. Independence, Ossipee, Agamenticus	3.673
51.	Wachusett, Thompson, Unkonoonuc	12.350
52.	Wachusett, Thompson, Blue	9.646
53.	Wachusett, Beacon-pole, Blue	6.069
54.	Wachusett, Patuccawa, Thompson	14.915
55.	Gunstock, Agamenticus, Unkonoonuc	9.758
56.	Gunstock, Agamenticus, Patuccawa	5.006
57.	Gunstock, Agamenticus, Mt. Independence	10.780
58.	Gunstock, Thompson, Unkonoonuc	12.453
59.	Wachusett, Unkonoonuck, Blue	10.775
60.	Gunstock, Agamenticus, Thompson	9.703
61.	Gunstock, Agamenticus, Ossipee	5.307
62.	Gunstock, Patuccawa, Ossipee	5.971
63.	Mt. Pleasant, Agamenticus, Mt. Independence	8.358
64.	Mt. Pleasant, Ossipee, Mt. Independence	4.498
65.	Gunstock, Mt. Pleasant, Ossipee	6.408
66.	Gunstock, Mt. Pleasant, Mt. Independence	9.106
67.	Gunstock, Mt. Pleasant, Agamenticus	11.528
	For equation XV.—McSparran, Great Meadow, Spencer	1.361
	XVI.—Great Meadow, Pocasset, McSparran	1.502
	XLVII.—Patuccawa, Holt, Thompson	4.115

The spherical excesses were checked by adding together the excesses of the triangles covering the same area, and were found correct to unity in the third place of decimals.

The numerical quantities contained in the equations of condition given by the figure are the following, in which the number of the equation is expressed by the Roman numeral, the angles by the numbers at the angular points for subsequent reference, and the angles deduced by least squares and by the methods of dependent angular quantities and of dependent directions, as before, by the columns (B) and (A). The logarithms of the sines of the angles are carried only to seven places of decimals, in the equation of the sides (side equations,) as sufficient for the present purpose. The side equations, for convenience of printing, are arranged together after the angle equations, the numbers showing their places in the series.

Residuals of the numerical equations, &c.

Number.	Angles by number.	Stations at angular point.			(B.)	(A.)	Number.	Angles by number.	Stations at angular point.			(B.)	(A.)
			°	′	″	″				°	′	″	″
I	3.1.2	South End of Base	81	00	16.253	16.253	II	3.4.2	Great Meadow	58	49	14.800	14.769
	1.2.3	North End of Base	44	52	58.725	58.725		4.2.3	North End of Base	70	09	30.029	30.029
	2.3.1	Beacon-pole	54	06	45.281	45.239		2.3.4	Beacon-pole	51	01	17.164	17.381
		Sum = S			0.259	0.217						1.993	2.179
		Spher. excess = ε			0.655	0.655						0.968	0.968
		Residual = S − ε			−0.396	−0.438			Residual			+1.025	+1.211
III	3.5.4	Spencer	39	56	26.131	26.122	IV	5.6.4	Copecut	60	41	34.737	34.773
	5.4.3	Great Meadow	77	39	48.897	48.920		6.4.5	Great Meadow	82	50	10.410	10.490
	4.3.5	Beacon-pole	62	23	46.945	47.017		4.5.6	Spencer	36	28	15.807	15.748
					1.973	2.059						0.954	1.011
					1.846	1.846						1.764	1.764
		Residual			+0.127	+0.213			Residual			−0.810	−0.753
V	5.6.3	Copecut	50	38	36.355	36.596	VII	3.7.6	Pocasset	84	28	29.001	29.160
	6.3.5	Beacon-pole	52	56	45.538	45.540		7.6.3	Copecut	78	03	25.736	25.780
	3.5.6	Spencer	76	24	41.938	41.870		6.3.7	Beacon-pole	17	28	6.335	6.520
					3.831	4.006						1.072	1.460
					3.179	3.179						1.478	1.478
		Residual			+0.652	+0.827			Residual			−0.406	−0.018

The details of the remaining triangles are omitted, only the residuals derived from them being given.

Numerical quantities of the conditional equations, &c.

VI.—Spencer, Copecut, Great Meadow, Beacon-pole.

Sin 5. 4. 3. sin 5. 6. 4. sin 6. 3. 5 = sin 4. 3. 5. sin 6. 4. 5. sin 5. 6. 3.

	(B.)	(A.)		(B.)	(A.)
	"	"		"	"
5. 4. 3 = 77° 39′	48. 897	48. 920	4. 3. 5 = 62° 23′	46. 945	47. 017
5. 6. 4 = 60 41	34. 737	34. 773	6. 4. 5 = 82 50	10. 410	10. 490
6. 3. 5 = 52 56	45. 538	45. 540	5. 6. 3 = 50 38	36. 355	36. 596
Log. sin (B.)	Log. sin (A.)	Diff. 1″	Log. sin (B.)	Log. sin (A.)	Diff. 1″
9. 9898545	9. 9898545	4. 6+	9. 9475191	9. 9475192	11. 0+
9. 9405212	9. 9405212	11. 8+	9. 9965964	9. 9965965	2. 6+
9. 9020398	9. 9020398	15. 9+	9. 8883000	9. 8883004	17. 3+
9. 8324155	9. 8324155		9. 8324155	9. 8324161	
9. 8324155	9. 8324161				
0	— 6				

IX.—Beacon-pole, Spencer, Pocasset, Copecut.

Sin 3. 7. 6. sin 3. 5. 7. sin 5. 6. 3 = sin 7. 6. 3. sin 5. 7. 3. sin 3. 5. 6.

	(B.)	(A.)		(B.)	(A.)
	"	"		"	"
3. 7. 6 = 84° 28′	29. 001	29. 160	7. 6. 3 = 78° 03′	25. 736	25. 780
3. 5. 7 = 90 29	54. 553	54. 611	5. 7. 3 = 54 01	29. 455	29. 317
5. 6. 3 = 50 38	36. 355	36. 596	3. 5. 6 = 76 24	41. 938	41. 870
Log. sin (B.)	Log. sin (A.)	Diff. 1″	Log. sin (B.)	Log. sin (A.)	Diff. 1″
9. 9979775	9. 9979775	2. 0+	9. 9904962	9. 9904963	4. 4+
9. 9999836	9. 9999836	0. 2—	9. 9080944	9. 9080942	15. 3+
9. 8883000	9. 8883004	17. 3+	9. 9876702	9. 9876702	5. 1+
9. 8862611	9. 8862615		9. 8862608	9. 8862607	
9. 8862608	9. 8862607				
+ 3	+ 8				

The remaining details of the side equations are omitted; the resulting differences for 1″ and differences in logarithms by methods B and A being given in abstract.

III. The following is a recapitulation of the residuals in the thirty-eight triangles by the two methods:

No. of triangle.	No. of equation.	Stations.	Residuals. (B.)	Residuals. (A.)
			"	
1	I	South End of Base, North End of Base, Beacon-pole	−0.396	−0.438
2	II	Great Meadow, North End of Base, Beacon-pole	+1.025	+1.211
3	III	Spencer, Great Meadow, Beacon-pole	+0.127	+0.213
4	IV	Copecut, Great Meadow, Spencer	−0.810	−0.753
5	V	Copecut, Beacon-pole, Spencer	+0.652	+0.827
6	VII	Pocasset, Copecut, Beacon-pole	−0.406	−0.018
7	VIII	Pocasset, Beacon-pole, Spencer	+0.938	+0.675
8	X	Pocasset, Copecut, Great Meadow	+0.558	+0.545
9	XII	McSparran, Pocasset, Spencer	−0.109	−0.193
10	XIII	McSparran, Pocasset, Beacon-pole	+0.943	+0.722
11	XV	McSparran, Spencer, Great Meadow	−0.119	−0.054
12	XVII	Quaker Hill, Copecut, Beacon-pole	+0.406	+0.564
13	XVIII	Quaker Hill, Great Meadow, Beacon-pole	+0.411	+0.287
14	XX	Quaker Hill, Copecut, Spencer	+2.483	+2.201
15	XXII	Quaker Hill, Spencer, McSparran	−1.319	−1.335
16	XXIV	Quaker Hill, Copecut, Pocasset	−0.967	−1.010
17	XXVI	Cuttyhunk, Copecut, Quaker Hill	−0.614	−0.723
18	XXVII	Cuttyhunk, Quaker Hill, McSparran	−1.659	−1.562
19	XXIX	Blue, Beacon-pole, Great Meadow	+1.532	+1.205
20	XXX	Blue, Beacon-pole, Copecut	+0.939	+0.895
21	XXXII	Manomet, Beacon-pole, Copecut	−0.297	−0.743
22	XXXIII	Manomet, Blue, Copecut	+0.278	−0.047
23	XXXV	Indian Hill, Manomet, Copecut	−1.917	−1.852
24	XXXVI	Indian Hill, Copecut, Cuttyhunk	+0.225	+0.313
25	XXXVIII	Shootflying, Manomet, Indian Hill	+2.729	+2.637
26	XXXIX	Thompson, Blue, Manomet	+0.258	−0.278
27	XLI	Holt, Thompson, Blue	−0.691	−0.493
28	XLIII	Unkonoonuc, Blue, Thompson	+0.598	+0.738
29	XLIV	Unkonoonuc, Blue, Holt	+0.276	+0.157
30	XLVII	Patuccawa, Holt, Thompson	+2.757	+2.724
31	XLVIII	Patuccawa, Unkonoonuc, Holt	−0.143	−0.229
32	LI	Agamenticus, Holt, Thompson	+1.979	+2.391
33	LII	Agamenticus, Unkonoonuc, Holt	+0.308	−0.096
34	LIV	Agamenticus, Patuccawa, Thompson	+0.199	+0.358
35	LVIII	Ossipee, Patuccawa, Agamenticus	−1.527	−1.554
36	LX	Mount Independence, Ossipee, Agamenticus	+1.229	+1.269
37	LXII	Mount Pleasant, Agamenticus, Mount Independence	−1.909	−1.710
38	LXIII	Mount Pleasant, Ossipee, Mount Independence	+0.204	−0.046

This gives for the comparison of the two methods—

First. From the residuals in the triangles.

1. The error in the sum of the angles in thirty-eight triangles by (B) is positive in twenty-three cases, and negative in fifteen; by (A) is positive in nineteen and negative in nineteen, which gives a result in favor of (A.)

2. The sum of the positive errors by method (B) is 21.064; by (A) is 19.932
The sum of the negative errors by method (B) is 12.873; by (A) is 13.154

Difference, 8.191 6.778; a result which is also in favor of the method (A.)

3. The sum of all the errors in the thirty-eight triangles (without regard to signs) is, by method (B,) 33″.937, or the mean error in a triangle, 0″.893; by method (A) 33″.086, or the mean error in a triangle 0″.871, and the mean error of any angle by method (B) $=\frac{0''.893}{\sqrt{3}}=0''.619$; the mean error of an angle by method (A) $=\frac{0''.871}{\sqrt{3}}=0''.604$, which is also in favor of method (A.)

Second. From the side equations.

To obtain a quantity for comparison, divide the remainder in each equation by the sum of the logarithmic differences for 1″. The following list of numbers is obtained:

No. of equation.	Mean correction.		No. of equation.	Mean correction.		No. of equation.	Mean correction.	
	(B.)	(A.)		(B.)	(A.)		(B.)	(A.)
	″	″		″	″		″	″
VI	0.00	0.10	XXVIII	0.67	0.58	L	0.31	0.22
IX	0.12	0.32	XXXI	0.19	0.30	LIII	0.34	0.48
XI	0.05	0.01	XXXIV	0.09	0.01	LV	0.09	0.17
XIV	0.27	0.23	XXXVII	0.09	0.16	LVI	0.36	0.24
XVI	0.12	0.15	XL	0.41	0.36	LVII	0.33	0.25
XIX	0.19	0.22	XLII	0.85	0.58	LIX	0.71	0.61
XXI	0.47	0.43	XLV	0.51	0.49	LXI	0.55	0.62
XXIII	0.24	0.18	XLVI	0.71	0.55	LXIV	0.08	0.13
XXV	0.25	0.30	IL	0.18	0.24	LXV	0.52	0.64

The number of these equations is twenty-seven. The sum by method (B) is 8″.50, and by method (A) is 8″.57; mean 0″.314 for method (B,) and 0″.316 for method (A;) so that the side equations are nearly equally well satisfied by both methods. The mean correction to an angle required by the side equations is, approximately, $\pm$ 0″.31 $\sqrt{6} = \pm$ 0″.76.

Third. The methods B and A were next compared by the test of the agreement of the results among themselves, at a sufficient number of stations. The probable error of an angle was found by methods given at the close of this paper, marked T.

Station.	Occupied in—	Probable error.				
		By method (B.)		By method (A.)		
		Of one observation of an angle.	Of final value of an angle.	Of one observation of a direct'n.	Of final value of a direction.	Of final value of an angle.
		″	″	″	″	″
McSparran	1844	$\pm$ 1.361	$\pm$ 0.263	$\pm$ 0.972	$\pm$ 0.188	$\pm$ 0.266
Spencer	1844	1.048	.170	.745	.121	.171
Pocasset	1844	1.461	.259	.887	.156	.221
Copecut	1844	1.261	.219	.938	.150	.212
Beacon-pole	1844	1.015	.180	.726	.119	.168
Manomet	1845	1.271	.205	.918	.149	.211
Holt	1846	1.333	.227	.965	.178	.252
Agamenticus	1847	1.238	.210	.912	.158	.223
Unkonoonuc	1848	0.925	.159	.714	.125	.177
Mount Pleasant	1851	1.095	.179	.784	.085	.120
Ossipee	1851	1.569	.220	1.163	.164	.232

Mean probable error of a single observation of an angle by method B = $\pm$ 1″.234, method A = $\pm$ 1″.250
Determination of an angle .... " $\pm$ 0″.208 " $\pm$ 0″.205

So that both methods give the same result.

In discussing the equations of sides, three directions were found, to which an equable distribution of error should not be applied: two of these had already been indicated in the record of observations where a defective adjustment of the signal was noted; the other was probably a case of lateral refraction. After making the correction indicated by a discussion of these three cases, the results were again elaborately compared by Mr. Schott; but the conclusions were essentially the same, the numerical results only differing slightly, but within the limits of the probable error of the determination in favor of method (B) in reference to geometrical conditions of the figure of the triangulation, as will be seen by the annexed, which will serve also as a connected recapitulation of the results of the comparison.

First. Comparison by the filling of the triangles.

1. The error in the sum of the triangles in thirty-eight triangles is positive in twenty-four cases by method (B,) and negative in fourteen cases; positive in nineteen cases by method (A,) and negative in nineteen cases.

2. The sum of the positive errors by method (B) is 16″.436; by method (A) is 15″.578
The sum of the negative errors by method (B) is 9″.905; by method (A) is 10″.440

Difference... 6″.511 Difference... 5″.138

3. The sum of the errors, disregarding signs, is by (B) 26″.361; by (A) 26″.018.

	Method (B.)	Method (A.)
4. The mean error in—	″	″
A triangle	± 0.694	± 0.685
An angle	± 0.401	± 0.395
A direction	± 0.283	± 0.280

The results are also in favor of the treatment by method A.

Second. Comparison by the side equations, (twenty-seven in number.)

	By method (B.)	By method (A.)
1. The mean of positive errors is	15	13
The mean of negative errors is	11	14
2. The difference in the sum of the positive and negative errors	″ 0.581	″ 0.727
3. The sum of the errors, disregarding signs, is	10.259	11.265
4. The mean error of an angle	± 0.380	± 0.417

The mean error of an angle is within 0″.02 of the result derived from the filling of the spherical triangles.

It appears, then, as a final conclusion:

1. That from the test of the agreement of the different results among themselves, the methods are equal.

2. That from the test of filling the spherical triangles, the method (A) has the advantage.

3. That the side equations are equally well satisfied by both methods.

The balance is thus so nearly equal that from the nature of the observations, and the rigid impartiality of the first method denoted by A, the decision must be given in its favor in the discussion of the primary triangulation.

S.

ADJUSTMENT OF HORIZONTAL ANGLES OF A TRIANGULATION.

By Chas. A. Schott, Computing Division Coast Survey Office.

When we attempt to deduce the best results from observed quantities, which are supposed to exist in greater number than are absolutely required, it becomes of paramount importance to make use of a method which, in leading to a result approximating nearest the truth, admits, at the same time, of no arbitrary choice among the materials collected.

The method of least squares fulfils both conditions by making the sum of the squares of the errors a minimum, and by admitting of but one result—the most probable. Its application implies that the differences necessarily occurring in the measurements, or the incidental errors, are of such an order that we can treat them as differentials.

In the special application of this method to the adjustment of horizontal angles of a triangulation, its general theory is supposed to be known.

The discrepancies met with in the angular measurements and deduced parts of a series of triangles arise from two distinct causes, which are, for the sake of convenience, treated separately.

1. *Disagreement of the observations among themselves.*

The first of these causes is, that the reading of the directions at a given station, or the lines of vision, deviate from the true ones from the influence of lateral refraction, the imperfections of the instrument, the changes produced by variation of temperature, etc., etc. By the application of this method in this case, we deduce the most probable value of each direction, or of each angle, observed at this station. This process of partially or fully closing the horizon is effected in two ways, depending on the nature of the observations, which give either the directions from which to deduce the angles, or the angles and their combinations directly, independent of directions.

The first method recommends itself for (non-repeating) instruments of superior graduation; the second, for (repeating) instruments whose circle is of smaller size, and of less perfect graduation.

2. *Discrepancies exhibited by the geometrical conditions of the triangulation not being strictly fulfilled by the observed quantities.*

Secondly, discrepancies arise from the fact that we are unable to centre the instrument exactly in the vertical of the object observed upon, or to observe the same vertical from the surrounding stations; also from irregularities in the spheroidal form of the earth. The adjustment involves two kinds of equations—the equations of angles and the equations of sides, so called by Bessel. The angle equations subsist between the observed sums of the angles forming a spheroidal triangle, and the side equations involve the condition that the several directions to any one station intersect in the same vertical line or point.

The object of this paper is to give a brief account of the adjustment of the discrepancies between the observations made at any one station by either of the methods, (A and B,) and also of those arising from the geometrical conditions, (C.)

From the above two considerations, the corrections to any observed angle O are δ and Δ; the one resulting from the adjustment of the directions or angles at a station, the other from the geometrical conditions existing in the figure of the triangulation. The method requires $\Sigma\ (\delta+\Delta)^2 =$ a minimum, which is identical, according to its principles, with making $\Sigma\delta^2$ and $\Sigma\Delta^2$, respectively, minima. The conditional equations arising from considerations (1) and those arising from (2) are coexistent, and increase enormously the number of equations as well as the number of terms in each, rendering the solution impracticable for any extended or complex triangulation; it becomes, therefore, of great importance to diminish this labor.

It has been found in the primary triangulation of Section I, which presents all required facilities, that the probable error in any resulting angle is $= \pm 0''.205$ (with an uncertainty of $0''.008$) from observations of either directions or angles at any one station; and the same probable error in any resulting angle $= \pm 0''.266$, (with an uncertainty of $0''.038$,) as deduced from the geometrical conditions of the figure, and the same from angle as well as side equations. Hence, the proportion of the errors of the former and latter results is as 4 : 7 nearly, or the discrepancies arising from the figure are nearly double those from the coincidence of the observations themselves. This ratio, however, is variable, and is a function of the size of the triangles.

This justifies the method of first equating the angles at any one station, and with these corrected angles $O+\delta$, to enter the angle and side equations which determine the further corrections Δ: no subsequent notice of the conditions (1) is taken.

For other triangulations, in which the above ratio is less favorable for this division of labor, it may become necessary to sacrifice a small portion of accuracy in order to diminish the amount of labor; cases may even occur when this is absolutely demanded. As it is, the effect of the first adjustment will necessarily remain in the second operation.

(A.)—*Adjustment of horizontal angles at a single station from observations of directions, or method A of reduction.*

The method to be followed generally is now to be explained, and consists in finding the most probable value of the angles, so far as they depend on observations of directions made at the station. If all the stations were observed upon in every series of observations, the mean would represent the result. This is seldom the case, as some of the signals may not be visible, or may not be sufficiently steady to be observed.

Let A, B, C, etc., (Figure A, Plate 58,) denote the angles between the lines of direction from the point of observation to the several signals, m, m', m'', etc., the readings of any series, which readings we suppose to have been corrected for run of micrometers and phase of signals, if necessary, and which, generally, are means of the several verniers. Corrections for inclination of signals and for eccentricity can, in most cases, be applied to the final result, and need not further be noticed here.

$x =$ the angle between the zero of the instrument and the first direction.

Then a single series of observations gives the equations $o = m - x$, $o = m' - x - A$, $o = m'' - x - B$, etc., there being as many such equations as there are observed directions. To make these equations general, they may be multiplied by $\sqrt{p}\ \sqrt{p'}\ \sqrt{p''}$, etc., in which the value of these factors, for all observed directions, will be unity; and for those not observed, zero. The equations then become:

$$o = \sqrt{p}\,(m - x),\quad o = \sqrt{p'}\,(m' - x - A),\quad o = \sqrt{p''}\,(m'' - x - B), \text{ etc.}$$

A second series of observations will, in like manner, give the equations:

$$o = \sqrt{p_{,}}\left(m_{,} - x_{,}\right),\quad o = \sqrt{p'_{,}}\left(m'_{,} - x_{,} - A\right),\quad o \quad \sqrt{p''_{,}}\left(m''_{,} - x_{,} B\right), \text{ etc.}$$

A third:

$$o = \sqrt{p_{,,}}\left(m_{,,} - x_{,,}\right),\quad o = \sqrt{p'_{,,}}\left(m'_{,,} - x_{,,} - A\right),\quad o \quad \sqrt{p''_{,,}}\left(m''_{,,} - x_{,,} - B\right), \text{ etc.}$$

The values of the angles A, B, C, etc., must be such as to render a minimum.

$$\begin{aligned} 2\,\Omega = {} & p\ (m - x)^2 + p'\,(m' - x - A)^2 + p''\,(m'' - x - B)^2 + \text{etc.} \\ & + p_{,}\,(m_{,} - x_{,})^2 + p'_{,}\,(m'_{,} - x_{,} - A)^2 + p''_{,}\,(m''_{,} - x_{,} - B)^2 + \text{etc.} \\ & + p_{,,}\,(m_{,,} - x_{,,})^2 + p'_{,,}\,(m'_{,,} - x_{,,} - A)^2 + p''_{,,}\,(m''_{,,} - x_{,,} - B)^2 + \text{etc.} \\ & + \text{etc.} \end{aligned}$$

where $2\,\Omega$ expresses the sum of the squares of all the errors. This will be the case when the unknown quantities x, $x_{,}$, $x_{,,}$, etc., and A, B, C, etc., are determined from the equations:

$$\begin{aligned} p\ m + p'\ m' + p''\ m'' + \ldots\ldots &= (p + p' + p'' + \ldots)\ x + p\ A + p'\ B + p''\ C + \ldots \\ p_{,}\ m_{,} + p'_{,}\ m'_{,} + p''_{,}\ m''_{,} + \ldots\ldots &= (p_{,} + p'_{,} + p''_{,} + \ldots)\ x_{,} + p_{,}\ A + p'_{,}\ B + p''_{,}\ C + \ldots \\ p_{,,}\ m_{,,} + p'_{,,}\ m'_{,,} + p''_{,,}\ m''_{,,} + \ldots\ldots &= \left(p_{,,} + p'_{,,} + p''_{,,} + \ldots\right) x_{,,} + p_{,,}\ A + p'_{,,}\ B + p''_{,,}\ C + \ldots \\ \text{etc.} & \qquad\qquad \text{etc.} \end{aligned}$$

$$\begin{aligned} p'\ m' + p'_{,}\ m'_{,} + p'_{,,}\ m'_{,,} + \ldots\ldots &= \left(p' + p'_{,} + p'_{,,} + \ldots\right) A + p'\ x + p'_{,}\ x_{,} + p'_{,,}\ x_{,,} + \ldots \\ p''\ m'' + p''_{,}\ m''_{,} + p''_{,,}\ m''_{,,} + \ldots\ldots &= \left(p'' + p''_{,} + p''_{,,} + \ldots\right) B + p''\ x + p''_{,}\ x_{,} + p''_{,,}\ x_{,,} + \ldots \\ p'''\ m''' + p'''_{,}\ m'''_{,} + p'''_{,,,}\ m'''_{,,,} + \ldots\ldots &= \left(p''' + p'''_{,} + p'''_{,,} + \ldots\right) C + p'''\ x + p'''_{,}\ x_{,} + p'''_{,,}\ x_{,,} + \ldots \\ \text{etc.} & \qquad\qquad \text{etc.} \end{aligned}$$

which equations are obtained by differentiating with reference to the unknown quantities. If x, $x_{,}$ $x_{,,}$ etc., in the second set of equations, are eliminated by means of the first, the resulting or normal equations will contain only A, B, C, etc., and present themselves in the well known form:

$$\begin{aligned} [a\,n] &= [a\,a]\ A + [a\,b]\ B + [a\,c]\ C + \ldots\ldots \\ [b\,n] &= [a\,b]\ A + [b\,b]\ B + [b\,c]\ C + \ldots\ldots \\ [c\,n] &= [a\,c]\ A + [b\,c]\ B + [c\,c]\ C + \ldots\ldots \\ & \qquad + \text{etc.} \end{aligned}$$

where [ ] is the sign for a sum of similar quantities, as used by Gauss, and where, for instance,

$$\begin{aligned} [a\,n] = {} & p'\ m' + p'_{,}\ m'_{,} + p'_{,,}\ m'_{,,} + \ldots\ldots - p'\,\frac{p\ m + p'\ m' + p''\ m'' + \ldots\ldots}{p + p' + p'' + \ldots\ldots} \\ & - p'_{,}\,\frac{p_{,}\ m_{,} + p'_{,}\ m'_{,} + p''_{,}\ m''_{,} + \ldots\ldots}{p + p'_{,} + p''_{,} + \ldots\ldots} - \text{etc.} \end{aligned}$$

$$[a\,a] = p' + p'_{,} + p'_{,,} + \ldots\ \ldots\ldots - \frac{p'\ p}{p + p' + p'' + \ldots\ldots} - \frac{p'_{,}\ p_{,}}{p_{,} + p'_{,} + p''_{,}} - \text{etc.}$$

and so on.

The solution of these normal equations gives the value of A, B, C, etc., as determined at the station. The further dependence of these values, when we consider the observations at other stations of the scheme of triangles, may be expressed by the equations:

$$P = [a\,a]\,(1) + [a\,b]\,(2) + [a\,c]\,(3) + \ldots\ldots$$
$$Q = [a\,b]\,(1) + [b\,b]\,(2) + [b\,c]\,(3) + \ldots\ldots$$
$$R = [a\,c]\,(1) + [b\,c]\,(2) + [c\,c]\,(3) + \ldots\ldots$$
etc.

where (1) (2) (3,) etc., denote corrections to our A, B, C, etc., as found above. Agreeably to what has been said in the preface, we will not further pursue this subject.

It is obvious that the reduction will be accomplished most readily if all the combinations of a like sort are placed together, and that fewer figures will be necessary, if from each direction a preceding one is subtracted, taking as a zero the first observed direction in each series. By this process of diminishing the readings of each direction by the first in the series, the remainders become comparable for the several series of the same initial direction. This also enables us to take means of the quantities in all similar series for the purpose of obtaining the assumed directions as near as possible to the true ones, which will greatly add to the facility of the reduction.

To illustrate the above, I propose to introduce so much of an example as will suffice to show the actual working of the method. The observations at station Agamenticus of the primary triangulation of Section I, are selected for this purpose.

Station Agamenticus.

Abstract of resulting readings of the directions in each series:

The first line in each series of the following abstract contains the readings of each direction, expressed in seconds, with the instrument in direct position; the second line the same, with instrument in reversed position. The readings are means to which the necessary corrections have already been applied. In the primary triangulation alluded to, each of the above quantities is the mean of six readings of the three verniers, and is corrected for run of micrometers. The third line contains the mean of the quantities in the first and second lines; and the fourth, the remainders obtained by subtracting the first direction in each series from the others. The last line will be explained further on.

Stations.

Date.	Isles of Shoals.	Thompson.	Holt.	Unkonoonuc.	Patuccawa.	Gunstock.	Mount Pleasant.	Ossipee.	Blue.	Fletcher's N.
1847.	29.9	....	....	50.2	....	40.4	55.1	35.2	23.0	....
September 6	22.1	....	....	43.7	....	32.7	51.4	31.1	16.3	....
A. M.	26.00	....	....	46.95	....	36.55	53.25	33.15	19.65	....
Pos. I.	00.00	....	....	20.95	....	10.55	27.25	07.15	53.65	....
Ser. I.	00.00	....	....	59.25	....	58.65	59.75	59.25	00.55	....
	29.0	52.2	45.4	54.1	55.3	43.0	56.7	39.8	24.2	31.3
September 6	24.9	45.5	39.2	48.5	49.9	36.6	53.4	31.8	13.4	24.7
P. M.	26.95	48.85	42.30	51.30	52.60	39.80	55.05	35.80	18.80	28.00
Pos. I.	00.00	21.90	15.35	24.35	25.65	12.85	28.10	08.85	51.85	01.05
Ser. II.	00.00	00.00	01.55	02.65	02.35	00.95	00.60	00.95	58.75	03.45
			58.6	....	....	....	07.2	....	....	36.1
August 30	....	....	44.8	....	....	....	56.4	....	....	28.8
P. M.	....	....	51.70	....	....	....	01.80	....	....	32.45
Pos. III.	....	....	00.00	....	....	....	10.10	....	....	40.75
Ser. ——	....	....	00.00	....	....	....	56.40	....	....	56.95

and so on.

Next, approximate values for the angles are obtained from the means of the full series. The complements of the seconds, with which alone we have to deal, are formed, and this is done for each initial direction, in order to facilitate the subtraction in the last line of the above abstract. This line shows the differences between each measure and the assumed angles, and, supposing the measures perfect, these residuals would equal 00.000 or 60.000.

Assumed approximate angles.

Stations.	Assumed angles.			Compl.	Quantities for addition.							
	°	′	″	″								
Isles of Shoals	0	00	00.0	00.0								
Thompson	16	20	21.9	38.1	00 0							
Holt	41	28	13.8	46.2	08.1	00.0						
Unkonoonuc	83	56	21.7	38.3	00.2	52.1	00.0					
Patuccawa	88	19	23.3	36.7	58.6	50.5	58.4	00.0				
Gunstock	134	44	11.9	48.1	10.0	01.9	09.8	11.4	00.0			
Mount Pleasant	187	02	27.5	32.5	54.4	46.3	54.2	55.8	44.4	00.0		
Ossipee	188	12	07.9	52.1	14.0	05.9	13.8	15.4	04.0	19.6	00.0	
Mount Independence	220	23	53.1	06.9	28.8	20.7	28.6	30.2	18.8	34.4	14.8	00.0
Fletcher's Neck	242	17	57.6	02.4	24.3	16.2	24.1	25.7	14.3	29.9	10.3	55.5

From the last line of each series in the above abstract, we next form the abstract of diminished measures by placing together the series of an equal number of directions, beginning with their maximum number. The means in the last column of the following abstract are first formed; next the sum for each column; and, by their addition, we check the means, after multiplying them by their respective numbers. This check is indispensable to insure correctness in the following somewhat tedious operation of the formation of coefficients for the normal equations.

Abstract of diminished measures.

Isles of Shoals.	Thompson.	Holt.	Unkonoonuc.	Patuccawa.	Gunstock.	Mount Pleasant.	Ossipee.	Mt. Independence.	Fletcher's Neck.	Means.
00.00	00.00	01.55	02.65	02.35	00.95	00.60	00.95	58.75	03.45	
00.00	02.55	00.60	02.60	02.90	01.45	00.85	02.10	59.25	02.40	
00.00	01.55	00.50	02.30	01.95	00.45	00.70	01.00	00.85	01.45	
etc.		(22 line	s in all.)						etc.	(10)
00.00	59.75	01.00	00.55	02.05	02.35	00.75	01.15	00.30	03.45	+ 14.7000
00.00	00.90	00.70	00.35	00.80	02.20		59.85	59.32	00.00	
00.00	01.45	01.50	01.30	01.20	00.00		59.20	01.90	59.55	+ 1.1355
00.00	56.35		55.25	56.77	00.65	01.15	59.95	59.05	58.35	(9)
00.00	01.70		01.60	56.95	57.80	01.55	59.40	00.25	01.30	— 1.3255
	00.00	00.40	56.20	55.70	57.20	56.80	54.45	58.05	53.95	
	00.00	00.10	02.95	03.15	01.85	02.75	58.30	00.55	02.05	— 1.7278
etc.	etc.									(8)
										etc.
etc.	etc.									(4)
00.00	00.55			02.30						
00.00	57.55			59.10						— 0.1667
										(3)
		00.00				56.40			56.95	— 2.2167
						00.00	58.35	01.00		
						00.00	01.30	59.20		— 0.0500
Sums.	+7.00	+14.33	+11.08	+12.95	+21.63	+14.38	+13.71	+19.90	+17.50	+132.4800
33	41	34	38	41	38	37	40	37	35	No. of series, 374
x	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	Index.

The sum 132.4800 being checked, the formation of the coefficients is effected as follows:

+ 7.0000	− 14.7000	41 − 2.2000 = $\frac{22}{10}$	− 2.2000 = $\frac{22}{10}$	− 2.2000
1.3255	1.1355	0.6667 = $\frac{6}{9}$	0.4444 = $\frac{4}{9}$	0.6667
1.7278	0.3375	0.6250 = $\frac{5}{8}$	0.3750 etc.	0.5000
0.4688	1.1062	0.4286 = $\frac{3}{7}$	0.2857	0.4286
3.2250	1.5363	0.1667 = $\frac{1}{6}$	0.5000	0.5000
0.9286	1.5571	0.5000 = $\frac{2}{4}$		
1.6625	2.7143	0.6667 = $\frac{2}{3}$	[a b] = − 3.8651	[a c] = − 4.2953
0.1667	0.4583			
		− 5.2537	similarly	
+ 16.5049	− 23.5452		[a d] , [a e] etc.	
[a n] = − 7.0403		[a a] = + 35.7463	and	
similarly		similarly	[b c] , [b d] etc.	
[b n] , [c n] etc.		[b b] , [c c] etc.	etc.	

For the above coefficients we have the following two checks:

1. [a n] + [b n] + [c n] + ... = [x n] where [x n] is formed in like manner as [a n] etc. The check gives + 9.7556 − 9.7542 = o. Residual 0.0014 due to loss by decimals.

2. $\left.\begin{array}{l}[a\,a] + [b\,b] + [c\,c] + \ldots\ldots \\ + [a\,b] + [c\,c] + \ldots\ldots \\ + [b\,c] + \ldots\ldots\end{array}\right\} = \frac{\Sigma o - \Sigma s}{2}$ or equal to one-half of the difference of the number of observations and the number of series. The sum of the coefficients is + 164.0002

and the 2d term $\frac{374 - 46}{2} =$ 164.0000

Residual 0.0002 due to loss by decimals.

We next form the normal equations:

Normal equations at station Agamenticus.

	A.	B.	C.	D.	E.	F.	G.	H.	I.
− 7.0403 =	+ 35.7463	− 3.8051	− 4.2953	− 5.1108	− 3.9441	− 3.4301	− 3.9441	− 3.6524	− 3.6941
+ 1.2993 =		+ 29.8616	− 3.6801	− 3.8051	− 3.1622	− 3.1483	− 3.1622	− 3.0372	− 3.3705
− 2.7125 =			+ 33.5380	− 4.1524	− 3.8191	− 3.5968	− 3.8191	− 3.6941	− 3.4024
+ 1.9240 =				+ 35.6392	− 4.0512	− 3.5372	− 4.0512	− 3.5095	− 3.5512
+ 5.5569 =					+ 33.6393	− 3.8468	− 4.3607	− 3.6762	− 3.5512
+ 1.6986 =	Here the coefficients in the columns correspond with those in the respective lines.					+ 32.1532	− 4.5135	− 3.9956	− 3.3705
− 2.3131 =							+ 34.9726	− 4.3429	− 3.5512
+ 7.6271 =								+ 32.5142	− 3.4024
+ 3.7156 =									+ 30.9726

The solution of these equations is effected either in the ordinary way, for which a short and convenient scheme for the logarithmic computation has been devised, based on the identity of the coefficients in the horizontal and vertical lines; or they may be solved by the method of indirect elimination, as recommended by Gauss. If this latter method, now used in preference to the first, is well understood, it will save time, and it is the only one of practical value for equations of a great number of unknown quantities. The first or direct method has been used for the solution of eleven equations, with as many unknown quantities, without experiencing any inconvenience.

The solution of the above equations gives—

A = + 0.1289″	F = + 0.3651″
B = + 0.3480	G = + 0.2578
C = + 0.2374	H = + 0.5210
D = + 0.3479	I = + 0.4184
E = + 0.4581	

which values, after substitution in the original equations, leave the following residuals:

In the 1st equation + 0.0001
" 2d " 0.0000
" 3d " − 0.0003 ; and so on.

Applying the corrections A, B, C, etc., to the assumed angles, we obtain the most probable value for the directions at this station, viz:

Stations.	Assumed directions.			Corrections.	Resulting directions.	
	°	′	″	″	″	
Isles of Shoals	00	00	00.0	00.000	00.000	
Thompson	16	20	21.9	+0.129	22.029	
Holt	41	28	13.8	+0.348	14.148	
Unkonoonuc	83	56	21.7	+0.237	21.937	
Patuccawa	88	19	23.3	+0.348	23.648	
Gunstock	134	44	11.9	+0.458	12.358	
Mount Pleasant	187	02	27.5	+0.365	27.865	+28″.416 reduction to centre.
Ossipee	188	12	07.9	+0.258	08.158	
Mount Independence	220	23	53.1	+0.521	53.621	
Fletcher's Neck	242	17	57.6	+0.418	58.018	

(B.) *Adjustment of horizontal angles depending on conditions between the angular quantities obtained at any single station, or method B of reduction.*

This method applies to the observations of angles, usually obtained by repetitions; and instead of equating directions, as in the first method, its object is to furnish the most probable values for the several observed angles from a supernumerary number of angles. Between n objects, surrounding a station, we necessarily have $n-1$ angles, and any additional angle between the same objects, which is, of necessity, one of sums of the others, furnishes a conditional equation. When no such sum-angles have been observed, the method of least squares in its application to this case, is simply reduced to the taking of means.

For instance, if, in Sketch 58, figure B, we measure the angles as indicated, and also sum-angles, and reduce them, we would equate the horizon but partially; but as soon as the angle between E and A (or any of the other stations and A) is measured, the operation is known as that of closing the horizon, and the sum of the angles between A and B, B and C, &c., and E and A, must equal 360°.

Method A gives, without further consideration, proper weight to its results, in reference to the number of observations of each direction. This is not the case, however, in method B, unless specially introduced. It is not the place here to explain the mode of obtaining the relative weight of repetitions, in reference to a single observation, and of deducing the best value from m repetitions, by making use of the readings of $m-1$, $m-2$ $m-3$, &c., repetitions. (See Bessel on this subject.) The angles which enter the equations are supposed to have been rigidly deduced, similar to the supposition made for the values m, m', m'' ...... of the first method, before they could enter the formulæ.

The shortest way of introducing weights (p) is by the ratio of unity to the square of the probable error (e_0.) The method of deducing the probable error of observation of horizontal angles will be found explained in another part of this report.

Method B will be explained, first, without the introduction of weights, and, secondly, with the consideration of weights. It may be remarked that this method is almost exclusively applied to secondary triangulations; both methods, A and B, being applied to primary surveys.

To satisfy strictly the demands of theory, the conditional equations subsisting between the readings of the successive repetitions of any angle must be introduced simultaneously with the conditions imposed by the sum-angles at the station. This is analogous to the introduction of the conditions of method A or B, to those of the geometrical conditions of the figure of the triangulation, and can, with equal propriety, be disposed of in the same manner. The conditions among the successive readings ...$m-2$, $m-1$, m, demand, therefore, no further attention.

Let us now consider method B, without introducing weights, or supposing the angles as equally well measured.

The application of the method of least squares to the case under consideration, is of such simplicity that the formulæ can be given in connection with the example. According to the general theory, the steps to be followed successively are, 1st, to obtain approximate values for the quantities sought, called by Gerling the elements (E;) 2d, to establish differential equations between these elements and the observed quantities; 3d, to strictly deduce values for the observations from the preliminary elements; 4th, to introduce the numerical values into the differential equations; 5th, 6th, and 7th, to establish the conditional and normal equations, and to solve the latter; but, as already stated, the above operations are greatly reduced, as seen in the following example.

Given the observed angles. (See figure C, Sketch 58.)

	°	′	″
1.2 McSparran—Spencer	57	46	12.924
1.3 McSparran—Beacon-pole	100	07	16.871
1.4 McSparran—Great Meadow	125	00	08.407
2.3 Spencer—Beacon-pole	42	21	03.911
2.4 Spencer—Great Meadow	67	13	55.666
2.5 Spencer—Pocasset	95	42	18.644
&c., &c.,		&c.	
6.7 Copecut—Cuttyhunk	77	19	17.225
7.1 Cuttyhunk—McSparran	116	42	18.459

This last equation effects the closing of the horizon.

These are average values, and each was corrected for run of micrometers. We will assume the following approximate angles, counting from the first, and applying the corrections A, B, C, etc.

Assumed angles.

	°	′	″	
1. McSparran	0	00	00.0	
2. Spencer	57	46	12.8	+ A
3. Beacon-pole	100	07	16.6	+ B
4. Great Meadow	125	00	08.3	+ C
5. Pocasset	153	28	31.4	+ D
6. Copecut	165	58	24.0	+ E
7. Cuttyhunk	243	17	41.3	+ F

And omitting the degrees and minutes, we obtain the following equations:

$$
\begin{array}{ll}
1.2 & 12.8 + A = 12.924 \\
1.3 & 16.6 + B = 16.871 \\
1.4 & 08.3 + C = 08.407 \\
2.3 & 03.8 + B - A = 03.911 \\
 & \text{etc., etc.} \\
7.1 & 18.7 - F = 18.459
\end{array}
$$

From which result the conditional equations:

I	0=	−0.124	+A					
II	0=	−0.271		+B				
III	0=	−0.107			+C			
IV	0=	−0.111	−A	+B				
etc		etc				etc.		
XIII	0=	+0.241						−F
		(*n*)	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)

The normal equations—

$$
\begin{array}{l}
0 = [a\,n] + [a\,a]\ A + [a\,b]\ B + [a\,c]\ C + \\
0 = [b\,n] + [a\,b]\ A + [b\,b]\ B + [b\,c]\ C + \\
0 = [c\,n] + [a\,c]\ A + [b\,c]\ B + [c\,c]\ C + \\
\quad \text{etc.}
\end{array}
$$

can befound by multiplying each conditional equation by the coefficient of the first unknown quantity and by adding up these equations; this operation performed on each equation for each of the unknown quantities, will produce the normal equations:

	A.	B.	C.	D.	E.	F.
0= +0.029	+5	—1	—1	—1	—1	0
0= —0.264	—1	5	—1	—1	—1	0
0= +0.029	—1	—1	+4	0	—1	0
0= —0.024	—1	—1	0	+2	0	0
0= —0.347	—1	—1	—1	0	+4	—1
0= —0.166	0	0	0	0	—1	+2

Hence the corrections—

A = + 0.1607″ C = + 0.1534″ E = + 0.2725″
B = + 0.2096 D = + 0.1972 F = + 0.2193

When weights are introduced, the above normal equations become—

$0 = [p\,a\,n] + [p\,a\,a]\,A + [p\,a\,b]\,B + [p\,a\,c]\,C + \ldots\ldots$
$0 = [p\,b\,n] + [p\,a\,b]\,A + [p\,b\,b]\,B + [p\,b\,c]\,C + \ldots\ldots$
$0 = [p\,c\,n] + [p\,a\,c]\,A + [p\,b\,c]\,B + [p\,c\,c]\,C + \ldots\ldots$
etc.

The observations at Pine Mount, a station in another section of the survey, may serve to illustrate the method when weights are introduced, and the process requires no further explanation.

Observed angles.

		° ′ ″	Weight.
1.2	Joscelyne—Deepwater	65 11 52.500	3
2.3	Deepwater—Deakyne	66 24 15.553	3
3.4	Deakyne—Burden	87 02 24.703	3
4.1	Burden—Joscelyne	141 21 21.757	1

Assumed angles.

		″
1.	Joscelyne	00.0
2.	Deepwater	52.5 + A
3.	Deakyne	08.0 + B
4.	Burden	32.7 + C

Formation of conditional equations.

1.2	52.5 + A = 52.500.
2.3	15.5 + B — A = 15.553
3.4	24.7 + C — B = 24.703
4.1	27.3 — C = 21.757

Conditional equations.

		p
1.2	0 = 0.000 + A	3
2.3	0 = — 0.053 — A + B	3
3.4	0 = — 0.003 — B + C	3
4.1	0 = + 5.543 — C	1

Formation of coefficients.

0.000	3	— 3	etc.
+ 0.159	3		
+ 0.159 = p a n	6 = p a a	— 3 = p a b	etc.

Multiplying the conditional equations by √ *p* first, and then forming [*a n*,] [*a a*,] &c., would be another way of obtaining the coefficient.

Normal equations.

$$0 = +0.159 + 6A - 3B$$
$$0 = -0.150 - 3A + 6B - 3C$$
$$0 = -5.552 - 3B + 4C$$

and
$$A = +0.9145$$
$$B = +1.8820$$
$$C = +2.7995$$

Hence the equated angles—

	° ′ ″
Joscelyne—Deepwater	65 11 53.414
Deepwater—Deakyne	66 24 16.468
Deakyne—Burden	87 02 25.617

A method is given by Bessel, and an example will be found in his survey of an arc in East Prussia, for combining, by least squares, observations of single directions, and repetitions at a station.

Having explained these two methods, we can proceed to the consideration of the geometrical conditions of a triangulation.

(C.) *Adjustment of horizontal angles of a triangulation depending on the geometrical conditions of its figure.*

We will now proceed to the adjustment of the angles so far as they depend on the geometrical conditions of the scheme of triangles. This consideration is the more important of the two. The parts of a triangle being determined when the base and two angles are known, any additional measure such as the third angle or a second side will furnish a condition, and when it is difficult to decide about the best distribution of the error in the sum of the three angles in any single triangle, this difficulty greatly increases when we come to a combination of such. It is obvious that no two computors would arrive at the same result without the application of least squares, and that it would otherwise be impossible to correct the angles in such a manner that any resulting side (the length of which we can obtain from different triangles) would have identical values. To the former imperfect and arbitrary mode of adjustment we have no need to refer, since the introduction of the method of least squares into geodesy. The problem reduces itself to the following: to deduce a system of corrections ($\triangle$) to the observed quantities, (as already corrected by the method A or B,) the sum of the squares of which is a minimum, and which satisfy all conditions of the polygonic figure of the survey. Such conditions are, for instance, that the computed length of a base, when brought forward to the verification base, which we suppose measured with equal accuracy, should be of the same length with it; that the sum of the angles in a triangle should equal two right-angles augmented by the spheroidal excess; that the sum of the angles round a central station should close the horizon; and, finally, that any side computed from different series of angles should be found of equal length.

The above conditions we can bring under the two classes of angle and of side conditions, remarking merely that the first effects the closing of the triangles, and the second the intersection of all lines converging to a station.

Before, however, proceeding with the explanation of the angle and side equations themselves, the notation used in the following exposition requires first to be stated.

An angle may be considered as formed by a difference of two directions; hence the notation $-\frac{1}{2}+\frac{3}{2}$ for the angle 1.2.3 (see Sketch No. 53, figure D) will easily be understood. Corrections to either direction will be included in parenthesis: thus $(\frac{1}{2})$ expresses a correction to $\frac{1}{2}$ and $-(\frac{1}{2})+(\frac{3}{2})$ the correction to the above angle; 1.2 and 3.2 signify the sides themselves.

Another question arises in reference to the weight to be given to directions. If all signals appeared equally distinct, we should assign to the directions equal weight; but considering that we have, by the treatment of the measures by either method (A or B,) already assigned weights to directions, and, further, that by actual investigation of the appearance of the signals in this triangulation in connection with the conditions required to be satisfied, no result in favor of signals marked "well-defined, or distinct" was obtained, we need not introduce any different weights; which view is supported also by other observers. There is, however, one case when the observer uses different instruments; the conditional equations will then have to be multiplied into the square root of the weights. The weights to be given to instruments of different size cannot further be pursued here, but may approximately be taken proportional to the diameter of the circle. Bessel gives an example for the relative weights of results by a repeating theodolite, and a non-repeating one taking single directions.

The adjustment to be explained here belongs to that class which is called, by Gerling, adjustment of conditional observations of equal accuracy, and in its general application requires but one additional operation to those stated when treating method B, which consists in the establishment of the equations of correlatives, (so called by Gauss.) We may therefore proceed at once to the application.

1. Angle equations:

The condition between the angles in any triangle is readily put in shape; and as the further treatment will be shown in connection with the side equations, it will be sufficient to establish the conditional equations in this place and to explain the formation of the equations of correlatives afterwards. Suppose we have given the measured spherical angles

2.1.3 = 41° 58′ 51″.475
1.3.2 53 53 55″.455
3.2.1 84 07 18″.089

$s =$ 5″.019

and the approximate latitude of the centre of gravity of the triangle, together with the approximate length of one of its sides. Compute the spherical excess (ϵ) by the well-known formula $\epsilon = \frac{a\,b \sin C\,(1 + e^2 \cos 2\,L)}{2\,R^2 \sin 1''} = 4''.140$ for the above; and take the sum of the angles, the residual $s - \epsilon$ will be the numerical term in the equation. We have $s - \epsilon = + 0''.879$, and the condition—

$$2.1.3 - \binom{2}{1} + \binom{3}{1} + 1.3.2 - \binom{1}{3} + \binom{2}{3} + 3.2.1 - \binom{3}{2} + \binom{1}{2} = 180 + \epsilon$$

subtract $2.1.3 + 1.3.2 + 3.2.1 = 180 + s$

$$o = s - \epsilon - \binom{2}{1} + \binom{3}{1} - \binom{1}{3} + \binom{2}{3} - \binom{3}{2} + \binom{1}{2}$$

which is the resulting angle equation. The closing of the horizon is effected similarly.

2. Side equations:

The establishment of a side equation consists in finding the relation between the sides and angles of any polygon in the triangulation. In the following pentagon, (see Sketch No. 53, figure E,) for instance, we have—

$$k_1 \sin \beta_1 = k_2 \sin \gamma_1$$
$$k_2 \sin \beta_2 = k_3 \sin \gamma_2$$
$$k_3 \sin \beta_3 = k_4 \sin \gamma_3$$
$$k_4 \sin \beta_4 = k_5 \sin \gamma_4$$
$$k_5 \sin \beta_5 = k_1 \sin \gamma_5$$

Hence, $\sin \beta_1 \sin \beta_2 \sin \beta_3 \sin \beta_4 \sin \beta_5 = \sin \gamma_1 \sin \gamma_2 \sin \gamma_3 \sin \gamma_4 \sin \gamma_5$

or,

$1 = \frac{\sin \gamma_1 \sin \gamma_2 \sin \gamma_3 \sin \gamma_4 \sin \gamma_5}{\sin \beta_1 \sin \beta_2 \sin \beta_3 \sin \beta_4 \sin \beta_5}$, and substituting for the ratio of the sines that of the opposite sides,

$1 = \frac{2.1}{3.1} \cdot \frac{3.1}{4.1} \cdot \frac{4.1}{5.1} \cdot \frac{5.1}{6.1} \cdot \frac{6.1}{2.1}$, or as above.

$1 = \frac{\sin 1.3.2}{\sin 3.2.1} \cdot \frac{\sin 1.4.2}{\sin 4.3.1} \cdot \frac{\sin 1.5.4}{\sin 5.4.1} \cdot \frac{\sin 1.6.5}{\sin 6.5.1} \cdot \frac{\sin 1.2.6}{\sin 2.6.1}$, where the angles round the central station do not occur.

Our angles $o + \delta$, however, will not satisfy this equation; including, therefore, the corrections $\triangle$, which we will suppose to be expressed in seconds, we obtain the following logarithmic equation:

$$o = \begin{cases} + lg.\ \sin.\ [1.3.2 + (1.3.2)] + lg.\ \sin.\ [1.4.3 + (1.4.3)] + \text{etc.} \\ - lg.\ \sin.\ [3.2.1 + (3.2.1)] - lg.\ \sin.\ [4.3.1 + (4.3.1)] - \text{etc.} \end{cases}$$

but as we cannot find the log. sin. of the measured angles + △'s, we first write down the log. sin. of the measured angles 1.3.2 etc., and multiply the unknown corrections (1.3.2) etc., by the tabular logarithmic difference for 1″ corresponding to the angles 1.3.2 etc. Thus we obtain the following form:

$$o = \begin{cases} lg.\ \sin.\ 1.3.2 + lg.\ \sin.\ 1.4.3 + \text{etc.} \\ - lg.\ \sin.\ 3.2.1 - lg.\ \sin.\ 4.3.1 - \text{etc.} \\ + d_{\prime}\,(1.3.2) + d_{\prime\prime}\,(1.4.3) + \text{etc.} \\ - d'\,(3.2.1) - d''\,(4.3.1) - \text{etc.} \end{cases}$$

and as soon as the corrections, (1.3.2) etc., become known, the log. sin [1.3.2 + (1.3.2)] can be formed. By substituting the approximate angles 1.3.2, etc., in the place of the true ones 1.3.2 + (1.3.2) etc., the numerical value of the first two lines equals the value of the third and fourth with the opposite sign. The coefficients of the unknown corrections are the logarithmic differences $d_{,}\ d_{,,} \ldots d'\ d'' \ldots\ldots\ldots$ Another treatment by means of Taylor's theorem is far less convenient, and consequently requires no further illustration. (See Fischer's Geodesy, p. 73, vol. 3.)

It may also be remarked in this place, that when we have measured two base lines in a series of triangles, considering both as absolutely correct, we are led to a similar equation, but the absolute term 1 becomes $\frac{b_{,}}{b_{,,}}$, $b_{,}$ and $b_{,,}$ being the length of the base lines.

For the above corrections, (1.3.2) etc., we write as usual — $(^1_3)$ + $(^2_3)$ etc., and then multiply each term by its respective d. It will be well to adhere to the above order of the notation of an angle, taking the left-hand number first, as it will facilitate the operation.

Multiplying the first condition equation by K_1, the second by K_2, and so on, we form by summation the equations of correlatives. (See Gerling, p. 177.)

$$v_1 = a_1 K_1 + b_1 K_2 + c_1 K_3 + \ldots\ldots\ldots$$
$$v_2 = a_2 K_1 + b_2 K_2 + c_2 K_3 + \ldots\ldots\ldots$$
$$v_3 = a_3 K_1 + b_3 K_2 + c_3 K_3 + \ldots\ldots\ldots$$
$$+ \ldots\ldots\ldots\ldots$$

and the normal equations become—

$$o = w_1 + [a\,a]\,K_1 + [a\,b]\,K_2 + [a\,c]\,K_3 + \ldots\ldots$$
$$o = w_2 + [a\,b]\,K_1 + [b\,b]\,K_2 + [b\,c]\,K_3 + \ldots\ldots$$
$$o = w_3 + [a\,c]\,K_1 + [b\,c]\,K_2 + [c\,c]\,K_3 + \ldots\ldots$$
$$+ \ldots\ldots\ldots$$

we next obtain, by solving the equations, $K_1\ K_2\ K_3 \ldots\ldots\ldots$ and then by substitution in the equations of correlatives the corrections themselves. When weights are introduced the equations of correlatives become—

$$v_1 = \frac{a_1}{p_1} K_1 + \frac{b_1}{p_1} K_2 + \frac{c_1}{p_1} K_3 + \ldots\ldots$$
$$v_2 = \frac{a_2}{p_2} K_1 + \frac{b_2}{p_2} K_2 + \frac{c_2}{p_2} K_3 + \ldots\ldots$$
$$v_3 = \frac{a_3}{p_3} K_1 + \frac{b_3}{p_3} K_2 + \frac{c_3}{p_3} K_3 + \ldots\ldots$$
$$+ \ldots\ldots$$

and the normal equations—

$$0 = w_1 + \left[\frac{a\,a}{p}\right] K_1 + \left[\frac{a\,b}{p}\right] K_2 + \left[\frac{a\,c}{p}\right] K_3 + \ldots\ldots$$
$$0 = w_2 + \left[\frac{a\,b}{p}\right] K_1 + \left[\frac{b\,b}{p}\right] K_2 + \left[\frac{b\,c}{p}\right] K_3 + \ldots\ldots$$
$$0 = w_3 + \left[\frac{a\,c}{p}\right] K_1 + \left[\frac{b\,c}{p}\right] K_2 + \left[\frac{c\,c}{p}\right] K_3 + \ldots\ldots$$

For the purpose of forming the coefficients, we may use the following form for the equations of correlatives—

p.	Corr's.	K_1	K_2	K_3	etc.
p_1	v_1	a_1	b_1	c_1	
p_2	v_2	a_2	b_2	c_2	
p_3	v_3	a_3	b_3	c_3	
	etc.				

which are to be understood—

$$
\begin{aligned}
p_1\, v_1 &= a_1\, K_1 + b_1\, K_2 + c_1\, K_3 + \dots\dots\dots \\
p_2\, v_2 &= a_2\, K_1 + b_2\, K_2 + c_2\, K_3 + \dots\dots\dots \\
p_3\, v_3 &= a_3\, K_1 + b_3\, K_2 + c_3\, K_3 + \dots\dots\dots \\
&+ \dots\dots\dots
\end{aligned}
$$

forming now the quantities...

$$
\left|\begin{array}{c|c|c}
\frac{a_1\, a_1}{p_1} & \frac{a_1\, b_1}{p_1} & \frac{a_1\, c_1}{p_1} + \dots\dots\dots \\
\frac{a_2\, a_2}{p_2} & \frac{a_2\, b_2}{p_2} & \frac{a_2\, c_2}{p_2} \\
\frac{a_3\, a_3}{p_3} & \frac{a_3\, b_3}{p_3} & \frac{a_3\, c_3}{p_3} \\
+ \dots\dots\dots & &
\end{array}\right.
$$

the coefficients for the normal equations result by summing up the numbers in each column.

The number of angle equations next claims our attention, and some caution is necessary in order not to repeat equations; for instance, in a quadrilateral, in which all angles are measured, we might easily be led to establish four angle equations, one for each closed triangle when there are but three, the fourth being a consequence of the others.

The stations between which side equations consist may readily be recognised by their forming polygons or systems round a central point, including it either with a triangle (the most simple case) or a polygon. Frequently the central point or pole, as, for instance, station Gunstock, of the primary triangulation, Section I, falls outside the figure, which, however, alters nothing in the above conclusions. Both kinds of figures have the following characteristic property. At every point three lines meet, save one, where p—1 meet, when the figure includes p stations. Complications arise from systems within systems, which case frequently occurs. In a given quadrilateral any one of the four stations may be taken for the pole, though it is more convenient to select that one where the three triangles meet, which furnish the angle equations. The figures (F) and (G) contain the smallest number of sides between which a side equation is possible; their identity becomes apparent when we suppose the point m to fall inside the triangle $n\ o\ p$. The side equations are equally true for plane and spherical angles.

The following example is given for illustration of a case in which there is but one conditional equation. As usual, we express by a full line an observed direction, and by a broken line a concluded one. (See figure H.)

Given the measured (and equated) angles—

	°	′	″
4.2.1 =	37	18	11.542
3.2.4 =	46	49	05.167
1.3.2 =	53	53	54.075
4.3.1 =	49	17	21.310
1.4.3 =	66	34	02.745

$$1 = \frac{2.1}{3.1} \cdot \frac{3.1}{4.1} \cdot \frac{4.1}{2.1}$$

sin 1.3.2 sin 1.4.3 sin 4.2.1 = sin 3.2.1 sin 4.3.1 sin 1.4.2.

sin 1.3.2 sin 1.4.3 sin 4.2.1 = sin (3.2.4 + 4.2.1) sin 4.3.1 sin (1.3.2 + 3.2.4 + 1.4.3 + 4.3.1 — 180)

and from the above—

3.2.1 = 84° 07′ 16″.709
1.4.2 = 36° 34′ 23″.297

$$\sin\left[-{}^{1}_{3} + {}^{2}_{3}\right] \sin\left[-{}^{1}_{4} + {}^{3}_{4}\right] \sin\left[-{}^{4}_{2} + {}^{1}_{2}\right] = \sin\left[-{}^{3}_{2} + {}^{1}_{2}\right] \sin\left[-{}^{4}_{3} + {}^{1}_{3}\right] \sin\left[+{}^{2}_{3} - {}^{3}_{2} + {}^{4}_{2} - {}^{1}_{4} + {}^{3}_{4} - {}^{4}_{3} - 180.\right]$$

Angle.	Log. sin.	*d.* for 1″	Angle.	Log. sin.	*d.* for 1″.
1.3.2	9.9073968.256	+15.35	3.2.1	9.9977100.082	+ 2.17
1.4.3	9.9626196.629	+ 9.12	4.3.1	9.8796760.842	+18.12
4.2.1	9.7824962.098	+27.64	1.4.2	9.7751357.952	+28.38
	9.6525126.983			9.6525218.876	
	9.6525218.876				
	—91.893				

and the conditional equation becomes—

$$0 = -91.893 - 15.35\binom{1}{3} + 15.35\binom{2}{3} - 9.12\binom{1}{4} + 9.12\binom{3}{4} - 27.64\binom{4}{2}$$
$$+ 27.64\binom{1}{2} + 2\ 17\binom{3}{2} - 2.17\binom{1}{2} + 18.12\binom{4}{3} - 18.12\binom{1}{3}$$
$$- 28.38\binom{2}{3} + 28.38\binom{3}{2} - 28.38\binom{4}{2} + 28.38\binom{1}{4} - 28.38\binom{3}{4} + 28.38\binom{4}{3}$$
$$0 = -91.893 - 33.47\binom{1}{3} - 13.03\binom{2}{3} + 19.26\binom{1}{4} - 19.26\binom{3}{4}$$
$$- 56.02\binom{4}{2} + 25.47\binom{1}{2} + 30.55\binom{3}{2} + 46.50\binom{4}{3}$$

Equations of correlative.

v.	$a\,K_1$.
$\binom{1}{3}$	—33.47
$\binom{2}{3}$	—13.03
$\binom{1}{4}$	+19.26
$\binom{3}{4}$	—19.26
$\binom{4}{2}$	—56.02
$\binom{1}{2}$	+25.47
$\binom{3}{2}$	+30.55
$\binom{4}{3}$	+46.50

$a\,a$.	
1120.24	$\Sigma\, a\, a = 8914.43$
169.78	
370.95	
370.95	
3138.24	
648.72	
933.30	
2162.25	

Normal equation—

$$o = -91.893 + 8914.43\ K_1$$
$$K_1 = +0.01031$$

and the corrections to the directions become—

$\binom{1}{3} = -0''.3447$ $\binom{4}{2} = -0''.5770$

$\binom{2}{3} = -0\ .1342$ $\binom{1}{2} = +0\ .2623$

$\binom{1}{4} = +0\ .1984$ $\binom{3}{2} = +0\ .3147$

$\binom{3}{4} = -0\ .1984$ $\binom{4}{3} = +0\ .4790$

From these corrections we deduce the angles as follows:

$4.2.1 = 37°\ 18'\ 11''.542 - \binom{4}{2} + \binom{1}{2} = 37°\ 18'\ 12''.381$

$3.2.4 = 46\ \ 49\ \ 04\ .275$

$1.3.2 = 53\ \ 53\ \ 54\ .286$

$4.3.1 = 49\ \ 17\ \ 20\ .486$

$1.4.3 = 66\ \ 34\ \ 02\ .348$

which values will best satisfy the condition of the quadrilateral. In the following example (see fig. I) we have a combination of three angles and one side equation. Given the measured (and equated) spherical angles, as indicated in the figure marked I. We select the following three triangles, having assumed the pole at 1.

	1.4.2 = 36° 34′ 21″.731	2.1.3 = 41° 58′ 51″.475	3.1.4 = 64° 08′ 37″.766
	4.2.1 = 37 18 13 .179	1.3.2 = 53 53 55 .455	1.4.3 = 66 34 04 .633
	2.1.4 = 106 07 29 .241	3.2.1 = 84 07 18 .089	4.3.1 = 49 17 23 .198
Sums s =	4 .151	5 .019	5 .597
Spherical excess ϵ =	4 .912	4 .140	5 .665
Residual	$s - \epsilon = -0\ .761$	$s - \epsilon = +0.879$	$s - \epsilon = -0.068$

$$1=\frac{2.1}{3.1}\cdot\frac{3.1}{4.1}\cdot\frac{4.1}{2.1}$$

$$\sin 1.3.2 \sin 1.4.3 \sin 4.2.1 = \sin 3.2.1 \sin 4.3.1 \sin 1.4.2$$

$$\sin\left[-\tfrac{1}{3}+\tfrac{2}{3}\right]\sin\left[-\tfrac{1}{4}+\tfrac{3}{4}\right]\sin\left[-\tfrac{4}{2}+\tfrac{1}{2}\right]=\sin\left[-\tfrac{3}{2}+\tfrac{1}{2}\right]\sin\left[-\tfrac{4}{3}+\tfrac{1}{3}\right]\sin\left[-\tfrac{1}{4}+\tfrac{2}{4}\right]$$

Angle.	Log. sin.	d. for 1″.	Angle.	Log. sin.	d. for 1″.
1.3.2	9.9073989.450	+ 15.35	3.2.1	9.9977103.074	+ 2.17
1.4.3	9.9626213.860	+ 9.12	4.3.1	9.8796795.048	+ 18.12
4.2.1	9.7825007.339	+ 27.63	1.4.2	9.7751313.514	+ 28.38
	9.6525210.649			9.6525211.636	
	9.6525211.636				
	− 0.987				

And hence the four conditional equations—

$$\text{I.}\quad 0=-0.761-\binom{1}{4}+\binom{2}{4}-\binom{4}{2}+\binom{1}{2}-\binom{2}{1}+\binom{4}{1}$$

$$\text{II.}\quad 0=+0.879-\binom{2}{1}+\binom{3}{1}-\binom{1}{3}+\binom{2}{3}-\binom{3}{2}+\binom{1}{2}$$

$$\text{III.}\quad 0=-0.068-\binom{3}{1}+\binom{4}{1}-\binom{1}{4}+\binom{3}{4}-\binom{4}{3}+\binom{1}{3}$$

$$\begin{aligned}\text{IV.}\quad 0=-0.987&-15.35\binom{1}{3}+15.35\binom{2}{3}-9.12\binom{1}{4}+9.12\binom{3}{4}\\&-27.63\binom{4}{2}+27.63\binom{1}{2}+2.17\binom{3}{2}-2.17\binom{1}{2}\\&+18.12\binom{4}{3}-18.12\binom{1}{3}+28.38\binom{1}{4}-28.38\binom{2}{4}\end{aligned}$$

For the latter equation we can write—

$$\begin{aligned}\text{IV.}\quad 0=-0.987&-33.47\binom{1}{3}+15.35\binom{2}{3}+19.26\binom{1}{4}+9.12\binom{3}{4}\\&-27.63\binom{4}{2}+25.46\binom{1}{2}+2.17\binom{3}{2}+18.12\binom{4}{3}-28.38\binom{2}{4}\end{aligned}$$

Equations of correlatives.

v.	a K_1.	b K_2.	c K_3.	d K_4.
$\binom{1}{4}$	− 1		− 1	+ 19.26
$\binom{2}{4}$	+ 1			− 28.38
$\binom{4}{2}$	− 1			− 27.63
$\binom{1}{2}$	+ 1	+ 1		+ 25.46
$\binom{2}{1}$	− 1	− 1		
$\binom{4}{1}$	+ 1		+ 1	
$\binom{3}{1}$		+ 1	− 1	
$\binom{1}{3}$		− 1	+ 1	− 33.47
$\binom{2}{3}$		+ 1		+ 15.35
$\binom{3}{2}$		− 1		+ 2.17
$\binom{3}{4}$			+ 1	+ 9.12
$\binom{4}{3}$			− 1	+ 18.12

Coefficients for normal equations.

$[a\,a]=+6$ $\qquad$ $[a\,b]=+2$

$[b\,b]=+6$ $\qquad$ $[a\,c]=+2$

$[c\,c]=+6$ $\qquad$ $[a\,d]=+5.45$

$[d\,d]=+4360.07$ $\qquad$ $[b\,c]=-2$

$[b\,d]=+72.11$

$[c\,d]=-61.73$

Normal equations.

	K_1.	K_2.	K_3.	K_4.
I. 0 = − 0.761	+ 6	+ 2	+ 2	+ 5.45
II. 0 = + 0.879	+ 2	+ 6	− 2	+ 72.11
III. 0 = − 0.068	+ 2	− 2	+ 6	− 61.73
IV. 0 = − 0.987	+ 5.45	+ 72.11	− 61.73	+ 4360.07

The solution gives, $K_1 = +0.2914$ and the residuals in I. 0.0001

$K_2 = -0.3361$ II. 0.0014

$K_3 = -0.1660$ III. 0.0015

$K_4 = +0.00307$ IV. 0.0024

and by substitution in the equations of correlatives—

$$\binom{1}{4} = -1\,K_1 - 1\,K_3 + 19.26\,K_4 = -0''.0663$$
$$\binom{2}{4} = +1\,K_1 \qquad - 28.38\,K_4 = +0\ .2043$$
$$\binom{4}{2} = -1\,K_1 \qquad - 27.63\,K_4 = -0\ .3762, \text{ and so on.}$$

$\binom{1}{2} = +0''.0335$	$\binom{3}{1} = -0''.1701$	$\binom{3}{2} = +0.3428$
$\binom{2}{1} = +0\ .0447$	$\binom{1}{3} = +0\ .0674$	$\binom{3}{4} = -0.1380$
$\binom{4}{1} = +0\ .1254$	$\binom{2}{3} = -0\ .2890$	$\binom{4}{3} = +0.2216$

And by substituting in the conditional equations we have the residuals—

in I. 0.000

II. 0.001

III. 0.001

IV. 0.094, equalling a few thousandths of a second, and the angles themselves become $1.4.2 - \binom{1}{4} + \binom{2}{4}$ etc.

1.4.2 = 22″.002	2.1.3 = 51″.260	3.1.4 = 38″.061
4.2.1 = 13 .589	1.3.2 = 55 .099	1.4.3 = 04 .561
2.1.4 = 29 .322	3.2.1 = 17 .780	4.3.1 = 23 .044

omitting the degrees and minutes.

It is remarked by Bessel, that difficulties are sometimes experienced in finding the exact number of angle and side equations; and in order to guard against either omissions or excesses—the former producing an imperfect adjustment, the latter an unnecessary labor—it becomes of importance to establish formulæ by which we can check this number.

However, by following strictly the rule, to commence with the base and to add successively the several directions, establishing the angle as well as side equations, in the order in which they present themselves, the difficulty spoken of will almost disappear. By this process we re-produce the figure of the triangulation. A suitable selection may be made for the establishment of the side equations, and no other rule can be given except that of selecting for the pole such a station where few or no directions were observed, which will greatly diminish the labor. Great care must be taken to obtain, also, the correct number of terms in these equations.

The least number of lines necessary to form a closed figure by connecting p points is p, and gives one angular condition: every additional line, which must necessarily have been observed in two directions, furnishes a condition; hence, a system of l lines between p points, gives $l - p + 1$ angle equations; where, it must be borne in mind that each of the l lines must have a forward and backward sight.

When, in any system, the first two points are determined in reference to one another by the measurement of the line joining, then the determination of the position of any additional station requires two sides, or necessarily two directions; hence, in any system of triangles between p points, we have to determine $p - 2$ points, which require $2\,(p - 2)$ directions, and by adding the first $2\,p - 3$. Consequently, in a system of l sides, $l - 2\,p + 3$ sides appear supernumerary, and give an equal number of side equations. One direction for each suffices for this purpose.

If it should happen that each side was observed in two directions, the total number of conditional equations would amount to $2\,l - 3\,p + 4$. The limits of l are $2\,p - 3$, and $\frac{p\,(p-1)}{2}$.

The treatment of conditions between linear measures, and between linear measures in connection with angular measures, is excluded in accordance with the plan of this paper.

There are two investigations, however, which we cannot pass without at least a slight notice; they are, the accuracy of the derived (equated) values for each of Gerling's three principal divisions of direct, of indirect, and of conditional observations, and the adjustment of the angles, in a system in which certain quantities are considered as absolutely correct, (their $\triangle$'s become zero;) this case is of frequent occurrence when we come to adjust secondary measures, or systems where the primary measures must remain unaltered, by the adjustment of the secondary system. This latter process may be called that of secondary adjustment. An exposition of the formulæ for accuracy of results will be found in Gerling's admirable work, and the secondary adjustment can be accomplished with the knowledge of the preceding method.

The number of normal equations, equal to the number of conditions in the figure of a triangulation, becomes formidable in any extensive or complete scheme of triangles. In that part of the primary triangulation in Section I, bounded by the lines Cuttyhunk, Indian, in the south, and by Mount Pleasant, Mount Independence, in the north, the number of equations to be solved is 65, containing as many unknown quantities. Gauss has furnished us with the means of completing an adjustment of such magnitude, in his method of indirect elimination, and in this theorem of the compensatio imperfecta seu manca, of which, however, this is not the place for further explanation. Without this assistance, such a work as the complete adjustment of the triangulation in Section I could not be accomplished.

For those who desire further information on the general theory of the method of least squares, and on the application of it to the operations of geodesy, the following works may be referred to: Gauss, Theoria Motus Corporum Coelestium, 1809; Theoria Combinationis Observationum Erroribus Minimis Obnoxiæ, 1823; and Supplementum Theoriæ Combinationis, etc., by Gauss, 1826; Legendre, Nouvelles Methodes pour la Determination des Orbites des Comètes, Paris, 1806; Bessel's Gradmessung in Ostpreussen, 1838; Rosenberger's paper in the Astronomische Nachrichten, Nos. 121 and 122, (1827;) and Bessel's paper in No. 438, ibid. (1841.) Application of the method to a portion of the ordnance survey of England, by Th. Galloway, 1843, in the Memoirs of the Royal Astronomical Society, volume XV, 1846; Ch. L. Gerling, die Ausgleichungs—Rechnungen der practischen Geometrie, Hamburg and Gotha, 1843; J. J. Baeyer's Kustenvermessung, 1849; Enke on the method of least squares, in the Berliner Jahrbuch, 1834, 1835, 1836, and 1853.

T.

1. Probable error of observation derived from observations of horizontal angles at any single station, and depending on directions. (Method A of reduction.)

The measures having been treated by the method of least squares, the mode adopted for finding the probable error of observation was as follows:

The resulting corrections, A, B, C, D, etc., to the assumed directions, were applied with the opposite sign to the quantities in each respective column of the abstract of diminished measures. These corrections usually amount to but a few tenths of a second, and may in many cases be neglected; this, however, was not done in the following computation, the assumed angles not being considered close enough. In the abstract of remaining differences, thus formed, the readings of each direction were compared with the mean reading of their series, which process furnished the remaining errors ($\triangle$).

The squares of these errors for each station, and forming a set containing an equal number of directions (n) were then summed up, and the several results $\frac{\Sigma \triangle^2}{n-1}$ and their sum formed.

If we divide this sum or $\left[\frac{\Sigma \triangle^2}{n-1}\right]$ by the total number of series (s), we obtain the square of the mean error of a single direction; and if we divide this by the mean sum, or by $\frac{[a\,a]+[b\,b]+[c\,c]+\text{etc.},}{m}$ the average mean error of a resulting direction.

Hence the square of the average probable error of a single direction at any given station becomes

$$e_i^2 = \frac{0.4549\left[\frac{\Sigma \triangle^2}{n-1}\right]}{s}$$

and the same for a resulting direction.

$$\epsilon_{,}^{2} = \frac{0.4549 \left[\frac{\Sigma \triangle^{2}}{n-1} \right]}{s \; \frac{[a\,a] + [b\,b] + [c\,c] + \text{etc.},}{m}}$$

$e_{,}^{2}$ and $\epsilon_{,}^{2}$ have been computed for eleven selected stations.

The average probable error of a single observation of an angle or $e_{\angle}$ and of a resulting angle $\epsilon_{\angle}$ are connected with the above by the formulæ—

$$e_{\angle} = e_{1} \sqrt{2} \text{ and } \epsilon_{\angle} = \epsilon_{1} \sqrt{2}$$

2. Probable error of observation of a horizontal angle derived from separate measures of angles. (Method B of reduction.)

For the method of deducing this probable error a short explanation will suffice.

The resulting measures for each angle has been compared with its respective mean value. The squares of these differences ($\triangle$) were then summed up, and also the number of observations (n) of each angle. The square of the mean error becomes then $\frac{[\triangle^{2}]}{[n]-s}$ where s denotes the number of series or angles measured.

We obtain

$$e_{\angle}^{2} = \frac{0.4549\,[\triangle^{2}]}{[n]-s} \text{ and } \epsilon_{\angle}^{2} = \frac{0.4549\,[\triangle^{2}]}{([n]-s)\;\frac{[n]}{s}}$$

$e_{\angle}^{2}$ and $\epsilon_{\angle}^{2}$ were deduced for the same stations as above, and the results by the two methods (A and B) compared.

EXAMPLE.—*Discussion of Probable Errors.*—(Abstract A.)

STATION POCASSET.

Abstract of remaining errors referred to the direction Quaker.

Quaker.	McSpar.	Spencer.	College.	Beacon.	G. Meadow.	Blue.	Copecut.	Means.
00.0	58.6	00.2	59.3	59.2	00.1	58.0	58.6	59.2
00.0	59.3	01.4	01.6	59.5	59.9	59.3	02.1	60.4
00.0	59.9	58.7	00.6	59.2	01.4	00.7	59.6	60.0
00.0	01.7	00.8	02.5	59.8	59.6	01.3	00.0	60.7
00.0	01.2	00.5	58.1	58.1	56.4	59.3	59.0	59.1
00.0	01.2	58.8	00.4	01.4	59.6	59.9	00.7	60.2
00.0	00.3	56.0	59.0	58.2	01.1	00.7	01.1	59.5
00.0	00.4	00.4	00.9	00.9	03.5	59.7	03.0	61.0
00.0	00.1	59.2	59.1	58.8	59.5	57.9	58.8	59.2
00.0	00.6	00.2	59.6	02.1	00.5	01.7	01.8	60.8
00.0	00.6	02.4	00.2	59.3	01.0	59.6	06.0	61.1
00.0	00.8	00.1	01.9	02.7	00.4	01.6	59.5	60.9
00.0	59.5	59.0	00.8	01.6	00.5	00.9	00.8	60.4
00.0	57.7	59.1	01.6	01.4	00.8	01.1	03.0	60.6
00.0	59.3	58.3	01.3	02.0	01.9	00.9	02.3	60.7
00.0	59.0	58.6	00.7	59.9	01.2	58.7	02.1	60.0
00.0	00.0	00.8	58.8	00.9	01.5	04.4	57.8	60.5
00.0	00.0	01.1	57.6	59.6	58.3	59.1	58.1	59.2
00.0	59.3	00.1	56.4	57.1	54.0	58.1	52.8	57.2
00.0	59.1	59.9	58.9	59.6	58.0	01.2	57.8	59.3
00.0	58.8	55.7	02.4	03.7	58.1	02.2	58.0	59.9
00.0	58.7	59.9	59.8	00.9	00.5		58.6	59.8
00 0	58.0	58.1	58.8	01.3	01.7		57.3	59.3
00.0	03.4	03.2	01.8		03.0		01.2	62.1

Discussion of probable errors—Continued.

Quaker.	McSpar.	Spencer.	College.	Beacon.	G. Meadow.	Blue.	Copecut.	Means.
00.0	59.8	01.9	01.9		01.7		59.4	60.8
00.0	58.3	58.1	57.0		00.4		59.1	58.9
00.0	00.0	00.3	00.2		01.0		01.4	60.5
00.0	00.8	02.4	00.0		00.3		01.7	60.9
00.0	01.0	59.4	59.4		00.9		00.3	60.2
00.0	00.6	00.0	01.6		00.7		58.7	60.3
	00.3	00.5		04.6	04.9	03.7	03.7	62.9
	00.3	59.9	55.9	55.1	55.8	54.7		56.9
	00.3	59.3	00.5	00.1	00.2	59.3		59.9
00.0	00.6	00.7			00.3		00.3	60.3
00.0	59.2	00.2			00.4		00.1	60.0
00.0			56.6	53.8	56.9		56.5	56.8
00.0	00.7		59.8		00.0		59.7	60.0
	01.1	00.8		57.3	57.8	58.3		59.1
	00.9	59.2		59.2	57.4	57.8		58.7
	00.3	01.5		57.0	55.9	55.9		58.1
00.0	58.9				59.8		00.7	59.9
	00.3	01.3			01.2		01.2	61.0
		00.1		59.2	58.1	58.1		58.9
00.0	02.1	00.7						60.9
00.0	58.4	59.5						59.3
	00.3	01.7						61.0
				00.1		02.9		61.5
				00.7		00.1		60.4
				00.1		00.8		60.4
				00.1		58.8		59.4
				00.7		59.5		60.1
				00.1		59.6		59.9

Abstract of remaining errors or differences from the mean reading of the series.

Quaker.		McSparran.		Spencer.		College.		Beacon P.		G. Meadow.		Blue.		Copecut.	
△	△²	△	△²	△	△²	△	△²	△	△²	△	△²	△	△²	△	△²
0.8	0.6	0.6	0.4	1.0	1.0	0.1	0.0	0.0	0.0	0.9	0.8	1.2	1.4	0.6	0.4
0.4	0.2	1.1	1.2	1.0	1.0	1.2	1.4	0.9	0.8	0.5	0.2	1.1	1.2	1.7	2.9
0.0	0.0	0.1	0.0	1.3	1.7	0.6	0.4	0.8	0.6	1.4	2.0	0.7	0.5	0.4	0.2
0.7	0.5	1.0	1.0	0.1	0.0	1.8	3.2	0.9	0.8	1.1	1.2	0.6	0.4	0.7	0.5
0.9	0.8	2.1	4.4	1.4	2.0	1.0	1.0	1.0	1.0	2.7	7.3	0.2	0.0	0.1	0.0
0.2	0.0	1.0	1.0	1.4	2.0	0.2	0.0	1.2	1.4	0.6	0.4	0.3	0.0	0.5	0.2
0.5	0.2	0.8	0.6	3.5	12.2	0.5	0.2	1.3	1.7	1.6	2.6	1.2	1.4	1.6	2.6
1.0	1.0	0.6	0.4	0.6	0.4	0.1	0.0	0.1	0.0	2.5	6.2	1.3	1.7	2.0	4.0
0.8	0.6	0.9	0.8	0.0	0.0	0.1	0.0	0.4	0.2	0.3	0.1	1.3	1.7	0.4	0.2
0.8	0.6	0.2	0.0	0.6	0.4	1.2	1.4	1.3	1.7	0.3	0.1	0.9	0.8	1.0	1.0
1.1	1.2	0.5	0.2	1.3	1.7	0.9	0.8	1.8	3.2	0.1	0.0	1.5	2.2	4.9	24.0
0.9	0.8	0.1	0.0	0.8	0.6	1.0	1.0	1.8	3.2	0.5	0.2	0.7	0.5	1.4	2.0
0.4	0.2	0.9	0.8	1.4	2.0	0.4	0.2	1.2	1.4	0.1	0.0	0.5	0.2	0.4	0.2
0.6	0.4	2.9	8.4	1.5	2.2	1.0	1.0	0.8	0.6	0.2	0.0	0.5	0.2	2.4	5.8
0.7	0.5	1.4	2.0	2.4	5.8	0.6	0.4	1.3	1.7	1.2	1.4	0.2	0.0	1.6	2.6
0.0	0.0	1.0	1.0	1.4	2.0	0.7	0.5	0.1	0.0	1.2	1.4	1.3	1.7	2.1	4.4
0.5	0.2	0.5	0.2	0.3	0.1	1.7	2.9	0.4	0.2	1.0	1.0	3.9	15.2	2.7	7.3
0.8	0.6	0.8	0.6	1.9	3.6	1.6	2.6	0.4	0.2	0.9	0.8	0.1	0.0	1.1	1.2
2.8	7.8	2.1	4.4	2.9	8.4	0.8	0.6	0.1	0.0	3.2	10.2	0.9	0.8	4.4	19.4

Abstract of remaining errors—Continued.

Quaker.		McSparran.		Spencer.		College.		Beacon-pole.		G. Meadow.		Blue.		Copecut.	
Δ	Δ²	Δ	Δ²	Δ	Δ²	Δ	Δ²	Δ	Δ²	Δ	Δ²	Δ	Δ²	Δ	Δ²
0.7	0.5	0.2	0.0	0.6	0.4	0.4	0.2	0.3	0.1	1.3	1.7	1.9	3.6	1.5	2.2
0.1	0.0	1.1	1.2	4.2	17.6	2.5	6.2	3.8	14.4	1.8	3.2	2.3	5.3	1.9	3.6
	16.7		28.6		65.1		24.0		33.2		40.8		38.8		84.7
0.2	0.0	1.1	1.2	0.1	0.0	0.0	0.0	1.1	1.2	0.7	0.5			1.2	1.4
0.7	0.5	1.3	1.7	1.2	1.4	0.5	0.2	2.0	4.0	2.4	5.8			2.0	4.0
	0.5		2.9		1.4		0.2		5.2		6.3				5.4
2.1	4.4	1.3	1.7	1.1	1.2	0.3	0.1			0.9	0.8			0.9	0.8
0.8	0.6	1.0	1.0	1.1	1.2	1.1	1.2			0.9	0.8			1.4	2.0
1.1	1.2	0.6	0.4	0.8	0.6	1.9	3.6			1.5	2.2			0.2	0.0
0.5	0.2	0.5	0.2	0.2	0.0	0.3	0.1			0.5	0.2			0.9	0.8
0.9	0.8	0.1	0.0	1.5	2.2	0.9	0.8			0.6	0.4			0.8	0.6
0.2	0.0	0.8	0.6	0.8	0.6	0.8	0.6			0.7	0.5			0.1	0.0
0.3	0.1	0.3	0.1	0.3	0.1	1.3	1.7			0.4	0.2			1.6	2.6
		2.6	6.8	2.4	5.8			1.7	2.9	2.0	4.0	0.8	0.6	0.8	0.6
		3.4	11.6	3.0	9.0	1.0	1.0	1.8	3.2	1.1	1.2	2.2	4.8		
		0.4	0.2	0.6	0.4	0.6	0.4	0.2	0.0	0.3	0.1	0.6	0.4		
	7.3		22.6		21.1		9.5		6.1		10.4		5.8		7.4
0.3	0.1	0.3	0.1	0.4	0.2					0.0	0.0			0.0	0.0
0.0	0.0	0.8	0.6	0.2	0.0					0.2	0.0			0.1	0.0
3.2	10.2					0.2	0.0	3.0	9.0	0.1	0.0			0.3	0.1
0.0	0.0	0.7	0.5			0.2	0.0			0.0	0.0			0.3	0.1
		2.0	4.0	1.7	2.9			1.8	3.2	1.3	1.7	0.8	0.6		
		2.2	4.8	0.5	0.2			0.5	0.2	1.3	1.7	0.9	0.8		
	10.3		10.0		3.3		0.0		12.4		3.4		1.4		0.2
0.1	0.0	1.0	1.0							0.1	0.0			0.8	0.6
		0.7	0.5	0.3	0.1					0.2	0.0			0.2	0.0
				1.2	1.4			0.3	0.1	0.8	0.6	0.8	0.6		
	0.0		1.5		1.5				0.1		0.6		0.6		0.6
0.9	0.8	1.2	1.4	0.2	0.0										
0.7	0.5	0.9	0.8	0.2	0.0										
	1.3		2.2		0.0										
		0.7	0.5	0.7	0.5										
								1.4	2.0			1.4	2.0		
								0.3	0.1			0.3	0.1		
								0.3	0.1			0.4	0.2		
								0.7	0.5			0.6	0.4		
								0.6	0.4			0.6	0.4		
								0.2	0.0			0.3	0.1		
			0.5		0.5				3.1				3.2		

STATION POCASSET.

$\Sigma\ \Delta^2$	n	$\frac{\Sigma\ \Delta}{n-1}$	Number of series $s = 52$
331.9	8	47.4	$aa = 36.5$
21.9	7	3.6	$bb = 35.8$
90.2	6	18.0	$cc = 29.2$
41.0	5	10.3	$dd = 29.5$
4.9	4	1.6	$ee = 36.3$
3.5	3	1.7	$ff = 27.0$
7.3	2	7.3	$gg = 31.5$
	Sum	89.9	225.8 Mean, 32.3

$e_1^2 = 0.786$ $\epsilon_1^2 = 0.024$

$e_1 = \pm 0''.887$ $\epsilon_1 = \pm 0''.156$

(using but the first 21 series, e_1^2 results 1.027)

RECAPITULATION OF RESULTS.

The average probable error of any single direction, (e_1) and of the result (ϵ_1) for some selected stations, is exhibited in the following table:

(METHOD A.)

Station.	Occupied in—	e_1.	ϵ_1.	$\epsilon_{\angle}$.
		"	"	"
McSparran	1844	±0.972	±0.188	±0.266
Spencer	1844	0.745	.121	.171
Pocasset	1844	0.887	.156	.221
Copecut	1844	0.938	.150	.212
Beacon-pole	1844	0.726	.119	.168
Manomet	1845	0.918	.149	.211
Holt	1846	0.965	.178	.252
Agamenticus	1847	0.912	.158	.223
Unkonoonuc	1848	0.714	.125	.177
Mount Pleasant	1851	0.784	.085	.120
Ossipee	1851	1.163	0.164	0.232
Mean		±0.884	±0.145	±0.205

From the above we have

$$e_{\angle} = \pm 1''.250$$
$$\epsilon_{\angle} = \pm 0''.205$$

Discussion of probable errors of angles—(Abstract B.)

STATION POCASSET.

Quaker—Spencer.			Quaker—Beacon pole.			McSparran—Spencer.		
20.22	△	$△^2$	49.67	△	$△^2$	20.30	△	$△^2$
21.10	0.8	0.6	44.45	5.2	27.0	19.00	1.3	1.7
19.85	0.3	0.1	50.55	0.8	0.6	20.80	1.5	2.2
20.25	0.0	0.0	50.95	1.2	1.4	21.50	1.2	1.4
23.60	3.3	10.9	48.90	0.7	0.5	21.60	1.3	1.7
22.25	2.0	4.0	49.20	0.4	0.2	20.20	0.1	0.0
21.05	0.8	0.6	48.85	0.8	0.6	22.45	2.1	4.4
18.50	1.7	2.9	47.40	2.2	4.8	20.50	0.2	0.0
20.55	0.3	0.1	47.75	1.9	3.6	20.55	0.2	0.0
21.80	1.5	2.2	51.05	1.3	1.7	21.[illegible]0	1.1	1.2
19.10	1.1	1.2	47.85	1.8	3.2	22.00	1.7	2.9
21.10	0.8	0.6	50.60	0.9	0.8	20.05	0.2	0.0
20.90	0.6	0.4	48.45	1.2	1.4	18.70	1.6	2.6
19.15	1.0	1.0	51.75	2.0	4.0	21.60	1.3	1.7
16.40	3.8	14.4	[illegible]	0.6	0.4	22.55	2.2	4.8
20.75	0.4	0.2	52.35	2.6	6.8	20.55	0.2	0.0
19.55	0.6	0.4	51.30	1.6	2.6	19.25	1.1	1.2
20.60	0.3	0.1	51.05	1.2	1.4	19.55	0.7	0.5
22.80	2.5	6.2	51.70	2.0	4.0	19.70	0.6	0.4
20.60	0.3	0.1	49.05	0.6	2.6	19.95	0.3	0.1
18.50	1.7	2.9	50.55	0.8	0.6	17.95	2.3	5.3
20.70	0.4	0.2	49.25	0.4	0.2	16.10	4.2	17.6
22.75	2.5	6.2	46.75	2.9	8.4	20.35	0.0	0.0
19.75	0.4	0.2	49.25	0.4	0.2	19.50	0.8	0.6
20.35	0.1	0.0	53.40	3.7	13.7	20.05	0.2	0.0
20.45	0.2	0.0				22.20	1.9	3.6
19.35	0.8	0.6		Sum....	90.7	21.45	1.1	1.2
19.45	0.7	0.5				20.25	0.0	0.0
18.65	1.5	2.2				20.70	0.4	0.[illegible]
18.95	1.2	1.4				22.00	1.7	2.9
21.20	0.9	0.8				18.80	1.5	2.2
21.50	1.2	1.4				19.80	0.5	0.2
20.45	0.2	0.9				19.35	0.9	0.8
20.30	0.0	0.0				19.65	0.6	0.4
16.05	4.1	16.8				19.90	0.4	0.2
	Sum...	79.2				21.75	1.4	2.[illegible]
						19.35	0.9	0.[illegible]
						20.00	0.3	0.1
						21.25	0.9	0.[illegible]
						21.55	1.2	1.4
						21.20	0.9	0.8
						21.20	0.8	0.[illegible]
						17.25	3.0	9.0
							Sum....	77.5

STATION POCASSET.

McSparran—College.			McSparran—Beacon-pole.			Spencer—College H.		
52.95	△	$△^2$	49.70	△	$△^2$	32.65	△	$△^2$
54.05	1.1	1.2	51.40	1.7	2.9	32.45	0.2	0.0
52.10	0.8	0.6	53.10	3.4	11.6	31.15	1.5	2.2
51.40	1.5	2.2	50.35	0.6	0.4	32.60	0.0	0.0
55.05	2.1	4.4	45.85	3.8	14.4	33.25	0.6	0.4
53.80	0.8	0.6	48.00	1.7	2.9	31.65	1.0	1.0
53.65	0.7	0.5	46.40	3.3	10.9	32.75	0.1	0.0
55.30	2.3	5.3	49.95	0.2	0.0	34.45	1.8	3.2
53.70	0.7	0.5	54.00	4.3	18.5	34.25	1.6	2.6
53.80	0.8	0.6	49.00	0.7	0.5	30.10	2.5	6.2
49.80	3.1	9.6	45.85	3.8	14.4	28.55	4.1	16.8
52.10	0.8	0.6	46.55	3.1	9.6	34.15	1 5	2.2
51.65	1.3	1.7	44.45	5.2	27.0	35.55	2.9	8.4
53.40	0.4	0.2	49.85	0.1	0.0	33.05	0.4	0.2
53.00	0.0	0.0	47.55	2.1	4.4	33.50	0.8	0.6
52.00	0.9	0.8	50.20	0.5	0.2	31.95	0.3	0.5
52.50	0.4	0.2	48.40	1.3	1.7	30.30	2.3	5.3
51.65	1.3	1.7	51.20	1.5	2.2	31.40	1.2	1.4
53.15	0.2	0.0	48.40	1.3	1.7	32.45	0.2	0.0
48.50	4.4	19.4	49.45	0.2	0.0	30.15	2.5	6.2
52.15	0.8	0.6	51.55	1.8	3.2	32.55	0.1	0.0
51.35	1.6	2.6	51.85	2.1	4.4	34.15	1.5	2.2
53.95	1.0	1.0	53.35	3.6	13.0	33.75	1.1	1.2
53.10	0.1	0.0	52.40	2.7	7.3	34.40	1.7	2.9
54.05	1.1	1.2	50.60	0.9	0.8	34.35	1.7	2.9
54.25	1.3	1.7	50.60	0.9	0.8	35.10	2.4	5.8
56.35	3.4	11.6	49.30	0.4	0.2	35.60	2.9	8.4
54.95	2.0	4.0	47.50	2.2	4.8	34.65	2.0	4.0
54.65	1.7	2.9	50.15	0.4	0.2	30.50	2.18	4.4
51.75	1.2	1.4	54.60	4.9	24.0	29.05	3.6	13.0
50.60	2.3	5.3				28.85	3.8	14.4
50.05	2.9	8.4		Sum....	202.0	31.50	1.1	1.2
52.70	0.2	0.0				39.30	6.6	43.6
50.55	3.6	13.0						
							Sum....	161.2
	Sum....	103.8						

STATION POCASSET.

Spencer—Beacon-pole.			Spencer—Great Meadow.			College—Great Meadow.		
29.45	△	△²	49.07	△	△²	16.42	△	△²
30.30	0.8	0.6	49.80	0.7	0.5	16.70	0.2	0.0
32.45	3.0	9.0	48.65	0.4	0.2	17.05	2.6	6.8
28.35	1.1	1.2	48.75	0.3	0.1	16.55	0.1	0.0
25.80	3.6	13.0	48.50	0.5	0.2	17.50	1.0	1.0
29.30	0.1	0.0	53.95	4.8	23.0	16.15	0.2	0.0
24.80	4.6	21.2	48.80	0.2	0.0	19.20	2.7	7.3
27.40	2.0	4.0	48.85	0.2	0.0	17.20	0.7	0.5
33.45	4.0	16.0	45.95	3.1	9.6	14.60	1.8	3.2
29.75	0.3	0.1	47.15	1.9	3.6	17.15	0.7	0.5
26.30	3.1	9.6	43.30	5.7	32.5	13.45	2.9	8.4
26.85	2.6	6.8	47.35	1.7	2.9	14.65	1.7	2.9
24.50	4.9	24.0	53.30	4.2	17.6	16.30	0.1	0.0
31.90	2.4	5.8	51.60	3.5	12.2	15.55	0.8	0.6
31.45	3.0	9.0	47.70	1.3	1.7	18.45	2.0	4.0
29.85	0.4	0.2	44.75	4.3	18.5	19.00	2.5	6.2
28.90	0.5	0.2	44.85	4.2	17.6	15.75	0.6	0.4
31.15	1.7	2.9	49.70	0.6	0.4	17.25	0.8	0.6
26.20	3.2	10.2	54.00	4.9	24.0	17.20	0.7	0.5
28.35	1.1	1.2	52.05	2.9	8.4	19.80	3.3	10.9
30.10	0.6	3.4	49.25	0.1	0.0	17.10	0.6	0.4
31.90	2.4	5.8	49.20	0.1	0.0	17.70	1.2	1.4
31.95	2.5	6.2	47.50	1.5	2.2	16.85	0.4	0.2
31.60	2.1	4.4	49.05	0.0	0.0	15.50	0.9	0.8
33.05	3.6	13.0	51.20	1.1	1.2	16.10	0.3	0.1
30.60	1.1	1.2	49.55	0.4	0.2	14.85	1.5	2.2
29.35	0.1	0.0	46.85	2.2	4.8	16.05	0.3	0.1
27.75	1.7	2.9	50.40	1.3	1.7	15.50	0.9	0.8
26.30	3.1	9.6	49.65	0.5	0.2	16.95	0.5	0.2
28.95	0.5	0.2	49.90	0.8	0.6	16.85	0.4	0.2
37.35	7.9	62.4	49.25	0.1	0.0	19.05	2.6	6.8
			50.40	1.3	1.7	17.05	0.6	0.4
	Sum....	241.1	50.60	1.5	2.2	14.00	2.4	5.8
			52.55	3.4	11.6	15.50	0.9	0.8
			51.50	2.4	5.8	12.05	4.3	18.5
			46.85	2.2	4.8			
			49.55	0.4	0.2		Sum....	92.5
			46.10	2.9	8.4			
			42.85	6.2	38.4			
			47.00	2.0	4.0			
			51.35	2.2	4.8			
				Sum....	265.8			

STATION POCASSET.

Beacon-pole—Copecut.		
29.00	△	△²
26.95	2.0	4.0
31.95	2.9	8.4
25.25	3.7	13.7
28.55	0.4	0.2
31.75	2.7	7.3
28.25	0.7	0.5
29.60	0.6	0.4
31.35	2.3	5.3
30.15	1.1	1.2
28.55	0.4	0.2
32.10	3.1	9.6
31.25	2.2	4.8
29.20	0.2	0.0
28.90	0.1	0.0
35.85	6.8	46.2
26.05	2.9	8.4
28.35	0.6	0.4
30.80	1.8	3.2
29.45	0.4	0.2
31.40	2.4	5.8
26.15	2.8	7.8
27.75	1.2	1.4
24.95	4.0	16.0
27.40	1.6	2.6
23.45	5.5	30.2
	Sum....	177.8

Great Meadow—Copecut.		
09.38	△	△²
09.20	0.1	0.0
07.75	1.6	2.6
09.25	0.1	0.0
07.85	1.5	2.2
08.25	1.1	1.2
09.65	0.2	0.0
05.25	4.1	16.8
09.60	0.2	0.0
08.05	1.3	1.7
11.80	2.4	5.8
08.40	0.9	0.8
07.75	1.6	2.6
09.95	0.5	0.2
11.85	2.4	5.8
10.75	1.3	1.7
09.55	0.1	0.0
09.05	0.3	0.1
08.85	0.5	0.2
10.85	1.4	2.0
14.55	5.1	26.0
09.35	0.0	0.0
08.40	0.9	0.8
10.05	0.6	0.4
11.00	1.6	2.6
09.00	0.3	0.1
07.55	1.8	3.2
08.70	0.6	0.4
10.70	1.3	1.7
09.90	0.5	0.2
11.80	2.4	5.8
09.95	0.5	0.2
10.50	1.1	1.2
05.95	3.4	11.6
09.40	0.0	0.0
08.40	0.9	0.8
09.35	0.0	0.0
09.45	0.0	0.0
	Sum....	98.7

RECAPITULATION.	
△²	No. of series.
79.2	34
90.7	24
77.5	42
103.8	33
202.0	29
161.2	32
241.1	30
265.8	40
92.5	34
177.8	25
98.7	27
1590.3	350—11

$e_{\angle}^2 = 2.134$

$e_{\angle} = \pm 1''.461$

$\varepsilon_{\angle}^2 = 0.667$

$\varepsilon = \pm 0''.259$

RECAPITULATION OF RESULTS.

The following table exhibits the average probable error of any single observation of an angle ($e_\angle$) and of the result ($\varepsilon_\angle$):

(METHOD B.)

Station.	Occupied in—	$e_\angle$	$\varepsilon_\angle$
		"	
McSparran	1844	±1.361	±0.263
Spencer	1814	1.048	.170
Pocassett	1844	1.461	.259
Copecut	1844	1.261	.219
Beacon-pole......	1844	1.015	.180
Manomet.........	1845	1.271	.205
Holt	1846	1.333	.227
Agamenticus	1847	1.238	.210
Unkonoonuc	1848	0.925	.159
Mt. Pleasant	1851	1.095	.179
Ossipee..........	1851	1.569	.220
		"	"
	Mean	1.234	±0.208

APPENDIX No. 34.

Extracts from the abstract of reports made in 1854 *by Captain T. J. Cram, Corps of Topographical Engineers, assistant United States Coast Survey, in charge of a secondary triangulation party.*

In this abstract, of course, it will not be attempted to go any further into the details of the field-work, for obtaining the data for the results herein reported, than will be necessary to lead the mind to a proper understanding of the main features of the general report, consisting of four parts, from which this abstract has been compiled.

In my secondary triangulations in the States of Maine and New Hampshire, it became necessary to determine the heights above the mean level of the sea of the various stations established for the survey. Indeed, without the vertical ordinates of the points of a survey, it cannot be regarded complete.

It is well known that there are four methods, all independent of each other, for obtaining the heights of a point s'' above another point s' upon the earth's surface:

I. By levelling with the levelling instrument from s' to s''.

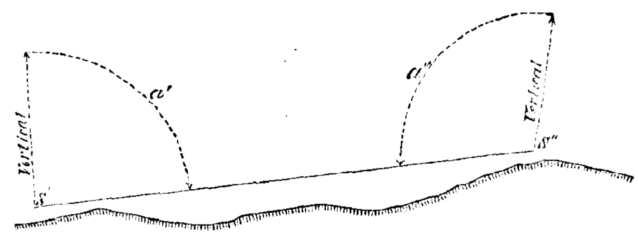
II. By measuring with a theodolite, or any other suitable instrument, planted at s', the angle of elevation of s'', or its zenith distance; and knowing the distance from s' to s'' with that angle and this distance, we compute the height of s'' above s' by means of formulæ constructed for the purpose.

III. By the barometer and thermometer used at both stations s' and s'', and computing by a formula the difference of elevation.

IV. By observing the boiling-point of water and the temperature of the air at the two stations, s' and s'', and from these observations computing by a formula the difference of elevation of s' and s''.

By authority and under the direction of the Superintendent of the U. S. Coast Survey, I have, in connection with my secondary triangulations, put all four of these methods in requisition, to a very great extent, having conducted my observations in such a manner as to give what are denominated "simultaneous results;" so that a result obtained by either of the four methods may be fairly compared with the results obtained by the other three methods. In this consists one of the several peculiar merits of the plan I have followed in my observations.

In order to render what is here meant a little plainer than words alone can well do, I illustrate by the following simple diagram:



1. I have levelled direct and reversed, as explained in Part I of my report, so as to avoid errors due to terrestrial refraction between s' and s'', and obtained the difference of level of s' and s'', which I will here represent by..............d^{i}.

2. With a first-rate repeating theodolite stationed at s', and another stationed at s'', the reciprocal zenith distances a', a'', have been measured with these zenith distances and the known distance (horizontal or otherwise) between s' and s''. I have computed, by the existing formulæ, the height of s'' above s', which I will designate by..............d^{ii}.

3. Precisely at the *same minute* of measuring the zenith distances aforesaid, I have had taken (with a double set of standard barometers and thermometers, of the most approved form, especially constructed for the occasion) the usual barometric observations at s' and s'', and with these observations, and by the barometric formula, I have computed the difference of elevation between s' and s'', which I will designate by..............d^{iii}.

5. Precisely at the *same minute* of measuring the zenith distances and taking the barometrical observations aforesaid at s' and s'', with a double set of boiling-point apparatus, of the most approved form, I have had the boiling-point of water and the temperature of the atmosphere observed, and from these, with the formula and tables applicable to this method, I have computed the difference in elevation of s' and s'', which I will designate by..............d^{iv}.

By these four methods, and in the manner now explained, I have applied the instruments to many cases in the field, during two seasons, and have taken especial pains, sparing no labor or personal fatigue, to select such examples as would give results of practical utility in furthering the objects of the survey on which I have been engaged, and likewise of service in the general problem of determining the vertical ordinate of any point on the earth's surface.

The summit of Mount Washington having been observed upon in the primary triangulation, I have carried my observations to its very summit, in the manner I have explained for the levelling instrument, the barometer, and the boiling-point. I divided the whole elevation of that mountain into steps of five hundred feet difference in elevation, thus forming twelve benches or stations at which I have conducted my simultaneous observations.

The examples afforded by these benches, and many others selected among the numerous Coast Survey stations I have established and occupied with instruments in the seasons I have been engaged on the Coast Survey, will all be given in Part I, Part III, and Part IV, of the general report which I have rendered to the Superintendent, and in Part II, which I have not yet rendered, but which is in progress.

Part I contains the results, &c.	d^{i}
Part II......do...........do..	d^{ii}
Part III......do...........do..	d^{iii}
Part IV......do...........do..	d^{iv}

It will be observed that I have so conducted my observations that d^{i} becomes a proper standard of comparison by which to ascertain the error incidental to each of the four methods in general use for the determination of the height of a point on the earth's surface.

In my general report I have, among other things, especially aimed at attaining to a measurement of these errors, and then to point out the sources of these errors, and to suggest what may be done to avoid or to correct them, so that the results obtained by the methods of which d^{ii}, d^{iii}, d^{iv}, are the exponents, may be made to correspond more nearly with the results d^{i} given by the levelling instrument, the method by this instrument being regarded as the standard.

I. Sources of errors in the existing published formulæ for determining d^{ii}.

Of these formulæ, at present, two will be considered—the French and the Prussian. The first is adopted in Capt. Lee's Collection of Formulæ and Tables, published by the Bureau of Topographical Engineers. The Prussian has been translated by Mr. Schott for the Coast Survey, and put into my hands for trial.

I have shown, in Part II of my report, that there is an assumption made in the construction of the French formula that militates against a well-known and recognised geodetic principle. This assumption is alone sufficient to entitle that formula to be regarded as of little merit for purposes where accuracy is required.

Again, in the same collection of tables, published by the Bureau of Topographical Engineers, there is one purporting to be from Lieut. Frome, of the British service, for correcting for the effect of terrestrial refraction. In this table, it is assumed that this effect has always the same sign for all distances, heights, &c.; and in Gummere's surveying, the idea is inculcated that the effect is generally to apparently elevate the signal observed on, or to diminish the zenith distance. Now, I have proved beyond cavil, in my experience, that neither of these assumptions is in accordance with the truth.

In the Prussian formula it is assumed, that by observing simultaneously the reciprocal zenith distances a', a'' (see Figure) and placing these in the formula, the effect of refraction, as it enters a', will cancel the effect as it enters a''; and this same idea is entertained in the French formula. Now I have shown, in Part II, that this is tantamount to supposing that, in observing at s' upon s'', the amount of the refraction is the same, and of the same sign as observing at s'' upon s'. This is an assumption which I prove, by my experience, to be erroneous.

Again, in the French and Prussian formulæ, a quantity enters by the name of "coefficient of refraction," and its value is given for different seasons as applicable to the atmosphere of France and Prussia. But if applicable to those climates, it will not serve, as determined by those formulæ, as a coefficient applicable to our Atlantic coast east of Massachusetts. I have shown, that if we use the Prussian formula for that portion of our coast, we must adopt a very different value for this element in the computation of d^{ii}.

Having pointed out all I intend at present in reference to the sources of error in d^{ii}, I will exhibit the amounts of the errors in d^{ii}, computed by the Prussian formula, for a few of my cases, in the following tabular form:

Heights d^{i}, given by the levelling instrument.

Same heights d^{ii}, by theodolite zenith distances, using the Prussian formula with Capt. Cram's coefficient of refraction, and this formula with the Prussian coefficient of refraction.

Stations s'.	Stations s''.	d^{i} in feet.	d^{ii} in feet.	Error in d^{ii} coefficient of Capt. C.	Error in d^{ii} coefficient Prussian.
Fairfield	Agamenticus	539.3	541.1	+1.7	−5.5
Summit	Fairfield	67.9	67.2	−0.7	−2.5
Stage Island	Fairfield	126.5	127.1	+0.6	−1.1
Cape Neddock	Agamenticus	625.6	626.2	+0.6	−5.6
Great Boar's Head	Hampton Falls	198.5	196.8	−1.7	−11.6
Cole's Hill	Agamenticus	551.6	553.2	+1.6	−5.3
Great Boar's Head	Isles of Shoals	24.2	25.3	+1.3	+27.1

From the foregoing table, it is seen that if we use the Prussian formula for determining heights trigonometrically, we shall very materially reduce the error in the results d^{ii} by using my coefficient of refraction.

I have determined the coefficient of refraction in a large variety of cases, and the values of this element will be reported in Part II of my report.

Angle of refraction—In measuring the zenith distances a', a'', (see the figure.) The effect of the vertical component of refraction called "terrestrial refraction," has been generally considered in Part I of my report; but the measurements of this component are all contained in Part II, wherein I have recorded a very great number of these measurements, made with great labor, not only in the field but likewise in the office. I have constructed a general formula, applicable in any case that occurs on the coast survey, for determining the amount and the sign of the angle of refraction, so that, having it, we can correct the observed zenith distance, and make it such as would have been observed were there no such cause existing. Of course, in making an abstract, it would be out of place to insert all these numerous measurements, with the simultaneous measures of the density and temperature of the atmosphere. To give an insight, however, into the plan I have adopted for the angle of refraction, I abstract the accompanying table. The negative sign before the "angle of refraction" expresses that refraction apparently depressed the signal observed upon, and the positive sign indicates that it apparently elevated the signal.

The true zenith distance given in the table is that which would have been observed if unaffected by refraction. The angle E, seen in the table, has a signification not necessary to be explained here, but it is fully explained in Part II.

The case I take is one of reciprocal simultaneous observations of zenith distances.

c' and c^{i} are the centres of the vertical limbs of the instruments; K the Coast Survey distance of the stations.

Diff. of level c' above c=38^{m}.56; c above the mean sea-level =8^{m}.95, K=5646^{m}.24.

Topography of the ground from Fairfield Hill to Stage Island, ¼ green woods, ½ pasture and field, ¼ tide-water.

At Fairfield Hill, C. S. station, E affected by refn. = 0° 02′ 18″.83 True *z. d.* of c = S″ =90° 25′ 00″.11				At Stage Island, C. S. station, E affected by refn. = 0° 13′ 8″.28 True *z. d.* of c' = S′ =89° 38′ 2″.79			
Time of observation.	Stand. barom. to 32° F.	Temp. atmosphere, F.	Angle of refraction.	Time of observation.	Stand. barom. to 32° F.	Temp. atmosphere, F.	Angle of refraction.
1852.			″	1852.			″
July 29, 10 to 11 M.	29.647	75.90	−41.34	July 29, 10 to 11 M.	29.782	70.92	+22.44
July 29, 1 to 2 A..	29.566	79.00	−14.94	July 29, 1 to 2 A..	29.701	70.67	− 4.31
July 30, 4 to 5 A..	29.276	84.95	−26.47	July 30, 4 to 5 A..	29.412	82.32	− 0.91
August 4, 6 to 7 A.	29.836	62.35	+ 0.28	August 4, 6 to 7 A.	29.974	61.70	+22.44

From this table, giving the angle of refraction, we see how erroneous is the assumption, that the refraction in one zenith distance will cancel that in the other, when we come to compute the height by the Prussian, or indeed by any formula known.

It is evident, however, that by obtaining the amount and sign of the angle of refraction, we can free the observed zenith distance from its effect, and then, by a formula properly constructed, we could compute the height free from errors incident to refraction. Such a formula I have constructed, and presented in very convenient shape in Part II. The formula is entirely original with me, and I have the satisfaction, after a vast deal of labor spent upon it, of believing it is, in connexion with the plan of using the angle of refraction, far better calculated to give d^{ii} in agreement with d^{i} than any formula known. In connexion with this I had intended to arrange my numerous tables of the angle of refraction in proper classification, in reference to distance, difference of elevation, season of the year, hour of the day, topography, density of the atmosphere, temperature, &c., &c., and thus to present to the Superintendent of the Coast Survey, for future use in the work under his charge, what I regard as an unequalled formula, with its appropriate tables in extenso—purely American—for geodetically determining the heights of the Coast Survey stations, or indeed any point on the earth's surface, so that the result will be the same, or exceedingly near the same, as would have been obtained by the levelling instrument.

I have the data all reduced to standard values for ten cases of the angle of refraction, *in the same vertical plane*, so selected that the visual ray from instrument to instrument occupies all directions under a fixed line in the atmosphere; also the data for a great variety of cases, where the instrument is placed at different elevations above the sea, to observe across the sea, and this at low tide, high tide, mean ebb, and mean flood; also numerous cases of observing over a sand and pebble beach, at various given stages of tide; likewise a very large number of cases of observing in different vertical planes upon the same signal, and upon different signals; also cases of observing along and near to the sea-side, and then in directions perpendicular thereto; likewise cases of observing over ground when dry, and the same ground when covered at highest stages of water, &c., &c. For each and all these, the original plan on which I commenced this work was, to obtain the angle of refraction and tabulate, as shown in the example herewith submitted; all this and more, of practical use for the Coast Survey, I had intended to present in Part II of my report.

II. Sources of error in the existing published formulæ for determining d^{iii}.

This, it will be remembered, involves the consideration of the determination of heights by the barometer. The results of many of my measurements of the errors in d^{iii} are given in Part III of my report rendered to the Superintendent. I abstract what is seen in the accompanying tables, to exhibit the amounts of these errors, in a few cases taken from each of the four methods explained in Part III, of combining the observations.

Heights d^{i}, by levelling instrument, used as explained in Part I of my report.

Same heights d^{iii}, by barometer; first method by two barometers simultaneously at the two stations, as explained in Part III of my report. The barometric formula used is Baily's, as elegantly republished in the collection by Topographical Bureau, probably the best in use.

Station s'.	Station s''.	d^{i} in feet.	d^{iii} in feet.	Least error in d^{iii}.	Greatest error in d^{iii}.
Summit (1)	Fairfield	68.3	72.1 77.3	+3.8	+9.0
Stage Island	Fairfield	126.3	130.9 133.4	+4.6	+7.1
Cape Neddock	Agamenticus	624.6	626.3 633.1	+1.7	+8.5
Great Boar's Head	Hampton Falls	198.7	197.1 176.0	−1.6	−22.7
Little Boar's Head	Great Boar's Head	3.5	1.9 72.7	−1.6	+69.2

Heights d^{i}, by levelling instrument, &c.

Same heights d^{iii}, by barometer; second method, interpolated simultaneous observations, one barometer, case *a*, explained in Part III of my report. Formula from Baily's collection.

Station s'.	Station s''.	d^{i} in feet.	d^{iii} in feet.	Least error in d^{iii}.	Greatest error in d^{iii}.
Summit (2)	Fairfield	56.8	53.9 66.6	−2.9	+9.8
Stage Island	Fairfield	126.3	126.2 135.3	−0.1	+9.0
Cape Neddock	Agamenticus	624.6	621.3 642.2	−3.3	+17.6
Great Boar's Head	Hampton Falls	198.7	181.3 172.9	−17.4	−25.8
B. M., No. 7	B. M., No. 3	2000.0	2017.5		+16.5

Heights d^{i}, by levelling instrument.

Same heights d^{iii}, by barometer; third method, interpolated simultaneous single observations, one barometer, case *b*, explained in Part III of my report. Formula from Baily's collection.

Station s'. On side Mount Washington.	Station s''. On Mount Washington.	d^{i} in feet.	d^{iii} in feet.	Least error in d^{iii}.	Greatest error in d^{iii}.
B. M., No. 8	B. M., No. 7	500.0	506.5 491.3	+6.5	—8.7
B. M., No. 8	B. M., No. 6	1000.0	952.1	....	—47.9
B. M., No. 8	B. M., No. 5	1500.0	1472.4	....	—27.6
B. M., No. 10	B. M., No. 6	2000.0	3037.1	....	+37.1
B. M., No. 8	B. M., No. 3	2500.0	2512.3	....	+12.3

Heights d^{i}, by levelling instrument, &c.

Same heights d^{iii}, by barometer; fourth method, indiscriminate means of observations, explained in Part III of my report. Formula from Baily's collection.

Station s'.	Station s''.	d^{i} in feet.	d^{iii} in feet.	Least error in d^{iii}.	Greatest error in d^{iii}.
B. M., No. 12 Near tide-water, Portland, Maine.	B. M., No. 0 Summit Mount Washington, White mountains, N. H.	6280	6206	....	—74
B. M., No. 12	B. M., No. 5	3780	3732	....	—48
B. M., No. 12	B. M., No. 9	1780	1655	....	—125
B. M., No. 6	B. M., No. 2	2000	1988	....	—12
B. M., No. 5	B. M., No. 0	2500	2550	....	+50

It is clearly proven, by the numerous results I have obtained by taking my B. M. for s', at different elevations, from mean tide to over 6,000 feet above it, that the constants in the barometric formula now in use need to be modified. In other words, the constant that will answer in the formula for measuring differences of elevation, when s' and s'' are both near the level of the sea, will not answer when s' and s'' are higher up in the atmosphere. For example, suppose s'' the summit of Mount Washington, and s' the B. M. 500 feet below the summit; for this 500 feet difference in elevation so high up in the atmosphere, there needs to be a different constant than for an equal difference of elevation near the base of the mountain.

One of the ends I had in view in being so particular in establishing my B. M.'s on the side of Mount Washington, was for the very purpose (in connection with what will be explained in Part II) of determining more befitting values of the constant in the barometric formula. Then, and not until then, can we expect to reduce the errors that we now find so conspicuously pervading d^{iii}. In my opinion, it is in this constant that we must look for the principal source of the errors in d^{iii}, and not in the construction of the instrument.

I intended to construct a table of corrections to apply to the constant, according as we are observing at the top and bottom of a height more or less elevated in the atmosphere.

III. Sources of error in determining the heights d^{iv}.

This involves the consideration of heights determined by the boiling-point. The results of many of my measurements of the errors in d^{iv} are given in Part IV of my report rendered to the Coast Survey office.

What I shall abstract from that, for present purposes, will be briefly to the point under consideration, viz: sources of error pertaining to the method.

I take some of the cases, few in number, in which s' and s'' may be supposed to be ascending in the atmosphere. It will be remembered I call the method of determining d^{iv}, when we use the usual form of the Fahrenheit thermometer for noting the degree of the boiling-point; the "thermometric method," as explained in Part IV, using the formula of Dubuat and the tables published by Regnault for this purpose; and that when d^{iv} is determined by using Würdemann's apparatus, giving the height of the boiling-point on a scale of barometric equivalents, and then using the formula for the barometer, as explained Part IV, I call it the "thermo-barometric method."

Dubuat's formula is constructed upon the plan, that, observing by an F. thermometer the temperature at which water boils, we can compute, from his formula, the equivalent height of the mercury which a barometer would have indicated at the same time and station. Regnault, in his table, assumes that, by noting the temperature by a C. thermometer at which the water boils, his table will also give the simultaneous height that would have been shown by the barometer at the same place. This table has been adapted to the F. thermometer, and introduced into the publication, by the Bureau of Topographical Engineers, as Table XXIII. At s' and s'' I have, in a great many cases, used the barometer simultaneously with noting the boiling-point, and the following tables show the results:

Comparison of weights of the atmosphere indicated simultaneously by the boiling-point of water and by the barometer, to test Dubuat's formula.

Observe.—The mercurial column in the barometer measuring the above weight is the observed reduced to 32° F. attached thermometer. Likewise is the equivalent column computed from Dubuat's formula reduced to the same 32° F.

Stations s'.	Stations s''.	Weight of atmosphere by barometer.	Weight of atmosphere by Dubuat's form'a.	Error by Dubuat's formula.
		Inches.	*Inches.*	
Cape Neddock harbor		29.877	29.830	—0.047
	Cape Neddock, C. S. station	29.785	29.514	—0.271
Piscataqua river		29.949	30.149	+0.200
	Bartlett, C. S. station	29.863	29.830	—0.033
Fort Constitution		29.912	29.593	—0.319
	New Castle, C. S.	29.832	29.357	—0.475
Tide Gauge, Kennebunkport		30.065	29.682	—0.383
	Crow Hill, C. S.	29.846	30.332	+0.486
Wells harbor		29.967	30.497	+0.530
	Cole's Hill, C. S.	29.822	29.521	—0.301

Comparison of the weights of the atmosphere indicated simultaneously by the boiling point of water and by the barometer, to test M. Regnault's table as adopted by Bureau of Topographical Engineers.—Table XXIII.

Stations s'.	Stations s''.	Weight of atmosphere by barometer.	Weight of atmosphere by boiling-point. Table XXIII.	Error in Regnault, or Table XXIII.
Cape Neddock harbor		29.884	30.281	+0.395
	Cape Neddock, C. S. station	29.785	29.921	+0.136
Piscataqua river		29.949	30.522	+0.573
	Bartlett, C. S.	29.863	30.221	+0.358
Fort Constitution		29.912	29.996	+0.084
	New Castle, C. S.	29.832	29.773	—0.059

There are many more, but the above are those in which the error is the least; all the others would show greater discrepancies.

Heights d^{i}, by levelling instrument, used as explained in part I of my report.
Same heights d^{iv}, by boiling-point, "thermometric method," using Dubuat's formula or Regnault's table, or Table XXIII Topographical Bureau.

Stations s'.	Stations s''.	d^{i} in feet.	d^{iv} in feet.	Errors in d^{iv}.
Cape Neddock harbor	Cape Neddock, C. S.	60.9	367.4	+306.5
Piscataqua river	Bartlett, C. S.	96.5	293.4	+196.9
Fort Constitution	New Castle, C. S.	56.6	221.4	+164.8
Tide Gauge, Kennebunkport	Boothbay, C. S.	46.8	74.3	+ 27.5
Tide Gauge, Kennebunkport	Fairfield, C. S.	132.3	149.4	+ 17.1

Three thermometers were made by Mr. Würdemann, of Washington, for observations of the boiling-point, from which the foregoing results have been derived.

It is now apparent that either Table XXIII, derived from that of M. Regnault, is grossly in error, or that such thermometers as were made by Mr. Würdemann especially for the purpose are entirely inadequate to indicate the proper boiling-point, or both causes may exist to vitiate the results.

I now pass to the consideration of the "Thermo-Barometer." This is a form given to the thermometer for the purpose of determining the boiling-point that shall at once give the equivalent weight of the atmosphere, as would be had by the barometer in inches instead of degrees of temperature, superseding the necessity of a reduction by a formula like that of Dubuat, or a table like that of Regnault. This instrument is fully described, with a drawing, in Part IV of my report. The boiling apparatus made by Mr. Würdemann was provided with three of these, which, in their scales, partake of the barometer scale, and in their bulbs and stems containing the mercury, partake of the thermometer. It is for these reasons I denominate them "Thermo-Barometers." I have used these quite extensively at s' and s'', for a great many cases simultaneously with the barometer. These are all recorded in Part IV, from which I abstract a few in order to show the comparison of results and the degree of reliance to be put in this instrument.

In the table I shall introduce the height determined simultaneously with the barometer, in order to bring the results given by the "Thermo-Barometer" boiling-point, by the barometer, and by the levelling instrument, into juxtaposition—that is, we shall have d^{ii}, d^{iii}, and d^{iv} compared, and the errors in each case with their signs.

Heights d^{i}, by levelling instrument.
Same heights d^{iii}, by barometer .... } Observations simultaneously
Same heights d^{iv}, by thermo-barometer boiling-point water } taken.

Stations s'.	Stations s''.	d^{i} in feet.	Barometer.		Thermo-barometer boiling-point.	
			d^{iii} in feet.	Error in d^{iii}.	d^{iv} in feet.	Error in d^{iv}.
Cape Neddock	Bald Head	83.7	77.9	—5.88	111.8	+28.2
Cape Neddock	Agamenticus	680.0	794.7	+14.7	787.2	+86.5
Great Bay	Stratham	289.4	323.3	+33.9	277.0	—12.4
Great Boar's Head	Hampton Falls	198.9	186.7	—12.2	72.6	—126.3
B. M., No. 12	B. M., No. 0	6280.0	6206.0	—74.0	6116.0	—164.0
B. M., No. 12	B. M., No. 6	3280.0	3206.0	—74.0	2804.0	—476.0
B. M., No. 6	B. M., No. 0	3000.0	3020.0	+20.0	3304.0	+304.0
B. M., No. 5	B. M., No. 2	1500.0	1506.0	+6.0	1602.0	+102.0
B. M., No. 6	B. M., No. 4	1000.0	982.0	—18.0	997.0	—3.0
B. M., No. 2	B. M., No. 0	1000.0	1049.0	+4.90	1244.0	+244.0
B. M., No. 3	B. M., No. 1	1000.0	990.0	—10.0	1117.0	+117.0

By inspecting the foregoing table, it will at once be seen that the results given by the barometer, however erratic they may seem, wander less from those by the levelling instrument than do the results given by the thermo-barometric boiling-point apparatus.

Whatever errors in d^{iii} may be attributed to the constant in the barometric formula, will likewise be found in the results d^{iv}, as this formula is used for both instruments.

But there are other causes—the defects inherent in the essential parts of the "Thermo-Barometer"—which must be remedied by the manufacturer before it can be brought into successful competition with the barometer. I refer to the mercury with which the thermo-barometer is filled; the glass of which the bulbs and stems are made; the metallic scales. During the act of heating to boiling-point at one station, s'', these three parts expand; and on cooling, do they return to the same condition as before? I am satisfied this question must be answered in the negative for the apparatus made by Mr. Würdemann which I used, not only in respect to thermometers A, B, C, but likewise in reference to thermo-barometers No. 1, No. 2, No. 3. There is a want of uniformity in the expansion and contraction of each of the substances, which the observer cannot remedy, but which I find to exist in the use of the instrument, and which is, and, unless a remedy be applied, must continue to be, the cause of great discrepancies. To one acquainted with the laws of expansion and contraction, it is only necessary to hint the fact to enable him at once to realize the force of this objection to the boiling-point apparatus, as one to greatly impair confidence in its capacity to give results at all to be relied on, whoever may be the instrument maker.

I have the honor to be, most respectfully, your obedient servant,

T. J. CRAM,

Captain Topographical Engineers, Assistant Coast Survey.

Professor A. D. Bache, L. L. D.,
Superintendent U. S. Coast Survey.

APPENDIX No. 35.

Description of the United States Coast Survey apparatus for measuring base lines. By Lieut. E. B. Hunt, U. S. A., and assistant United States Coast Survey, (Sketch No. 54.) Communicated to the American Association for the Advancement of Science, by authority of the Treasury Department.

In conducting a trigonometrical survey, each connected scheme or system of triangulation involves the lineal measurement of a base line, besides the angular measurement of the vertical and horizontal angles special to each triangulation station, and the astronomical determinations of latitudes, longitudes, and azimuths. As angular measures can be repeated with great facility, a high accuracy is always attainable with portable instruments, arranged so as to permit the free use of the principle of repetitions. But linear measurements consume so much time, and are so costly, that it is only to a limited extent practicable to repeat extended base line measures, such as those executed in geodetic operations. Hence the apparatus for base measurements requires to be sufficiently perfect to insure, if possible, from a single measurement, a degree of accuracy corresponding with that resulting from the numerous repetitions of observations by the angle instruments employed. As the apparatus length enters a great number of times in a base line, any error of the apparatus is likely to enter the total base length in a highly magnified form, as also an error of the base length will, in exact proportion, affect the general geodetic results. As the elements of the earth's figure and magnitude are entirely deduced from the several triangulations executed, and as a very minute accuracy of these elements is essential to the discussion of station errors and local actions, it follows that any serious imperfection of the base apparatus will greatly diminish the general geodetic value of the results and the scope of the local discussions. For these reasons the requisition for extreme accuracy is eminently rigorous in the construction of a geodetic base apparatus.

The United States Coast Survey extends along the entire Atlantic, Gulf, and Pacific seaboard of our country, and is limited to the narrowest belt which will suffice for the due location of the primary triangles. For this reason, as also to promote the accuracy and facility of its results, our coast has been, since 1844, progressively distributed into eleven sections, (nine on the Atlantic and Gulf, and two on the Pacific,) in each of which the triangulation proceeds separately, starting from its own base, and, by its connections with the adjoining triangulations, giving and deriving a verification of all prior operations. In two or three of these sections it is almost certain that extra bases will be found necessary or advantageous, as, in flat, heavily-wooded countries, the primary triangles must be small and numerous, so that accuracy will require some additional bases. Thus it will be seen that certainly eleven, and probably fourteen or more, bases will ultimately have to be measured with the utmost accuracy, as part of the Coast Survey operations. As each of these will be from five to ten miles long, the total length of Coast Survey base line required will approach near to a hundred miles. Hence it is evident, that even for economical reasons, the apparatus employed should be as portable and every way as convenient for field use as possible, consistently with its accurate working.

The main essentials for a base-measuring apparatus are embraced in the following general conditions:

I. The extreme points of the apparatus used as measuring limits must, under all circumstances of operation, remain at an invariable distance from each other, or the corrections for variations in this distance must be capable of easy and accurate determination.

II. The distance between the measuring limits must be compared with the standard unit of length to the last degree of attainable accuracy, and its precise length so determined.

III. In the apparatus, the necessary parts and constructions for its easy and safe transportation, firm support, accurate contacts or coincidences, for slope measurements, and also all requisite auxiliaries to the several adjustment manipulations, must be so provided and combined as to give the whole a union of portability, convenience, and delicacy.

The Coast Survey apparatus, as it now stands, was devised with special regard to all the conditions for extreme accúracy and convenience in the field. Some slight modifications, indicated by experience in its use during the measurement of three base lines, have since been embodied; but, in the main, the apparatus remains unaltered from the plans devised by Professor Bache in 1845, and executed, under his direction, in 1845 and 1846, by Mr. Wm. Würdemann, then mechanician of the Coast Survey, to whom many of the details of arrangement are due. It may here be stated, that the experience of three base-line measurements with this apparatus, has fully shown it to be a highly satisfactory solution of the problem proposed, and it has been found to excel alike in accuracy, economy, and facility of use.

A base-line being duly reconnoitred, opened, and graded, and monuments being fixed for the permanent preservation of its extremities, or the base station points, the measurement proper proceeds. The apparatus sent to the field for this purpose, when a primary base is to be finally measured, consists of the following parts: 1. Two measuring tubes exactly alike, each being packed for transportation in a wooden box. 2. Six trestles for supporting and adjusting the tubes, three being fore-trestles and three rear-trestles, each of which is packed for transportation in a three-sided wooden box. 3. Eight or more iron foot-plates on which to support the trestles; and a wooden frame is afterwards made, to serve as a guide in laying down the foot-plates. 4. Manipulating handles for the adjustments; a theodolite for making the alignment, and for occasionally referring the tube end to stakes driven for the purpose; also some minor auxiliaries. 5. A standard six-metre bar of iron, in its wooden case, arranged for comparisons, and a Saxton's pyrometer, arranged for indicating minute variations in length.

The measuring-tubes are carefully compared with the standard-bar before beginning the measurement, and again after its completion, to make sure of the exact condition of the somewhat complex mechanism in the measuring-tubes. For these field-comparisons the pyrometer is simplified, by causing the bar or tube undergoing comparison, to abut against the spherical head of an arm, springing horizontally from the vertical axle, to which is attached the mirror for reflecting the remote arc-graduations into the telescope fixed on this arc. Variations or inequalities of the bars examined act on the arm, and thus turn the mirror, causing it to reflect the corresponding arc-reading into the telescope. A spring is so arranged as to make the arm-head press with a constant pressure against the bar-end.

When the comparison with the standard is completed, the foot-plates are successively placed, by the aid of the wooden spacing frame, which gives an approximate distance and alignment. Four trestles are so placed and levelled on these plates, that the three foot-screws of each rest in three radial grooves of the plates. The two tubes are then mounted on their trestles, and the rear extremity having been adjusted vertically over the station-point, the fore-tube is then adjusted to make a contact with the rear-tube extremity by means of a level of contact. Both tubes have to be first aligned by the aid of a theodolite advanced some distance on the line, or following the measurement, in the field of which two standing sights, one on each tube, are made to cover. The placing of plates proceeds as fast as is necessary for keeping work always provided for the tubes, and the extra trestles being duly placed and approximately adjusted, the rear-tube is carried forward in place, and the adjustments executed. Thus the components of the apparatus are carried from rear to front, in a determined order; and the measuring operations consist in the preparation for, and execution of, these progressive transfers, in effecting the more delicate adjustments, and in making a full record of all the essential circumstances. Points marked on copper nails in the heads of well-driven stakes, usually indicate temporarily the end of each day's work, and great care is taken permanently to secure the precise extremity, or base-station point, from all disturbance.

From this synopsis of the general character and mode of using the Coast Survey base apparatus, a ready and intelligent transition to the details of its composition and construction can now be made. While many minute arrangements and parts of this apparatus must here be unnoticed, I will endeavor to present a satisfactory summary, such as will enable the members of this association to inspect, with all necessary insight, the apparatus itself, which is now open to their examination at the Coast Survey office.

The tube is a spar-shaped double casing, Fig. 1, designed especially to embrace and protect the trusses which support and stiffen the system of bars on which the actual measurement depends. Its length is nearly six metres, or about twenty feet. The length of any simple bar of iron, or other metal, is so much affected by variations of its temperature as to make it necessary, where such bars are used for base measurements, constantly to observe and correct for the temperature, the formula for correction being derived from previous experiments. But changes of temperature cannot, in this case, be exactly determined so as to know, at a given moment, the precise condition of the bar undergoing change; hence the temperature correction is always uncertain in its value, besides causing much extra labor in observing and reducing. This makes apparent the importance of an arrangement, the limiting points of which will always be found at a constant distance apart under all field-circumstances of temperature. No single material can give this exemption from expansions and contractions. It is found, however, in a combination of two metals having different rates of expansion, and hence admitting a resort to the principle of compensation, illustrated in the gridiron or compensating clock pendulum.

This principle was independently applied to the construction of base apparatus, composed of two bars, one of brass and one of iron, connected by a lever of compensation at their ends, first by Colonel Colby, in the Ordnance Survey of Ireland in 1827; (see Captain Yolland's Lough Foyle Base, p. 10;) and again by Mr. Borden, of Fall River, in the Massachusetts Survey, during the winter of 1830. (See Palfrey's Tables, Survey of Mass., p. 1; Am. Phil. Trans., vol. IX, p. 34; and N. Am. Rev., Oct., 1845, pp. 458-461.) Mr. Borden made no provision for causing the two bars in his apparatus to change their temperatures at the same rate, though his tin tubular arrangement admirably checks the frequency and rapidity of such changes as, in practice, they must undergo. Colonel Colby attempted, by the aid of varnishes and lampblack coatings, as fixed by numerous experiments in 1827, to make both bars maintain the same temperature during the changes of surrounding heat. He made both bars of the same cross-section, and thought, by regulating the surface radiation and absorption, to effect the required equalization of rate for heating and cooling. His method, though giving a good approximation, is radically faulty, in not taking the specific heats and conducting powers of the bars into the account. The method first introduced and originated by Professor Bache, is capable of insuring a very perfect equalization of temperature in the two bars. By numerous experiments, in 1845 and '46, he so arranged the cross-sections of the bars, as that while the two have equal absorbing surface, their masses are inversely as their specific heats, allowance being made for their different conducting powers. Thus, while each receives the same accession of heat in a given time, the temperature of the two will continue equal, because, except for the conducting-rates, their masses are inversely as their specific heats. The same varnish on both surfaces gives them equal absorbent powers. The last minute adjustment of compensation was effected by making one surface slightly more absorbent than the other, as required by circumstances. Thus, as both bars vary essentially together, the point of compensation is never shifted by their diverse actions under thermal variations.

A bar of brass and a bar of iron, each less than six metres long, are supported parallel to each other, and at one end are so firmly connected together by means of an end-block, in which each bar is mortised and strongly screwed, as there to preserve an unalterable relation. The brass bar, which has the largest cross-section, is sustained on rollers, mounted in suspending stirrups, and the iron bar rests on small rollers, which are fastened to the iron bar, and run on the brass one. Supporting screws through the sides of the stirrups are adjusted to sustain the bars in place, and also serve to rectify them. Thus, while the two bars are relatively fixed at one end, they are elsewhere free to move, and hence the entire expansions and contractions are manifested at the free end. The medium of connection between the free ends of the two bars is the *lever of compensation*, which is joined to the lower or brass bar by a hinge-pin, around which it turns during changes of temperature. A steel plane on the end of the iron bar abuts against an agate knife-edge on the inner side of the lever of compensation. This lever terminates in a knife-edge, turned outward at such a distance from the centre pin and the other knife-edge bearing, that the end edge will remain unmoved by equal changes of temperature in the two bars. The end edge presses against a steel face in a loop made in the *sliding rod*. This rod slides in a frame fastened to the top of the iron bar, and passes through a spiral spring which acts with a constant force to press the loop against the knife-edge. The outer end of the sliding rod bears the limiting agate plane. Thus the end agate is not effected in position by the expansions of the brass and iron, acting as they do at proportional distances along the lever of compensation, measured from its sliding-end bearing. The rates of expansion for iron and brass may safely be taken as uniform, between the extreme expansions and contractions to which they are subject in practice, and the compensating adjustment once made is permanent.

The stirrups sustaining the rollers on which the brass bar runs, are made fast to the main horizontal sheet of the iron supporting and stiffening work. This consists of a horizontal and a vertical plate of boiler-iron, joined along the middle line of the horizontal sheet by two angle irons, all being permanently riveted. Circular openings are cut out from both plates to lighten them as much as practicable. A continuous iron tie-plate, turned up in a trough-form, connects the bottoms of all the stirrups. At the ends, stiffening braces connect the two plates.

We now pass from the compensating to the *sector end* of the tube, at which extremity are arranged the parts giving the readings, and for adjusting the contacts between successive tubes in measuring, thus making it the station of the principal observer. The sector end terminates in a *sliding rod*, which slides through two upright bars, and at its outer end bears a blunt agate knife-edge, horizontally arranged, which in measuring is brought to abut with a uniform pressure against the limiting agate plane of the compensating end of the previous tube. At its inner end this sliding rod rests against a cylindrical surface on the upright *lever of contact*, so mounted as at its bottom to turn around a hinge pin. At top this lever rests against a tongue or drop lever descending from the middle of the *level of contact*, which is mounted on trunnions. The sliding rod, when forced against the side of the lever of contact, presses its top against the tongue of the level, and thus turns the level by overcoming a preponderance of weight given to its farther end to insure the contact being always at a constant pressure between the agates, the same force being always required to bring the bubble to the centre.

The sector is a solid metal plate, mounted with its centre of motion in the line of the sliding rod, and having its arc graduated from a central zero to the limits of ascending and descending slopes on which the apparatus is to be used. A fixed vernier in contact with the arc gives the slope readings. A long level and bubble scale are so attached and adjusted to the face of the sector plate, that the zeros of the level and of the limb correspond to the horizontal position of the whole tube. If, then, on slopes, the bubble be brought to the middle by raising or lowering the arc end of the sector, (a movement made by a tangent screw, whose milled head projects above the tin case of the tube,) the vernier will give the slope at which the tube is inclined, and the sloping measure is readily reduced to the horizontal by means of a table prepared for the purpose. The level of contact and the lever of contact, with their appendages, are all mounted on the sector and partake of its motions.

A knife-edge end of the sliding rod presses on the cylindrical face of the contact lever, this cylinder being concentric with the sector, and the sector can therefore be turned without deranging the contact. In fact, the contacts are made with the sector level horizontal, thus insuring the accuracy of the contact pressure. The contact lever is supported at bottom by two braces dropping down from the sector plate, and a spring, acting on a pin in the lever, steadies it against an adjusting screw end. A bracket from the sector plate receives the trunnions of the contact level. A small screw projects from the end of the tube to clamp or set the lever and level of contact against a pin in the sector for security in transportation.

What is called the *fine motion*, required for adjusting the contacts between the successive tubes, is produced by means of a compensating rod or tube, one end of which is attached to the truss frame by a bracket over the rear trestle, and the other receives a screw terminating in a projecting milled head. This screw turns freely in a collar, bearing, by a projecting arm, against the cross-bar which joins the main brass and iron bars, and its nut is in the end of the compensation rod. By turning the screw in one direction the bars are pushed forward, and the opposite turning permits a spiral spring, arranged for the purpose, to push back the system of bars, which slides through its supports. Thus the contact is made, by turning the screw until the contact level is horizontal. The compensating rod is composed of several concentric tubes, alternately of brass and iron, arranged one within the other, and fastened at opposite ends alternately. Thus when a contact has been made by the *fine motion* screw, changes of temperature will not produce derangement, as would be the case if this rod were not compensating. The arrangement permits the observer conveniently to work the fine-motion screw, and to observe its action on the contact level.

The apparatus thus described is enclosed in a double tin tubular case, diaphragms being adapted for supporting and strengthening the whole. The air chamber between the two cases, 1½ inches apart, is a great check on heat variations. Three side openings, with tin and glass doors in each tube, permit observations of the parts and of inserted thermometers. The ends are *closed*, only the sliding-rod ends projecting at each extremity, exposing the agates. Brass guard-tubes protect these, and for transportation tin conical caps are screwed on the tube ends. The fine-motion screw, the sector-tangent screw, and the contact lever-clamp screw, project beyond the case. The tube is painted white, which, with the air-chamber and thorough-compensation, effectually obviate all need of a screen from the sunshine, which has usually been deemed requisite.

The tube rests on a fore-trestle and rear trestle, which are alike, except in the heads. Each trestle has three legs, composed of one iron cylinder, moving in another by means of a rack, pinion and crank, so as to raise or sink the head plate. The levelling and finer adjustment is by means of a foot-screw in each leg, by working which a circular level on the connecting frame is adjusted. A large axis screw, resting on the connecting frame, and rising into a tubular nut, is turned by bevelled pinions worked by a crank, and thus raises or lowers this tubular nut, and the cap piece which it supports at top. The axis-screw, the leg-racks, and the foot-screws, give three vertical movements in the trestle, by which its capacity for slope measurements is much amplified.

In the cap of the rear trestle a lateral and a longitudinal motion are provided for, by means of two tablets arranged to slide, the upper one longitudinally on the lower one, and the lower laterally on the head plate of the axis-screw tube. Long adjusting screw handles extend to the observer's stand from these two plates, and from the axis-screw enabling him to raise or lower, to slide forward or back, to the right or the left, the rear end of the tube The fore-trestle is similar, except that its head is only arranged for a lateral movement, and a second observer makes its adjustments by a simple crank.

Four men can carry a tube, by levers passed through staples in blocks, strapped under the tubes. The principal observer, and an assistant, make the contacts and rectifications, the first assistant directs the forward tube, and another preserves the alignment with a theodolite. A careful recorder notes down the observations, and an intelligent aid places the trestles and foot-plates. The labor of grading, especially in level sand-lines, is quite trifling.

The first base line measured with the apparatus now described was the Dauphine Island base, near Mobile, and about seven miles long, which was measured by Professor Bache in 1847. (Coast Survey Report 1847, p. 39.) The party was on the ground six weeks, between April 30th and June 12th, though only 17 working days were consumed in the final measurement. The greatest day's work was 183 tubes, or near seven-tenths of a mile. From some remeasurements the greatest supposable error for the entire base was computed to be less than six-tenths of an inch.

The second base measurement with this apparatus was also by Professor Bache in 1848, (Coast Survey Reports, 1848, p. 43, and 1849, p. 38,) being the Bodie's Island base, N. C., of about six and three-quarter miles long. Ten working days were employed in the actual measurement, between the 4th and 23d of November. The greatest day's work was 1,692 metres, or 1.06 mile, in eight and a half hours. Several partial remeasurements give the total probable error for the entire base at less than one-tenth of an inch, and the greatest supposable error at less than three-tenths of an inch.

The only other base hitherto measured with these means is the Edisto Island base, S. C., which operation was conducted by Professor Bache between the 3d and 18th of January, 1850, (Coast Survey Report 1850, p. 34,) thirteen days being occupied in the actual measurement. Its length is about six and two-thirds miles, and it was much more uneven than the previous base. The greatest day's work was 1,122 metres, or about three-fourths of a mile. A partial remeasurement gave one-tenth of an inch as the probable accidental error of measurement for the whole base.

It will be abundantly evident, on examining the results of other modes of measurement, that the Coast Survey apparatus is a superior combination of the requisite elements for such operations, giving a gain in accuracy, rapidity, and economy of use, over its predecessors. The multiplication of bases is no longer a source of such formidable expenditures of time and money; hence geodetic operations are much facilitated and benefited by this fundamental improvement in the instruments employed. The more perfect compensation from regulating the masses of the bars, the application of the principle of contact indication by the level, the stiffness of the support for the bar system, the sector for slope measurements, and the trestles, combining such a variety of movement with very great firmness; these features all attest the thorough study of the problem which was made by Professor Bache, preparatory to calling forth the peculiar skill of Mr. Würdemann. Bessel's contact-level, before employed in the comparison of standards, has the same readily available accuracy in this apparatus, and should supersede the comparing microscope entirely for final measurements. For field comparisons with standards, the peculiarly elegant principle of Saxton's pyrometer is even better than the contact-level.

Whatever improvements may still need to be made in base measuring apparatus, this important point is now reached: that the bases are measured at once with an accuracy far exceeding that of the angular measures given by any practicable number of repetitions on portable angle instruments, and of the same order with the comparisons between the actual standards and their copies used in the measurements.

APPENDIX No. 36.

Letter of Professor Peirce, of Harvard, to the Superintendent of the Coast Survey, enclosing his report on longitude by moon culminations.

HARVARD UNIVERSITY, *November* 6, 1854.

DEAR SIR: I have the honor of submitting to you the following report of my investigations upon longitudes conducted under your directions. It embraces my complete report upon the subject of moon culminations, which I have introduced into its title.

Yours, very respectfully,

BENJAMIN PEIRCE.

Professor A. D. BACHE,
Superintendent U. S. Coast Survey.

Report upon the Determination of Longitude by Moon Culminations.

GENERAL CONSIDERATIONS.

1. When any fixed and constant quantity, such as the longitude or latitude of a place, the direction of the meridian of a place, the angle of one distant object from another at a given station, &c., is observed directly or determined indirectly by one observation, that one observation must, in the deficiency of all other information, be adopted as the true value of this constant. But the single observation does not of itself throw any light upon the degree of accuracy of this determination, or indicate how far it is to be relied upon.

2. A second observation gives a second determination, which is always found to differ from the first. The difference of the observations is an indication of the accuracy of each, while the mean of the two determinations is a new determination which may be regarded as more accurate than either.

3. Each additional observation corresponds to a new determination, but the mean of all is better than either, for it is less affected by the individual errors of observation than any other possible combinations of the observations. The comparison of the mean with the individual determinations has shown, in all cases in which such comparison has been instituted, that the errors of lunar observation are subject to law, and are not distributed in an arbitrary and capricious manner. They are the symmetrical and concentrated grouping of the shots of a skilful marksman aiming at a target, and not the random scatterings of a blind man, nor even the designed irregularity of the stars in the firmament. This law of human error is the more remarkable, and worthy of philosophic examination, that it is precisely that which is required to render the arithmetical mean of observations the most probable approach to the exact result. It has been made the foundation of the method of least squares, and its introduction into astronomy by the illustrious GAUSS is the last great era of this science.

4. If the law of error embodied in the method of least squares were the sole law to which human error is subject, it would happen that by a sufficient accumulation of observations any imagined degree of accuracy would be attainable in the determination of a constant; and the evanescent influence of minute increments of error would have the effect of exalting man's power of exact observation to an unlimited extent. I believe that the careful examination of observations reveals another law of error, which is involved in the popular statement that "man cannot measure what he cannot see." The small errors which are beyond the limits of human perception, are not distributed according to the mode recognised by the method of least squares, but either with the uniformity which is the ordinary characteristic of matters of chance, or more frequently in some arbitrary form dependent upon individual peculiarities—such, for instance, as an habitual inclination to the use of certain numbers. On this account it is in vain to attempt the comparison of the distribution of errors with the law of least squares to too great a degree of minuteness; and on this account *there is in every species of observation an ultimate limit of accuracy beyond which no mass of accumulated observations can ever penetrate.*

A wise observer, when he perceives that he is approaching this limit, will apply his powers to improving the methods, rather than to increasing the number of observations. This principle will thus serve to stimulate, and not to paralyze effort; and its vivifying influence will prevent science from stagnating into mere mechanical drudgery.

5. In approaching the ultimate limit of accuracy, the probable error ceases to diminish proportionably to the increase of the number of observations, so that the accuracy of the mean of several determinations does not surpass that of the single determinations as much as it should do in conformity with the law of least squares; thus it appears, in the present investigation, that the probable error of the mean of the determinations of the longitude of the Harvard Observatory, deduced from the moon culminating observations of 1845, 1846, and 1847, is $1^s.28$ instead of being $1^s.00$, to which it should have been reduced conformably to the accuracy of the separate determinations of those years.

6. When various determinations of the same constant are compared together, they are frequently found to differ to an extent which demonstrates errors peculiar to the different methods of determination, and which are called *constant errors*. When the constant errors are incident to a person, they are known as *personal equations*. The investigation of the constant errors is a difficult matter of research, but quite important to the present inquiry,

because they tend to conceal the law of error involving the ultimate limit of accuracy, and to give erroneous impressions in regard to the position of that limit.

7. When many determinations of the same constants are given, the form of their mutual grouping must indicate whether or not they are subject to constant error, and what amount of constant error is to be attributed to each determination. I am not, however, aware that there is any instance of a sufficient number of different determinations of the same constant to authorize such an examination.

8. When there are only a few determinations of kinds, in regard to which nothing is known as to their liability to constant error, the hypothesis of constant error is generally not required, and therefore not admissible, unless the combined result is less accurate than the best of the single determinations; that is, unless the probable error of the combined result is greater than the least of the probable errors of the single determinations. The probable errors in all these cases must be ascertained by the customary method of least squares. But the combined result cannot be obtained by the method of least squares, unless it be known what is the relative weights of observations in the different determinations.

9. If the observations are, in all respects, of the same kind, they may be assumed to be of equal value; or, in most cases, their relative value may be assumed to be reciprocally proportional to the squares of their probable errors, as ordinarily determined. The formulas for combining the determinations in these forms are given in the accompanying paper, (A.*)

10. The demonstration that given series of observations are liable to appreciable constant errors is so important, that it ought not to be considered as complete and satisfactory, if it can be shown that there is any method of combining the different determinations in which the combined result is more exact than the best of the single determinations. A special investigation of this question is, therefore, given in the annexed paper, (B.*)

11. The conclusion that there is a constant error in given determinations, is greatly strengthened when the application of the criterion would lead to the rejection of one of the determinations, or to the rejection of as many observations from the combined result as are contained in either of the determinations.

12. The existence of a constant error may, however, be proved, even when it fails to be detected by the preceding methods, if the determinations are of two classes which agree among themselves, while they differ from each other.

13. The application of these considerations to the determination of longitudes by moon culminations, will appear in subsequent portions of the report.

CORRECTION OF THE LUNAR EPHEMERIS.

14. The most serious difficulty in the reduction of moon culminations arises from the acknowledged errors of the lunar ephemerides, which often exceed twenty seconds of arc. These errors might be greatly diminished by the computation of a new ephemeris from the more exact "Tables of the Moon," published in the Office of the Nautical Almanac, under the direction of Commander Davis; but the labor of such a computation would be exceedingly great, and would not probably conduce to greater accuracy than can be more expeditiously obtained by empirical modes of deriving the corrections from direct observation, nor would it be likely to prevent the necessity of ultimately resorting to empirical corrections.

15. The empirical method sometimes adopted of correcting the lunar ephemeris by assuming the mean of all the observed errors of any period as the constant error for that period, cannot be safely employed for a longer period than two or three days, for the variations of the error are so great, that in a week they often change by twenty or thirty seconds of arc, passing from their maximum to their minimum values, or the reverse.

16. After carefully scrutinizing the Greenwich observations of the moon, I arrived at the conclusion that the variation of the error of longitude is usually subject to two maxima and minima in the course of the month, so that its principal period is about half a month. This variable portion must be the resultant of several errors of nearly the same period; for its modulus and argument are not constant, but differ considerably in different months. Notwithstanding the evident imperfection of the hypothesis, the convenience of a uniform

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* Omitted.

rule decided me to try if a sufficiently accurate empirical method of correcting the ephemeris could not be derived from supposing the variable portion of the error to have this period of a fortnight throughout each lunation, combined with the supposition that the constant portion of the error is different for each limb of the moon. The formulas for this method are given in the annexed paper, (C.)

17. The result of the trial seems to me to authorize the conclusion that this method may safely be used in all cases, and that it gives as accurate determinations of longitude as can be obtained from observations of moon culminations. It has the great advantage of retaining all the observations made in any place for finding its longitude, even if there are no simultaneous observations at the standard observatories; but the inquiry into the value of the method depends upon many and complicated elements, of which the ascertaining of some fixed standard, which may be adopted as the probable error to which observations of the moon are liable, is one of the most important.

STANDARD PROBABLE ERROR OF OBSERVATIONS OF A LUNAR TRANSIT.

18. The defects of the lunar ephemeris are an insurmountable obstacle to the determination of the probable error of observation of the moon by direct comparison with theory. There is even too great an uncertainty as to the nature of the theoretical errors to authorize the use of any of the elements of the ephemeris, except for quite a short interval of time.

19. The comparison of simultaneous transits, observed by different observers, on very nearly the same meridians, affords almost the only solution of this problem. The transits observed upon the same night at Greenwich and Edinburgh during the years 1836, 1838, 1839, 1840, 1843, 1845, 1846, and 1847, have accordingly been compared together; and also those made at Cambridge and Edinburgh in the year 1844, and those made at Washington in the year 1846 with the meridian circle and west transit. In instituting the comparison, the observations of the two limbs have been discussed separately. The average difference between the observations of either limb at two places has been regarded as constant error, and is not included in the probable error. The formulæ and directions for making this comparison are contained in the accompanying paper, (D.*)

20. The computations for the determination of the standard error are contained in the annexed sheets, marked (1 — 16, D′;) they have been prepared by Mr. Edward Goodfellow, the nicety of whose numerical arrangements is recommended to the favorable notice of the Superintendent of the Coast Survey. The sheets (1, 2, and 3, D′) contain the computations of the moon's motion in R. A. during the interval of passage from the Greenwich to the Edinburgh meridian for all hourly motions within the extreme limits of the lunar vibrations; these hourly motions are arranged in the table of the sheet, (4 D′.) In the same way the sheets (5 and 6, D′) contain the computations of the moon's motions in R. A., during the interval of passage from the Cambridge to the Edinburgh meridian, which are combined in the table of sheet (7 D′,) and sheet (8 D′) contains the table and its computations for Greenwich and Cambridge. The sheets (9, 10, and 11, D′) contain the comparisons of the right ascensions of the first limb of the moon observed at Greenwich and Edinburgh during the above named years, and the determination of the corresponding probable error of observation. A similar comparison of observations of the first limb of the moon at Cambridge and Edinburgh is contained in sheet (12 D′.) The comparison of the observations of both limbs observed in the meridian circle and west transit at Washington is contained in sheet (13 D′.) The observations of the second limb at Greenwich and Edinburgh are compared in sheets (14 and 15 D′,) and those of the second limb at Cambridge and Edinburgh are compared in sheet (16 D′.) The sheet (16 D′) also contains the combination of all these probable errors into a final *standard probable error of observation.*

21. The following abstract gives a condensed view of these results of the computations contained in the sheets (D′):

* Omitted.

Places of compared observations.	Limb of the moon.	No. of observations.	Constant error.	Probable error.
Greenwich and Edinburgh	I.	207	0″.061	0″.105
Cambridge and Edinburgh	I.	30	0 .015	0 .051
Washington, M. C., and W. T.	I.	17	0 .134	0 .112
Greenwich and Edinburgh	II.	92	0 .0	0 .102
Cambridge and Edinburgh	II.	14	0 .035	0 .068
Washington, M. C., and W. T.	II.	7	0 .16	0 .123
Final standard probable error of observation	....	367	....	0 .101

22. If no regard had been given to constant error, the final standard would only have been increased to 0″.104.

23. It is evident that these probable errors are influenced to some extent by the personal equations of the observers, although they are partially eliminated with the constant error.

24. Another method of obtaining the probable error of observation consists in the comparison of the longitudes of the moon, determined from the observations made with the meridian circle at Greenwich, with those determined from the observations made with the alt-azimuth instrument.

The details of this computation for the observations of the year 1851, are contained in the annexed paper (E.)* The number of meridian observations employed in this comparison is 105, and the resulting value of the probable error is 2″.087, which is equivalent to 0″.139 in right ascension.

THE LIMIT OF ACCURACY ATTAINABLE IN THE DETERMINATIONS OF LONGITUDE BY MOON CULMINATIONS.

25. If the lunar ephemeris were perfect, the error of the difference between the moon's observed and computed right ascension would be exclusively attributable to defects of observation; and the probable error of each difference would be the same as that of observation. The probable error of a determination of longitude from a single culmination of the moon would, therefore, be equal to the quotient of the probable error of observation divided by the moon's mean motion, during a second of time, in right ascension expressed in time. The standard probable error, adopted from the comparison of the culminations, gives, then, 2″.734 for the probable error of a single determination of longitude from a lunar transit, reduced by the aid of a perfect ephemeris.

26. The imperfections, from which the lunar ephemeris cannot be delivered in the present state of astronomical science and art, augment the error of the comparison with observation. The square of the probable error, obtained upon the hypothesis of the perfect ephemeris, must be increased by the square of the probable error of the ephemeris; and the probable error of the determination of longitude must be increased proportionally to the increment of the probable error of the comparison. *This obvious and simple rule for ascertaining the probable error of a comparison, affords a ready means for the comparison of the different methods of reducing moon culminations, and the determination of their relative accuracy.*

27. The original method of reducing moon culminations, and the only one, so far as I am aware, which has hitherto been adopted in the Coast Survey, is the simple comparison of the observations taken at the place whose longitude is sought, with observations made during the same night at the standard observations. The mean of all the observations made at the observatories, takes the place of the ephemeris, and is subject to a probable error dependent upon their number, combined with the error of the lunar motion, which is, in most cases, adopted from theory. The error of the lunar motion is unimportant, and may be rejected. The number of observations at the fixed observatories united in each mean, may be assumed as three; so that the square of the probable error of each mean is one-third of the standard probable error of observation. Hence the square of the probable error of each comparison made by this method, is four-thirds of the square of the probable error of observation. But the method involves the loss of about one-third of the

* Omitted.

moon culminations observed for longitude, the effect of which upon the mean result is equivalent to increasing, by its half, the square of the probable error. The value of the method is, therefore, the same as if the ephemeris were perfect, and the probable error of each observations were the square root of twice the square of the probable error of observation, or $0^s.142$. The probable error of each determination of longitude, by this process, is then $3^s.18$; but, in consequence of the loss of observations, it is equivalent to $3^s.89$, when it is compared with forms of reduction in which all the observations are retained.

28. The method of correcting the ephemeris for any interval of time by a constant quantity, which is equal to its average discrepancy from the observations at the fixed observatories for that interval, gives a probable error to the corrected ephemeris, which is distinct from the errors of observation. Its investigation must be made a special subject of discussion, and the details of such a research, applied to the Greenwich observations of the year 1846, are contained in the annexed paper (F.)* The fruit of this inquiry is a corrected ephemeris, of which the probable error is $0^s.087$. The probable error of each comparison with observation is, consequently, $0^s.133$; and that of each determination of longitude is $3^s.65$. This method is, therefore, more valuable than the preceding.

29. The modified method of correcting the ephemeris for each semi-lunation, which I propose for final adoption by the Coast Survey, which is referred to in my former report, and is described in paper (C.) has been subjected to the test of actual experiment by an application to Greenwich observations of the first six months of the year 1846. The corrected ephemeris, thus obtained, is liable to a probable error of $0^s.060$. The probable error of each comparison with observation is $0^s.117$, and that of each determination of longitude is $3^s.20$. This method surpasses, then, either of the others in accuracy, and seems to accomplish all that can be expected in the reduction of moon culminations. The details of the preliminary trial are contained in the annexed paper (G.)*

30. The accuracy of each of these methods is diminished when the observations made for longitude are inferior to the assumed standard. In such cases, the probable error of a determination of longitude, by either of the three methods, is greater than the value given in the preceding paragraphs, but the relative value of the different determinations is not much changed.

31. By the law of error, recognised in the method of least squares, the mean of ten thousand observations of moon culminations corresponds to a determination of longitude, of which the probable error is only one-hundredth part of that of a single determination, or about three-hundredths of a second; such a degree of accuracy would correspond to a probable error of only one-thousandth of a second in the moon's epoch, independently of the errors of the lunar theory. Such a result is a deceitful trick of numbers; it is an illusion emanating from the unwarrantable extension of a partial law of human error, to the neglect of other laws equally well authenticated. Even one-tenth part of this error is greater than can be claimed, with any show of reason, for observations in which no observer pretends to be capable of observing the transit over each wire of the telescope nearer than to the tenth of a second.

One of the fundamental principles of the doctrine of probabilities is, that the probability of an hypothesis is proportionate to its agreement with observation. But any supposed or computed lunar epoch may be changed by several hundredths of a second without perceptibly affecting the comparison with observation, provided the comparison is restricted within its legitimate limits of tenths of a second. Observations, therefore, gives no information which is opposed to such a change.

32. In order to arrive at a more definite conclusion as to the ultimate limit of accuracy, I propose to consider a few cases which, although they are hypothetical, seem to me to illustrate the argument.

First.—Suppose an observer, of perfect and unlimited powers of nice observation, to observe the transits of a star which constantly crossed the wire of his telescope (supposed to have but one,) at the same precise instant by his sidereal clock, and suppose the observer to record his observations only to seconds. In this case, the probable error, computed by the theory of least squares, would be nothing, for all the records would be identical; and yet the actual probable error of each record is, obviously, a quarter of a second, and the probable error of the mean is also one quarter of a second. If the actual instant of the star's transit was slightly variable to an unknown extent, but not enough to vary the recorded second, the probable error of the mean would be reduced, and might even become

*Omitted.

as small as an eighth of a second. If the instant of transit varied sufficiently to vary the recorded second, and introduce another second into the record, the probable error of the mean would be still more diminished, and might even be reduced to nothing. When the instant of transit varies, according to a known law, so far as to introduce more than two different seconds into the record, the probable error vanishes. But the vanishing of the probable error is due, not only to the unprecedented accuracy of the observer, but to the vibration of the instant of transit, and exhibits quite strikingly that which I have before alluded to as the evanescent influence of minute changes of error.

Secondly.—Suppose an observer of perfect powers of observation exterior to a certain limit, but within those limits totally incapable of distinguishing differences of error; suppose, for instance, that, according to seconds, he cannot detect an error of one second; in this case, however the instant of the star's transit may vibrate, the probable error of each observation is a quarter of a second, and that of the mean cannot be reduced beyond this limit.*

Thirdly.—The actual case of an ultimate limit of measuring perception with an ill-defined boundary cannot reasonably be supposed to have the advantage over the case just supposed of the exact boundary. It cannot, then, be that the ultimate limit of the accuracy of an average determination can be, more than in a four-fold degree, superior to the ultimate accuracy of measuring perception.

Now it may be safely assumed that one-tenth of a second is the ultimate limit of measuring capacity in the case of a lunar transit; and, therefore, the ultimate limit of the accuracy of a determination of the lunar epoch is $0^s.025$, and that of the longitude of a place by moon culminations is $0^s.55$.

33. This ultimate limit of accuracy of the longitude of a place derived from moon culminations, can be so nearly attained by the observations of a few years, that a longer continuance of them for this purpose must be censured as a waste of time and labor. It leads to a perplexing variety of results, without contributing to accuracy. By heaping error upon error it may crush the influence of each separate determination, but does not diminish the relative height of the whole mass of discrepancy.

34. In the preceding investigation of the ultimate limit of accuracy, the effect of those obscure sources of constant error, which are manifest in the discrepancy between the determinations derived from the two limbs of the moon, has not been regarded. This discrepancy, in the mean determinations of a year, often amounts to ten seconds. In the absence of all means for deciding how this discrepancy is to be divided between the two limbs, it cannot be doubted that the ultimate limits of accuracy must be extended, *and the assumption that it is as great as one second of time seems to be a very moderate widening of the limits.*

The opinion here given as to the ultimate accuracy of determinations of longitude by moon culminations, has been long since expressed by me at scientific meetings; and the error of a second which has just been detected in the established difference of longitude of Paris and Greenwich confirms this conclusion.

35. The admission of an ultimate limit of accuracy involves a modification of the mode of computing probable errors, and the formulæ for such a modification are contained in the annexed paper (H.)

36. An evidence of the difficulty of dividing the discrepancy between the determinations of longitude given by the two limbs is afforded by the comparisons in the paper (D′.) Thus the errors of the difference of longitude of Greenwich and Edinburgh, deduced from the comparisons of the two limbs, are as follows:

In 1836 and 1838, by I limb	$+5^s.8$	by II limb $-1^s.5$
1839 and 1840	$+1.7$	$+4.5$
1843 and 1845	-1.1	-0.2
1846 and 1847	-1.5	-2.7
On the average	$+1.5$	0

Those of Cambridge and Edinburgh are for the first limb $-0^s.4$, and for the second limb $+1^s.2$; and the corresponding meridian observations of the moon made at Washington upon the first limb place the meridian circle $3^s.3$ to the west of the west transit, while those made upon the second limb place it $3^s.9$ to the west. In no case, therefore, does an equal

* NOTE.—It is singular, that if this observer records to double-seconds, the probable error of the mean vanishes, so that in this imaginary case the attempt at greater accuracy by an over-nice record thwarts its own object.

distribution of the discrepancy lead to a correct result, and it is quite remarkable that the case of least discrepancy corresponds to that of the greatest actual error.

37. With this great liability to error, the method of moon culminations cannot come into competition or combination with other methods of determining longitude, which are susceptible of ten times greater accuracy. Such a degree of accuracy seems to be quite possible of attainment between Europe and America by means of chronometric expeditions, and perhaps still more accurate determinations can be derived from a judicious and thorough reduction of all the observations of occultations, especially of the Pleiades, as suggested by Bessel and Walker.

But in cases like that of the Atlantic ard Pacific coasts of America, in which chronometric expeditions cannot be undertaken, and in which there is no sufficient accumulation of observations of occultations, the method of moon culminations must be retained. On this account it is of great importance to free them as far as possible from the greatest element of discrepancy—that of *personal equation.* In view of its relation to this subject, I have made a special investigation of the influence of personal equation upon astronomical observations, and shall present you my report upon it within a few months.

THE LONGITUDE OF THE NATIONAL OBSERVATORY.

38. After having corrected the lunar ephemeris, the application of it to the determination of a special longitude is quite simple and requires no elucidation. The annexed papers (I) contain such an investigation for determining the longitude of the National Observatory from the Washington observations of 1845, 1846, the Harvard Observatory, and the Philadelphia High School observations of 1845, 1846, and 1847. The resulting longitude is 5*h.* 8*m.* 29*s.*, with a probable error of 1*s.*

ABSTRACT OF (C.)

The first portion of (C) consists of an investigation, from the Greenwich observations, of the nature of the defects of the lunar theory. The conclusion is, that these defects are involved in several terms, which for each lunation may be principally combined into two, of which one is constant and the other has a period of about half a month. General formulæ are given for discussing the corrections of the ephemeris upon this basis, which are applied to the years 1845, 1846, 1847, and 1851. But it is subsequently shown that, for all practical purposes, it is quite as accurate, and more convenient, to reduce the correction of the ephemeris for each semi-lunation to the form

$$A+Bt+Ct^2,$$

in which A, B, and C are constants which are to be determined from the observations at the fixed observatories, and t denotes the time.

Three different modes of investigating the value of A, B, and C are proposed, each of which has its peculiar advantages, and for which the forms are subjoined for the use of practical astronomers.

First form of correcting the lunar ephemeris, founded upon the method of least squares.

Let t denote the interval of time between the date of the observation and some assumed epoch, which had better be taken as near as possible to the mean of the observations of the semi-lunation. The value of t is expressed in days, and the fraction of the day may be neglected.

Find for the semi-lunation the values of T, T_2, T_3, and T_4, such that

T = the algebraic sum of the values of t,
T_2 = the sum of the squares of t,
T_3 = the algebraic sum of the cubes of t,
T_4 = the sum of the fourth powers of t.

Let n denote the excess of each observed right ascension of the moon's limb above that of the ephemeris. If the observation is not made at Greenwich, the observed right ascension is to be increased by the average excess for the year, determined by simultaneous observations of the observations of the right ascension of the moon's limb made at Greenwich above those made at the actual place of observation.

Find the values of N, N_1, and N_2, such that

N = the algebraic sum of the values of n,

N_1 = the algebraic sum of the product of n multiplied by t,

N_2 = the algebraic sum of the products of n multiplied by t^2.

If m denotes the number of observations, the equations for the determination of A, B, and C, are—

$$mA + TB + T_2 C = N$$
$$TA + T_2B + T_3 C = N_1$$
$$T_2A + T_3B + T_4 C = N_2$$

The algorithm of the solution of these equations is represented in the following expressions:

$$T_2' = T_2 - \frac{T^2}{m},$$

$$T_3' = T_3 - \frac{TT_2}{m},$$

$$T_4' = T_4 - \frac{T_2^2}{m}$$

$$N_1' = N_1 - \frac{TN}{m},$$

$$N_2' = N_2 - \frac{T_2N}{m},$$

$$T_4'' \quad T_4' - \frac{(T_3')^2}{T_2'},$$

$$N_2'' = N_2' - \frac{T_3' N_1'}{T_2'},$$

$$C = \frac{N_2''}{T_4''}$$

$$B = \frac{N_1' - T_3'C}{T_2'}$$

$$A \quad \frac{N - T_2C - TB}{m}$$

The probable error of the ephemeris for any time t is M ϵ,

in which ϵ = the probable standard error of observation,

$= 0^s.104$

$$M = \sqrt{\left(\frac{1}{m} \pm \frac{t'}{T_2'} \pm \frac{t'''}{T_4''}\right)}$$

The values of t' and t''' are given by the formulæ—

$$t' = t \quad - \frac{T}{m},$$

$$t'' = t \quad + \frac{T}{m} + \frac{T_3'}{T_2''},$$

$$t''' = t' \, t'' - \frac{T_2'}{m},$$

and the signs are to be taken in such a way in the values of M, that each of the terms under the radical may be positive. The fractions may be neglected in the values of t', t'', t''', T_2', and T_4'', when used in the computation of M, which usually reduces the values to—

$$t' = t'' = t,$$

$$t''' = t^2 - \frac{T_2'}{m}$$

Second form of correcting the lunar ephemeris, founded upon Cauchy's method of interpolation.

In this form the assumed epoch of t must be the nearest date to the mean of the observations of the semi-lunation.

Find the arithmetical mean of all the values of t, which are negative, and denote it by —H. Find the arithmetical mean of the squares of all these values of t, and denote it by K. Find the arithmetical mean of all the corresponding values of n, and denote it by L Find the arithmetical mean of all the values of t, which are positive, and denote it by H′. Find the arithmetical mean of the squares of all these values of t, and denote it by K′. Find the arithmetical mean of all the corresponding values of n, and denote it by L. Find all the observations in which

$$t^2 - Pt < . Q$$

$$\text{in which } P = \frac{K' - K}{H' + H}$$

$$Q = \frac{KH' + K'H}{H' + H}$$

And, in these observations, take the arithmetic mean of the values of t, and denote it by H″; take the arithmetic mean of the squares of those values of t, and denote it by K″; take the arithmetic mean of the corresponding values of n, and denote it by L″.

The remaining computation is represented in the following expressions, which must be successively computed—

$$R = \frac{L' - L}{H' + H}$$

$$S = \frac{H'L + HL'}{H' + H}$$

$$R' = L'' - S - H''R$$

$$S' = K'' - Q - H''P$$

$$C = \frac{R'}{S'}$$

$$B = R - PC$$

$$A = S - QC$$

Third form of correcting the lunar ephemeris, founded upon Normal corrections.

Divide all the observations of the lunation into three groups, as nearly equal as possible; but such that the extreme observations of each group shall not include an interval of more than four days. Find, then—

U, U′, U″, = the arithmetical means of the values of t for the three groups respectively.
V, V′, V″, = the arithmetical means of the values of the squares of t.
W, W′, W″, = the arithmetical means of the values of n.

The remaining computation is represented by the following equations:

$$V_1 = \frac{V' - V}{U' - U} \qquad V_1' = \frac{V'' - V'}{U'' - U'}$$

$$W_1 = \frac{W' - W}{U' - U} \qquad W_1' = \frac{W'' - W'}{U'' - U'}$$

$$C = \frac{W_1' - W_1}{V_1' - V_1}$$

$$B = \tfrac{1}{2}(W_1' + W_1) - \tfrac{1}{2}(V'_1 + V_1)\,C$$

$$A = W' - V'C - U'B$$

Of these forms, the advantage of the first is its superior accuracy; that of the second, its diminishing of the large error; of the third, its brevity of computation.

Example of the application of these forms.

The following observations were made at Greenwich and Edinburgh in the year 1846, upon the first limb of the moon:

Greenwich observations.				Edinburgh observations.	
Date.	n.	Date.	n.	Date.	n.
	s.		''		''
March 2	—.07	March 8	—0.08	March 4	—0.21
4	—.28	10	+0.11	5	— .26
5	—.24	11	.29	7	— .20
6	—.26	12	.51	9	+ .15
7	—.19				

By taking March 7 for the epoch, the values of t are, respectively, —5, —3, —2, - 1, 0, 1, 3, 4, 5, —3, —2, 0, 2.

First form of computation.

$$m = 13 \qquad T = -1 \qquad T_2 = 107$$
$$T_3 = 29 \qquad T_4 = 1799$$
$$N = -.43 \qquad N_1 = 8.24 \qquad N_2 = 13.18$$
$$T_2' = 107 - .077 = 106.923$$
$$T_3' = 29 + 8.231 = 37.231$$
$$T_4' = 1799 - 880.68 = 918.32$$

Example.

$$N_1' = 8.24 - .0331 = 8.2069$$
$$N_2' = 13.18 + 3.5393 = 16.7193$$
$$T_4'' = 918.32 - 12.96 = 905.36$$
$$N_2'' = 16.7193 - 2.8575 = 13.8618$$

$$C = \frac{13.8618}{905.36} = 0''.015311$$

$$B = \frac{8.2069 - .5700}{106.923} = 0''.07142$$

$$A = \frac{-.43 - 1.6383 + .0715}{13} = -0''.154$$

The probable error of the ephemeris at the time t is

$$M_t = M\,(0s.104)$$

in which

$$M^2 = \frac{1}{13} \pm \frac{t}{107} \pm \frac{t^2 - 8}{905}$$

so that at the dates of 0, 3, and 5, respectively, the probable error of the ephemeris is 0*s*.03, 0*s*.03, and 0*s*.04.

Second form of computation.

$$H = 2.7 \qquad K = 8.7 \qquad L = -0.22$$
$$H' = 3 \qquad K' = 11 \qquad L' = .\ 0.256$$

$$P = \frac{2.3}{5.7} = 0.4035$$

$$Q = \frac{56.4}{5.7} = 9.895$$

The limiting values of t for the determination of H'', K'', and L'', are obtained from the inequality

$$t^2 - Pt < Q$$

and are

$$-2.9 < t < 3.4$$

so that the observations in this group are those of March 5, 6, 7, 8, 9, and 10. Hence,

$$H'' = .12, \qquad K'' = 2.9, \qquad L'' = -.084$$

$$R = \frac{.476}{5.7} = 0.0835$$

$$S = \frac{.0312}{5.7} = 0.00547$$

$$R' = -0.0999 \qquad S' = -7.045$$

Example.

$$C = \frac{-0.0999}{-7.045} = 0''.01418$$

$$B = 0.0835 - 0.0057 = 0''.0778$$

$$A = 0.00547 - 0.1403 = -0''.135$$

Third form of computation.

In this form let the first group consist of the observations of March 2, 4, and 5; those of the second group of those of March 6, 7, and 8, and the third group of the remaining observations. Hence,

$$U = -3, \qquad V = 10.2, \qquad W = -0.212$$

$$U' = 0, \qquad V' = 0.5, \qquad W' = -0.1825$$

$$U'' = 3.5, \qquad V'' = 13.5, \qquad W'' = 0.34$$

$$V_{,} = \frac{-9.7}{3} = -3.233, \quad V_{,}' = \frac{13}{3.5} = 3.857$$

$$W_{,} = \frac{.0295}{3} = 0.00983, \quad W_{,}' = \frac{.5225}{3.5} = 0.14929$$

$$C = \frac{.13946}{7.09} = 0''.01967$$

$$B = .07956 - .00613 = 0''.07343$$

$$A = -0.1825 - .0098 = -0''.192$$

The following table contains the residual errors, after applying the results of these three forms of computation:

	By first form.	By second form.	By third form.
	"	"	"
Greenwich observations, March 2	0.06	+0.10	0.00
4	— .05	—0.03	— .04
5	0	— .01	.02
6	— .05	— .06	— .02
7	— .04	— .06	0
8	— .01	— .04	+ .02
10	.21	.20	.21
11	— .09	— .11	— .13
12	— .07	— .10	— .18
Edinburgh observations, March 4	.02	+ .04	.03
5	— .02	— .03	0
7	— .05	— .07	— .01
9	.10	.07	+ .12

Example.

The sums of the squares of the errors in these three forms are—

In the first form 0.0807
In the second form 0.0942
In the third form 0.1116

To correspond to the value of the standard probable error of observation the sum of the squares should have been 0.1082, so that either of these results is of the requisite degree of accuracy to conform to this test. The form of computation is so short in either case that I should advise the use of all of them in each case to verify and confirm their respective results by mutual comparison.

APPENDIX No. 37.

Report of Professor W. C. Bond on moon culminations, observed by him during the past year, by the "American method."

CAMBRIDGE, *November* 9, 1854.

DEAR SIR: Since my last report, of October, 1853, there have been observed at this place fifty-six moon culminations with the requisite number of star transits, and sixteen occultations of stars by the moon. The moon culminations and transits have all been recorded by the electric process—the occultations usually by two, and sometimes by three observers, furnished with chronometers and with telescopes of different powers.

All the moon culminations which have been observed here since 1848 up to the present time have been completely reduced, and copies will be forwarded to the office as soon as duplicates can be prepared.

The calculations incident to the chronometric expedition for determining the difference of longitude between this and the Greenwich observatory have been finished, under the conduct of Mr. G. P. Bond. The resulting longitude by ninety-two different chronometers in nineteen voyages is *4h.* *44m.* 30.66*s.*, with a probable error ± of two tenths of a second of time.

Very respectfully, yours,

W. C. BOND.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey, near Camden, Maine.

APPENDIX No. 38.

Report of Professor E. Otis Kendall on the number of moon culminations, &c., observed at the High School Observatory, Philadelphia.

HIGH SCHOOL OBSERVATORY,
Philadelphia, November 13, 1854.

DEAR SIR: The observations for the Coast Survey were continued as usual up to the time of removing the instruments, in April last, the moon culminations observed amounting to about fifteen. Not having the record at hand, I cannot state the precise number. As you expressed a wish to have the observations continued at the new observatory, I had made arrangements by which I expected to resume them in October, but circumstances beyond my control have retarded the completion of the observatory and the mounting of the instruments. I now hope to have everything in readiness by the first of next month, when I shall commence observations with as little delay as possible.

Respectfully and truly yours,

E. OTIS KENDALL.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 39.

Discussion by J. E. Hilgard, Esq., of the probable error of observation with a twenty-six inch portable transit by Würdemann, from observations of Assistant G. Davidson, in 1853.

The observations embraced in this discussion were made on twenty-six nights, extending from June to October, 1853, at fourteen stations, in connection with the transportation of chronometers for the determination of longitudes on the northwestern coast.

The construction of the instrument employed (C. S. No. 7) is novel in some respects, combining steadiness with portability in an unusual degree.

The mean clock-error and instrumental corrections have been deduced from each night's observations, by the method of least squares. By applying these corrections to the observed times of transit, we obtain for each star a clock-error, (ω) which, compared with the mean clock-error, (Ω) gives a residual as error of observation. From a large number of such residuals the *probable error* of an observation has been deduced.

The following is a specimen of the work:

Stations.	Star observed.	$\Omega-\omega$.	$(\Omega-\omega)^2$
Telegraph Hill, San Francisco, July 5.	α Virginis	−0″.21	0.0441
	η Urs. Mag	+0 .08	64
	η Bootis	+0 .03	9
	α Bootis	0 .00	0
	ε Bootis	+0 .11	121
	α² Libræ	+0 .02	4
	β Urs. Min	−0 .06	36
Haven's anchorage, July 10	β¹ Scorpii	−0 .02	4
	1346 T. Y. C.	+0 .03	9
	1390 T. Y. C.	0 .00	0
	1396 T. Y. C.	+0 .01	1
	1418 T. Y. C.	+0 .01	1
	ε Urs. Min	+0 .02	4
	α Herculis	−0 .04	16
	1474 T. Y. C	+0 .06	36
	β Draconis	−0 .07	49

The whole number of observations is...................... 191
The number of nights is...................................... 26
The average number of stars observed on one night... 7.4
The absolute sum of the errors is........................... 14.43*s.*
The sum of the squares of the errors is................... 1.8835
The average errors of an observation is................... 0.075*s.*
The probable error is .... $\sqrt{\frac{.45 \times 1.8835}{191-26}} = \pm 0.072s.$

In conclusion, it appears that when *eight* stars have been observed, suitably situated to determine the instrumental corrections, the probable error of the clock-correction from *one* star is ± 0.08*s.*, and that of the resulting *mean* clock-correction is ± 0.03*s.*

It will be seen that the errors of the tabular right ascensions are involved in this estimate, which is, therefore, not too favorable, but represents the actual working rate of the instrument. It may also be noted that on many occasions the instument was set up and used for observations on the same night.

We may further conclude that a transit instrument of this class is well adapted for determinations of longitude from lunar transits, and may be safely recommended to observers generally.

APPENDIX No. 40.

Observations on the Solar Eclipse of May 26, 1854, reported to the Superintendent of the Coast Survey.

1. OBSERVATIONS MADE ON THE SOLAR ECLIPSE OF MAY 26, 1854, BY ASSISTANT EDMUND BLUNT.

BROOKLYN, *June* 27, 1854.

DEAR SIR: We had a beautiful day for observing the eclipse of the sun on the 26th ultimo, and I selected the corner of Pierpont and Columbia streets, overlooking the bay, as a place where I would be free from the annoyance of noise or smoke from the city.

The time was determined at Mr. Rutherford's observatory, and the comparison of the chronometers was made before and after the observations.

	h.	*m.*	*s.*
Mean time first contact	4	15	31.65
Mean time last contact	6	37	40.7

Atmosphere remarkably steady *for an observation of this kind*, at the commencement, but towards the end the motion was *wavy*.

I send you drawings of the appearance of the moon's edge near the lower cusp. The table mountains, with the wide valley between, (4*h.* 57*m.*) are shown also on the daguerreotypes taken by Professor Loomis; but the three peaks (5*h.* 01*m.*) and the single peak (5*h.* 10*m.*) are not, as the edge is not sufficiently well defined on the plate to show small objects.

No spots were seen on the sun's disc, and I could not detect any roughness on the edge of the moon as shown on the sun, until (4*h.* 57*m.*) the table lands appeared.

Two telescopes were used, the powers of which, as determined by Plossel's dynameter, were 25 and 46.

Latitude 40° 41′ 45″, longitude 73° 59′ 32″ (approximately) from the Chart and Coast Survey determinations of 1851.

Yours, truly,

EDMUND BLUNT.

Prof. A. D. BACHE,
Superintendent Coast Survey, Washington.

2. ABSTRACT OF OBSERVATIONS ON THE SOLAR ECLIPSE, MADE AT SEATON STATION, WASHINGTON, D. C., BY C. O. BOUTELLE, ESQ., ASSISTANT U. S. COAST SURVEY.

With zenith telescope No. 4, C. S., by Simms. Observer, T. McDonnell. Time marked by Mr. F. P. Webber on mean time chronometer No. 106, by "Eggert," loaned to Coast Survey by Naval Observatory.

	h.	*m.*	*s.*
Observed time of first contact	9	42	26
106 fast	5	39	08
Mean time of observation	4	03	18

Red-shade glass used; a good deal of irradiation. Eye-piece with power of 55 engraved upon it.

With vertical circle of great theodolite, 48-inch telescope, and eye-piece, with power of about 60, used. Violet-colored shade used; limb well defined. C. O. Boutelle, observer; and marking his own time on mean time chronometer No. $\frac{779}{2227}$, by Cotterell, loaned by Naval Observatory.

	h.	*m.*	*s.*
Observed time of first contact	10	18	35
779 fast	6	15	19.9
Mean time of observation	4	03	15.1

Wind fresh from N. W. during p. m.; no clouds. Another observation, by Mr. Würdemann, with a large glass, was not noted with precision, but came between the above, or about 4*h*. 03*m*. 16.5*s*.

Directly after observing first contact, took the following coincidence with sidereal clock, by Kessel, No. 1447, viz:

	h. m. s.	h. m. s.
Clock,	8 05 35	8 08 00
779,	10 23 12.5	10 25 37.0
Clock,	8 06 10	8 08 55
106,	9 47 35.5	9 50 20

Wind fell during eclipse, and became nearly calm at time of greatest obscuration. For temperature see accompanying table.

Last contact observed by C. O. Boutelle, with same instrument and chronometer as the first. Calm; not much tremulous motion. Sun's limb well defined.

	h.	m.	s.
Observed time of last contact	12	43	01
779 fast	6	15	20.2
Mean time of observation	6	27	40.8

Last contact observed with zenith telescope No. 4, by Brevet Captain J. L. Reno, U. S. A., assistant Coast Survey. Time marked by Mr. F. P. Webber.

	h.	m.	s.
Observed time of last contact	12	06	54
106 fast	5	39	08.4
Mean time of observation	6	27	45.6

Comparison of chronometers with clock, after observing last contact:

Clock,	10 27 05	10 30 46
779,	12 44 19.5	12 47 00
Clock,	10 27 55	10 31 15
106,	12 08 57.5	12 12 17

After which the vertical circle was again placed on the transit-pier at Seaton's station, levelled, and brought into meridian, and observations of transits of stars for local time continued until 11 p. m., when the following comparisons were made:

Clock,	14 47 42	14 50 40
779,	17 04 15	17 07 12.5
Clock,	14 48 45	14 51 50
106,	16 29 05	16 32 09.5

Temperature before, during, and after eclipse.

Mean time at Seaton.	Temp. Fahr.	Mean time at Seaton.	Temp. Fahr.
h. m.	°	h. m.	°
3 46	82.0	4 59	79.0
3 51	82.0	5 09	77.8
3 56	82.25	5 19	77.5
4 01	82.0	5 29	76.0
4 05	82.0	5 40	75.8
		5 50	75.8
4 12	84.0	6 00	76.25
4 28	82.0	6 10	76.0
4 35	81.75	6 20	76.0
4 39	81.0	6 27	76.2
4 49	80.0	6 37	77.75

Thermometer suspended in shade on east side of observatory at Seaton station.

3. OBSERVATIONS OF ASSISTANT L. F. POURTALES AT ROSLYN STATION, NEAR PETERSBURG, VIRGINIA.

PETERSBURG, VIRGINIA, *June* 2, 1854.

SIR: I beg to submit the following report on the observation of the solar eclipse of May 26, made at Roslyn station, near Petersburg, Virginia.

The telescope used was U. S. C. S. No. 10, (Fraunhofer,) with an eye-piece marked 86—its magnifying power. Seven colored glasses had been provided, but, on trial, I found that none but the one marked No. 3 could be used with comfort; the others were all either too dazzling, or gave a blurred image of the sun. No. 2 could have been used also, but its bright-red color was very fatiguing. No. 3 was a yellow-colored glass, giving a bluish white appearance to the sun's disc. It cracked very soon after the telescope was pointed to the sun, and I had, in consequence, to look through the edge of it.

The telescope was mounted ten feet west and fourteen feet north of the eentre of the transit instrument. The beginning of the eclipse was noted at 4*h*. 4*m*. 31.9*s*., Roslyn mean solar time. This is probably two or three seconds too late, owing to the sun's limb not appearing sharp, but undulating.

The end was noted at 6*h*. 32*m*. 55.5*s*., Roslyn mean solar time; but from that time up to 6*h*. 33*m*. 13*s*., I thought I could see stronger undulations on the sun's edge at the point of last contact than along the rest of the limb. The exact instant of disappearance was hard to seize, on account of similar undulations, before the last contact, producing great and rapidly-changing distortions. At no time—before, during, or after the eclipse—could I see any appearance of the moon off the sun's disc.

The part of the sun's disc immediately adjoining the moon's edge appeared more brilliant than the rest.

Tne cusps were always sharp, but undulations appeared to set out from their extremities and to run along both edges, this direction agreeing with the direction of the wind.

A thermometer was hung up in the sun (free and uninfluenced by heated atmosphere) and another in the shade, and both read off, from time to time, with the following results:

Time.	Therm. in shade.	Therm. in sun.	Wind—force.
h. m.	°	°	
3 32	83.8	86.2	N.N.W. 2
4 8	83.4	87.3	N.N.W. 2
4 12	83.2	85.3	N.N.W. 2
4 39	81.2	83.5	N.N.W. 2
4 58	79.4	81.6	N.N.W. 2
5 13	77.2	79.0	N.N.W. 2
5 37	76.1	77.8	Calm.
5 57	75.3	79.4	Calm.
6 17	75.0	78.7	Calm.
6 30	73.6	77.3	Calm.

There seems to be an error in the reading of the thermometer in the sun at 3*h*. 32*m*., or it may have been the effect of a passing cloud.

About the time of greatest obscuration, the landscape presented a coloration very similar to that of a clear, calm day at sunset.

Respectfully submitted:

L. F. POURTALES.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

4. OBSERVATIONS OF ASSISTANT R. D. CUTTS.

CAMP, BLACK MOUNTAIN,
Santa Clara County, California, May 28, 1854.

DEAR SIR: I send you herewith my observations for the determination of the local time, and of the beginning and ending of the eclipse on the 26th instant. These observations were made at Black Mountain station, which, being from 1,500 to 1,700 feet above tide, was selected with the expectation that I would be able to overlook the fog, and in this I was not disappointed. The valleys below me, and as far as the eye could reach, were filled, on the 26th, with one dense mass of fog, while it was clear and bright at the station.

With the view, however, to have the eclipse observed in the best manner, and at more than one point, I engaged the following persons to make the necessary observations, and report their results to me to be forwarded to you. The arrangements with respect to telescopes were made when I was in town on the 18th:

Prof. Nooney, at Benicia, near triangulation point; Lieut. Cuyler, U. S. N., at Oakland, near triangulation point; Messrs. Tennent and Anderson at San Francisco.

The computations for San Francisco were published in the "Alta California;" and those for Oregon were forwarded to the editor of the "Oregonian," with a request that he would publish them, and interest himself in having the eclipse observed by any one having the requisite instruments. The triangulation will connect all the observations taken near San Francisco, with the Coast Survey observatory near the Presidio.

With respect to my own observations, I would observe that I think they can be relied on. I took every care and precaution. David Kerr, of Maryland, recorded. The local time has not, I think, a greater probable error than a quarter of a second, and the exact time of the first symptom of the appearance of the moon on the disc of the sun, and of its final disappearance, was obtained as faithfully as the phenomena would admit of. The method of determining the time, and the character of the instruments used, are mentioned in the record. The color of the screen of the eye-glass was red.

With the hope that the results will prove of service, I am, respectfully, yours,

RICHARD D. CUTTS.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

BLACK MOUNTAIN TRIANGULATION STATION,
Santa Clara County, California.

The latitude and longitude of the primary station called Black Mountain are approximately deduced from the published latitude and longitude of the Coast Survey observatory near the Presidio, San Francisco county. The two positions being connected by triangulation, so soon as the final computations have been made, the difference in latitude and longitude will be known exactly.

	Observatory.	*Black Mountain Station.*
Latitude	37° 47′ 35.6″	37° 19′ 29″
Longitude	122° 26′ 15.0″ — 8*h*. 09*m*. 45*s*.	122° 06′ 58″ — 8*h*. 08*m*. 27.9*s*.

The observations for time were taken with a Gambey sextant, artificial horizon, and a pocket chronometer by Jules Jürgensen, and consist of equal altitudes of the sun.

The eclipse was observed with the two-foot telescope belonging to the twelve-inch Gambey theodolite, having an object-glass two and a quarter inches in diameter, and a magnifying power which admitted of about one-quarter of the sun's circumference being within the field of vision. A diagonal eye-piece was used.

Error and rate of Pocket Chronometer by Jules Jürgensen.

Date.	Error at approximate noon.	Rate per day.
1854.	*m.* *s.*	
May 22	Slow 23.7	*s.*
23	Slow 31.3	Losing 7.6
25	Slow 46.5	Losing 7.6
*26	Slow 3 38.3	
27	Slow 3 46.1	Losing 7.8

* The chronometer ran down on the night of the 25th. It was set, wound up, and started early on the morning of the 26th. The rate does not appear to have altered.

RESULTS.

Beginning of eclipse..................	11*h.* 23*m.* 32.4*s.*	3*m.* 38.14*s.*	11*h.* 27*m.* 10.54*s.*
Ending of eclipse......................	2 43 29.6	3 39.54	2 47 09.14

5. OBSERVATIONS MADE ON THE SOLAR ECLIPSE, BY PROFESSOR JAMES NOONEY, AT BENICIA, LATITUDE 38° 03′ 05″; LONGITUDE 122° 08′ 24″.—COMMUNICATED BY R. D. CUTTS, ASSISTANT U. S. COAST SURVEY.

Time by chronometer.	Double altitude sun's upper limb.	Time by chronometer, (equal altitude sun's lower limb.)
h. *m.* *s.*	° ′ ″	*h.* *m.* *s.*
4 39 31	82 8 40	11 49 52.5
4 41 11.5	82 48 40	11 48 8.5
4 43 21	83 39 00	11 45 56.5
4 45 00	84 18 50	11 44 16
4 46 41.5	84 58 45	11 42 32
4 48 3.5	85 29 40	11 41 18
4 49 31	86 5 00	11 39 42.5
4 50 58	86 39 10	11 37 15
4 52 24	87 12 30	11 36 52
4 53 37	87 40 20	11 35 36.5
Images approaching, used inverting telescope in all the observations.		

Second set.

Time by chronometer.	Double altitude sun's lower limb.	Time by chronometer, (equal altitude sun's lower limb.)
h. *m.* *s.*	° ′ ″	*h.* *m.* *s.*
6 23 21	120 27 20	10 8 36
6 25 31.5	121 14 40	Lost by accident.
6 27 52	122 2 10	10 4 5
6 29 41.5	122 40 40	10 2 15
6 31 18	123 13 40	10 0 38
Images separating.		Images approaching.

Solar eclipse ends 11*h*. 6*m*. 33*s*. by chronometer. Nothing very remarkable was noticed in the appearance of sun or moon. The western cusp of the moon showed at times quite a jagged appearance. The time of ending of the eclipse was entirely satisfactory; the beginning was unsatisfactory, owing to unsteadiness of the air and instrument. The instrument used was a pretty good three-inch repeater, and well mounted for such a portable instrument, but without a diagonal eye-piece. The eye-piece used was rather too high for this purpose, showing only about 45° of the limb of the sun.

The rate of the chronometer before going to Benicia was nothing; after returning, it was gaining one second daily, and performs well.

The sextant observations were designed to be equal altitudes of one limb of the sun; but by an inversion in the first set, different limbs were taken. But the observations themselves give the means of reducing one limb to the other with all accuracy. The observations were made in the yard of the Collegiate Institute, Benicia, Rev. Charles M. Blake, Principal.

JAMES NOONEY, Jr.

6. OBSERVATIONS MADE ON THE SOLAR ECLIPSE AT HUMBOLDT BAY, CALIFORNIA—LATITUDE 40° 44′ 39″.25; LONGITUDE 8^h 16^m 42^s—BY GEORGE DAVIDSON, ASSISTANT U. S. COAST SURVEY.

HUMBOLDT BAY, CALIFORNIA, COAST SURVEY STATION,
May 28, 1854.

DEAR SIR: Your letter concerning the eclipse was received a few days before the event. I had already calculated it for this place, where I determined to observe it; and had also calculated it for San Francisco, where I sent the times, &c., to be published.

The night and morning preceding the eclipse were very thick and cloudy, and threatening rain; but about half an hour before the commencement the clouds broke, and I got the time of beginning, (within eight seconds of my predicted time.) I then observed the transit of the moon's second limb as it was projected on the body of the sun, and of the sun's second limb.

The day continued clear, with a north wind blowing "fresh." I obtained the time of ending, and soon after observed two stars for time; clouds set in densely, and no other transits were obtained until next day. The chronometer had been running irregularly for some days previously, and the weather had been such as to preclude anything like transits, except once or twice the sun, and one or two large stars by day. Mr. Lawson also observed the times of commencement and ending, but the strong wind kept his telescope (Recon. No. 18) too unsteady to make the results reliable.

The following are the data of the solar eclipse of May 26, 1854:

Coast Survey Station, Humboldt, California—

	h. m. s.	
Assumed longitude	8 16 42,	(from chronometer trip.)
Assumed latitude	40 44 39.25,	(from twenty pairs Z. T.)

	h.	m.	s.
Sidereal time of commencement of eclipse	3	22	30.79
Sidereal time of ending of eclipse	6	53	36.19

	h.	m.	s.
Sidereal time of transit of moon's second limb	4	12	42.67
Sidereal interval of transit of moon's and sun's second limbs	0	1	25.88

Telescope used was zenith telescope No. 3 U. S. C. S., with large diagonal eye-piece, and power 65. Colored glass showed the sun white.

Very respectfully, yours,
GEORGE DAVIDSON.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 41.

Report of Dr. B. A. Gould, Jr., assistant in the Coast Survey, upon telegraphic observations made for difference of longitude, between Raleigh, N. C., and Columbia, S C.

CAMBRIDGE, *October* 1, 1854.

DEAR SIR: I have the honor to submit a report of the Coast Survey operations carried on under my immediate direction during the past year.

At the date of my last report the observations for the differences of longitude between the Seaton station and Raleigh, and between Raleigh and Charleston, were in course of discussion. The work of reduction and discussion has, since that time, gone very slowly forward, owing, in part, to the difficulties growing out of the character and mounting of the instruments used at Raleigh—in part, to the large amount of labor connected with the system of reduction adopted, and the small means at my disposal for its execution—and in part, also, to my protracted absence of more than half the year, rendered necessary by the continued injuries inflicted by storm and flood upon the single telegraph wire on which we were dependent for all the longitude results of the winter's expedition. The work is now rapidly approaching its completion, and I hope within a few weeks to be able to present a full and final report upon each of these two longitudes.

My earliest observations during the year were made for the determination of the latitude of Cloverden, in Cambridge, in the hope of determining with precision the amount of discordance between the geodetic and the astronomical results. This series of observations was carried on during the months of August and November.

In the last week of November, 1853, I left Cambridge to continue the telegraphic operations at the South, and, after making the necessary arrangements at Charleston, erected and occupied a station at Columbia, S. C.; Mr. Geo. W. Dean taking charge of the station at Raleigh. On account of the telegraph facilities, and for various other reasons, it appeared desirable that Columbia, rather than Charleston, should form a link in the great chain of telegraphic longitude-stations which are to connect the northeastern with the southwestern seaports of the United States—and here, as at Raleigh, a site selected in the grounds belonging to the State-house. By the courtesy and kindness of his excellency Governor Manning, and of the gentlemen of the committee of each House intrusted with the erection of the new State capitol, permission was readily accorded, and I cannot but acknowledge my sincere official and personal indebtedness to these gentlemen for their kind aid, and their continual manifestations of friendly interest. It was my intention to push the longitude connections as far as Macon, Georgia; and an astronomical station was also erected at that city, in the academy square, where permission to build was readily granted by the trustees of the academy, and every facility extended by the teachers to Mr. McDonnell. This station has not yet been occupied, but remains to be connected with Columbia, S. C., and Montgomery, Ala., during the coming winter.

The difficulty of obtaining a sufficiently good insulation upon the southern lines has uniformly been a source of great embarrassment. The large extent of thinly settled country, and the extensive swamps and barrens traversed, render that close attention to the line impossible which is easy in more densely populated regions. At the same time, the large tracts of forest through which the line passes occasion additional danger to the wire from the falling, and to the insulation from the proximity of the trees. The large and rapidly-swelling rivers habitually carry away the posts and wires during the great winter freshets, and render their replacement, for the time, impossible, and always difficult. Moreover, the climate prevents the attainment of the excellent insulation which any severe frost would afford. For these and other analogous reasons, the progress of the telegraphic operations in the southern States must, for some time to come, be extremely slow.

By the courtesy of Smith Mowry, esq., President of the Washington and New Orleans Telegraph company, the same facilities were accorded to the Coast Survey which had been granted for a series of years by his predecessors, Messrs. Kendall and Alexander, and the line placed at my disposal when the day's business was completed, which was, during the early part of the winter, about $10\frac{1}{2}$ p. m., and in the spring about midnight, although in exceptional cases the arrival of some steamer, or the press of political intelligence, occupied the wire for the entire night.

The observations were commenced at Columbia on the 4th of January. The original plan contemplated the exchange of signals on five nights, in this position of the observers, and on the same number after Mr. Dean and myself should have exchanged places, to eliminate the effect of personal equation. But an utterly unprecedented continuance of unfavorable weather, followed by floods on the Cape Fear, Pedee, and other interposing rivers, prevented any progress, and no opportunity for exchanging signals with Raleigh could be obtained until January 21st, on which occasion an exchange of some ten stars was effected. It was not until the 11th of February that three good series of star-signals had been exchanged; and, on account of the advanced season, I then judged it best to be satisfied with three good nights' telegraphic work in each position of the observers. Accordingly, I then took charge of the station at Raleigh, while Mr. Dean came to Columbia, and on the 12th of March we succeeded in completing the second series of three nights' satisfactory exchange of signals.

During the entire winter, a series of observations with the zenith telescope was carried on in Columbia for the determination of the latitude, as well as with the transit instrument at each station for the clock and instrumental corrections. The magnetic constants, both at Raleigh and at Columbia, were determined by Mr. Dean, and the latitude observations were made independently with two instruments, by each observer, for the investigation of such sources of error as may be due to peculiarities of the instrument used, or of the observer himself.

The season being too far advanced for the proposed connection of Columbia and Macon, the Columbia instruments were removed to Wilmington, North Carolina, and those at Raleigh to Roslyn station, near Petersburg, Virginia, occupied by yourself in 1852; and the observations for the connection of these two places commenced with the month of May. On the 18th of May I was relieved, by Mr. Pourtales, of the charge of the station, in order to make observations upon the annular eclipse of May 26th, for which purpose I erected a transit instrument on Mount Agamenticus, in the township of York, Maine, taking, also, the telescopes, chronometers, and other apparatus necessary for observations of both the time and the physical peculiarities, according to the plans recommended by the committee of the American Association for the Advancement of Science. But on this occasion, as on so many previous ones, the cloudy and rainy weather prevented any view of the sun during the entire day.

In the present condition of the methods for telegraphic determination of longitude, the limit to the distance between the stations, as prescribed by the condition of the line and relative strength of the current at the extremities of the circuit, is considerably less than that of practical communication. The reason of this difference is manifest, when it is borne in mind that an indispensable condition for the successful exchange of astronomical signals is, that the signals from both stations be recorded at each with the same adjustment of the recording magnet. In operating between remote stations, or during electrical disturbances of the atmosphere, or in unfavorable conditions of the line, it is usually found that signals from a remote station can only be accurately received when the armature is so adjusted as to make manifest the slightest variation in the electrical condition of the circuit, while the great and violent changes occasioned by interrupting the current at some neighboring part of the circuit can only be properly recorded by an adjustment of the opposite character in the receiving magnet. In the one case the distance of the armature from the helix must be a maximum, and the tension of the back-spring a minimum, while in the other precisely the reverse is requisite. But the telegraphic observations can only be made available for longitude measurements when star-signals from one station are interspersed and compared with clock-signals from the other on the same register. Hence the difficulty.

It appears to me not impossible that a receiving magnet might be constructed on some different principle, in such manner as to obviate, or at least diminish, this impediment, at present the most serious of all. I have not yet succeeded in devising any plan, in spite of long and careful consideration; but it may not be amiss to direct attention to the circumstance, that while both the distance of the armature from the helix and the tension of the spiral-spring are important elements of the adjustment under all circumstances, still their relative importance is very different in the two cases. The feasibility of a contrivance for attaining an armature adjustment which should be available for widely different amounts of change in the galvanic current, seems to me to be dependent upon this circumstance. It is hardly necessary to allude to the fact that no self-adjusting magnet, or other apparatus permitting a variation in the pass-time, could be made available.

I am also under the impression that in those cases where the chief obstacle is offered by the insufficiency of insulation, not merely the longitude observations, but the ordinary telegraphic communication, would be greatly facilitated by the use of battery elements, presenting a greater surface for chemical action ; or, to use the common phraseology, that a greater "quantity" of current, even at a considerable sacrifice of "intensity," might frequently render telegraphic communication practicable in spite of obstacles which are now sufficient to preclude it. This idea, originally suggested by yourself, has become more and more strongly impressed upon my mind by a two years' experience, and I believe that in many cases the use of the same amount of material in larger cups would probably be of considerable aid to the telegraph companies.

A very serious impediment to our operations in the southern climate, as spring advances, is occasioned by the extreme frequency of thunder-storms, the electrical disturbance which they produce in the circuit rendering telegraphic communication impossible. Materials are not at hand for forming a trustworthy estimate of the distance at which these storms begin to exert an appreciable influence upon the current; but an observation at Roslyn, bearing upon this point, and thoroughly confirmed by subsequent experience, is perhaps sufficiently important to deserve mention here. It was in the second week of May, on a warm evening, after a very sultry day, a few clouds were scudding and a bank of thunder-clouds rising in the north, but the sky was clear enough to permit transit observations from the pole to the south point, and to justify the hope, realized a few hours later, of successful exchange of signals with Wilmington. The local circuit, consisting of six cups and about thirty feet of copper wire, thickly coated with gutta percha, was connected with the transit-key. But, although the whole of the circuit was contained within the building, except the battery, which was in a wooden box nailed to the outside, the electrical disturbance occasioned by the approaching storm was sufficient to derange the current utterly. With each flash the normal battery-action was restored, so that the click of the armature was heard, and recorded, at each beat of the clock. But in the course of forty or fifty seconds the current ceased to flow, until, after the lapse of a minute and a half or two minutes, the flash restored the regular condition of the circuit. The distance of the discharge, as estimated by the interval between flash and report, must have been two or three miles, and the thunder was by no means loud. No better evidence could be wished of the fact that the disturbances of telegraphic communication exerted by thunder-storms are phenomena of induction. The interruption of telegraphic communication by auroras in the northern States is frequently quite as complete, but I am not aware that any influence of this kind upon short "local circuit" has ever been observed.

The local circuits of the Columbia and Roslyn stations were provided with one of Mathiot's self-sustaining batteries, similar to that in use for a year or two previous at the Seaton station, and the experience of the winter leads me to lay great stress on the efficacy and convenience of this form of battery for the local observations of a longitude station. The importance, for these observations, of a battery which is always ready for use, is to be highly estimated, for it is impossible that valuable observations should not frequently be lost in changeable weather in consequence of the time required for putting an ordinary battery into working condition. The peculiarities of Mr. Mathiot's arrangements seem to be especially adapted to the wants of a temporary station, and the modifications which he has recently introduced go far towards obviating the chief objections which have been urged against this arrangement.

In discussing the results of the three longitude expeditions with which I have been occupied, an important feature has been introduced in the systematic application of the "criterion for the rejection of doubtful observations," proposed, or rather elaborated, by Professor Peirce. In every case where a number of observations of apparently equal value were made for the determination of one or more quantities, this test has been applied, all the individual results permitted by the citerion being retained, and all rejected by it being excluded. To its consistent use I attach great importance, and attribute more reliable results than would otherwise be attained ; for while it forbids all unwarrantable tampering with observations or with individual results, the careful and legitimate discrimination which it exercises removes all apprehension that the result may be vitiated by the retention of absurdly incorrect values. The principle on which this criterion is based is simply this: "that observations should be rejected when the probability of the system of errors obtained by retaining them, is less than that of the system of errors obtained by their rejection, multiplied by the probability of making as many and no more abnormal observations." I propose soon to submit complete and accurate tables for its use, extended within limits not likely to be exceeded in any case in which the investigations of the Coast Survey may require its application.

During the year just elapsed, the telegraphic determination of longitude has been introduced into Germany and England and Belgium, and measurements made under the directions of Professors Airy, Encke, and Quetelet, of the differences of longitude between Berlin and Frankfort-on-the-Maine, Cambridge, England, and Greenwich and Brussels. The Astronomer Royal also announces that preparations are already advanced for a telegraphic connexion of the observatories of Greenwich and Paris. In none of these operations, however, does it appear that accurate recording registers have been in use, or that the results in the German operations were freed from the vitiating influences of personal equation in giving and receiving signals, or of a relatively large probable error in the determination of local time; this time, and not the star signals, having been communicated by telegraph.

In closing, I would express my sense of the invaluable aid of my collaborator, Mr. Dean, by whose energy and skill it was alone rendered possible to push the operations of the winter to a successful conclusion.

I remain, as ever, very respectfully yours,

B. A. GOULD, Jr.

Professor A. D. Bache, LL. D.,
Superintendent U. S. Coast Survey.

Report to Professor A. D. Bache, LL. D., Superintendent of the U. S. Coast Survey, containing directions and tables for the use of Peirce's Criterion for the Rejection of Doubtful Observations: by Dr. B. A. Gould, jr.

Dear Sir: In the *Astronomical Journal*, No. 45, Professor Peirce has given the results of the successful investigation of a singular problem, and one unquestionably among the most important of any which could be proposed, in its relation to all those exact sciences to which quantitative research or measurement may be applied. This problem was nothing less than the attainment of a formula which should be legitimately derived from the fundamental principles of the calculus of probabilities, and furnish an exact criterion for the recognition of those observations which differ so much from the average of a series as to indicate some abnormal source of error which would vitiate the result. The delicate task of discriminating between such observations and those whose discordance, although great, ought not to be deemed abnormal, has hitherto been left to the arbitrary judgment of individuals; and the present introduction of a rigorous mathematical ordeal for testing the extent of tolerable discrepancy, cannot fail to exercise a highly beneficial influence.

But, important as is the use of this criterion, and simple as is its practical application, I am not aware of its adoption in the published discussion of any extended series of observations. In the criticism, however, of various series with which I have had to do in the study of the telegraphic results of the Coast Survey, I have applied Peirce's Criterion with signal advantage, and have been led to the preparation of tables for facilitating its use. Such tables form a part of my report upon the difference of longitude between the Seaton station and Raleigh. Subsequently, having in mind its great importance for the discussion of other groups of observations, possibly extremely dissimilar in their character, it has seemed desirable to extend the limits of these tables, and to submit them in an independent form.

The discussion of the formulas is unnecessary after the reference to the original memoir. But it may not be amiss to repeat them concisely; and perhaps the slightly different form in which I have arranged them, with a view solely to facility in their practical employment, may not be deemed ill-judged.

Let, then,

m = the number of unknown quantities contained in the observations.
N = the whole number of observations.
E = the mean error of the series.
x' = the limit of error which demands the rejection of n observations.

y = the probability that an observation ought to be rejected on account of its discordance.

λ_ι = the mean error after the n observations have been rejected.

$\psi x = \frac{2}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{1}{2}x^2}$, e being the hyperbolic base.

Then, to authorize and require the rejection of n observations, we must have $\lambda^{1-y} e^{\frac{1}{2}y(x^2-1)} (\psi x)^y < Q$

or

$$\lambda^{N-n} e^{\frac{1}{2}n(x^2-1)} (\psi x)^n < Q^N \qquad \text{(A)}$$

the value of Q being determined by the formula—

$$Q^N = \frac{n^n (N-n)^{N-n}}{N^N} \qquad \text{(B)}$$

The assumption that the excess of the sum of the squares of the residual errors above the corresponding sum in the series remaining after the n observations have been excluded, is only equal to the sum of the squares of the rejected residuals, gives the approximate equation.

$$\lambda^2 = \frac{N-m-n\,x^2}{N-m-n}, \text{ whence}$$

$$x^2 = 1 + \frac{N-m-n}{n}(1-\lambda^2) \qquad \text{(C)}$$

Then, if

$$R = e^{\frac{1}{2}(x^2-1)} \psi' x \qquad \text{(D)}$$

the equation (A) becomes

$$\lambda^{N-n} R^n = Q^N \qquad \text{(A')}$$

In the practical employment of these formulas, it will be found most convenient to determine first the value of Q from (B.) Next, assuming any approximate R, the corresponding λ is determined by means of (A'), and, by substitution in (C), furnishes a value of x, from which R may be obtained with greatly increased precision. The computation is then repeated, if necessary.

Professor Peirce proposed three tables: The first, containing values of x for the double argument $m' = \frac{m}{N}$ and $y = \frac{n}{N}$, would include the values corresponding to any given number of unknown quantities; the second, a table of single entry, would give log. (Br.) Q for different values of y; and third contain log. R, for argument x, being deduced from the solution of equation (D).

This arrangement is unquestionably the neatest and most compendious; still I have concluded to give the tables a greater expansion, by employing both n and N as arguments. This demands a separate table for x, corresponding to each value of m; but as the number of unknown quantities implicitly involved will be large only in very rare cases, I have felt less hesitation upon this account, and the extreme facility of its use will more than compensate for a sacrifice of theoretical elegance. The most frequent case of a number of unknown quantities greater than two, is probably that presented by the elements of a celestial body—all of these elements being supposed unknown. Yet even here it will, in general, be found possible to consider two, if, indeed, not three of these, as sufficiently known for the purpose of ordinary investigations.

The following Tables I and II have, therefore, been computed by means of approximations through equations (A'), (B), and (C), for every number of observations up to 60 inclusive, and for the several hypotheses corresponding to the rejection of any number less than 10. The former table is calculated for the case of *one* unknown quantity; the latter for *two*. The function obtained by entering at the side with N, and at the top with n, is x^2, which, when multiplied by ϵ^2, gives the limit of Δ^2, the square of the residual of any observation which ought to be tolerated. The value of ϵ^2 is, of course, deduced from the formula $\Sigma\Delta^2 = (N-m)\,\epsilon^2$.

It will be carefully borne in mind, that in the application of these tables, each hypothesis must be tried in succession, beginning with $n = 1$. After it is found that one observation is excluded upon this supposition, the same criterion for two observations may be applied, using the column for $n = 2$, and so on in succession.

No further explanation seems to be required; but if examples be wished, they may be easily obtained by comparison with the two problems given by Peirce in his memoir, (A. J. II, 162.) For the first, where $N = 30, n = 1, m = 2$, our Table II shows $\chi^2 = 5.54$; the value obtained in the place cited was after two approximations $\chi^2 = 5.51$. For the second example, $N = 15$, $m = 2$, $n = 1$; the corresponding limit which the criterion furnishes for the rejection of one observation is $\chi^2 = 4.080$; and inasmuch as one observation was thus excluded, the limit for the rejection of two is found to be $\chi^2 = 2.991$.

For those cases especially which fall beyond the limits of Tables I and II, the Tables III and IV are added, the former giving, by double entry with the arguments n and N, the values of log. Q^N deduced from equation (B) for values of N up to 90, and of n to 9, inclusive. The table of single entry proposed by Professor Peirce, and giving the values of log. Q for y, may, like the tables for χ, be thus condensed into much smaller compass; but as the values of N increase, the influence of the neglected decimals becomes more and more important, and in the determination of N log. Q, we must always apprehend an error amounting to $\frac{1}{2}$ N in the last decimal place. Embarrassment from analogous reasons attends the computation of Q itself; and since many interesting problems in the theory of numbers lead to the use of analogous tables, it has appeared quite desirable to me, while engaged in its preparation, that it should be extended to a sufficient number of decimal places to permit of its convenient use in still other investigations. To attain the requisite precision, therefore, at least ten, and sometimes more, decimals have been employed, and the seventh place as given may, therefore, be considered reliable. For application in the criterion, more than five places will seldom be required, except when it is desired to push the ordeal to a refinement of criticism which will not ordinarily be exercised in a problem of probabilities, and especially when its solution depends upon an approximate assumption like that in equation (C.)

The last, Table IV, is that for log. R to argument χ, which has been computed by equation (D) to seven, and is here given to six decimal places. To aid in its calculation, the table of $\int_0^t \frac{2e^{-t^2}dt}{\sqrt{\pi}}$ given by Encke in the Berl. Astr. Jahbuch for 1834, has been employed, as advised by Professor Peirce. This table was itself deduced from Bessel's table of $e^{t^2}\int_t^\infty e^{-t^2}dt$. (Fundam. Astron., pp. 36, 37.) The limits are sufficient for all practical purposes, for $\chi = 3$, the highest value of the argument, corresponds to the case of $N = 156$, for one observation deserving exclusion. When the number of observations exceeds this, the series may conveniently be divided into groups of 150 observations each.

I append one of the examples adduced by Peirce, and already cited, to illustrate the practical application of Tables III and IV, for those who have not the original memoir at hand. The computation is greatly facilitated by the use of the Gaussian logarithms, which are now habitually inserted in the five-figure logarithm tables. For, as will readily be perceived on inspecting the figures in the example, we have but to enter column β with the arithmetical complement of log. λ^2, to obtain in column C the ar. co. log. $(1 - \lambda^2)$, and, similarly, the argument log. $(\chi^2 - 1)$ in column A, gives log. χ^2 in column C.

Example.—"To determine the limit for rejection of observations in the case of fifteen observations of the vertical semi-diameter."

Professor Peirce assumed two unknown quantities, one of them being constant and the other proportional to the horizontal parallax, and then found for the residual errors—

″	″	″	″	″
−0.30	+0.48	+0.63	−0.22	+0.18
−0.44	−0.24	−0.13	−0.05	+0.39
+1.01	+0.06	−1.40	+0.20	+0.10

We have then $N = 15$, $m = 2$, log. $\varepsilon^2 = 9.53050$.

For the rejection of *one* observation, $n = 1$, and by Table III, log. $Q^N = 8.40442$.

Assume for a first hypothesis log. $R = 9.3$.

		I. Approximation.	II.
by (A′)	log. λ^{14}	9.104	9.097
	log. λ^2	9.872	9.871
	log. $(1-\lambda^2)$	9.407	9.410
by (C)	log. 12	1.079	
	log. (χ^2-1)	0.486	0.489
	log. χ^2	0.6087	0.6111
	log. χ	0.3044	0.3056
	χ	2.015	2.021
by Table IV	log. R	9.307	

A third approximation would give $\chi = 2.019$, the same as would be afforded by the more natural assumption of log. R = 9.305, instead of 9.307, for the second hypothesis.

The first approximation would, in fact, have been sufficient to indicate that the observation corresponding to the residual — 1″.40 ought to be rejected, and we pass to the criterion for the rejection of *two* observations, as follows:

$$n = 2, \ \log. Q^N = 7.44195$$

		I.	II.	III.
Assume	log. R	9.3	9.362	9.3544
	log. R^2	8.6	8.724	8.7088
	log. λ^{13}	8.842	8.7179	8.7332
	log. λ^2	9.822	9.8028	9.8051
	log. $(1-\lambda^2)$	8.522	9.5622	9.5581
	log. $\frac{11}{2}$	0.740	0.7404	
	log. (χ^2-1)	0.267	0.3026	0.2986
	log. χ^2	0.455	0.4782	0.4755
	log. χ	0.228	0.2391	0.2378
	χ	1.689	1.734	1.729
	log. R	9.362	9.3544	9.3553

The third approximation and increase in the number of decimals is rendered necessary, in this especial case, by the close vicinity of the residual 1″.01 to the limit of exclusion. We find log., $\chi^2 \epsilon^2 = 0.005$, which *forbids* the rejection of this observation.

The precise value of χ^2, obtained by still further approximation, and the use of a higher number of decimal figures, would have been, as shown by Table II, $\chi^2 = 2.9914$, log. $\chi^2 = 0.47587$, log. $\epsilon^2 \chi^2 = 0.0064$, corresponding to a residual 1.015.

It is needless to remark, that in the actual application of these approximative formulas, the most convenient assumptions for the successive values of log. R would not be precisely those yielded by the preceding hypotheses. Moreover; if, owing to the magnitude of any excluded observation, apprehensions be entertained as to the allowableness of equation (C,) the most that need be feared is the necessity of a new determination of ϵ^2, and the corresponding series of residuals. It is but proper to state that I have been aided in the necessary computations by Mr. J. N. Stockwell, of Brecksville, Ohio.

In the hope that these tables may not be without their value, in the discussion of the results of the Coast Survey, I remain, as ever, most respectfully and truly yours,

B. A. GOULD, Jr.

Cambridge, *November* 15, 1854.

TABLE I.

Values of χ^2 *for* $m = 1$.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
3	1.480								
4	1.913	1.163							
5	2.278	1.433							
6	2.592	1.687	1.208						
7	2.866	1.910	1.409	1.045					
8	3.109	2.112	1.588	1.229					
9	3.328	2.295	1.753	1.386	1.091				
10	3.526	2.464	1.904	1.531	1.238				
11	3.707	2.621	2.036	1.662	1.373	1.122			
12	3.875	2.766	2.176	1.785	1.492	1.249	1.018		
13	4.029	2.902	2.299	1.901	1.603	1.362	1.145		
14	4.174	3.030	2.416	2.009	1.709	1.465	1.255	1.053	
15	4.309	3.150	2.526	2.111	1.806	1.561	1.354	1.163	
16	4.436	3.264	2.630	2.208	1.898	1.651	1.445	1.259	1.080
17	4.555	3.371	2.729	2.300	1.985	1.736	1.529	1.347	1.176
18	4.668	3.475	2.823	2.389	2.069	1.817	1.609	1.428	1.261
19	4.776	3.571	2.914	2.474	2.150	1.895	1.685	1.504	1.341
20	4.878	3.664	3.001	2.556	2.227	1.970	1.757	1.576	1.415
21	4.975	3.755	3.084	2.634	2.301	2.041	1.827	1.644	1.483
22	5.066	3.840	3.164	2.709	2.373	2.110	1.893	1.710	1.549
23	5.157	3.923	3.240	2.782	2.442	2.176	1.957	1.773	1.612
24	5.242	4.002	3.315	2.852	2.509	2.240	2.019	1.833	1.671
25	5.324	4.078	3.387	2.920	2.573	2.302	2.079	1.892	1.729
26	5.403	4.151	3.456	2.986	2.636	2.362	2.137	1.948	1.784
27	5.479	4.222	3.523	3.049	2.697	2.420	2.194	2.003	1.838
28	5.552	4.291	3.588	3.111	2.756	2.477	2.249	2.056	1.890
29	5.622	4.358	3.650	3.171	2.813	2.532	2.302	2.108	1.941
30	5.690	4.422	3.712	3.229	2.869	2.586	2.354	2.158	1.990
31	5.756	4.484	3.772	3.285	2.923	2.638	2.404	2.207	2.038
32	5.820	4.545	3.829	3.340	2.976	2.689	2.453	2.255	2.085
33	5.882	4.604	3.885	3.394	3.028	2.738	2.502	2.301	2.130
34	5.943	4.661	3.939	3.446	3.078	2.787	2.548	2.347	2.175
35	6.001	4.717	3.992	3.497	3.127	2.834	2.594	2.392	2.218
36	6.058	4.771	4.044	3.547	3.174	2.880	2.639	2.436	2.261
37	6.113	4.823	4.095	3.595	3.221	2.926	2.683	2.478	2.302
38	6.167	4.874	4.144	3.643	3.267	2.970	2.726	2.520	2.343
39	6.219	4.925	4.192	3.689	3.312	3.013	2.768	2.561	2.383
40	6.270	4.974	4.239	3.735	3.356	3.055	2.809	2.601	2.421
41	6.320	5.022	4.285	3.779	3.398	3.097	2.849	2.640	2.460
42	6.369	5.069	4.331	3.822	3.440	3.138	2.888	2.678	2.497
43	6.416	5.114	4.375	3.865	3.480	3.178	2.927	2.716	2.534
44	6.463	5.159	4.418	3.906	3.520	3.217	2.965	2.753	2.570
45	6.508	5.199	4.460	3.947	3.559	3.255	3.002	2.789	2.606
46	6.552	5.245	4.501	3.987	3.597	3.293	3.039	2.825	2.641
47	6.596	5.287	4.542	4.026	3.637	3.330	3.075	2.860	2.675
48	6.639	5.328	4.581	4.065	3.675	3.366	3.110	2.894	2.708
49	6.681	5.369	4.620	4.103	3.712	3.401	3.145	2.928	2.741
50	6.720	5.408	4.657	4.140	3.748	3.436	3.179	2.962	2.774
51	6.760	5.447	4.695	4.176	3.784	3.471	3.213	2.994	2.806
52	6.800	5.484	4.732	4.212	3.819	3.505	3.246	3.027	2.838
53	6.838	5.522	4.768	4.247	3.853	3.538	3.279	3.059	2.869
54	6.876	5.559	4.804	4.282	3.887	3.571	3.311	3.090	2.899
55	6.913	5.595	4.839	4.316	3.920	3.603	3.342	3.121	2.929
56	6.950	5.630	4.873	4.349	3.952	3.635	3.373	3.151	2.959
57	6.986	5.665	4.907	4.382	3.984	3.666	3.404	3.181	2.988
58	7.021	5.699	4.941	4.415	4.016	3.697	3.434	3.210	3.007
59	7.056	5.733	4.974	4.447	4.047	3.728	3.463	3.239	3.046
60	7.090	5.766	5.006	4.478	4.078	3.758	3.492	3.268	3.074

TABLE II.

Values of χ^2 for $m = 2$.

n.	1.	2.	3.	4.	5.	6.	7.	8.	9.
N.									
4	1.484								
5	1.887	1.235							
6	2.230	1.479	1.114						
7	2.528	1.705	1.288	1.025					
8	2.793	1.913	1.459	1.163					
9	3 029	2.102	1.620	1.304	1.066				
10	3.243	2.277	1.771	1.439	1.191				
11	3.437	2.440	1.913	1.566	1.310	1.098			
12	3.616	2.592	2.046	1.687	1.423	1.208	1.015		
13	3.781	2.734	2.171	1.802	1.529	1.310	1.122		
14	3.936	2.867	2.290	1.910	1.631	1.409	1.220	1.045	
15	4.080	2.991	2.403	2.014	1.727	1.501	1.312	1.141	
16	4.215	3.109	2.510	2.112	1.819	1.589	1.398	1.229	1.070
17	4.342	3.221	2.611	2.206	1.907	1.673	1.480	1.311	1.157
18	4.462	3.328	2.708	2.295	1.991	1.753	1.557	1.388	1.236
19	4.576	3.429	2.801	2.382	2.072	1.830	1.631	1.461	1.310
20	4.684	3.526	2.890	2.465	2.150	1.904	1.703	1.531	1.380
21	4.787	3.618	2.975	2.544	2.225	1.976	1.772	1.598	1.447
22	4.885	3.707	3.057	2.621	2.298	2.045	1.838	1.663	1.511
23	4.979	3.792	3.136	2.695	2.368	2.112	1.902	1.725	1.572
24	5.069	3.874	3.212	2.766	2.435	2.176	1.964	1.785	1.631
25	5.155	3.953	3 286	2.835	2.501	2.239	2.024	1.844	1.688
26	5.237	4.029	3.357	2.902	2.565	2.299	2.082	1.900	1.743
27	5.317	4.103	3.426	2.967	2.626	2.358	2.139	1.955	1.796
28	5.394	4.174	3.492	3.030	2.686	2.415	2.194	2.008	1.848
29	5.468	4.242	3.556	3.091	2.744	2.471	2.248	2.060	1.898
30	5.539	4.309	3.619	3.150	2.801	2.525	2.300	2.111	1.948
31	5.609	4.373	3.680	3.208	2.856	2.578	2.351	2.160	1.995
32	5.675	4.435	3.739	3.264	2.909	2.630	2.401	2.208	2.042
33	5.740	4.496	3.796	3.319	2.961	2.680	2.449	2.255	2.088
34	5.803	4.555	3.852	3.372	3.012	2.729	2.496	2.301	2.132
35	5.864	4.613	3.906	3.424	3.062	2.777	2.543	2.345	2.176
36	5.924	4.669	3.959	3.474	3.111	2.824	2.588	2.389	2.219
37	5.981	4.723	4.011	3.523	3.158	2.869	2.632	2.432	2.260
38	6.037	4.776	4.061	3.572	3.205	2.914	2.675	2.474	2.301
39	6.092	4.827	4.111	3.619	3.250	2.958	2.718	2.515	2.341
40	6.145	4.878	4.159	3.665	3.294	3.001	2.759	2.555	2.380
41	6.197	4.927	4.206	3.710	3.338	3.043	2.800	2.595	2.419
42	6.247	4.975	4.252	3.755	3.381	3.084	2.840	2.634	2.457
43	6.297	5.022	4.297	3.798	3.422	3.124	2.879	2.672	2.494
44	6.345	5.068	4.341	3.840	3.463	3.164	2.917	2.709	2.530
45	6.392	5.113	4.384	3.882	3.503	3.203	2.955	2.746	2.566
46	6.438	5.157	4.426	3.923	3.543	3.241	2.992	2.782	2.601
47	6.483	5.200	4.468	3.963	3.581	3.278	3.029	2.817	2.635
48	6.527	5.242	4.508	4.002	3.619	3.315	3.064	2.852	2.669
49	6.570	5.283	4.548	4.040	5.656	3.351	3.099	2.886	2.703
50	6.612	5.323	4.587	4.078	3.693	3.386	3.134	2.920	2.736
51	6.653	5.362	4.625	4.115	3.728	3.421	3.168	2.953	2.768
52	6.694	5.401	4.663	4.151	3.764	3.456	3.201	2.986	2.800
53	6.734	5.440	4.700	4.187	3.798	3.489	3.234	3.018	2.831
54	6.773	5.478	4.736	4.222	3.833	3.523	3.266	3.049	2.862
55	6.811	5.515	4.772	4.257	3.867	3.555	3.298	3.080	2.892
56	6.848	5.551	4.807	4.291	3.900	3.588	3.329	3.111	2.922
57	6.885	5.587	4.842	4.325	3.932	3.619	3.361	3.141	2.951
58	6.921	5.622	4.876	4.357	3.964	3.650	3.390	3.171	2.980
59	6.957	5.656	4.909	4.390	3.996	3.681	3.419	3.200	3.009
60	6.993	5.690	4.942	4.421	4.027	3.711	3.448	3.229	3.037

TABLE III.

Log. Q^N.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
2	9.3979400								
3	1706962	9.1706962							
4	9.0231238	8.7958800	9.0231238						
5	8.9133899	5385737	8.5385737	8 9133899					
6	8259425	3413925	8.1938200	8.3413925	8.8259425				
7	7532212	1812237	7.9239174	7.9239174	8.1812237	8.7532212			
8	6909664	8.0462476	7014939	7.5917600	7.7014939	8.0462476	8.6909664		
9	6365373	7.9295637	5120887	7.3149074	7.3149074	7.5120887	7.9295637	8.6365373	
10	5881826	8267799	3470500	7.0771475	6.9897000	7.0771475	7.3470500	7.8267799	8.5881826
11	5446805	7349230	2007641	6.8686067	7084380	6.7084380	6.8686067	7.2007641	7.7349230
12	5051446	6518850	7.0693714	6827849	4603613	6.3876401	6.4603613	6.6827849	7.0693714
13	4689114	5761159	6.9501002	5151590	2383063	6.1033302	6.1033302	6.2383063	6.5151590
14	4354711	5064424	8408908	3624475	6.0372401	5.8478349	5.7855801	5.8478349	6.0372401
15	4044236	4419547	7401698	2221906	5.8534811	6157212	4990373	4990373	5.6157212
16	3754492	3819328	6467076	6.0924952	6842498	4029878	5.2379491	5.1835201	5.2379491
17	3482881	3257972	5595246	5.9718719	5273933	2065954	4.9980546	4.8952708	4.8952708
18	3227266	2730746	4778276	8591274	3812085	5.0241774	7761007	6298148	4.5814601
19	2985867	2233732	4009651	7532904	2443241	4.8538527	5695428	3837210	4.2918642
20	2757185	1763652	3283955	6535598	5.1156190	6941001	3763499	4.1542949	4.0229022
21	2539947	1317732	2596637	5592664	4.9941646	5436712	1948736	3.9393783	3.7717523
22	2333062	0893609	1943832	4698461	8791827	4015282	4.0237502	7372134	5361472
23	2135587	0489250	1322234	3848182	7700149	2667989	3.8618658	5463486	3142349
24	1946704	7.0102892	0728992	3037701	6660986	1387428	7082481	3655698	3.1044817
25	1765696	6.9733000	6.0161625	2263449	5669497	4.0167257	5620912	1938513	2.9056021
26	1591932	9378227	5.9617969	1522319	4721482	3.9002004	4226977	3.0303179	7165072
27	1424854	9037386	9096119	0811586	3813274	7886911	2894646	2.8742167	5362660
28	1263968	8709422	8594391	5.0128849	2941654	6817816	1618666	7218949	3640761
29	1108829	8393397	8111289	4.9471982	2103779	5791058	3.0394433	5817831	1992406
30	0959043	8088472	7645478	8839094	1297126	4803397	2.9217889	4443812	2.0411501
31	0814251	7793894	7195761	8228491	4.0519446	3851952	8085436	3122476	1.8892691
32	0674132	7508983	6761064	7638655	3.9768723	2934152	6993872	1849904	7431235
33	0538393	7233125	6340414	7068219	9043149	2047691	5940333	2.0622601	6022924
34	0406768	6965761	5932931	6515944	8341086	1190492	4922247	1.9437438	4663996
35	0279016	6706385	5537815	5980709	7661061	3.0360679	3937296	8291600	3351081
36	0154915	6454531	5154337	5461492	7001725	2.9556551	2983382	7182547	2081142
37	8.0034262	6209778	4781831	4957362	6361855	8776562	2058601	6107980	1.0851437
38	7.9916871	5971733	4419686	4467465	5740334	8019301	1161221	5065809	0.9659479
39	9802570	5740041	4067341	3991018	5136135	7283478	2.0289659	4054127	8503006
40	9691200	5514370	3724279	3527303	4548319	6567910	1.9442466	3071196	7379954
41	9582615	5294415	3390023	3075656	3976019	5871509	8618313	2115419	6288478
42	9476679	5079894	3064132	2635464	3418436	5193273	7815976	1185329	5226724
43	9373266	4870545	2746198	2206160	2874831	4532277	7034327	1.0279579	4193222
44	9272258	4666124	2435841	1787219	2344519	3887664	6272323	0.9396922	3186464
45	9173546	4466405	2132708	1378150	1826866	3258641	5528998	8536206	2205095
46	9077029	4271175	1836471	0978499	1321279	2644469	4803457	7696363	1247861
47	8982609	4080238	1546822	0587842	0827209	2044463	4094866	6876402	0.0313599
48	8890199	3893409	1263475	4.0205783	3.0344142	1457983	3402450	6075402	9.9401229
49	8799715	3710514	0986161	3.9831952	2.9871599	0884432	2725486	5292501	9.8509743
50	7.8711077	3531392	0714629	9466000	9409129	2.0323250	2063297	4526899	7638205
51	8624212	3355889	0448642	9107603	8956313	1.9773916	1415251	3777845	6785738
52	8539051	3183864	5.0187978	8756455	8512755	9235939	0780755	3044638	5951523
53	8455528	3015179	4.9932429	8412268	8078083	8708857	1.0159254	2326619	5134793
54	8373580	2849708	9681797	8074771	7651949	8192238	0.9550255	1623171	4334826
55	8293151	2687332	9435897	7743710	7234023	7685675	8953177	0933713	3550949
56	8214184	2527935	9194553	7418843	6823995	7188782	8367647	0.0257695	2782524
57	8136627	2371411	8957600	7099943	6421571	6701197	7793197	9.9594610	2028952
58	8060431	2217659	8724880	6786794	6026475	6222577	7229416	8943965	1289669
59	7985549	2066581	8496246	6479192	5638444	5752599	6675915	8305302	9.0564141
60	7.7911937	6.1918086	4.8271555	3.6176945	2.5257229	1.5290955	0.6132323	9.7678185	8.9851865
61	7.7839551	6.1772087	4.8050675	3.5879868	2.4882596	1.4837355	0.5598294	9.7062219	8.9152365
62	7768352	1628503	7833477	5587789	4514320	4391523	5073494	6456982	8465189
63	7698301	1487253	7619842	5300540	4152190	3953196	4557612	5862132	7789910
64	7629363	1348264	7409654	5017967	3796004	3522128	4050347	5277311	7126122
65	7561501	1211464	7202803	4739917	3445569	3098080	3551417	4702185	6473439
66	7494684	1076786	6999186	4466250	3100702	2680828	3060552	4136438	5831496
67	7428880	0944164	6798703	4196828	2761230	2270157	2577495	3579768	5199944
68	7364057	0813537	6601259	3931522	2426986	1865862	2102002	3031889	4578452
69	7300188	0684845	6406762	3670209	2097811	1467749	1633838	2492526	3966703
70	7237245	0558032	6215127	3412769	1773554	1075630	1172781	1961419	3364397
71	7175200	0433045	6026271	3159090	1454070	0689329	0718618	1438318	2771246
72	7114030	0309831	5840113	2909063	1139221	1.0308675	0.0271147	0922985	2186975
73	7053709	0188340	5656578	2662584	0828873	0.9933505	9.9830172	9.0415193	1611321
74	6994215	6.0068525	5475593	2419555	0522900	9563663	9395508	8.9914724	1044035
75	6935525	5.9950340	5297087	2179880	2.0221181	9199000	8966976	9421369	8.0484876
76	6877617	9833742	5120995	1943467	1.9923598	8839373	8544405	8934929	7.9933614
77	6820472	9718689	4947252	1710229	9630039	8484644	8127632	8455213	9390028
78	6764068	9605140	4775795	1480082	9340398	8134682	7716500	7982037	8853908
79	6708388	9493056	4606566	1252945	9054571	7789361	7310858	7515225	8325052
80	6653412	9382400	4439506	1028740	8772458	7448558	6910561	7054607	7803264
81	6599124	9273137	4274562	0807393	8493965	7112157	6515470	6600022	7288358
82	6545506	9165231	4111681	0588831	8219060	6780046	6125451	6151313	6780155
83	6492542	9058648	3950811	0372985	7947474	6452117	5740376	5708330	6278482
84	6440216	8953359	3791903	3.0159789	7679302	6128265	5360121	5270929	5783173
85	6388513	8849330	3634910	2.9949178	7414403	5808390	4984566	4838971	5294069
86	6337419	8746532	3479786	9741091	7152697	5492396	4613597	4412321	4811016
87	6286918	8644937	3326188	9535467	6894109	5180190	4247103	3990851	4333866
88	6236998	8544516	3174973	9332248	6638565	4871682	3884977	3574437	3862476
89	6187646	8445244	3025200	9131381	6385995	4566786	3527116	3162958	3396709
90	7.6138847	5.8347093	4.2877129	2.8932809	1.6136329	0.4265417	9.3173421	8.2756299	7.2936433

TABLE IV.

Log. R.

	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	9.501485	9.499209	9.496941	9.494682	9.492431	9.490188	9.487955	9.485729	9.483512	9.481303
1.1	.479102	.476910	.474725	.472549	.470380	.468220	.466067	.463923	.461786	.459657
1.2	.457536	.455422	.453316	.451218	.149127	.447044	.444968	.442900	.440839	.438785
1.3	.436739	.434700	432669	.430644	.428629	.426616	.424613	.422617	.420627	.418645
1.4	.416670	.414701	.412739	.410765	.408836	.406895	.404960	.403032	.401111	.399196
1.5	.397287	.395385	.393490	.391601	.389718	.387842	.385972	.384108	.382251	.380400
1.6	.378555	.376716	.374883	.373056	.371236	.369421	.367612	.365809	.364013	.362222
1.7	.360437	.358657	.356884	.355116	.353354	.351598	.349847	.348102	.346363	.344629
1.8	.342901	.341178	.339461	.337749	.336042	.334341	.332646	.330956	.329271	.327591
1.9	.325917	.324247	.322583	.320925	.319271	.317622	.315979	.314310	.312707	.311178
2.0	.309455	.307837	.306223	.304615	.303011	.301413	.299819	.298229	.296645	.295065
2.1	.293491	.291920	.290355	.288794	.287238	.285686	.284139	.282597	.281059	.279526
2.2	.277998	.276463	.274954	.273438	.271927	.270420	.268917	.267419	.265925	.264437
2.3	.262952	.261472	.259996	.258524	.257057	.255593	.254133	.252678	.251226	.249779
2.4	.248335	.246895	.245459	.244027	.242600	.241176	.239757	.238342	.236931	.235524
2.5	.234121	.232721	.231326	.229935	.228548	.227164	.225784	.224406	.223032	.221662
2.6	.220296	.218933	217575	.216219	.214868	.213520	.212176	.210836	.209499	.208166
2.7	.206837	.205511	.204188	.202868	.201551	.200239	.198929	.197625	.196324	.195027
2.8	.193733	.192443	.191157	.189874	.188595	.187319	.186046	.184777	183511	.182253
2.9	.180998	.179746	9.178498	9.177252	9.176009	9.174770	9.173533	9.172300	9.171069	9.169842
3.0	9.168617	9.								

List of Errata in the two preceding reports of Doctor B. A. Gould, jr.

Page *130, line 25 from bottom, for "local circuit," read "local circuits."
Page *130, line 17 from bottom, for "arrangements," read "arrangement."
Page *130, line 8 from bottom, for "citerion," read "criterion."
Page *131, line 6 from top, dela "*and*" after "Germany."
Page *131, line 8 from top, read "Cambridge (England) and Greenwich, and Greenwich and Brussels."
Page *131 et seq., *passim:* for "χ," read "*x;*" for "N," read "*N;*" for "n," read "*n;*" for "t," read "*t*"; and for "E," read "ε."
Page *131, bottom line, for "χε," read "*x*ε."
Page *132, line 4 from top, read $\int_x^\infty e^{-\frac{1}{2}} x$.

Page *132, expression (D) should read $R = e^{\frac{1}{2}(x^2-1)} \psi x$.
Page *132, line 20 from bottom, for "third contain," read "the third contains."
Page *132, line 15 from bottom, for "only in very rare cases," read "in very rare cases only."
Page *133, lines 6 and 7 from top, for (A. J. II, 162,) read (Ast. Jour. II, 162.)
Page *133, line 25 from top, for "reliable," read "trustworthy."
Page *133, line 23 from bottom, read $\int_o^t \frac{2e^{-t^2} dt}{\sqrt{\pi}}$ and for "Jahbuch," read "Jahrbuch."

Page *133, line 21 from bottom, for e^{t2} and e^{-t2} read e^{t^2} and e^{-t^2}
Page *133, line 20 from bottom, for (,) after "purposes," put (;)
Page *133, line 12 from bottom, for "β," read "B."
Page *133, line 9 from bottom, read "of Venus," after "semi-diameter."
Page *134, line 22 from top, for "8.522," read "9.522."
Page *135, opposite 22 in first column, for "5.066," read "5.063."
Page *136, column 7, in 4th line from bottom, for "3.361," read "3.360."

APPENDIX No. 42.

Letter of George P. Bond, esq., assistant astronomer, Harvard Observatory, communicating the result of computations of the chronometric expeditions of 1849, 1850, *and* 1851, *with his report upon them.*

CAMBRIDGE, MASS., *February* 18, 1854.

DEAR SIR: I have the pleasure of communicating the results of the chronometric expeditions of 1849, 1850, and 1851, as follows:

	h.	*m.*	*s.*	*s.*
Voyages of 1849–'50, Cambridge, west of G..................	4	44	30.49 ±	0.30
Do......1851...............do.........do........................	4	44	30.78 ±	0.25

Final result, 4*h.* 44*m.* 30.66*s.* ± 0.20*s.*

I hope, in a few days, to forward the results in detail.

Respectfully and truly yours,

G. P. BOND.

A. D. BACHE, LL. D., *Sup. U. S. Coast Survey.*

CAMBRIDGE, MASS., *February* 28, 1854.

DEAR SIR: Enclosed is my concluding report on the results of the chronometric expeditions of 1849, 1850, and 1851, for the difference of longitudes of Cambridge and Liverpool, commencing with the date of my communication of October 1, 1853.

The difference between the longitudes by east and west voyages is very evident in the voyages of 1851, as well as in those of 1849–'50. I am satisfied that the effect of temperature on the rates of the chronometers affords a sufficient explanation of this difficulty; but, unfortunately, we are not in possession of a complete thermometric record of the exposures of the chronometers. It is certain, however, that the average sea exposure has been lower than that on shore, and further from the point of best compensation of the chronometers, which is usually between 60° and 70°. Below this point, their tendency is, with very few exceptions, to lose on their rates. They must, therefore, on the average have lost, while at sea, more than is indicated by the *shore* rates. The effect would be to give too small a longitude for the voyages from Liverpool to Cambridge, and too large from Cambridge to Liverpool; which answers to our case.

The best security which we have for the accuracy of our final result is in the assumption—fortunately, a very probable one—that the temperature at sea has differed from the shore temperature by nearly the same average amount for both east and west voyages. * *

REPORT

On the computation of the results of the chronometric expeditions of 1849, 1850, *and* 1851, *between Cambridge and Liverpool.*

At the date of my last report of progress, October 1, 1853,* the reduction of the chronometric comparisons had been commenced. This, when completed, furnished a series of errors on mean solar time, which was the basis of the remainder of the work.

The following is the combination of these results, considered to be the best adapted to the circumstances of the different voyages:

Let u_1 = the error of the chronometer at the times.................................... T_1
u_2 = ...do..................do...............do.. T_2
u_3 = ...do..................do...............do.. T_3
u_4 = ...do..................do...............do.. T_4

$$t = T_2 - T_1 \qquad t' = T_3 - T_2 \qquad t'' = T_4 - T_3$$

λ = the difference of longitude of the two stations.

$$a = \frac{du}{dt}, \quad b = \frac{ddu}{dt^2} \text{ at the time } T_n.$$

$\delta \dfrac{du}{dt}$ = the difference between the sea and shore values of a $\delta\lambda = \delta \dfrac{du}{dt} t'$

Take the signs of these quantities as positive when they tend to increase u when t increases, u being considered positive when the chronometer is too fast, T_1, T_2, &c., being the terms as indicated by the chronometer.

If now, in the interval between T_2 and T_3, the chronometer has been transported from Liverpool to Cambridge, we shall have the following equations, in which u, a, and b correspond to the time $T_{\frac{5}{2}} = T_2 + \frac{1}{2} t'$.

$$(1) \quad \begin{aligned} u_1 &= u - a\,(t + \tfrac{1}{2} t') + \tfrac{1}{2} b\,(t + \tfrac{1}{2} t')^2 \\ u_2 &= u - \tfrac{1}{2}\ a\,t' + \tfrac{1}{8} b\,t'^2 \\ u_3 &= u + \tfrac{1}{2}\ a\,t' + \tfrac{1}{8} b\,t'^2 + \lambda + \delta\lambda \\ u_4 &= u + a\,(t'' + \tfrac{1}{2} t') + \tfrac{1}{2} b\,(t'' + \tfrac{1}{2} t')^2 + \lambda + \delta\lambda \end{aligned}$$

$$u_2 - u_1 = a\,t - \tfrac{1}{2} b\,t\,(t + t') \qquad a = \frac{u_2 - u_1}{t} + \tfrac{1}{2} b\,(t + t')$$

* See Appendix No. 34, report of Superintendent Coast Survey for 1853, p. 88.

(2) $u_4 - u_3 = a\, t'' + \frac{1}{2}\, b\, t''\, (t'' + t')$ (3) $a = \frac{u_4 - u_3 - \frac{1}{2}\, b\, (t'' + t')}{t''}$

$u_3 - u_2 = a\, t' + \lambda + \delta\lambda.$ $\lambda + \delta\lambda = u_3 - u_2 - a\, t'$

(4) $a = \frac{1}{2}\left[\frac{u_2 - u_1}{t} + \frac{u_4 - u_3}{t''}\right] + \frac{1}{4}\, b\, (t - t'')$

Hence, for the voyage from Liverpool to Cambridge—

(5) $$\lambda + \delta\lambda = u_3 - u_2 - \frac{1}{2}\left[\frac{u_2 - u_1}{t} + \frac{u_4 - u_3}{t''}\right] t' + \frac{1}{4}\, b\, (t'' - t)\, t'$$

If, in the interval between T_2 and T_3, the chronometer at T_1 and T_2, supposed to be at Cambridge, had been transported to Liverpool, then the equations (1) become

(6)
$$\begin{aligned}
u_1 &= u - a\,(t + \tfrac{1}{2}t') + \tfrac{1}{2}\, b\, (t + \tfrac{1}{2}\, t')^2 + \lambda \\
u_2 &= u - \tfrac{1}{2}\; a\, t' \quad + \tfrac{1}{8}\, b\, t'^2 + \lambda \\
u_3 &= u + \tfrac{1}{2}\; a\, t' \quad + \tfrac{1}{8}\, b\, t'^2 + \delta\lambda \\
u_4 &= u + a\,(t'' + \tfrac{1}{2}\, t') + \tfrac{1}{2}\, b\, (t'' + \tfrac{1}{2}\, t')^2 + \delta\lambda
\end{aligned}$$

And for the voyage from Cambridge to Liverpool—

(7) $$\lambda - \delta\lambda = -(u_3 - u_2) + \frac{1}{2}\left[\frac{u_2 - u_1}{t} + \frac{u_4 - u_3}{t}\right] t' + \frac{1}{4}\, b\, (t - t'')\, t'$$

The term $\frac{1}{4}\, b\, (t'' - t)\, t'$ in (5) and (7) is insensible, being on the average equal to t'', and b being very small in all cases. We have also, on account of the voyages being of nearly equal length, $\delta\lambda$ for the voyage L. to C., equal to $\delta\lambda$ for the voyage from C. to L. We have, therefore—

$$\lambda + \delta\lambda = u_3 - u_2 - \frac{1}{2}\left[\frac{u_2 - u_1}{t} + \frac{u_4 - u_3}{t''}\right] t' \text{ for the voyage L. to C.,}$$

$$\lambda - \delta\lambda = u_2 - u_3 + \frac{1}{2}\left[\frac{u_2 - u_1}{t} + \frac{u_4 - u_3}{t''}\right] t' \text{ for the voyage C. to L.,}$$

and the resulting value of λ becomes—

$$\lambda = \frac{1}{2}\left[(\lambda + \delta\lambda) + (\lambda - \delta\lambda)\right]$$

From which the effect of the acceleration of rates, and of the difference of sea and shore rates, will be eliminated.

Probable errors of $\lambda + \delta\lambda$ and of $\lambda - \delta\lambda$.

If we represent the probable error of a determination of longitude by a single chronometer and voyage by ϵ, we may suppose it to result from two independent sources of error:

1st. That depending upon u only, denoted by ϵ'.

2d. The probable error of the assumption that the true gain or loss of the chronometer on the voyage is represented by our equations (1) and (6); this we will denote by ϵ''.

We then have—

$$\epsilon^2 = \epsilon'^2 + \epsilon''^2$$

If ϵ'' is supposed to be proportional to the length of the voyage and to the liability of the chronometer to error, we shall have—

$$\epsilon'' = k''\, t'$$

k'' being the index of irregularity of the performance of each chronometer.

The probable errors of (8) and (9) dependent on ϵ', may be simplified by a substitution, admissible for most voyages, of—

$$\epsilon_0 = \tfrac{1}{2}\,[\text{probable error of } u_2 + \text{probable error of } u_3]$$

$$t_0 = \tfrac{1}{2}\,(t + t'')$$

We then have—

$$\epsilon' = \epsilon_0 \sqrt{2 + \left(\frac{t^1}{t_0}\right)^2}$$

In other cases a more exact formula has been used.

The constant k'' has been found for each chronometer by two independent processes.

1st. From shore rates.

2d. From the discrepancies of the single results for longitude from the mean of all: in other words, from a comparison of sea rates with the previous and subsequent shore rates. For the voyages, in which the chronometers were liable to exposure to low temperatures, distinct values of k'' have been used, in order that ϵ'' should include their susceptibility to such exposures.

The weights have been assigned from the probable errors ϵ' and ϵ'' by the formula.

$$W = \frac{g}{\epsilon'^2 + \epsilon''^2}$$

For the combination of the results the relative weights are needed only. For convenience $g = 50$ has been adopted; we have then,

For $W = 10$ $\quad \epsilon = \pm\ 2s.24$
$W = 1$ $\quad \epsilon = \pm\ 7s.07$

The absolute value of the unit of weight has been deduced from the discrepancies of the individual results.

With the weights found from the formula $W = \frac{g}{\epsilon'^2 + \epsilon''^2}$, the means of the east and west voyages have been separately deduced, as well as those by each chronometer. The following are the results for Cambridge, west of Liverpool:

		h.	m.	s.	s.
1849–'50, voyages L. to C.	$\lambda + \delta\lambda =$	4	32	29.08	± 0.34
" " C. to L.	$\lambda - \delta\lambda =$	4	32	31.82	± 0.48
Voyages of 1849–'50	$\lambda =$	4	32	30.45	± 0.29
1851, voyages L. to C.	$\lambda + \delta\lambda =$	4	32	29.10	± 0.37
" C. to L.	$\lambda - \delta\lambda =$	4	32	32.40	± 0.33
Voyages of 1851	$\lambda =$	4	32	30.75	± 0.25
		h.	m.	s.	s.
Mean of both expeditions by weights	$\lambda =$	4	32	30.63	± 0.19
Liverpool west of Greenwich		+	12	00.05	± 0.04
Correction for personal equations			—	.02	± 0.03
Concluded longitude of Cambridge		4	44	30.66	± 0.20

	s.
The rejection of the result most discrepant from the mean, alters the final longitude by	—0.01
Rejection of the two most discrepant	—0.03
" four most discrepant	—0.02
" eight most discrepant	+0.01
" twenty-six most discrepant	—0.04

The probable error of the personal equation correction can scarcely be regarded as a true index of the uncertainty of this element.

We are not in possession of data sufficient to enable us to say with certainty how far the effect of temperature will serve to explain the existing difference of east and west voyages; but that it has an appreciable influence is certain.

It is a well-established fact, that the average temperature compensation of chronometers is of such a nature as to cause the instrument to lose on its daily rate when exposed to a temperature either above or below a certain point, for which the compensation is most perfect.

If we represent by θ the temperature of exposure, and by θ_0 that of the best compensation, I have found from a large number of chronometers that the rate of gain may be expressed for a range of 20° above and below θ_0 by the formula:

$$\frac{d\,u}{d\,t} = a = a_0 + \frac{K}{1.2}(\theta - \theta_0)^2$$

in which K has, with rare exceptions, a *negative* sign.

If we make—

$$h = \int_0^t (\theta - \theta_0)^2\, d\,t$$

$$H = -h' + \tfrac{1}{2}\left[\frac{h}{t} + \frac{h''}{t''}\right] t' \text{ from the voyage L. to C.,}$$

$$H = +h' - \tfrac{1}{2}\left[\frac{h}{t} + \frac{h''}{t''}\right] t' \text{ from the voyage C. to L.,}$$

we shall have for the temperature correction of longitude

$$\delta_\theta \lambda = \frac{K}{1.2} H.$$

The average sea exposures give a negative sign to H for the voyages from Liverpool to Cambridge, and a positive sign for those in the opposite direction. Combined with the negative sign of K, this gives for the sign of $\delta_\theta \lambda$,

+ for the voyages L. to C.
— for the voyages C. to L.

From the most reliable values of θ which could be obtained or estimated, H has been computed for all the voyages giving a correction of the concluded longitude $\delta_\theta \lambda = -0s.15$; which, however, rests upon precarious data. It is quite possible that the true correction may exceed this amount.

Although this has not been applied, it should be noticed that the probable errors of $\lambda + \delta \lambda$, and of $\lambda - \delta \lambda$, that is, of λ by the west and east voyages, include the probable effect of temperature. But there is no reason to doubt that the temperature effect, which is of itself sufficient to account for the difference of east and west voyages, might be completely eliminated in future expeditions by means of an accurate thermometric record of the exposures of the chronometers;* the values of the co-efficient being determined experimentally for each of them.

In the accompanying tabular view‡, in the column "voyage," L. indicates the first voyage *from* Liverpool, C. that from Cambridge. The voyages of 1849–'50 extended from August, 1849, to January, 1850. Those of 1851, from July to October.

The index of irregularity of each chronometer, deduced both from the sea and shore rates, is k'': this constant includes the probable effect of the average temperature exposure; t' is the length of the voyage in days, or, more properly, the interval between the epochs of u_2 and u_3; ϵ' is the probable error of λ, attributable to errors in the determination of local time, independent of the personal equation of the observers; ϵ'' is the probable error of λ dependent on k'' and t'.

Respectfully submitted:

G. P. BOND.

Dr. A. D. BACHE, *Supt. U. S. Coast Survey.*

APPENDIX No. 43.

Table of Magnetic Declination.

The magnetic declinations observed during the progress of the survey, from 1844 to 1854, are collected in the following table. The localities are arranged in a natural geographical order, beginning with the northeastern part of the Atlantic coast. The latitudes and longitudes are given to the nearest tenth of a minute. Most of these stations are trigonometrical points, and may be found in the list of geographical positions published in the annual reports for 1851 and 1853.

The magnetic meridian has generally been determined with the portable declinometer of Gauss and Weber; in some instances with a variation-transit or a magnetic theodolite. Observations were generally made about the time of the day maxima and minima—the mean of which is the declination given in the table. In some cases half-hourly observations from 6*h*. a. m. to 6*h*. p. m. were made; and in a few instances the observations were continued for half an hour only. All of which have been reduced to the same mean position by means of the curves of daily variation derived from observations at the magnetic observations at Girard College and Toronto.

The astronomical meridian has generally been obtained from the azimuths of the triangulation, or occasionally by special observations of the sun or Polaris.

At some of the stations where local attraction was suspected, observations have been made at different times and at different localities, not far distant from each other.

* Such an expedition has been provided for.—*Superintendent.*
‡ Omitted.

U. S. Coast Survey—Magnetic Declination.

Sec.	Station.	Lat.	Long.	Decl. W.	Date.	Locality—Geology—Remarks.
		° ′	° ′	° ′		
I.	Ragged Mountain	44 13.0	69 09.0	14 17.5	1854, September	Waldo county, Me. Gneiss. Near the geodetic station, on the summit.
	Camden Village	44 12.0	69 05.0	14 00.1	1854, October	On Penobscot bay, Waldo county, Me. Gneiss. On ground of Mr. Hugier.
	Mount Sebattis	44 09.1	70 04.5	12 53.5	1853, July 25–27	At the foot of Mount Sebattis, town of Wales, Me., in the meadow of Colonel H. Marr. On top of the hill the declination was found to vary from 9° to 14° in a space of 50 yards. The hill is composed of granite, with quartz veins and detached masses of mica.
	Mount Pleasant	44 01.6	70 49.0	14 32.1	1851, Aug. 21–25	Town of Denmark, Me. Granite.
				11 10	1853, June 20	Near summit. Observations by compass needle.
	Cape Small	43 46.7	69 50.4	12 05.5	1851, Oct. 16–20	Town of Phippsburg, Me., on the property of M. R. Morrison, 50 yards to south of geodetic station. Gneiss.
				10 45	1853, June 22	10 yards to N.N.W. of geodetic station. By compass.
	Mount Independence	43 45.5	70 18.9	11 46.4	1849, Oct. 6–9	Town of Falmouth, Me., in a field of Mr. Josiah Hobbes, close to the old road to Gray.
				12 00.0	1853, July 30	By compass. Diluvial clay and gravel.
	Bowdoin Hill	43 38.8	70 16.2	11 41.1	1851, Aug. 18–20	In the grounds of J. B. Brown, city of Portland. Diluvial sand and gravel.
				11 50.0	1853, July 30	By compass, south of the grounds.
	Richmond island	43 32.6	70 14.1	12 18.1	1850, Sept. 14–16	In a field near the dwelling-house of Dr. Cummings. Talcose and mica slate, intersected by a large trap-dike.
	Fletcher's Neck	43 26.8	70 20.2	11 17.5	1850, Sept. 10–12	Mouth of Saco river, extremity of south point. Metamorphic slate.
	Kennebunkport	43 21.4	70 27.8	11 23.6	1851, Aug. 25–27	150 yards N.N.W. of Kennebunkport observatory. Granite.
	Mount Agamenticus	43 13.4	70 41.2	10 09.8	1847, Sept. 23, Oct. 2.	On the summit of Mount Agamenticus, town of York, Me. Sienite.
	Cape Neddick	43 11.6	70 36.1	11 09.0	1851, Aug. 29–31	Town of York, Me., in a field of Mr. James Myer, on the north side of Cape Neddick river, to the south of and near the road leading to the sea-shore. Granite underlying the soil.
	Patuccawa	43 07.2	71 11.5	10 42.8	1849, Aug. 15–19	On the summit of the hill, in the town of North Deerfield, N. H.
	Kittery Point	43 04.8	70 42.7	10 30.2	1850, Aug. 28, Sept. 12.	In an enclosure to the east of Mr. R. F. Gerrisk's cottages. Argillaceous slate.
	Mount Unkonoonuc	42 59.0	71 35.0	09 04.1	1848, Oct. 6–8	The highest and most easterly summit of that name in Goffstown, 10 miles west of Manchester.
	Isles of Shoals	42 59.2	70 36.5	10 03.5	1847, Aug. 12–19	On the south side of the harbor of Hog island, 100 yards from the water.
	Plum island	42 48.0	70 48.5	10 05.6	1850, Sept. 18–20	Near Thompson's hotel, on Plum island, near Newburyport, Mass. Diluvium, covered with sea-sand.
	Annisquam	42 39.4	70 40.3	11 36.7	1849, Aug. 28	Sienite.
	Beacon Hill	42 36.2	70 38.3	11 21.1	1849, Aug. 24–27	On the eastern point, Gloucester, Mass. Sienite.
	Baker's Island light	42 32.2	70 46.8	12 17.0	1849, Sept. 1–4	100 yards from the light, in the direction to Half-way Rock. Sienite.
	Fort Lee	42 31 9	70 52.1	10 14.5	1849, Aug. 20	Salem, Mass. Sienite.
	Coddon's Hill	42 30.9	70 50.9	11 49.8	1849, Sept. 6–8	Marblehead, Mass. Sienite.
	Little Nahant	42 26.2	70 55.5	09 40.9	1849, Aug. 15–17	On the hill. Sienite.
	Dorchester heights	42 20.0	71 02.2	09 31.4	1846, Sept. 6–8	Argillaceous slate.
	Nantasket	42 18 2	70 54.0	9 37.4	1847, Sept. 1–3	Argillaceous slate.
	Blue Hill	42 12.7	71 06.5	9 13.5	1845, Sept. 28, Oct. 5.	Dedham, Mass. Sienite.
	Beacon-pole Hill	41 57.9	71 26.7	9 27.0	1844, Oct. 31, Nov. 18.	Near Cumberland Hill village, R. I. Granite.
	Manomet Hill	41 55.6	70 35.1	9 16.9	1845, Sept. 9–11	Near Plymouth. Mass. Drift.
	Copecut Hill	41 43.3	71 03.3	9 08.8	1844, Sept. 27, Oct. 17.	In the town of Fall River, Mass. Granite.
	Spencer's Hill	41 40.7	71 29.3	9 05 9	1844, July 29, Aug. 31.	Near East Greenwich, R. I. Metamorphic slate.
	Shootflying Hill	41 41.1	70 20.3	9 37.4	1845, Aug. 15–22	Near Barnstable, Mass. Drift.
				9 40.3	1846, Aug. 28–30.	
	Hyannis	41 37.9	70 18 1	9 21.6	1846, Aug. 14–26	On a hill near Hyannis port, about 60 feet high. Drift.
	Fairhaven	41 37.4	70 53.7	8 54.2	1845, Oct. 17–19	Opposite New Bedford, Mass., 22 yards east of fort. Gneiss.
	Tarpaulin Cove	41 28.1	70 45.1	9 12.1	1846, Aug. 7–9	Nashua, Mass., northeast of the light, near the south shore of the cove. Drift.
	Indian Hill	41 25.7	70 40.3	8 43.9	1843, July 13, Aug. 2.	Martha's Vineyard. Tertiary strata.
				8 49.4	1846, Aug. 12–13.	
	Sampson's Hill	41 22.7	70 28.7	8 48.7	1846, July 22–27	On Chappaquidick island, opposite Edgartown, Martha's Vineyard. Drift.
	Nantucket	41 17.0	70 05.6	9 14.0	1846, July 30–31	On the north beach, near the edge of the town, due north of Mitchell's observatory. Drift.
	McSparran's Hill	41 29.7	71 27.1	8 48.5	1844, July 10–24	South Kingston, R. I., in a field near the angle of the roads to Kingston and Wickford.
	Point Judith light	41 21.6	71 28.6	8 59.7	1847, Sept. 5–9	100 yards towards Beavertail light.
II.	Watch Hill	41 18.8	71 50.9	7 33.4	1847, Sept. 17–19	Half a mile north of Watch Hill lights, near Stonington, Conn. Granitic gneiss.
	Stonington	41 20.0	71 54.0	7 38.1	1845, Aug. 8, 9	Connecticut.
	Groton Point	41 18.0	72 00.0	7 29.5	1845, Aug. 14	Connecticut.
	Saybrook	41 16.0	72 20.0	6 49.9	1845, Aug. 20	Connecticut.
	Greenport	41 06.0	72 21.0	7 14.4	1845, Aug. 19	In Southold, Long island. Drift.
	Sachem's Head	41 17.0	72 43.0	6 15.2	1845, Aug. 23	Connecticut. Reddish granite gneiss.
	Fort Wooster	41 16.9	72 53.2	7 27.2	1847, Sept. 25, Oct. 2.	Near New Haven, Conn. Trap.
				7 25.5	1848, Aug. 21–29	Trap.
	New Haven	41 18.0	72 54.3	6 17.3	1845, Sept. 10	Near Pavilion Hotel. Trap.
				6 37.9	1848, Aug. 10–14.	Trap.
	Oyster Point	41 17.0	72 55.4	6 31.9	1848, Aug. 30, Sept. 1.	Near New Haven, in the meridian of Yale College observatory. Trap.
	Milford	41 16.0	73 01.0	6 38.3	1815, Sept. 19	Greenstone and chloritic slate.
	Bridgeport	41 10.0	73 11.0	6 19.3	1845, Sept. 18	Connecticut. Gneiss and mica slate.
	Black Rock	41 08.6	73 12.6	6 53.5	1845, Sept. 20	Connecticut. Gneiss and mica slate.
	Norwalk	41 07.0	73 24.0	6 49.4	1844, Sept. 14	Connecticut; on Judge Isaacs' hill. Granite.
	Stamford	41 03.0	73 32.0	6 36.0	1844, Sept. 12	Connecticut; in the rear of the Union Hotel. Granite.
	Sawpits	40 59.0	73 39.0	5 58.0	1844, Sept. 11	Steamboat landing at Port Chester, Westchester county, N. Y. Gneiss.

Magnetic Declination—Continued.

Sec.	Station.	Lat.	Long.	Decl. W.	Date.	Locality—Geology—Remarks.
		° ′	° ′	° ′		
II.	Drowned Meadow	40 56.0	73 03.5	6 03.6	1845, Sept. 12	Near Drowned Meadow village, north shore of Long island. Drift.
	Lloyd's harbor	40 55.6	73 24.8	6 11.6	1844, Sept. 15	Huntingdon, Long island. Drift, with boulders.
	Oyster bay	40 52.3	73 31.3	6 50.5	1844, Sept. 16	North shore of Long island. Drift.
	New Rochelle	40 52.5	73 47.0	5 29 5	1844, Sept. 10	About 100 yards south of the Neptune House, in New Rochelle, Westchester county, N. Y. Gneiss and hornblendic rocks.
	Sand's Point	40 52.0	73 43.0	7 14.6 6 09.9	1845, Sept. 27 1847, Oct. 8–11.	40 yards E N.E. from Sand's Point light. Drift, covered with alluvium.
	Legget	40 48.9	73 53.0	5 41.0	1847, Oct. 16–20	In a cove north of Ricker's island, Long Island sound. Gneiss, covered with alluvium.
	Bloomingdale asylum	40 49.0	73 57.0	5 09.7	1846, April 30	Island of New York. Gneiss rock underlying the soil.
	Columbia College, N. Y	40 42.7	74 00.1	6 13.1 6 25.3	1844, Aug. 24 1845, Sept. 4.	City of New York. Gneiss rock underlying drift, loam, and gravel.
	Newark.	40 44.8	74 07.0	5 35.1	1846, May 14	New Jersey. Alluvial soil, sand, and gravel, superimposed on the new red sandstone in place.
	Mount Prospect	40 40.3	73 57.7	5 54.7	1846, May 6	Near Brooklyn, Long island. Drift, with small boulders of granite and trap.
	Cole	40 31.9	74 13.8	5 37.4	1846, May 7	In Westfield, southwestern part of Staten island. Drift, with small boulders.
	Sandy Hook	40 28.0	73 59.8	5 51.0	1844, Aug. 20–22	250 yards north of light. Green sand formation, alluvial sand.
	Mount Rose	40 22.2	74 42.9	5 31.8	1852, Aug. 13–15	About 5 miles west of Princeton, N. J., in a field near the house of Mr. Th. Hunt. Trap rock, protruding through new red sandstone.
	Whitehill	40 08.3	74 43.6	4 25.9	1846, May 20	Near Bordentown, N. J., on the bank of the Delaware river. Tertiary marl.
	Vanuxem	40 06.7	74 53.0	4 27.8	1846, July 10-11	At Professor Vanuxem's, two miles above Bristol, on the Delaware river, 100 yards northwest of the canal. Diluvium of clay, sand, and gravel, superimposed on primitive rock.
	Girard college	39 58.4	75 09.9	3 51.1	1846, May 23	In the yard of the Magnetical observatory, at Girard college, Philadelphia.
	Chew	39 48.2	75 09.7	3 45.2	1846, July 15	Near Woodbury, N. J. Marl and green sand.
	Tucker's island	39 30.8	74 16.9	4 27.8	1846, Nov. 10	Entrance to Little Egg Harbor, N. J., northwestern point of island. Alluvium white sand.
	Wilmington	39 44.9	75 33.6	2 30.7	1846, May 27	Delaware. A hill 1¼ mile W.N.W. of the town hall. Trap, covered with red clay. Local attraction.
	Sawyer	39 42.6	75 33.8	2 48.3	1846, June 3	Three miles south of Wilmington, Del. At the edge of the tertiary formation no rocks or boulders apparent.
	Church Landing	39 40.6	75 30.4	5 49.1	1846, June 6	New Jersey; on the Delaware river. Drift. Local attraction ascertained to exist, by partial observations, at three localities.
	Fort Delaware	39 35.3	75 33.8	3 16.8	1846, June 14	Pea Patch island, Delaware river. Alluvial mud at least 70 feet deep.
	Hawkins	39 25.6	75 17.0	2 58.8	1846, June 20	Near Roadstown, N. J. Tertiary formation; some ferruginous sandstone in vicinity.
	Pine Mount	39 25.0	75 19.9	3 14.2	1846, June 19	An isolated hill near Greenwich, N. J. Tertiary; unmagnetic iron ore.
	Bombay Hook light	39 21.8	75 30.3	3 18.5	1846, June 17	About 60 yards E.S.E. of the light-house. Diluvial clay and sand.
	Port Norris	39 14.6	75 01.0	3 04.4	1846, June 23	New Jersey. Tertiary marl and sand.
	Egg Island light	39 10.5	75 08.0	3 03.0	1846, June 25	Delaware bay, 60 yards south by west of light-house. Tertiary marl and sand.
	Town Bank	38 58.6	74 57.4	2 59.0	1846, June 30	At Price's, near Cape May. Tertiary marl and sand.
	Cape May light, (old)	38 55.8	74 57.6	3 05.1	1846, June 28	70 yards southeast of old light-house. Tertiary marl and sand.
	Pilot Town	38 47.1	75 09.2	2 42.7	1846, July 2, 3	On Cape Henlopen. Clay and sand.
III.	Osborne's Ruin	39 27.9	76 16.6	2 32.4	1845, June 19–24	Near Abingdon, Md. Talcose slate and hornblende.
	Susquehanna light	39 32.4	76 04.8	2 13.7	1847, July 6, 7	A short distance to northwest of light-house, at the mouth of Susquehanna river. Ferruginous clay and sand.
	Finlay	39 24.4	76 31.2	2 14.6 2 18.5	1845, June 13, 14 1846, April 16	On Cub Hill, the property of L. B. Finlay, 9 miles north of Baltimore, on the Harford turnpike. Primitive rocks underlying gravel and sand.
	Pool's island	39 17.1	76 15.5	2 29.3	1847, June 24–27	Chesapeake bay, near the dwelling of P. Wethered, on the upper island. Diluvial clay and sand.
	Rosanne	39 17.5	76 42 8	2 10.9	1845, June 10	On Prospect Hill, 5 miles from Baltimore, north of the old Frederick road. Diluvial clay and sand.
	Fort McHenry	39 15.7	76 34.5	2 18.6	1847, April 29	Baltimore harbor, between the hospital and western stable. Ferruginous sand and clay.
	North Point	39 11.7	76 26.3	7 36.7 7 39.6	1846, July 7, 8 1847, April 27	Between the two lights at the mouth of Patapsco river. Ferruginous sand and clay.
	Bodkin light	39 08.0	76 25.2	2 05.9	1847, April 25, 26	20 yards S.S.E. from light-house. Ferruginous sand and clay.
	Kent island, I	39 01.8	76 18.8	2 30.2	1849, June 27, July 4	North end of Kent island, Chesapeake bay. Ferruginous sand and clay.
	South base, Kent island	38 53.8	76 21.7	2 24.3	1845, June 3, 4	On the west shore of Kent island, opposite Thomas' Point, 21 yards north of monument. Ferruginous sand and clay.
	Taylor	38 59.8	76 27.6	2 14.4 2 18.0	1845, May 31, June 1. 1847, May 28, June 3.	On the north side of Severn river, opposite Annapolis, Md. Ferruginous sand and clay.
	Marriott	38 52.4	76 36.2	2 09.4 2 05.0	1846, May 24, June 6 1849, June 12–20	A prominent hill near West river, Md., the property of Bushrod Marriott. Green sand formation, ferruginous clay and marl.
	Webb's Hill	39 05.3	76 40.2	2 07.9	1850, Nov. 20–23	Anne Arundel county, Md., near the Annapolis railroad, 12 miles from Annapolis. Green sand formation, ferruginous clay and marl.
	Soper's Hill	39 05.1	76 56.7	2 07.1	1850, July 20–26	Prince George's county, Md., 14 miles from Washington city, on the old Columbia road; property of J. B. Downes. Talcose slate.

Magnetic Declination.—Continued.

Sec.	Station.	Lat.	Long.	Decl. W.	Date.	Locality—Geology—Remarks.
		° ′	° ′	° ′		
III.	Hill's Hill	38 53.9	76 52.5	2 18.6	1850, Sept. 19–22	Prince George's county, Md., 6 miles east of Washington city. Ferruginous clay and sand.
	Caustin's Hill	38 55.5	77 04.1	2 11.3	1851, June 14–19	Near Georgetown, D. C., 122 yards west of the geodetic station, in the grounds of J. H. Caustin. Gneiss, underlying ferruginous clay and gravel.
	Davis	38 20.4	75 06.0	2 33.0	1853, Sept. 25–27	On the west shore of Sinepuxent bay, east of Berlin, Md. Ferruginous clay and sand.
	Roslyn	37 14.4	77 23.6	0 26.5	1852, Aug. 9–13	Near Petersburg, Va. Drift, ferruginous clay.
IV.	Stevenson's Point	36 06.3	76 10.7	1 39.6	1847, Jan. 30, Feb. 15.	Western point, at the mouth of Little river, Albemarle sound, N. C. Tertiary clay and sand.
	Shellbank	36 03.3	75 43.8	1 44 8	1847, Mar. 27, April 8.	On Albemarle sound, east point of entrance into Currituck sound. Alluvial mud, sand, and shells.
	Bodie's island	35 51.8	75 34.2	1 13.4	1846, Dec. 26–28	North Carolina, near the beach, about 5 miles N.N.W. of the light-house. White sand.
				East.		
	Raleigh, N. C	35 46.8	78 37.8	0 44.5	1854, Jan. 7–11	Station 105 feet east and 26 feet north of centre of Capitol dome. Primitive rock underlying the soil.
	De Rosset	34 14 0	77 56.5	1 13.5	1854, May 30, June 2.	On a lot adjoining Dr. Drum's residence, north side of Market street, Wilmington, N. C. Tertiary clay, gravel, and sand.
V.	Columbia, S. C	34 00.0	....	3 01.7	1854, Feb. 19–23	In the Capitol square, 164 feet from the southwest corner, and 293 feet from the northwest corner, of the new Capitol. Tertiary formation.
	Allston	33 21.7	79 12.3	2 06.5	1853, Dec. 21–27	Near Georgetown, S. C. Diluvium.
	Breach inlet	32 46.3	79 48.7	2 16.5	1849, April 1–22	On Sullivan's island, Charleston entrance, S. C. White sand.
	East Base, Edisto island	32 33.3	80 10.0	2 53.6	1850, April 2–7	Edisto island, S. C. Tertiary formation, diluvial mud, clay, and sand.
	Savannah	32 05.0	81 05.2	3 40.3	1852, April 26–28	On Hutchinson's island, in range of Exchange and Presbyterian church steeples, near the second embankment from the river. Diluvium.
	Tybee island	32 01.5	80 50.6	3 32.1	1852, April 30, May 2.	Near the mouth of Savannah river, on a sand dune, near the boat-house.
VI.	Cape Florida	25 40.4	80 09.8	4 25.2	1850, Feb. 22–25	On the inside beach of Key Biscayne, the light-house bearing southeast. Black mud and white sand.
	Sand key	24 27.2	81 52.7	5 28.8	1849, Aug. 19–21	Near Key West, Florida. A small island on the Florida reef, composed of detritus of marine shells and coral.
VII.	Depot key	29 07.5	83 02.8	5 20.5	1852, March 14–16	Cedar Keys, Florida, on the highest point of the island. Drifted white sand on diluvial mud.
	St. Mark's light	30 04.4	84 10.6	5 29.2	1852, April 2	In the salt marsh, about 400 yards north of the light.
	Dog island	29 47.1	84 36.1	5 51.2	1853, April 1	Appalachicola entrance. White sand.
VIII.	Fort Morgan	30 13.9	88 00.3	7 04.1	1847, May 21–30	400 yards northeast of the northwest bastion of Fort Morgan, Mobile Point, Ala. Drifted white sand.
	East Pascagoula	30 20.7	88 31.8	7 12.6	1847, June 18–20	Mississippi. About a mile east of the mouth of Pascagoula river, in the village near the shore. Tertiary formation, ferruginous clay and white sand.
	Fort Livingston	29 16.7	89 54.5	7 38.4	1853, January	Barrataria bay, La. Diluvium, covered with drifted white sand.
IX.	Dollar Point	29 26.0	94 52.6	8 57.4	1848, April 24–28	On Galveston bay, 10 miles northwest of Galveston, Texas. Sandy loam.
	East Base	29 12.9	94 55.0	9 05.0	1853, March 16–21	On G lveston island, 10 miles southwest of Galveston, and half a mile from the Gulf shore. Sandy loam.
	Jupiter	28 54.8	95 19.8	9 08.7	1853, May 10–15	Four miles southwest of Quintana, Texas, near the beach. Drifted sand.
	Rio Grande	25 57.4	97 07.6	9 00.9	1853, November	Near the mouth on the American side. Diluvium.
X.	San Diego	32 42.0	117 13.0	12 28.8	1851, April 28, May 7.	California, at the Plaza, near the "quarters." Very coarse sandstone. The high ridge of Point Loma is to the west.
				12 31.7	1853, Oct. 15	At the Plaza, near the custom-house.
	San Pedro	33 46.0	118 16.0	13 30.5	1853, Nov. 24–26	On the open plain, about 3 miles north of San Pedro. Gravel, resting on beds of recent fossil shells.
	Point Conception	34 26.9	120 25.6	13 50.2	1850, Sept. 5–8	California; near the mouth of the valley of El Coxo. A rich soil. Surrounding hills show limestone, quartz, &c.
	San Luis Obispo	35 10.6	120 43.5	14 16 9	1854, Jan. 30, Feb. 7.	California. The surrounding hills are of soft limestone, resting on coarse red sandstone, bearing enormous fossil rem ins.
	Point Pinos	36 38.0	121 54 4	14 58.3	1851, Feb. 6–10	Near Monterey, Cal. A rich soil, resting on sandstone. Beach formed of large granite boulders.
	San Francisco	37 47.6	122 26.8	15 26.9	1852, Feb. 18–28	Near the Presidio. Surrounding hills limestone.
	Bucksport	40 46.6	124 10.7	17 06.5	1853, July 19, 20	California; on the beach. Sand and marsh.
	Humboldt	40 44.7	....	17 04.5	1854, April 25, May 2.	At the foot of the western part of the bluff, composed of ferruginous clay and sand, resting on gravel bearing fossil remains of *elephans primo genus*.
XI.	Ewing harbor	42 44.4	124 28.8	18 29.7	1851, Nov. 19–29	Near Cape Orford, Oregon. Geology very varied. South of Port Orford, coal and plumbago; north, limestone, filled with fossil shells.
	Cape Disappointment	46 16.6	124 02.0	20 19.1	1851, July 5–9	On the beach, white sand mixed with black ferruginous and auriferous sand. Surrounding hills basalt.
				20 45.3	1851, July 14–19	On the summit of the Cape. Horizontal columnar basalt.
	Scarboro' harbor	48 21.8	124 37.2	21 29.9	1852, Aug. 17–23	Near Cape Flattery, Washington Territory. Sand. Surrounding hills varied, limestone principally; basalt cropping out at Tatoosh island.

APPENDIX No. 44.

Extracts from reports of Assistant George W. Dean on the establishment of meridian lines at Petersburg, Va., and Raleigh and Wilmington, N. C.

PETERSBURG, VA.

* * While your party was engaged in astronomical observations at Roslyn Hill, (in 1852,) a committee of the city council of Petersburg expressed a wish for the establishment of a meridian line in or near the city, and by your direction a line was traced south from Roslyn Hill, and permanently marked in the following manner:

The forty-three inch transit by Troughton & Simms, (C. S. No. 8,) was adjusted to the meridian by observations on circumpolar and equatorial stars. Two marble posts were then placed a hundred and twenty metres apart, in the range of the instrument directly south of the city gas-works, and firmly imbedded in the earth; and a third, two feet in length, was planted at the southern terminus of the line, distant two and a half miles on the south side of the Appomattox river, and near the residence of Mr. Russell. This was marked by the intersection of two lines cut on the top of the post.

The north terminus was marked by a drill-hole in the top of the granite block upon which the transit instrument had been adjusted.

RALEIGH, N. C. (1854.)

* * A meridian line, five hundred and twenty feet in length, extending across the *Capitol square,* was accurately traced by means of the forty-six inch transit, (C. S. No. 6,) which had been adjusted in the meridian for astronomical purposes.

The ends of this line were marked by copper bolts inserted in the top of the granite foundation which supports the iron fence of the square. The point directly below the transit instrument, coincident with its centre, was fixed by the intersection of lines cut at right-angles upon a granite post ten inches square at the end, and sunk two feet and three quarters in the ground, leaving the top of the post level with the surface. This was inscribed with the letters U. S. C. S.

WILMINGTON, N. C. (1854.)

* * By your direction a meridian line was established in this city during the progress of the astronomical observations made by your party.

The line was traced with the forty-three inch transit (C. S. No. 8) previously adjusted for the meridian by observations upon equatorial and circumpolar stars. The north terminus is in the rear of the building known as the "*Old Theatre,*" and was permanently marked by a marble post inscribed with the letters U. S. C. S. The southern terminus, marked in a similar manner, is located near the rear entrance gate of the St. James Episcopal church on Market street, the top of the post being sunk eighteen inches below the ground surface, with reference to a contemplated grading of the site. Its exact position will be found at the intersection of lines 23.5 feet from a copper nail in the trunk of the locust tree within the yard, and 9.5 feet from the northeast corner of the church.

The meridian lines thus established, besides facilitating the operations of the engineer and surveyor, might also be made of general convenience to residents in the vicinity of their location.

At small expense convenient sun-dials could be erected, and by means of the *equation of time* usually given in the common almanacs, the *local time* could be readily determined to the nearest minute.

Very respectfully,

GEORGE W. DEAN, *Assistant.*

A. D. BACHE, LL. D.,
Superintendent Coast Survey.

APPENDIX No. 45.

Preliminary determinations of co-tidal lines on the Atlantic coast of the United States, from the Coast Survey tidal observations, by A. D. Bache, Superintendent.

(Communicated to the American Association for the Advancement of Science, by authority of the Treasury Department.)

In the progress of the hydrography of the Atlantic coast of the United States, numerous tidal observations have necessarily been made for correcting the soundings and determining the establishments of the ports. With them I have connected observations of a more permanent character, intended to furnish the data for ascertaining the laws of the tides in important localities, and others for tracing the progress of the tide-wave along the coast generally, and in special cases in sounds, bays, and rivers. These observations are still in progress; indeed, those for developing the laws of the tides, and determining the constants of theory, depend for their value upon their long continuance. So many authentic results have now, however, been obtained, that it appears desirable to put them together, and to ascertain the conclusions towards which they tend as to the co-tidal lines, and by the agreement of the separate results with general laws, or their departure from them, to determine which of them require further observations to check their first results, and where new stations of observations are necessary for the purpose. My attention has been called, also, by the request of a valued friend, the Master of Trinity College, Cambridge, to some attempt of this sort, and his labors in connection with this subject on our own coast have entitled his request to the most respectful consideration.

I am indebted to L. F. Pourtales, esq., in charge of the tidal party of the U. S. Coast Survey, for the revision of the computations given in this paper. The labor of reducing the observations themselves has fallen chiefly upon Messrs. Heaton, Fendall, and Hawley. The diagrams have been prepared by Mr. C. Fendall, under the direction of Mr. Pourtales.

The stations at which observations of the tides have been made, of the more reliable class, are thirty-three in number, extending on the Atlantic coast from Cape Florida to Portland, Maine. I have been able, through the kindness of Captain Shortland, R. N., in charge of the Admiralty survey of Nova Scotia, to extend the results to the entrance of the Bay of Fundy.

Table No. 1 gives the names of the places of observation, with the time during which the observations of high and low water were made, and remarks in relation to them. The stations marked (*) in Table No. 2, have been made use of in determining the co-tidal lines for this paper. A few stations have been embraced in the results where the number of observations is not comparable to those at the other points, chiefly to introduce localities important in position, and to sift the observations already made at them. Old Point Comfort, New York, and Boston harbor, have been permanent stations for some years: Charleston, Tybee entrance, Portsmouth, and Portland, have been more recently added to them.

TABLE No. 1.

Observations for co-tidal hours.

Stations.	No. of observed lunations.	Years.	Remarks.
Cape Sable, N. S.			Furnished by Captain Shortland, R. N.
Ellenwood's island, N. S.			
Fourchue island, N. S.			
Portland, Me.	6½	1852–3	Self-registering.
Portsmouth, N. H.	11	1851–2–3	Self-registering in 1852–3; all the sets agree pretty well.
Newburyport, Mass.	2	1851–2	
Ipswich	2	1852	
Gloucester	1	1853	
Salem	2½	1850	
Boston Light	3½	1847	Results reliable.
Boston Dry-dock	6½ yrs.	1847–'53	Best series.

Table No. 1—Continued.

Stations.	No. of observed lunations.	Years.	Remarks.
Wellfleet	1	1849	
Provincetown			From Major Graham's survey.
Monomoy	1½	1852	
Great Point, Nantucket	1½	1849–'50	
Siasconsett	3	1853–4	
Nantucket harbor	13	1846 to 1850	Irregular.
Tuckernuck	1	1850	
Wasque Point	1	1852	
Edgartown	7	1846–7–'51–2	
Holmes' Hole	6	1846–'51–2	
Wood's Hole (east)	3	1849–'52	
Tarpaulin Cove	3	1849–'51	
Quicks' Hole (south)	2	1851	
Menamsha Bight	1	1852	
Fort Adams	16	1844–'46	
Point Judith	6	1844–5	
Watch Hill	2¾	1848	
Montauk Point	2½	1848	Not a good series.
Fire island	2	1850	Not a good series.
Sandy Hook	17	1835–6–'44–'51	
Cold Spring inlet	11	1843–4	Day tides only.
Cape May landing	2	1847	
Delaware breakwater	10½	1840–'41–'43–'47	
Old Point Comfort	65	1846–'51	
Hatteras	1	1850	
Beaufort, N. C	2		
Smithville	9	1851–2	
Georgetown, S. C	1½	1852	
Charleston	6	1853	
Fort Pulaski	13	1851	
St. John's river	1	1853	
Cape Canaveral	11 tides	1850	Quite unreliable.
Cape Florida	1	1852	

To the short series of observations, especially, there should be applied corrections for declination and parallax; but after computing several cases, I was satisfied that the errors from other sources, and especially from the positions almost indispensably necessary to the tide-gauges, more than made up for any irregularities from this source, and determined in the preliminary inquiry to omit these corrections, which amount only to a few minutes even in extreme cases.

A much more important correction is that for the position of the gauge in a harbor or river entrance, in many cases within a bar. Where our charts are completed, we have the elements for computing this correction by the law of depth, supposing the wave to move in the channel with a velocity proportional to the square root of the depth. This law, when applied to two very different cases, Savannah river and Boston harbor, where we had the means of testing it by measured distances and known depths, was so completely verified, that I have not hesitated to apply it in the other cases.

The following Table No. 2 contains in the first column a number for reference; second, the names of the stations; third, the mean luni-tidal intervals or establishments; fourth, the longitude from Greenwich; fifth, the approximate co-tidal hour obtained by adding to the establishment the difference of longitude; sixth, a correction of one minute for every half hour of the establishment, to correct for the different transits of the moon used in reducing the observations, (see Mr. Whewell's paper, Phil. Trans. 1836, p. 293;) seventh, the co-tidal hour thus corrected; eighth, the co-tidal hour corrected for depth, where data were at hand for the purpose; ninth, the latitude of the station.

TABLE No. 2.

Co-tidal hours of ports on the Atlantic coast.

No.	Stations.	Corrected establishment.	Longitude from Greenwich.	Corrected establishment in Greenwich time.	Correction.	Co-tidal hour.	Co-tidal hour carried to coast by correcting for depth of water.	Latitude.
		h. m.	*h. m.*	*h. m.*	*m.*	*h. m.*	*h. m.*	° ′
1	*Cape Sable	8 50	4 23	13 13	18	12 55	....	43 25
2	*Ellenwood's island	9 45	4 24	14 9	19	13 50	....	43 39
3	*Fourchue island	10 00	4 25	14 25	20	14 5	....	43 47
4	*Portland, Maine	11 25	4 41	16 6	23	15 43	....	43 35
5	*Portsmouth, New Hampshire	11 23	4 42	16 5	23	15 42	....	43 3
6	*Newburyport, Massachusetts	11 22	4 43	16 5	23	15 42	15 27	42 48
7	Ipswich .... do	11 32	4 43	16 15	23	15 52	....	42 41
8	*Gloucester .... do	11 10	4 43	15 53	22	15 31	....	42 37
9	*Salem .... do	11 13	4 43	15 56	22	15 34	15 19	42 31
10	*Nahant .... do	11 12	4 43	15 55	22	15 30	....	42 25
11	*Boston Light ...... do	11 12	4 43	15 55	22	15 33	....	42 20
12	*Boston Dry Dock	11 22	4 43	16 5	22	15 53	15 30	42 20
13	*Wellfleet	11 5	4 40	15 45	22	14 43	....	41 56
14	*Provincetown	10 35	4 41	15 16	21	14 55	....	42 3
15	Monomoy	12 5	4 40	16 45	24	16 21	....	41 36
16	Great Point	12 4	4 40	16 44	24	16 20	....	41 23
17	Siasconsett	11 53	4 40	16 33	24	16 9	....	41 15
18	Nantucket	12 11	4 40	16 51	24	16 27	....	41 17
19	Tuckernuck	11 35	4 41	16 16	23	15 53	....	41 18
20	Wasque Point	9 19	4 42	13 1	19	12 42	....	41 21
21	Edgartown	11 6	4 42	15 48	22	15 26	....	41 24
22	Homles' Hole	11 43	4 42	16 25	23	16 2	....	41 28
23	Wood's Hole (east)	8 12	4 42	12 54	16	12 38	....	41 31
24	Tarpaulin Cove	8 4	4 42	12 46	16	12 30	....	41 28
25	*Quicks' Hole (south)	7 32	4 42	12 16	15	11 59	....	41 26
26	Menamsha Bight	7 52	4 43	12 35	16	12 19	....	41 20
27	*Fort Adams (Newport harbor)	7 45	4 45	12 30	15	12 15	....	41 29
28	*Point Judith	7 32	4 45	12 17	15	12 2	....	41 22
29	Watch Hill	9 00	4 47	13 47	18	13 29	....	41 19
30	Montauk Point	8 10	4 46	12 56	16	12 40	....	41 4
31	Fire Island	7 18	4 52	12 10	15	11 55	....	40 38
32	*Sandy Hook	7 29	4 56	12 25	15	12 10	....	40 28
33	*Cold Spring Inlet	7 32	4 59	12 31	15	12 16	....	38 57
34	*Cape May (landing)	8 19	4 59	13 18	17	13 1	....	38 56
35	*Delaware Breakwater	8 00	5 0	13 00	16	12 44	....	38 48
36	*Old Point Comfort	8 17	5 6	13 23	17	13 6	12 3	36 55
37	*Hatteras	6 57	5 2	11 59	14	11 45	....	35 15
38	*Beaufort, North Carolina	7 40	5 7	12 47	15	12 32	12 18	34 37
39	*Smithville ..... do	7 19	5 12	12 31	15	12 16	11 40	33 54
40	Georgetown, South Carolina	7 52	5 16	13 08	16	12 40	....	33 22
41	*Charleston, (Castle Pinkney)	7 13	5 19	12 32	14	12 18	11 38	32 43
42	*Fort Pulaski, (Tybee Entrance)	7 20	5 23	12 43	15	12 28	12 00	32 1
43	*St. John's River	7 31	5 26	12 57	15	12 42	12 27	30 20
44	*Cape Canaveral	7 21	5 22	12 43	15	12 28	....	28 27
45	*Cape Florida	8 26	5 20	13 46	17	13 29	....	25 40

In order to obtain the best results from the observations, they have been divided into groups, in the way and from considerations which will be hereafter explained.

Supposing the stations to be really connected in the physical group, and assuming that the space over which the observations extend is such that the co-tidal lines may be taken as straight lines, we obtain by least squares the position of the co-tidal lines, which will best satisfy the equation. The mean latitude and longitude of each group is taken, and the group is referred to this point as the origin of co-ordinates; the mean co-tidal hour is also taken. In the equation of the co-tidal line—

$$\mathrm{M}x + \mathrm{N}y = z$$

x and y represent the known co-ordinates, the difference of longitude being reduced to the same unit of the geographical mile as the difference of latitude. The co-efficients M and N are determined by the equations—

$$\mathrm{M}\,\Sigma x^2 + \mathrm{N}\,\Sigma xy = \Sigma xz$$
$$\mathrm{M}\,\Sigma xy + \mathrm{N}\,\Sigma y^2 = \Sigma yz$$

$-\frac{N}{M}$ is the tangent of the angle which the co-tidal line makes with the meridian, and $\sqrt{M^2 + N^2}$ gives the motion of the tide-wave, or difference of co-tidal hour for one geographical mile perpendicular to the co-tidal lines.

In this I have merely followed the admirable example given by Professor Lloyd, in the joint paper of himself and Colonel Sabine, on the magnetic survey of the British Islands.

Having investigated separate groups in this way, it is easy to draw the co-tidal curves which represent the observations; the investigation tests the grouping in an interesting way, by the coincidence or discrepancy of the computed and observed co-tidal hours.

The first approximate indication from the discussion is the correspondence of the tides on our Atlantic coast to the supposition of a tide-wave moving from S. 53° E. to N. 53° W.; but this is only a rude statement of the phenomena.

In scanning the co-tidal hours along the coast, we observe that they divide themselves into two groups, one south of Martha's Vineyard, and the other north of Cape Cod, with a short anomalous group between them.

The co-tidal hours from Cape Florida to Quicks' Hole, Martha's Vineyard sound, are not greater than 13*h.* 30*m.*, nor less than 11*h.* 38*m.* Hatteras is decidedly, as was pointed out by the Master of Trinity, the Rev. Mr. Whewell, a point of divergence, the establishments on the north and east of it, and the south and west of it, being, as a general rule, greater than the establishment of Hatteras. Our value for the co-tidal hour there differs from Mr. Whewell's, and further observations, now in progress, will decide between the two results.

From Provincetown, Cape Cod, to Cape Sable island, the co-tidal hours vary between 12*h.* 55*m.* and 15*h.* 43*m.*

Beginning at Tybee entrance, Fort Pulaski, Savannah river, we have a good series of tidal stations to Hatteras, five in number, forming group *a*, Table No. 3. The mean co-tidal hour is 11*h.* 52*m.*, and the angle which the co-tidal line makes with the meridian is 50° 09′, agreeing very nearly with the trend of the coast.

The motion perpendicular to the direction of the co-tidal line is twenty-four miles in half an hour, agreeing nearly with the velocity due to the depths, as will be seen by inspecting the chart of co-tidal lines which accompanies this paper, upon which the fifty and one hundred fathom curves are drawn from the best data we yet have. The mean discrepancy of the computed establishments and of those observed for this group, is 16*m.*; that of Beaufort differing most, and for Cape Fear the least.

If no correction had been applied for the positions of the tide-gauges within harbors, the results would have been as stated in group *a bis*, Table No. 3, which, while the position of the co-tidal line is but little changed, gives a result for the movement of the tide-wave which is entirely too small, as must of course be the case.

The next group north and east of this, *b*, consists of Old Point Comfort, Delaware Breakwater, Cold Spring inlet, and Sandy Hook, embracing a part of the coast having the same general direction. The mean co-tidal hour is 12*h.* 18*m.*; the angle of the co-tidal line with the meridian is 22° 21′, agreeing again with the general trend of the coast, which is about 26°, the true value of the motion being masked by the irregularities of the establishments. The computed establishments agree well with the observed, differing but five minutes in the average, and six minutes at the greatest.

In the next group, *c*, four stations are placed from Sandy Hook to Quicks' Hole, viz: Sandy Hook, Point Judith, Newport, carried to the entrance of the bay by the depth, and Quicks' Hole; the mean co-tidal hour is 12*h.* 6*m.*, the direction of the co-tidal line 63° 27′ east of the meridian; the distance gone over by the tide-wave in half an hour, forty miles; the mean difference in the computed and observed establishments is less than three minutes, and the greatest difference five minutes. Fire island and Montauk are omitted from this series as anomalous; if, however, they are included, the result shown in *c bis*, Table No. 3, is given, in which the direction of the co-tidal line is 58° 36′, and from which a decidedly erroneous velocity results.

Montauk looks like a point of convergence, as termed by Mr. Whewell; but its result is uncertain, and the observations there and at Fire island must obviously be repeated.

The group *d* consists of six stations between Cape Cod and Cape Ann, viz: Provincetown, Wellfleet, Boston, Nahant, Salem, and Gloucester. It gives for the mean co-tidal hour 15*h.* 15*m.*, for the inclination of the co-tidal line to the meridian 31° 17′, and for the distance gone over by the tide-wave in 30*m.* thirty-two miles. The average difference between the computed and observed co-tidal hour is less than four minutes, and the greatest difference less than ten.

Group *e* contains Newburyport, Portsmouth, Portland, Fourchue, Ellenwood's island, and Cape Sable. The mean co-tidal hour is 14*h.* 37*m.*, the angle of the co-tidal line with the meridian 44° 04′, and the motion of the tide-wave thirty miles in 30*m.* The average difference of the computed and observed co-tidal hour is rather more than ten minutes, and the greatest difference in the case of Cape Sable island amounts to 23*m.* Newburyport, which is brought to the sea establishment by the depth, differs but six minutes in the computed and observed numbers.

The twelve stations of the last two groups combined in one group, give 14*h.* 56*m.* for the mean co-tidal hour, 38° 46′ for the inclination of the co-tidal line, and thirty-three miles in half an hour for the motion.

Between *c* and *d* is the anomalous group which occupies Martha's Vineyard and Nantucket sounds, and includes the sea of the southern and eastern shores of these islands, and the passage between them. A side sketch shows the anomalous co-tidal hours, varying from 12*h.* 19*m.* at Menamsha Bight, and 12*h.* 38*m.* at Wood's Hole, to 16*h.* 02*m.* at Holmes' Hole. The observations yet collected are not sufficient to trace with precision the details of these changes, though abundantly so to establish the general phenomena. They show, conclusively, that this is a case of interference, and point to the nature and amount of it. I prefer to obtain further observations necessary to give the particulars of this interference, before entering upon a discussion of this curious series. The heights concur with the times in giving the same solution to these cases, a mean rise and fall of one foot at Nantucket island being placed, as it were, between a rise and fall of 3.3 feet at Menamsha Bight, and of 11.5 feet at Provincetown. The shoal ground off Nantucket, and its influence in the direction of the co-tidal lines, are roughly traced upon the chart.

Group *f* is at the extreme southern portion of the series where the tide-wave is turned by the Bahama Banks, and makes its way through the Straits of Florida. The three stations in that group are Cape Florida, Cape Canaveral, and St. John's entrance; of this, Cape Canaveral affords but a vague result. The co-tidal line makes an angle of 117° 12′ with the meridian, and the motion in half an hour is twenty-nine miles. These results are collected in Table No. 3.

TABLE No. 3.

Letter of group.	Groups of stations.	Mean co-tidal hour.	$-\frac{N}{M}$	$\angle$	Increase of *z* for every minute of distance perpendicular to co-tidal hour $\sqrt{M^2+N^2}$.	Geographical perpendicular to co-tidal lines for 30*m.* o *z*.	
		h. m.		° ′			
a.....	Five stations from Savannah to Hatteras.	11 52	1.303	50 9	1.25	24	Tybee, Charleston, Cape Fear, Beaufort, Hatteras.
a bis..	The same uncorrected for depth.	12 16	1.298	52 23	2.31	13	
b.....	Four stations from Old Point Comfort to Sandy Hook.	12 18	0.411	22 21	4.47	6	Old Point Comfort, Delaware breakwater, Cold Spring inlet, Sandy Hook.
c.....	Four stations from Sandy Hook to Quick's Hole.	12 6	2.00	63 27	0.76	40	Sandy Hook, Point Judith, Beavertail, Quicks' Hole.
c bis..	Six stations from Sandy Hook to Quick's Hole.	12 10	1.638	58 36	0.13	231	Sandy Hook, Fire island, Montauk Point, Point Judith, Beavertail, Quicks' Hole.
d.....	Six stations from Provincetown to Cape Ann.	15 15	0.608	31 17	0.924	32	Provincetown, Wellfleet, Boston, Nahant, Salem, Gloucester.
e.....	Six stations from Cape Ann to Cape Sable.	14 37	0.968	44 4	1.006	30	Newburyport, Portsmouth, Portland, Fourchue island, Ellenwood's island, Cape Sable island.
e bis..	Twelve stations from Provincetown to Cape Sable.	14 56	0.803	38 46	0.910	33	
f.....	Three stations................	12 48	—0.514	117 12	1.05	29	St. John's river, Cape Canaveral, Cape Florida.

From the general indications of these groups, and with the approximate form of the curves of depth, it is not difficult to trace the probable forms of the co-tidal lines. With the assistance of Mr. Pourtales the chart now presented has been prepared. It shows the co-tidal line of 12*h*, following the trend of the southern coast from Tybee towards Hatteras, running close to the shore as it passes southward into the Straits of Florida, interrupted between Cape Lookout and Hatteras in passing northward and eastward, re-appearing again north and east of Hatteras, and following the coast inwards towards Sandy Hook, and then towards Point Judith, and leaving the coast off the shoals of Nantucket and Cape Cod. The lines of 11½*h*. and 11*h*. are approximately drawn outside of the line of 12*h*., which, in general, is quite near to the coast, and conforms to its sinuosities from Tybee to Narragansett entrance.

The co-tidal line of 15*h*. is the one which characterises the indentation between Cape Cod and Cape Sable, the probable connection of the depth of the sea there, and of the co-tidal lines, being traced on the chart. The lines connecting these two systems are uncertain. The tide-wave appears to move backward from the northern extremity of Cape Cod to the southern, or Monomoy Point; but this part of the subject requires further observations for its elucidation.

I have tried, in discussing these observations, several other groups, but chiefly to learn whether stations must be multiplied or observations repeated; and it is not necessary to occupy the time of the Association with a detail of these trials, or with their results. They will be used in the progress of the further observations.

APPENDIX No. 46.

Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, on the Pacific coast of the United States, from observations in connection with the Coast Survey, by A. D. Bache, Superintendent.

(Communicated to the American Association for the Advancement of Science, by authority of the Treasury Department.)

At a meeting of the American Association in August, 1853, I submitted some remarks on the diurnal inequality of the tides as observed at San Francisco. I propose now to compare this important inequality at the three ports of San Diego in California, San Francisco in California, and Astoria in Oregon. The results are the first fruits of the tidal observations under the immediate charge of Lieut. Trowbridge, of the Corps of Engineers, to which I referred at the same meeting, as in progress. The series is intended to develop the tidal phenomena of that coast, and the three stations referred to are those for permanent reference, at which self-registering tide-gauges have been put up. The results now communicated are derived from observations at Astoria, from July 11 to October 31, 1853; at San Francisco, from January 17 to February 15, 1852, and from January 5 to February 26, 1853; and at San Diego, from September 22 to November 31, 1853. All the observations were made with Saxton's self-registering gauge. I submit specimens of the actual curve traced by the gauge. The results have been computed, under the direction of L. F. Pourtales, esq., assistant United States Coast Survey, by Messrs. H. Heaton and P. R. Hawley, and the diagrams were drawn by Mr. C. Fendall.

Some of the curves of observation on a reduced scale are shown in diagram No. 1. The place of observation, and the dates for each series of curves, are stated on the diagram. The diagram represents the times from 0 hours to midnight, on a scale in which the distance between the vertical lines corresponds to two hours, and the heights on a scale of half a foot of rise or fall of the tide to each division between the horizontal lines. The phases and declinations of the moon are inserted at the top of the diagrams, and the times of the moon's transit at the foot.

The curves have a striking similarity, and show a large diurnal inequality in both high and low water, in time and in height, at or near the greatest declination of the moon. The greatest inequality of the height is 2.76 feet at Astoria, 2.40 feet at San Francisco, and 2.77 feet at San Diego. The mean rise and fall, estimating the highest high and lowest low waters of each day only, is for the three places respectively, 7.86 feet, 5.92 feet, and

5.46 feet. Some of the daily curves of San Diego, near the period of greatest declination of the moon, approach in form to those at Fort Morgan, on the Gulf of Mexico.

The curves of half-monthly inequality of high and low water will be so much better determined hereafter, that I merely refer to them now in passing, to show their general resemblance to those formerly produced for San Francisco.

The crude corrected establishment for the three places is—

For Astoria	12*h*.	53*m*.
For San Francisco	12	4
For San Diego	9	37

The value of A (the tangent of the difference of luni-tidal interval for three and for nine hours) and of E of Mr. Lubbock's notation, (half the difference in height of neap and spring tides divided by 2 A) are, for—

Places.	Data for A.		A.	E.
	In time.	In arc.		$\frac{h-h'}{2A}$
Astoria	1*h*. 08*m*.	17° 30′	0.31	2.83
San Francisco	1 18	19 30	0.35	1.59
San Diego	1 26	21 30	0.39	1.71

These, of course, are but approximations.

Diurnal inequality in intervals and heights of high and low water at San Francisco, San Diego, and Astoria.

	Inequality in interval of high water.			Inequality in height of high water.			Inequality in interval of low water.			Inequality in height of low water.		
	S. Francisco.	San Diego.	Astoria.	S. Francisco.	San Diego.	Astoria.	S. Francisco.	San Diego.	Astoria.	San Francisco.	San Diego	Astoria.
	h. m.	*h.* m.	*h. m.*	*feet.*	*feet.*	*feet.*	*h. m.*	*h. m.*	*h. m.*	*feet.*	*feet.*	*feet.*
	1 44	1 56	1 19	—1.85	—1.62	—1.94	—0 51	—2 00	—1 15	3.01	2.90	3.81
	1 57	1 16	2 00	—1.81	—1.18	—1.58	—1 63	—1 13	—1 12	3.44	2.87	3.27
	1 47	1 36	1 14	—1.63	—0.67	—1.31	—0 47	—0 35	—0 53	3.75	2.48	3.20
	2 17	1 12	1 05	—1.59	—0.17	—1.02	—0 40	—0 05	—0 41	3.72	1.76	2.56
	1 41	0 46	0 53	—1.62	0.07	—0.75	—0 40	0 00	—0 33	3.46	1.01	1.68
	1 43	0 17	0 33	—1.33	0.45	—0.17	—0 30	0 06	—0 16	3.07	0.28	1.25
Zero dec. ☽	1 41	—0 05	0 18	—1.05	0.83	0.27	—0 23	0 30	0 02	2.57	—0.35	0.74
	1 20	—0 20	—0 02	—0.66	1.20	0.67	0 07	0 29	0 19	2.01	—0.99	0.09
	0 39	—0 37	—0 16	—0.17	1.49	1.21	0 38	0 33	0 41	1.37	—1.39	—0.61
	0 52	—0 58	—0 27	0.32	1.78	1.42	1 05	0 47	1 09	0.50	—1.70	—1.14
	0 23	—1 16	—0 51	0.71	1.97	1.53	0 50	1 17	1 04	—0.41	—2.05	—1.74
	—0 18	—1 15	—1 12	1.72	2.10	1.54	0 58	1 36	1 09	—1.44	—2.26	—2.70
	—1 01	—1 50	—1 33	1.90	2.04	1.63	1 01	1 57	1 02	—2.19	—2.34	—2.75
☽'s dec. max. N.	—1 42	—2 23	—1 47	2.01	2.25	1.42	1 14	1 45	1 03	—2.85	—2.65	—3.36
	—1 55	—2 51	—1 47	1.88	2.07	1.28	1 12	2 22	0 45	—3.36	—2.71	—3.39
	—2 01	—3 10	—1 37	1.86	0.98	1.14	1 00	1 39	0 48	—3.48	—2.69	—3.27
	—1 49	—3 03	—1 31	1.84	0.58	0.86	0 57	0 57	0 34	—3.48	—2.48	—2.98
	—1 12	—2 00	—1 22	1.90	0.41	0.71	0 41	0 36	0 24	—3.28	—2.32	—2.33
☽'s dec. zero	—1 41	—1 26	—0 51	1.65	0.27	0.60	0 42	—0 04	0 21	—2.99	—1.81	—2.06
	—1 26	—0 50	—0 33	1.42	0.09	0.20	0 35	—0 21	0 21	—2.50	—1.14	—1.40
	—1 09	—0 46	—0 13	1.00	0.65	—0.25	0 20	0 31	0 06	—1.90	—0.93	—0.83
	—0 59	—0 20	0 02	0.29	0.32	—0.30	—0 08	0 03	—0 21	—1.29	—0.29	—0.11
	—0 32	0 05	0 17	—0.30	—1.08	—1.12	—0 35	—0 46	—0 35	—0.50	0.97	0.81
	—0 09	0 41	0 22	—0.97	—2.33	—1.70	—1 15	—0 38	—0 52	0.26	2.49	1.24
	0 29	0 55	0 46	—1.42	—2.68	—2.00	—1 17	—1 16	—0 54	0.95	2.96	2.12
	0 46	2 06	1 01	—1.56	—2.41	—2.18	—1 12	—1 42	—1 18	1.85	2.47	2.75
☽'s dec. max. S.	1 51	1 53	1 15	—1.70	—2.22	—2.25	—0 46	—1 43	—1 21	2.51	2.84	3.24
	1 58	2 23	1 38	—1.62	—1.95	—2.01	—0 30	—2 00	—1 20	2.99	2.79	3.85
	2 11	2 55	1 34	—1.35	—1.32	—2.54	....	—2 27	—1 08	....	3.09	3.79
	1 22	1 25	0 59	1.36	1.28	1.23	0 47	1 02	0 46	2.36	1.97	2.17

The foregoing table shows the diurnal inequality in time and height of high and low water at the three places before named.

The whole difference in height and interval between the A. M. and P. M. tides is taken as representing the diurnal inequality, and no correction is made for the half-monthly inequality in preparing the tables. I may observe that upon trying the corrections with the half-monthly inequality, as at present determined, no special advantage resulted; and until the half-monthly inequality is determined by more numerous observations, I adhere to this form of discussion.

The results are shown in diagram No. 2, in which the ordinates denote the inequality in interval and height on the days from zero of declination of the moon, denoted by the abscissæ. The dots show the actual observations, and the curves are drawn with a free hand among them. The results for the three places are distinguished as marked on the diagram. The following are the inferences from the discussion:

1. In every case, the inequalities increase and decrease with the moon's declination, reaching zero at or near the time of the moon's crossing the equator. The average epoch of the inequalities agrees almost exactly with the time of the zero of declination.

2. The inequality in height of high water, and in interval of low water, increase and decrease together, and so for the inequality in time of high water and in height of low water, as was remarked in the case of San Francisco.

3. The declination of the moon, and the inequality in interval of high water and in height of low water, have contrary* signs at all three of the places; the reverse being true of the other two inequalities.

4. The inequality in the height of low water is, in general, greater than that of high water, as was before stated for San Francisco. The proportion of the average and maximum inequalities is nearly as follows:

Places.	Average inequality.	Maximum inequality.
San Francisco	1.8 to 1	1.9 to 1
San Diego	1.5 to 1	1.2 to 1
Astoria	1.8 to 1	1.5 to 1

5. The inequality in the interval of high water is, in general, greater than that of low water, as follows:

Places.	Average value.	Maximum value.
San Francisco	1.7 to 1	1.8 to 1
San Diego	1.4 to 1	1.3 to 1
Astoria	1.3 to 1	1.5 to 1

*The reverse is stated, by mistake, in my former paper.

6. The average and greatest inequalites in interval and height are shown in the following table:

Places.	Average inequality.				Greatest inequality.			
	Time.		Height.		Time.		Height.	
	H. W.	L. W.	H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
	h. m.	*h. m.*	*feet.*	*feet.*	*h. m.*	*h. m.*	*feet.*	*feet.*
San Francisco	1 21	0 47	1.36	2.36	2 17	1 17	2.01	3.75
San Diego	1 25	1 02	1.28	1.97	3 10	2 27	2.68	3.09
Astoria	0 59	0 46	1.23	2.17	2 00	1 21	2.54	3.85

7. The comparison of the values of the diurnal inequality in height with the theoretical expression $m \sin 2\delta'$ is given in the annexed table and diagram, in which the value of m is taken at 2.35. The inequality results are grouped by the declinations.

Comparison of daily inequality with moon's declination.

	San Diego.			Astoria.		
	Obs. inequality, h't of H. W.	$m \sin 2\delta'$.	Diff.	Obs. inequality, h't of H. W.	$m \sin 2\delta'$.	Diff.
	Feet.	*Feet.*		*Feet.*	*Feet.*	
1	2.03	1.90	.13	1.94	1.80	.14
2	1.93	1.83	.10	1.75	1.72	.03
3	1.55	1.70	—.15	1.73	1.60	.13
4	1.26	1.48	—.22	1.32	1.40	—.08
5	.84	1.14	—.30	.98	1.10	—.12
6	.63	.75	—.12	.49	.71	—.22
7	.69	.28	.41	.24	.28	—.04

The observations of which these form a part are still in progress, under the direction of Lieutenant Trowbridge, whose assiduity and intelligence have already been rewarded by the success I had ventured to anticipate in my former reference to the tides of the Western coast.

APPENDIX No. 47.

On the distribution of temperature in and near the Gulf Stream, off the coast of the United States, from observations made in the Coast Survey. By A. D. Bache, Superintendent.

[Communicated to the American Association for the Advancement of Science, by authority of the Treasury Department.]

I propose to present to the Association a brief summary of the result of observations made in the progress of the Coast Survey, in exploring the Gulf Stream, so far as the distribution of temperature is developed by them. The entire observations have been reduced anew, under my immediate direction, by Professor Pendleton, U. S. N., assistant in the Coast Survey, who has also gone over with me, systematically, the discussion of the work preparatory to its publication in detail, and whose care, assiduity, and intelligence in the matter I desire here to acknowledge.

At the Cambridge meeting of the Association, in 1849, I explained the general plan of the exploration of the Gulf Stream, and presented the results of the observations made up to that time by Lieutenants C. H. Davis, Geo. M. Bache, S. P. Lee, and Richard Bache, of the U. S. Navy, in command of hydrographic parties in the survey.

Since then, the work has been continued by Lieutenants T. A. M. Craven and J. N. Maffitt, U. S. N., and has been extended south from Hatteras to Cape Canaveral. In addition to the sections across the stream, upon which the temperature had then been examined, between Cape Cod and Cape Hatteras, others have been since explored from Cape Fear, Charleston, St. Simon's, St. Augustine, and Cape Canaveral, and new and interesting results have been developed in relation to the distribution of temperature across the sections, and to the connection, at least in some of them, between the peculiar distribution and the form of the bottom of the sea.

The examination now made extends from about 42° north latitude to 28½°, and from about 65½° west longitude to 80½°. It authorizes the construction of a chart of the Gulf Stream, showing the distribution of temperature in and near it, not only at the surface but at various depths.

1. *Distribution of temperature at different depths.*

Having gone very fully into this subject, which was one of the first satisfactorily shown by the observations, I do not intend to repeat here what was then stated, except in a general way. The distribution of temperatures below a certain depth, in the cold current which exists between the shore and the Gulf Stream, and over which the warm waters of the Gulf flow, thinning out as they approach the land, was shown to belong to a state of equilibrium of temperature which would be assumed by a mass of water having warm water above it and cold water below it, to be represented by a logarithmic curve, and therefore to be due to conduction. That in the Gulf Stream varied according to a different law, indicating a disturbance of equilibrium. Diagram No. 1 shows the distribution of temperature with depth, in the water between the shore and Gulf Stream, as deduced from the observations of Lieutenant G. M. Bache. The ordinates of the curve represent the depths, and the abscissæ the temperatures. The depths, in fathoms, are written at the side of the diagram, and the temperatures, by Fahrenheit's scale, at the top. The position at which the temperatures at various depths, recorded in this diagram, were obtained, was in latitude 36° 15′ north, longitude 73° 52′ west, on the section intended to be made from Cape Henry perpendicular to the axis of the stream. This curve, and others of the same kind, were compared with the logarithmic curves which would best represent the observations, and their close coincidence with them shown. The curves were deduced by least squares, from an ingenious investigation by J. H. Lane, esq., then of the Coast Survey, now one of the chief examiners in the U. S. Patent Office.

Diagram No. 2, taken also from Lieut. G. M. Bache's observations, shows the character of the curve of distribution near the axis of the Gulf Stream. These particular results were obtained in one of the positions on the Cape Henry section, in latitude 35° 53′ N., and longitude 73° 34′ W.

The projecting form of the curve towards 300 fathoms, and the moderate change of temperature, ten degrees, from 150 to 400 fathoms, shown in that diagram, are characteristic features of the distribution in similar positions. The change from the surface to 150 fathoms was 17° Fahrenheit. Diagram No. 3 represents a corresponding curve to No. 2, from Lieut. Maffitt's observations on the Charleston section, in latitude 33° 58′ N., longitude 73° 58′ W. In this the change between 100 and 400 fathoms is still less than in the former case, being but five degrees.

Diagram No. 3 *bis* shows the curve corresponding to that of diagram No. 1, but on the Charleston section nearer to the shore than the axis of the stream in latitude 31° 48′ N., longitude 78° 47′ W.

2. *Distribution of temperature at the same depth, on sections perpendicular to the axis of the Gulf Stream.*

Diagram No. 4 contains the results of observations on the section perpendicular to the stream from Sandy Hook, and shows the mode in which the observations were discussed. The positions where the temperatures were observed are marked at the head of the diagram, and above them the distance from Sandy Hook in nautical miles. The temperatures are marked on the side of the diagram. At each position a diagram was drawn similar to those of Nos. 1, 2, and 3, and from the curves traced with a free hand among the points, the results at the several depths, which are shown on diagram No. 4, were obtained. The curves traced among these points so as to preserve as far as possible consistent results for the various depths, are those given in the diagram. In the preliminary discussion of the results, I used the observations themselves at the different depths, and am, therefore, enabled to say, that while the curves present fewer irregularities by the last mode of discussion, as might be expected, the general results are not in any essential particular changed by its adoption. The diagram shows the curve of distribution of temperature at thirteen different depths from the surface to five hundred fathoms. The depths at which observations were taken were the more numerous nearer the surface, where the changes of temperature were the most rapid. These curves were next separated into groups, following the arrangement which seemed best to apply to the sections generally. On the Sandy Hook section, for example, as shown in diagram No. 5, the results from the surface to 30 fathoms, from 40 to 100 fathoms, at 200 and 300 fathoms, are grouped respectively in the curves *n*, *o*, and *p*, and that for 400 fathoms is given in curve *r*.

The point where the axis of the Gulf Stream, or line of highest temperature, is cut by the section, is distinctly shown on the diagram, and the minimum of temperature or "cold wall" within thirty miles of it, nearer the shore. These are the prominent features in every case. Further from shore than the axis of the stream, the Sandy Hook curves show one point of maximum and two points of minimum temperature. In the comparatively cold water of the in-shore counter-current, two maximum points and one minimum are also distinctly marked. This diagram is in fact a general type of the results according to which the ocean in and near the Gulf Stream is divided into successive warmer and colder bands. The number and the general arrangement of them can, of course, only be made out by a comparison of the several sections. In the discussion, such a diagram was drawn for each section.

The curves of diagram No. 5 do not at all indicate at what depths the temperature would approach to equality across the section.

The corresponding results for the Cape Henry section are shown in diagram No. 6 *bis*. The first or "cold wall" minimum, the axis maximum, two minima and two maxima beyond the axis, are well made out in all the groups for the surface to four hundred fathoms. The mean of the results at 0, 5, 10, 20, and 30 fathoms, is shown by the curve *n*; that of 50, 70, 100, and 150 fathoms, by *o*; and of 200, 300, and 400 fathoms, by *s*.

Not to multiply diagrams too much, I have omitted those for Hatteras and Cape Fear, which, besides, have nothing very especially characteristic in them, unless it may be that the Hatteras section is one where the results are most disturbed.

The next diagram, No. 7, shows the results of the Charleston section. The groups *m*, *n*, and *o*, from 5 and 10 fathoms, 20 and 30 fathoms, and 20, 30, and 50 fathoms, resemble each other very much; *p*, the mean of 70, 100, and 150 fathoms, is slightly irregular; and so is *r*, the 400 fathoms curve. The curves from 5 to 50 fathoms show extremely well the division of the stream, the first or "cold wall" minimum, the first, second, and third maxima, and the second and third minima. In-shore, from the first minimum, is a maximum. The irregularities in these observations, though obtained with registering instruments at such considerable depths, are less than those which stationary thermometers, sunk in the ground, show in the passage of heat to them.

Diagram No. 8 represents the Canaveral section, where the same results which have been stated are shown, but on a very much diminished scale. The observations were not carried far enough from the shore to reach the second maximum. The first and second minima and the axis maximum are well marked.

I have omitted, for reasons already stated, the diagrams of the other sections. The same phenomena are in general repeated in all the sections.

The permanency of the division of the stream in different years, and the accuracy and sufficiency of the observations, may be tested in two ways: the first by comparing the results of running the same section in different years by different observers; the second by the consistency or inconsistency of the results obtained at one depth when compared with those at other depths.

In order to compare the results of different years, some one section was to be explored in the successive seasons. Thus the Cape Henry section connected the work of Lieuts. G. M. Bache, S. P. Lee, and R. Bache, having been explored by each. The Hatteras section was common to the work of Lieuts. R. Bache and J. N. Maffitt, and the same Charleston section was intended to be run by Lieuts. Maffitt and Craven.

The Cape Henry section was three times run over; and it appears, by comparing the results of each season with the mean of the whole, that in each group of observations represented by one of the curves of diagram No. 6, there is an uncertainty of rather less than seven miles in the determination of the maxima and minima generally. The best determined points are the first and second minima and maxima—the "cold wall" minimum and axis maximum having an average probable error of 5½ miles, and the other three points have an average probable error of eight miles.

This accordance is satisfactory whether viewed in relation to the probability of recognising the band in passing through it, or in reference to the determination of the positions of the observations themselves, or to the distances apart of the positions. Diagram No. 6 represents in different colors the results of three years' observations on the Cape Henry section, showing, with differences which might be expected, the same general division of the stream. The observations were made during the summer season, partly for nautical reasons, and also as giving a nearer approach to equilibrium than the winter.

The differences in the temperature of the whole mass of water at the same season of different years are often more considerable than the difference in distribution.

The second test of the probable accuracy of determination of the several principal maxima and minima was by a comparison of the independent determination of the maximum and minimum points in the curves of distribution at the same depth, corresponding to various depths from the surface. It was first established, by a general induction, that all the points of maximum and minimum, except the "cold wall" minimum and axis maximum, are probably, as a rule, vertically over each other. Next the curve was found, by which the recession of the first minimum and maximum from the shore, as the depth increased, could be represented. The differences then, from the mean curve of recession, for the first two points, and from the vertical line or average position for the other points, gave the probable discrepancy of determination. It would be out of place here to give all these labored details. This discussion gives, as might be expected, smaller probable errors than the other; for this takes in accidental errors only, and that includes real changes. The mean probable error of determination of the first four points from this investigation was for Cape Henry section, for the mean of the three years, one mile; and of the other three points rather more than two miles. This includes three determinations, of which each result is the average.

The corresponding results for all the sections are given in Table No. 1, and show on the average less than one mile of uncertainty for the mean determination of the first or "cold wall" minimum; two miles and a half for the first or axis maximum, and the second minimum between them; and four miles for the next three points, and about eight and a half for the fourth minimum, which was shown on but three of the sections.

TABLE No. I,

Showing the probable uncertainty in determination of the maximum and minimum points.

Name of section.	Uncertainty, in miles.						
	Cold wall, or first minimum.	Axis of, or first maximum.	Second minimum.	Second maximum.	Third minimum.	Third maximum.	Fourth minimum.
Sandy Hook	....	.75	1.00	3.94	7.99	....	....
Cape May	.82	1.25	2.54	1.57	....	4.03	4.87
Cape Henry, (3 years)	.84	.61	.55	1.70	1.06	.94	4.42
Cape Hatteras, (2 years)	....	6.77	6.36	9.31	5.69	6.23	....
Cape Fear	....	1.25	....	....	2.98	3.49	13.37
Charlerton	1.25	1.57	.72	2.09	2.40	.82	——....
St. Simon's	.00	.74	1.27	.41	....	....	....
St. Augustino.	.52	.51	.44	.44	.55	....	....
Cape Canaveral	.95	1.69	.39	....	....	....	....
Final value	.83	2.49	2.49	4.01	4.01	3.71	8.45

The Hatteras section presents, as before remarked, the most considerable discrepancies in its results, incident, most probably, to the nature of the phenomena themselves in that region.

3. *Connection of the figure of the bottom of the sea with the distribution of temperature.*

The discovery that soundings could be carried nearly across the Charleston section of the Gulf Stream, and that after losing them on this section for a short distance they were reached beyond the axis of the stream, was communicated to the Association at the Cveveland meeting, as resulting from the observations of Lieuts. J. N. Maffitt and T. A. Craten, U. S. N., assistants in the Coast Survey. The connection between the figure of the bottom and the division of the stream, which the observations of these officers established as applicable to the sections south of Charleston, is illustrated in diagram No. 9, in which the curves of equal temperature, the depths corresponding to them, and the figure of the bottom, are given. In the diagram the distances from the shore are marked in nautical miles on the top, as also the positions at which the temperatures were explored; and the depths in fathoms are stated on the left-hand side. Each curve is marked with the temperature (by Fahrenheit's scale) which it indicates, and the curves are drawn for every five degrees from 57° to 77° Fahrenheit.

The bottom of the sea slopes gradually on this section for some fifty miles, reaching a depth of about twenty fathoms; then more rapidly to about sixty-five miles, and the depth of one hundred fathoms; and suddenly falling off to a depth greater than six hundred fathoms—at about one hundred miles from the shore, where the depth is three hundred fathoms, a ridge, with a very steep slope on the inshore side, and a little less so to seaward, occurring fifteen hundred feet above the hollow to seaward of it, and distant about twelve miles from it. A second rise of five hundred feet, on a base of twelve miles, is followed by a depression of three hundred feet on a base of fifteen miles, and then by a gentle slope upward.

It is altogether probable that all the depths found by observation are greater than the actual ones; but the bottom was brought up in several cases, showing that the lead had reached it, and it is most probable that the proportions are not far from correct.

The close conformity of the curves of temperature to those of the bottom is obvious from an inspection of the diagram. The descent of the curve of 57° in the deepest part of the section is a remarkable feature, not obliterated in the curves above it, but reaching nearly to the surface. In the midst of general coincidences there is one discrepancy which indicates that there may be other causes which produce the distribution of temperature in warm and cold bands besides the figure of the bottom. Further observations will show if this is so, or if it is an error of observation.

We see in this diagram the cold water pressing towards the shore-side, following the form of the bottom along which it lies, and forcing the layers above it to take the same general conformation.

On the crest of the steep slope in the St. Simon's section there is a forcing up of the cold water to a considerable height, as is shown less distinctly at position No. 1 of the Charleston diagram. This corresponds to the "cold wall" in those sections.

Whether this remarkable discovery may be the clue to the general distribution of temperature in the Gulf Stream, on the deeper sections north of these, is well worth examining, and instructions have been given accordingly.

4. *The "Cold Wall."*

It is difficult to fix the depth of the Gulf Stream current, though easy to see, from the observations, that it is comparatively superficial, extending certainly, on the Charleston section for example, to a less depth than three hundred to five hundred fathoms, and resting upon cold water belonging to a much higher latitude than that in which it is found. Off Cape Florida, about twelve nautical miles east from the light-house, at the depth of 550 fathoms, the temperature was but 49° Fahrenheit in June, 1853. The mean temperature of the coldest month in the year, on the coast in the same latitude with the point of the axis of the Gulf Stream at the surface on the Charleton section, is about 53½° Fahrenheit. At Key West the mean temperature of the coldest month of the year is, from the report of the Surgeon General U. S. Army, 69.3°. Deep-sea temperatures of the ocean generally, are required for determining this and other questions of a similar kind.

The lateral limits of the stream are more easily defined, especially in the northern sections, where the change is so sudden from the warm water of the Gulf to the cold stream inside of it towards the shore, that the cold stream was likened, by Lieut. Geo. M. Bache, to a "cold wall" confining the warm water.

The diagrams of the Sandy Hook sections, Nos. IV and V, show this sudden change very strikingly between positions 13 and 14, the probable minimum lying, however, inside of 13. So, also, the Cape Henry diagrams, Nos. VI and VI *bis*. The "cold wall" minimum and axis maximum are shown on diagram X, on the same scale of miles at the top of the diagram, and temperature at the side. That the "cold wall" exists south of Hatteras is proved by the same diagram, where the Cape Fear, Charleston, and St. Simon's sections are compared with those for Cape Henry, Cape May, and Sandy Hook. The difference of temperature is less for the southern sections, but it is still strikingly marked.

In the cold water inshore from the Gulf Stream, Acting Master Jones, of Lieut. Maffitt's party, found a current setting southward, as also in the cold band outside of the axis. These results, if shown to be permanent, will be in the highest degree important. As it is, the existence of them at any time shows the cause of many anomalies noticed by navigators in relation to the currents of the Gulf Stream.

The investigations relating to currents remain to be made in detail, though some results have already been procured. It is important in work like this to confine the special attention of observers to a few problems at a time, that they may receive close examination.

As the warm water of the Gulf Stream flows onward and outward from the axis at and near the surface, the stratum, as a general rule, becomes thinner. The current is then outward from the axis as well as onward.

5. The changes of the position of the remarkable points in the sections with the season, and other circumstances, are undergoing investigation, some results having been already collected.

6. *Chart of the Gulf Stream.*

The alternate bands of warm and cold water into which the ocean in and near the Gulf Stream is divided, are shown in the chart now presented, as deduced from the discussion already referred to. The higher temperatures are represented by the darker shades. The axis of the stream is marked by the darkest full line, and the axis of the colder and warmer bands on each side of it by thinner lines, distinguished as stated on the chart. The axis marked A, where it crosses the Sandy Hook section, is seen to take the general direction of the trend of the coast, which is even more closely followed by the "cold wall" axis, which crosses the Sandy Hook section at B. These lines are drawn with a free hand among the points by which they would be rigidly determined in the several sections, so as to give a general consistency to their form. The variations from the points rigidly determined are generally of the same order with the probable errors of those points. On the Sandy Hook section the point D corresponds to the second minimum temperature, C to the second maximum, F to the third maximum. The probable outer limit of warm water is designated on the chart.

Within the "cold wall" minimum is a band of higher temperature crossing the Sandy Hook section at F, and generally well marked, followed by a minimum which appears pretty well determined on the northern sections.

The limits of the chart show the limits of the Gulf Stream explorations up to the summer of 1853, inclusive, the work being still in progress.

APPENDIX No. 48.

Report of Charles A. Schott, Esq., of the Computing Division U. S. Coast Survey, on the currents of Nantucket Shoals. (Sketch A, No. 12.)

COAST SURVEY OFFICE, *July* 18, 1854.

DEAR SIR: I respectfully submit the result of my investigation of the currents on Nantucket shoals. In a preliminary report, dated April 18, 1854, reference was made to the stations and observation available for this discussion, and certain localities were pointed out which it was desirable to have occupied for further observations.

The observations were made during the months of July and August, between 1846 and 1853, inclusive; and the results consequently refer to this period of the year.

With but a few exceptions, the surface-current was observed; and when otherwise, the directions and velocity of the under-current was identical with that at the surface.

The stations are numerous enough to point out the general features of the current, except in the northeast quarter of the shoals. The extension of the observations (if practicable) in all directions beyond the limits of the sketch, is desirable for the following reasons: to ascertain the extent of the tidal current further out at sea; to trace its connection with the currents of the adjacent sounds and bays, and to furnish valuable additional information for tracing the co-tidal lines, yet very imperfectly understood in this locality; and, lastly, to ascertain its own limits.*

It seems probable to me that a region may be found, towards which the flood converges, similar to that near the Straits of Dover. The flood in the case of the Nantucket currents comes from the southwest, but is likely to meet with another flood current off Cape Cod, coming from the north.

As a general result of the discussion of these currents, I find that, except near Old South shoal, there appears to be a tendency of the current, during the period of its greatest velocity, to run parallel with the major axis of the shoals. On the Old South shoal, the tendency is across the shoal.

In considering the subject, the following subdivisions were found convenient:

A. The general nature of the currents.
B. The general direction of the tidal current of flood or ebb.
C. The direction or set at each station, and results.
D. The velocity at each station, and results.
E. The "establishment" of the current.
F. Investigation of the path described by any particle of water during the period of flood and ebb.

A. A glance at the observations shows the current to be a *tidal current*, reversing its direction every six lunar hours, without, however, exhibiting any slack water. There are no indications of any current running permanently in the same direction, as appears from the comparison of the average velocities during ebb and flood; the difference of which would be twice its rate in that direction. The velocities perpendicular to it (during the period called slack-water) are also sensibly the same.

The general features of the current across the shoals are as follows: The ebb commences a short time before the high-water stand on the shore of Nantucket takes place, and runs a little to the eastward of south, with no indications of slack-water. It then attains, gradu-

* The existence of a probable counter-current near the shore, is also to be tested according to your own observations in July, 1854.—A. D. B.

ally, its greatest velocity in a direction to the westward and southward. After this the current slackens, the minimum velocity being about one-fourth the maximum velocity, and runs a little to the westward of north, and then in an opposite direction to that of the ebb; thus completing an entire circuit. The current may be observed to set in all directions of the compass during twelve lunar hours without ever being at rest, and turning in a direction in which we count our azimuths, or like the hands of a watch.*

B. The direction of the current at the time of its greatest velocity being nearly parallel with the shore-line, presents an exception to the general rule of the flood current running inland, and perpendicular to the shore.

The time midway between the ending of the flood and beginning of ebb, corresponding to the time of slack-water at high water, is generally identical, or may be supposed to be the same as the time of the middle of stand at high water; but on the shoals, a difference, amounting, at the greatest, to two hours, is observed, by which the horizontal motion precedes the vertical. The current observed shortly after the above period must be the ebb; and by comparing the direction of the current at the time of high water for all the current stations near the shore, it was found from seven stations, within five miles of the shore, and occupied in 1847–'48–'49, that the ebb runs to the westward and southward.

High water was computed from the known tidal establishments at Wasque 9*h*. 19*m*., at Siasconsett 11*h*. 54*m*., and at Great Point Light 12*h*. 4*m*.

Cases have been observed where the same current is a flood current for one end of a channel, and an ebb current for the opposite one, along the same shore, of which Bristol channel is an example.

C. The direction of the current at the time of maximum velocity remains nearly constant for three hours, or does not deviate more than about 20° from it; but little difficulty was therefore met in finding the average direction of either flood or ebb. The direction is indicated by an angle counted like the geodetic azimuths, and has been corrected, when necessary, for 9° of westerly magnetic declination.

To ascertain the variation in the direction, it was first made out for successive tides; next, for the same locality at different times; and lastly, for the same time at places a small distance apart. It appears that the two last cases show a greater deviation from the mean direction than the first, and that no direction can be relied upon within 15°, or at the most 30°. The mean direction for flood and ebb was made out for each station and plotted on the accompanying sketch. A table was also formed of these values, separating them into two groups, a northern one and a southern one; in each group the directions differ so little, that means could be taken. (See line of separation of groups on the sketch running to the southward and eastward from Siasconsett.)

The mean set of the flood in the northern group is 212°.

The mean set of the ebb in the northern group is 27°; deviating from a straight line 5°.

The mean set of the flood in the southern group is 257°.

The mean set of the ebb in the southern group is 74°; deviation from a straight line 3°.

Hence flood and ebb run in exactly opposite directions, and form an angle of 46° in the two groups.

The mean direction has been illustrated graphically by curves drawn at convenient distances for the flood and for the ebb. (See the sketch and notes of explanation accompanying it.) It is only near Davis' South shoal that the flood and ebb directions disagree sensibly. A table of directions is appended to this, marked No. 1.

The direction at the period called slack-water is 90° to the above, and lasts about an hour. The influence of the wind on the mean direction and velocity is small, as the observations were made in moderate weather.

D. The velocity when near the maximum changes but little, and it was found that the variability at the same station at different periods is about $\pm$ 0.5 knot. The mean maximum velocity has been tabulated for each station, (see table appended, No. 2,) and is expressed in miles per hour, written opposite the head of the arrows in the sketch. It was found, by inspection, that the velocity increases with the distance from Nantucket, and that there is a marked difference in the drift when we divide the space by a circular line of about

* This is the main tidal current outside, not the shore current.—A. D. B.

eighteen miles radius, with its centre at Siasconsett, the outer portion showing the greater velocity. The grouping of the stations has been made accordingly, (see curve on sketch.)* The mean drift of the inner group is at ebb 1.7, and at flood 1.7 knots; for the outer group at ebb 2.2, and at flood 2.8 knots, respectively. The velocity at ebb and flood appears to be nearly the same, with the average maximum value of 1.7 for the inner, and 2.5 for the outer group. The greatest velocity observed was four knots in 1852, (August 2,) on the southern part of Fishing Rip. The velocity during the turn of the current is, before the beginning of the ebb, 0.6 (mean value from 47 cases,) and before the flood 0.5 (mean value from 50 cases;) it is seldom less than 0. 3, nor more than 0.8, in the extreme 0.0, and 1.4 miles an hour.

E. The current establishment was made out in the same way as in my investigation of the Long Island Sound currents, with the additional values resulting from the flood current by adding six lunar hours; thus the number of results for luni current intervals has almost been doubled.

The variation of this interval at any given station is greater than the monthly inequality of the tides; this correction, however, has been applied to the mean value for each station, assuming it to be the same for the currents and tides. This correction amounts, at the greatest, to ± 22 *m.* for either Boston or New York. Intervals for stations not more than five or ten miles apart have all been united in one result, and in this way more reliable mean values have been obtained for this variable element.

The observations have been grouped considering the number of intervals observed and of geographical positions, and are given in Appendix No. 3. The groups were separated on the sketch, which contains all the individual luni-current intervals, and from those giving the means of groups. The following table contains these last results:

Group No.	Latitude.	Longitude.	Mean establishment.	No. of observations.
	° ′	° ′	*h.* *m.*	
VII	41 12	69 44	X 22	25
I	41 23	69 55	X 28	7
II	41 17	69 53	X 33	7
VIII	41 22	69 35	X 41	3
IX	41 03	69 31	X 47	29
III	41 08	69 56	XI 13	11
V	41 05	69 50	XI 21	27
IV	41 04	70 05	XII 00	8
VI	41 00	69 48	XII 00	20
			Sum....	137

From the above table the co-current lines on the sketch have been constructed. Joining the positions by straight lines and marking the intersection of the half and whole hours on each of them, positions for the co-current lines were obtained. The northern branch of the X½ hour curve* is very uncertain from want of observations. On Davis' South shoal the establishment appears to be XII*h.* 25*m.*, or twelve hours twenty-five minutes; after the moon's superior or inferior transit, the ebb current commences to set in. This was the information asked for in the Superintendent's letter of November 25, 1853. It is a singular fact, that the period of so-called slack-water at the beginning of ebb, occurs earlier on the middle of the shoals than near Davis' South shoal, although the ebb runs to the westward and southward.

The uncertainty in any of these half-hour lines is about ten minutes. This I have indicated by the width of the curves corresponding to 10*m.*

F. The idea of following any given particle of water, as suggested by Mr. Wiessner, may be carried out, either by following actually its course during the period of twelve lunar hours, or by observing a number of such particles at every stage of this period, all particles following the same law of motion. The latter view suits the observations.

I have assumed the time of middle of turn before ebb to start with, and referred the

* Omitted.

motion to two axes of co-ordinates, one parallel with the direction of the maximum velocity, the other perpendicular to it. The length of either axis was obtained by treating it as a simple dynamical problem, the time or duration, and the direction and velocity, being given. The mean orbit, as may be supposed from the preceding investigation, varies only in its major axis, the velocity during the turns being unchangeable for both groups of velocity. I found it best to work the problem trigonometrically, using the table of natural sines and co-sines. It cannot, however, be extended to many stations without consuming much time; nor is this necessary. As a general result, I find the length of the axis major for the outer group (of velocities) about nine nautical miles, and for the inner six miles; the minor axis of one and a half miles being the same for both.

The following values for the length of the axis in consecutive tides were obtained from observations near Old South shoal:

Major axis from ebb	7.6 nautical miles; from flood	8.1 miles.
	9.2	9.0
	7.6	9.0
	11.1	8.2
Mean,	8.9	8.6

Minor axis (from turn preceding ebb)	1.6; (from turn preceding flood)	0.6
	1.4	0.9
	1.7	1.1
	2.6	0.5
	1.8	
Mean,	1.8	0.8

Hence, for the mean length of the axes 8.7 miles, and 1.3 miles at this station. The above small value (0.8) of the minor axis, when compared with 1.8, may indicate a north-westerly current; but I do not feel justified in concluding so from the small number of observations. The path in this case would be as indicated in the figure No. 2, Sketch A No. 12, and the velocity of the current 0.5 mile an hour. A similar curve is produced when the direction of flood is not exactly opposite to that of ebb, as appears from figure No. 3. Some of the stations present such a case. The path described by a particle of water in rivers generally will be represented by figure No. 4, Sketch A No. 12.

The ratio of the axes for the Nantucket Shoal current is 1 : 6, or for stations within eighteen miles from the shore, as 1 : 4.

The velocity and direction remain nearly constant for one hour about the time of turn, and for three hours about the middle of flood and ebb.

This subject, headed F, might still further be pursued, if I did not fear to transgress practical limits. There is one obvious practical result, however, to be mentioned. *A vessel cannot be set on any of the shoals by the current alone, if its distance from it exceeds the length of the major axis of motion.*

For the details of the results in this report, see a volume deposited in the archives.

Very respectfully, yours,

CHARLES A. SCHOTT.

Capt. H. W. BENHAM,
Assistant in Charge.

(APPENDIX No. I.)

Table of mean directions.

Northern group.

Station No. 7, 1848, at ebb, 62°; at flood, 229°
No. 2, 1849, at ebb, 60°; at flood, 226°
No. 8, 1848, at ebb, 13°; at flood, 201°
No. 6, 1847, at ebb, 6°; at flood, 211°
No. 9, 1848, at ebb, —— at flood, 189°
No. 5, 1847, at ebb, 37°; at flood, 220°
No. 10, 1848, at ebb, 17°; at flood, 228°
No. 1, 1853, at ebb, 25°; at flood, 200°
No. 2, 1853, at ebb, 2°; at flood, ——
No. 1, 1852, at ebb, 17°; at flood, 220°
No. 11, 1848, at ebb, 9°; at flood, 194°
No. 14, 1852, at ebb, 47°; at flood, 232°
No. 15, 1852, at ebb, 25°; at flood, 193°

Mean directions.....27° 212°

Southern group.

No. 2, 1847, at ebb, 48°; at flood, 236°
No. 4, 1849, at ebb, 75°; at flood, 272°
No. 5, 1846, at ebb, 71°; at flood, 241°
No. 3, 1849, at ebb, 90°; at flood, 255°
No. 1, 1846, at ebb, 92°; at flood, 255°
No. 1, 1847, at ebb, 65°; at flood, 202° (?)
No. 4, 1846, at ebb, 89°; at flood, 276°
No. 5, 1849, at ebb, 70°; at flood, 292°
No. 6, 1849, at ebb, 65°; at flood, 290°

Mean directions....74° 257°

NOTE.—The above positions are marked on the sketch accompanying the preliminary report.

(APPENDIX No. II.)

Table of average maximum velocity.

MAXIMUM DRIFT OF INNER GROUP.

No. 7, 1848, at ebb, 1.9; at flood, 1.7; weather moderate.
No. 2, 1849, at ebb, —— at flood, 1.4; pleasant.
No. 8, 1848, at ebb, 1.4; at flood, 1.8; moderate.
No. 6, 1847, at ebb, 1.2; at flood, 1.9; fresh breeze from S. W.
No. 9, 1848, at ebb, (3.4;) excluded; fresh breeze from S. W.
No. 2, 1847, at ebb, 1.7; at flood, 1.8; moderate weather.
No. 5, 1847, at ebb, 1.7; at flood, 0.8; wind light and variable.
No. 1, 1853, at ebb, 1.5; at flood, 1.5; weather calm.
No. 1, 1852, at ebb, 1.8; at flood, 1.5; wind light and variable.
No. 11, 1848, at ebb, 2.3; at flood, 2.2
No. 10, 1848, at ebb, 2.1; at flood, 1.8; moderate.
No. 4, 1849, at ebb, 1.6; at flood, 1.7
No. 5, 1846, at ebb, 1.2; at flood, 1.6; moderate wind from S. W.
No. ?, 1849, at ebb, 1.5; at flood, 1.5
No. 1, 1846, at ebb, 2.6; at flood, 2.4; variable wind.
No. 1, 1847, at ebb, 1.2; at flood, 2.0; moderate.
No. 4, 1846, at ebb, 1.6; at flood, 1.9; S. W. wind and heavy swell.

Means....1.7 1.7

MAXIMUM DRIFT OF OUTER GROUP.

No. 2, 1853, at ebb, 1.8; at flood, ——; wind light.
No. 14, 1852, at ebb, 2.3; at flood, 3.5; moderate.
No. 15, 1852, at ebb, 2.2; at flood, 2.8; variable.
No. 5, 1849, at ebb, 2.7; at flood, 2.2
No. 6, 1849, at ebb, 2.2; at flood, 2.6

Means....2.2 2.8

(APPENDIX No. III.)

GROUPS OF LUNI-CURRENT INTERVALS.

No. of group.	Station	Lat.	Long.	Est.		Corr.	
I	No. 7, 1848,	lat. 41° 24′,	long. 69° 56′;	Est. X*h*. 38*m*.	(2)	corr. — 3 M.E.	X*h*. 35*m*.
	No. 2, 1849	41 24	69 55	X 54	(2)	— 4	X 50
	No. 8, 1848	41 21	69 55	IX 54	(3)	+ 4	IX 58
	Mean......	41 23	69 55		(7)		X 28
II.	No. 6, 1847	41 18	69 54	X 31	(2)	—22	X 09
	No. 5, 1847	41 17	69 51	X 40	(3)	×17	X 57
	No. 9, 1848	41 16	69 55	X 23	(2)	+11	X 34
	Mean......	41 17	69 53		(7)		X 33

No. of group.	Station	Lat.	Long.	Est.		Corr.	M.E.
III.	No. 2, 1847	lat. 41° 11′	long. 69° 58′	Est. XI*h.* 07*m.*	(2)	corr. −21	M.E. X*h.* 46*m.*
	No. 4, 1849	41 07	69 53	XI 31	(4)	+10	XI 41
	No. 5, 1846	41 05	69 56	XI 17	(5)	+ 8	XI 25
	Mean......	41 08	69 56		(11)		XI 13
IV.	No. 3, 1849	41 04	70 05	XII 01	(8)	− 1	XII 00
V.	No. 1, 1846	41 05	69 50	XI 06	(8)	−13	X 53
	No. 1, 1847	41 04	69 50	XI 49	(3)	− 5	XI 44
	No. 2, 1846	......	......	XI 03	(3)	+21	XI 24
	No. 3, 1846	......	......	XI 46	(3)	+21	XII 07
	No. 6, 1846	......	......	XI 09	(3)	+ 5	XI 14
	No. 3, 1847	......	......	XI 00	(2)	+ 2	XI 02
	No. 4, 1847	......	......	XI 04	(5)	+ 2	XI 06
	Mean......	41 05	69 50		(27)		XI 21± 7 m.
VI.	No. 4, 1846	41 01	69 51	XI 36	(7)	+17	XI 59
	No. 5, 1849	41 01	69 46	XI 53	(5)	+17	XII 10
	No. 6, 1849	40 59	69 48	XII 17	(8)	−21	XI 56
	Mean......	41 00	69 48		(20)		XII 00
VII.	No. 10, 1848	41 12	69 48	X 04	(5)	+20	X 24
	No. 1, 1852	41 12	69 43	IX 54	(6)	+20	X 14
	No. 11, 1848	41 12	69 41	X 22	(6)	+11	X 33
	No. 12, 1848	......	......	X 07	(8)	+10	X 17
	Mean......	41 12	69 44		(25)		X 22
VIII.	No. 1, 1853	41 22	69 40	X 33	(2)	−11	X 22
	No. 2, 1853	41 22	69 31	XI 15	(1)	−15	XI 00
	Mean......	41 22	69 35		(3)		X 41
IX.	No. 14, 1852	41 04	69 27	X 31	(3)	− 1	X 30
	No. 15, 1852	41 02	69 36	X 18	(3)	−11	X 07
	No. 2, 1852	......	......	X 06	(6)	+17	X 23
	No. 3, 1852	......	......	IX 53	(2)	+14	X 07
	No. 4, 1852	......	......	XI 44	(7)	+ 8	XI 52
	No. 5, 1852	......	......	XI 27	(4)	− 2	XI 25
	No. 6, 1852	......	......	X 53	(4)	+10	XI 03
	Mean......	41 03	69 31		29		X 47

APPENDIX No. 49.

Discussion of Currents in Muskeget channel and off the northeast coast of Martha's Vineyard, by Charles A. Schott.

COMPUTING DIVISION, C. S. OFFICE, *August* 11, 1854.

DEAR SIR: The following report on the result of my investigation of the currents in Muskeget channel and off the northeast coast of Martha's Vineyard is respectfully submitted. The immediate purpose of this discussion was to furnish notes for the charts now engraving. The observations show the current to be a tidal current, and were made when the influence of the wind was inconsiderable. The results refer to the surface, no observations being made below.

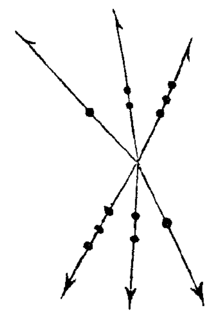
The number of stations in this locality is fifteen, (see accompanying sketch,) and were occupied as follows:

1 by Lieut. Chas. H. Davis in 1846,
1 by Lieut. Chas. H. Davis in 1847,
2 by Lieut. M. Woodhull in 1851,
2 by Lieut. Chas. H. McBlair in 1852,
9 by Lieut. M. Woodhull in 1852,
} In the months of July and August.

The positions of the above fifteen stations, except six and seven, are plotted on hydrographic charts Nos. 222 and 239.

General direction of the ebb.—In Muskeget channel the ebb runs to the seaward, and in the sound off the northeast coast of the island the ebb sets toward the west. From Edgartown harbor the ebb runs into the sound.

Course and rate of flood and ebb currents.—In the following table the set and drift of the tidal current is given at the middle between slack-water and maximum ebb or first quarter; the maximum ebb; the middle between the maximum ebb and next following slack or third quarter, and similarly for the flood. These periods are designated by the first quarter, the maximum ebb, the second quarter; the first quarter of flood, the maximum flood, the third quarter; and are represented as shown by the figure—the full arrow-heads indicating the flood, and the half the ebb and turn, the number of dots indicating the quarters. The velocity, as usual, stands at the head of the arrow.



In the table of the courses the direction is expressed in degrees, counted like azimuths, from south round by the west. (See my report on Nantucket Shoal currents.)

The directions, when necessary, were corrected for 9° westerly magnetic declination.

On account of the connection with the luni-current intervals, the table commences with the ebb stream. The first column contains the numbers designating the stations as used in the discussion and marked down on the sketch. The second column contains the numbers as found in the books of observation, and given by the observers; the other columns are explained by the above.

Table showing the course and rate of the current in Muskeget channel and off the northeast coast of Martha's Vineyard.

Hour.		Ebb.						Flood.					
No.	No. by observation.	1st quarter.		Maximum ebb.		3d quarter.		1st quarter.		Maximum flood.		3d quarter.	
		Set.	Drift.	Set.	Drift.	Set.	Drift.	Set.	Drift.	Set.	Drift.	Set.	Drift.
		°	k.	°	k.	°	k.	°	k.	°	k.	°	k.
1	16	71	1.4	75	1.7	73	1.1	243	1.4	243	1.6	245	1.1
2	1	6	2.0	4	2.3	4	1.9	197	1.9	195	2.4	200	1.3
3	12	—8	0.5	—15	0.8	4	0.6	196	0.7	195	1.0	198	0.5
4	2	9	0.4	31	0.8	34	0.6	198	0.6	220	0.7	221	0.4
5	10	121	0.5	146	0.6	175	0.4	253	0.9	262	0.9	267	0.5
6	7	....	....	....	1.2	......	0.8	......	1.2	......	1.2	......	0.8
7	13	....	....	....	1.5	......	....	......	....	......	1.2	......	....
8	9	98	1.6	93	1.6	101	0.8	236	0.9	243	1.2	243	0.7
9	7	101	0.9	122	1.4	124	1.1	273	1.9	285	2.2	303	0.8
10	8	84	1.2	89	1.8	95	1.2	245	1.7	258	2.1	261	1.3
11	6	118	2.5	124	3.2	134	1.8	264	3.0	260	3.1	260	2.3
12	8½	108	0.8	114	1.0	125	0.5	261	0.7	268	0.9	281	0.5
13	8¾	105	1.6	109	2.1	116	1.5	272	1.5	271	2.0	268	1.1
14	10	133	1.3	127	2.0	124	1.1	310	1.1	299	1.4	259	0.5
15	3	102	1.7	110	2.4	112	1.8	293	1.8	291	2.2	287	1.2

From Nos. 2, 3, 4, of the above table, we obtain the mean direction of ebb and flood in Muskeget channel proper 7° S. (7° W.) and 203° (N. 23° E.); and from Nos. 5, 8, 9, 10, 11, 12, 13, 14, and 15, for the sound, 114° (W. 24° N.) and 267° (E. 3° N.)

It will be observed that the course of ebb and flood is not exactly in opposite directions, but more than 180° in the channel, and less in the sound, tending to produce the mean direction in the Nantucket sound. The ebb setting 24° to the northward of west in the eastern entrance to Martha's Vineyard sound, changes its direction to the southward after it passes Nobska.

Velocity of current.

The mean maximum drift at ebb is 1.6 knots, at flood 1.6 knots. During the time of turn, the current comes to an absolute stand or slack at all the stations. The maximum rate observed, 3.2 knots, was off West Chop, where the sound narrows.

Duration of ebb, flood, and slack-water.

The duration of either ebb or flood is reckoned from the middle of one to the middle of the next following slack-water. From 20 observations the ebb lasts 6*h.* 12*m.*, and from 23 observations the flood 6*h.* 20*m.*, differing but 2 or 3 minutes from ¼ of the average length of a lunar day. The average duration of ebb or flood may be assumed to be 6*h.* 13*m.* The slack-water lasts 26*m.*, as found from 37 observations. The curve described by a par-tide of water is more depressed, and both axes are shorter than on the Nantucket shoals.

Current establishments.

The following table shows the luni-current intervals corrected for half-monthly inequality:

	Current stations, No.—														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Luni-current intervals.														
	h. m.	*h. m.*	*h. m.*	*h. m.*	*h. m*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
	10 19	11 35	10 02	11 18	12 08	11 13	11 09	12 01	9 50	12 02	11 15	11 33	12 19	11 08	12 07
	9 47	11 20	10 12	10 15	12 02	9 24	10 02	11 36	11 01	11 38	11 19	11 42	11 52	11 52	12 27
	10 03	....	9 55	....	12 05	10 05	10 35	11 34	10 43	11 47	10 47	11 50	11 47	12 11	11 47
	....	....	10 27	....	....	....	....	12 23	9 39	11 59	....	11 00	12 00	10 26	11 37
	....	....	9 35	....	....	....	....	....	10 40	12 02	....	11 20	11 56	....	......
Current establishment....	10 03	11 27	10 02	10 46	12 05	10 14	10 35	11 53	10 23	11 53	11 07	11 29	11 59	11 39	12 00
Corr'd current establishm't.	X 08	XI 43	IX 48	X 32	XI 44	X 00	X 14	XI 31	X 20	XI 31	XI 01	XI 41	XI 38	XI 31	XI 38

Corrections for the moon's parallax and declination should also be applied, but the tidal discussions near this locality are not yet sufficiently advanced to furnish data. No other corrections need be applied. The current establishments will finally be referred to the Greenwich meridian, and to a certain transit of the moon (yet to be ascertained by the discussion of tides;) they will then compare with the tidal establishments. An attempt was made to construct co-current lines, but the area covered by the discussion was found too limited for the purpose.

Co-current lines, and lines for direction, may be presented at some future time. The establishment at No. 2 disagrees very much with the rest, and further observations outside of Martha's Vineyard are required.

Approximate current establishment in Muskeget channel, from 1, 2, 3, 4...... X ½ hours.
Current establishment off Edgartown harbor, from 6, 7............................ X ¼ "
" " off Holmes' Hole, from 9, 11, 14............................ XI "
" " in the sound, 5, 8, 10, 12, 13, 15............................ XI ½ "

The deviations from the above mean numbers may amount to one hour.

Very respectfully, yours,

CHAS. A. SCHOTT.

APPENDIX No. 50.

Report on the Tidal Currents of Long Island Sound and approaches: by Charles A. Schott.

Coast Survey Office, *April* 28, 1853, (re-written in April, 1854.)

Dear Sir: The study of the current phenomena, as useful to the mariner as it is interesting to the scientific inquirer, became of additional interest, in this particular locality, from the fact that the sound is accessible to the ocean currents both at its eastern and western entrances, and from advantages that may result to navigation in this much frequented region from a more complete understanding of the motion of its waters.

In order to fully understand the current, it is essential to consider the horizontal as well as the vertical motion of any particle, or the tidal currents proper, or ebb and flood stream, and the tides, or rise and fall. These are the horizontal and vertical components.

To distinguish currents running always nearly in the same direction from such as reverse their motion, governed by the effects of the lunar and solar attraction, the latter have received the name of tidal currents, and such is the nature of those in Long Island sound; though an almost imperceptible current setting towards the sea (the discharge of the river-water) can barely be traced.

The known rise and fall of the tides will furnish the navigator with the means of adapting his soundings to the level of reference of his chart; generally, the mean low-water and known set and drift will guide him in his course.

The great tidal wave from the Atlantic enters the sound between Point Judith and Montauk Point, divided into two branches by the intermediate position of Block island; and another portion of this wave enters New York bay, and, passing through Hell Gate, meets the wave propagated through the sound from the eastward.

It was a matter of importance and interest to know the place of meeting and the limit of variation of these opposite waves. The material for this investigation was furnished from the observations of currents and tides by the officers of the survey under your instructions; the former commenced in 1844 and continued to '48, the latter dating further back.

The range of the tide, or the mean vertical motion, the epoch of the tide, as shown by the co-tidal lines,and the direction of the flood or ebb stream, together with certain lines depending on the epoch of the horizontal motion, presently to be explained, furnish us with as many separate means for determining the locality of the meeting of the eastern and western wave.

Under these different points of view, we can arrive with a very close approximation at the motion of the water throughout the sound.

Considering first the mean or average range, we observe that in a regular, straight, or slightly curved channel, of nearly the same profile, and accessible from both sides, opposite waves will produce the greatest range where they meet, this being equal to the sum of the ranges at the entrances; and in cases where the channel towards the head is wedge-shaped, this range will be still further increased proportionally to the contraction of the profile. At Montauk the mean range is 2.0 feet, and at Sandy Hook 4.8 feet; and from the narrowing of the sound the greatest range observed is one foot more than the sum, or 7.8 feet. From a table of observations of ranges (see Table No. 1,) at nineteen stations, a chart has been constructed, exhibiting the lines of equal mean range for each half foot of change. (See Sketch B, No. 2, diagram No. 1.) The line of the maximum range, by this chart, is off Sand's Point, and the most rapid increase occurs in the passage through Hell Gate.

Following next the co-tidal lines constructed from a table of mean luni-tidal intervals observed at twenty-three stations, (see Table No. 2,) and following up the channel-ways from both entrances, the crossing of the lines of the same hour will indicate the place of meeting of the opposite waves, or the point where the high water takes place latest in time. To the eastward or westward of it, high water occurs sooner. The co-tidal lines (see same Sketch, diagram No. 2) were constructed for local times, answering the purpose when the difference in time for the extent of the chart is nearly twelve minutes. Owing to the want of a sufficient number of observations, the co-tidal lines for the western portion of the chart could not be traced, and the 7½ hour and 8 hour lines, near Block island, are uncertain; there is, however, material enough to point out Hewlett's Point as the position of the latest tides with the hour XI*h.* 22*m.* At Montauk we had VIII*h.* 10*m.*, and at Sandy Hook VII*h.* 31*m.* The observations cannot be considered as closed, and a further accumulation of data will enable us to construct more complete charts and predict the currents and tides with much more precision than is at present possible.

The actually observed direction of the flood and ebb stream, or the direction of the current immediately following or preceding the low or high water, however, will best point out the headwaters of the sound. To the eastward and westward of Throg's Neck the currents have thus been found to flow in opposite directions.

From the above we conclude that the tides meet near Hewlett's Point as the mean position, and that the variable limits are Sand's Point and Throg's Neck, a few miles to the eastward and westward of it. The semi-mensual and diurnal inequality, together with the action of the wind, produce these changes.

The currents proper may be considered under the following three heads: The direction and velocity, or set and drift, and the time at any given stage of the stream.

A chart was constructed exhibiting the lines of direction for the ebb or outgoing stream, (see Table No. 3, and the curves in diagram No. 1,) when at its greatest velocity; this chart was also found to answer for the flood or ingoing stream, the set differing nearly 180°. These curves of direction are perhaps the most useful to the mariner. They follow the channel, or are nearly parallel to the shores. They were drawn equidistant as far as the observations and locality would admit of, and the velocity in miles per hour is written in figures against the places of observation. If the observations had been more numerous, the better method of varying the distance of the lines inversely proportional to the velocity, according to a definite scale, would have been preferable.

The latter representation, proposed by yourself, was used for other charts of the survey. Following any of the curves of direction, the change in velocity may be seen by inspection. It is, however, not to be supposed that a floating body would be carried throughout the length of any of the lines, as the reverse motion, after about six hours' duration, would restore it to nearly its original position. It appears, from the accompanying table, (see Table No. 3,) that the velocity of the flood stream was a little less than that of the ebb, caused by the discharge of the river-water in the sound. The more remarkable velocities were found as follows: 4.7 knots in the Race, (opposite the west end of Fisher's island,) 5.9 knots in Hell Gate, 3.7 knots on an average in New York harbor, and 3.0 in the bay. 2.2 knots is the average drift in Long Island sound. The drift is a function of the size of the section of the channel, and the quantity of water to be discharged through it.

The total number of current stations used in the discussion, and extending over the sound and New York bay and harbor, was seventy-five, occupied, generally, for thirteen hours each.

The time of turn, or the epoch of the current, occurring shortly after high water, is the last datum required to be known in order to predict the currents as we now do the tides. This I have attempted to ascertain by taking the intervals of time of the moon's superior or inferior transit, and the time of the middle of slack-water, at, or immediately following the high-water stand. It must be observed that it is by no means uncommon to perceive horizontal motion during the time of stand, or vertical motion during the time of slack-water. The interval just spoken of I call luni-current interval, analogous to luni-tidal interval, and the mean of these luni-current intervals gives the mean establishment of the tidal current, (see Table No. 4:) thus, by uniting all the places of the same current establishment by lines, co-current lines will be obtained. These lines may be regarded as corresponding to the co-tidal lines. The epoch of the beginning of the ebb stream for these curves (see diagram No. 2) was chosen for the purpose of a more ready comparison with the co-tidal lines, the difference indicating how much sooner or later one or the other of the motions commences, or the difference in time between the middle of stand and the middle of slack-water, immediately preceding the ebb stream. The duration of the slack-water, both for the ebb and flood streams, and the duration of either, is given in Table No. 5, so that the condition of the current at any given time may easily be inferred, the process being precisely similar to that employed for predicting tides. No current stations have as yet been occupied during the whole of a lunation, but to arrive at any of the inequalities of the tidal currents in this way appears to me less preferable. The corrections may safely be taken as found, from the inequalities of the tides. These lines disclose some remarkable features. First, their general tendency to run parallel to the channel or shore, arising from the more rapid propagation of the wave in deep water; secondly, the motion of the water after the high-water stand commences—first near the shore, and last in the channel-way. The current establishments have been given in the table from which the co-current lines have been constructed.

The instant of the beginning of the ebb stream (mean slack-water) was chosen for the epoch. It was not deemed necessary to refer the times to one meridian. Taking means of these luni-current intervals of stations near mid-channel, I found the hour between Block island and the Race, from eight stations, XI*h.* 33*m.*; in the middle of the sound, (widest part,) from seven stations, XII*h.*; near the head of the sound, from ten stations, XII*h.* 38*m.* The number of observations at each station range from one to three, taken in different years.

In New York bay we have, from thirteen stations - - - - -	VIII*h.*	20*m.*
In New York harbor, from three stations - - - - - - -	IX	29
In Hell Gate, from ten stations - - - - - - - - - -	IX	33
Between Hell Gate and Throg's Neck, from five stations - - -	X	41

Showing a remarkably slow propagation between Hell Gate and Hewlett's Point, which is accounted for below. The mean uncertainty in the above figures is shown in Table No. 6, and is found not greater than the irregularities of the tides from a prior consideration would indicate.

The ebb stream at the eastern entrance commences three hours later than at the western entrance, although the tides differ but one hour at Montauk and Sandy Hook. At half-ebb tide, the water in the channel of Montauk Point begins to run out; and before two-thirds of the ebb tide is completed, the water in the channel at the head of the sound begins its outward motion. The phenomenon is similar in New York bay, where the ebb stream begins its motion at one-sixth of the ebb tide; but at the head east of Hell Gate, the ebb stream is not perceptible till the tide at the entrance of the bay is almost reversed, or at five-sixths of the ebb tide. Lines showing the level of the surface of the sound at any stage of the tides, may be constructed with the aid of the co-tidal lines and the curves of mean equal range. As already indicated, the water begins its motion first nearest the shore, and not until a considerable time has elapsed in the channel. The X, XI, and XII-hour curves of the co-current lines near the Race, on both sides of the sound, are in this respect particularly interesting. The knowledge of this is made available by vessels navigating this part of the sound, and the earlier or later setting in of the currents is known to the local pilots. In mid-channel, throughout the sound, the outward motion commences shortly after the high water at the head of the sound, and evidently depends upon it, though it cannot be recognised west of Throg's Neck, on account of the disturbing influence of the rocky and narrow passage through Hell Gate.

The following practical note in reference to the eastern portion of the sound is deduced from these observations:

The currents commence running along the northern and southern shores of the eastern part of the sound at various intervals from one to two hours before running in the channel. The currents along the shore, between New Haven and New London, are earlier by one hour than between Fisher's island and Point Judith, making, in all, a difference of two and a quarter hours between the first-named places, and of one and a quarter hour between the last named and the beginning of the motion in the channel. The currents through the entrances formed by Block island begin to run simultaneously, and about one hour earlier than in the Race. The ebb through Plum Gut lasts about two hours longer, and the flood so much shorter, than at other places in the vicinity.

To find the time of slack-water at the beginning of the flood, add the duration of the ebb stream (which is given in Table No. 6) to the luni-current interval.

The duration of the ebb stream at the entrance, middle, or head of the sound appears to be the same, and this holds good for the duration of the slack-water. Taking means, I obtain for the eastern entrance, the middle and head of the sound, the duration as follows: 6*h.* 34*m.*, 6*h.* 38*m.*, 6*h.* 03*m.* for the ebb, and 6*h.* 08*m.*, 6*h.* 08*m.*, 5*h.* 48*m.* for the flood, and 5, 3, and 16 minutes for the slack-water.

All the remarks and deductions refer to the surface current. The motion in any given vertical section appears to begin first near the surface; but shortly after, the velocity is nearly the same throughout the whole depth. There appears to be no difference in the direction of the stream at or below the surface.

I had proceeded thus far in the investigation, when you suggested to me the attempt to ascertain how far the circumstances of propagation of the current could be explained by the mean depth of the sound. This I have attempted in the following investigation, which greatly facilitates the construction of the time curves, and thus aids in the prediction of the tides for places where no direct observations had been made.

The tidal wave, Russel's great primary wave, and Airy's free-tide wave, a wave of the first order, or any wave of the second order that has, by approaching the shore, become a wave of translation, travels with a velocity equal to that acquired by a heavy body falling freely by gravity through a height equal to half the depth of the fluid, reckoned from the top of the wave to the bottom of the channel. In any other than a rectangular channel, the effective height is from the top of the wave to the centre of gravity of the section. In a primary wave there is no oscillation proper; but the particles of the fluid in a vertical section, by the transit of the wave, are raised, moved laterally, and permanently brought to rest in the direction of the motion in a new place, with the same extent of transference of each particle throughout the whole depth of the wave. The height of this wave increases in a channel of the form of a wedge, and of equal depth nearly in the inverse ratio of the square root of the depth.

Waves of the second order, such as those caused by the wind, oscillate either circularly or elliptically, and their velocity is not a function of the depth of the water.

To apply the above empirical laws, it was necessary to obtain the correct time of the transit of a wave in the channel over two places at a considerable distance apart. A position near the Race, and another off Sand's Point, were found admirably fitted for the purpose, and the time of transit, as observed on the shore, had only to be referred to the mid-channel. Let h denote the effective depth, and v the corresponding velocity, then we have the simple formulæ for feet and seconds of time:

$$h = 0.015536\ v^2$$
$$v = 8.0227\ \sqrt{h};$$

or, for h in feet, and v in statute miles per hour,

$v = [0.73800]\ \sqrt{h}$; the number within brackets being a logarithm. Subtracting one minute for the time of transmission of the wave from the channel to the place of observation at Sand's Point, (computed by the above formula,) and seven minutes for New Rochelle, from the observed time of the transit of the crest of the wave or high water at this place, we find for the transit in the channel XI*h*. 12*m*. and, similarly, IX*h*. 21*m*. for the same at the Race. This difference increased by 10*m*. for difference in longitude, leaves 2*h*. 01*m*. as the observed time of the transmission of the wave from the Race to Sand's Point, a distance of ninety-five miles.

To obtain the computed time, the space was subdivided to allow mean depths to be used; and by adding the times together for the several sections, as computed by the above formula, an interval of 2*h*. 19*m*. was found differing but 18*m*. from the observed time.

An analytical investigation, by Andrew John Robertson, (see London, Edinburgh, and Dublin Philos. Mag., February, 1853,) based upon Scott Russel's experiments, and with consideration of Mr. Earnshaw's paper, (Philos. Mag., December, 1850–'51,) gives for the velocity of the transmission of the wave of translation $v = (h + 2\,k)\ \sqrt{\frac{g}{h+k}}$; and on another supposition, simplifying the investigation, $v = (h + 2\,k)\ \sqrt{\frac{g}{h}}$, where h = depth of undisturbed waters, $2\,k$ = height of a positive wave, g = accelerating force of gravity. Expressing h in feet and v in miles per hour, we have—

$v = [0.58739]\ (h + 2\,k)\ \sqrt{\frac{1}{h}}$, the number enclosed in brackets being a logarithm.

Applying this formula, the time for traversing the ninety-five miles becomes 2*h*. 14*m*., being five minutes nearer the observed time, and differing but a few minutes from it.

The wave travelling at the rate of sixty miles an hour near the Race, arrives at the head of the bay with but little more than half that velocity, sending out branches towards the shores; hence the parallelism of the co-tidal lines with the shore-line.

The propagation of the wave from some point in the channel towards the shore station takes place in the shortest possible time, and the line of propagation can be found by the method of trial and error with tolerable accuracy. The above has been verified by our tidal observations on the shores of the sound, but there is yet some obscurity in the time of the tides near the eastern entrance, which will be cleared by future observations.

Referring some observed tides below and above the Race to the channel, the resulting retardation of the tidal wave by the contraction of the shore-lines at this place, I computed to be eight minutes. The explanation for the remarkably slow transmission of the wave east of Hell Gate will be found in the intricacies of the channel. These narrow passages, turning frequently round acute angles, and destroying the acquired momentum of the water by friction, will not permit us to calculate the time of transmission through them.

At the southwest ledge the sea is said to break in heavy weather; the depth, however, being six fathoms, would, for a perfect breaker, require a wave of seventy-two feet from top to bottom. The interference of waves appears to favor the formation of imperfect breakers.

The currents on the dangerous ground of the Nantucket shoals are now undergoing investigation, the results of which I expect to submit to you in a short time.

I remain, sir, very respectfully, yours, CHAS. A. SCHOTT.

Prof. A. D. BACHE, *Superintendent U. S. Coast Survey.*

TABLE No. 1.

Range or mean rise and fall of tides in Long Island Sound and approaches. (*Data to April*, 1853.)

Eastern Series.		Western Series.	
Stations.	Feet.	Stations.	Feet.
Montauk Point	2.0	Sandy Hook	4.8
Point Judith	3.1	Governor's Island	4.9
Beavertail Light	4.0	Spitfire Pot Cove	6.3
Stonington	2.7	North Brother	7.2
New London	2.6		
Sachem's Head	5.3		
New Haven	5.8		
Bridgport	6.6		
Sheffield Island	7.4		
Huntington Bay	7.6		
Great Captain's Island	7.5		
Oyster Bay	7.2		
Sand's Point	7.7		
New Rochelle	7.6		
Throg's Neck	7.2		

TABLE No. 2.

Corrected or mean establishments in Long Island Sound and approaches. (*Data to April*, 1853.)

Eastern Series.		Western Series.	
Stations.		Stations.	
	h. m.		*h. m.*
Montauk Point	VIII 10	Sandy Hook	VII 31
Point Judith	VII 32	Governor's Island	VIII 31
Beavertail Light	VII 56	Hallett's Cove	X 00
Quick's Hole	VII 32	Spitfire Pot Cove	X 48
Watch Hill	IX 6	North Brother	XI 16
Stonington	IX 7		
Little Gull Island	IX 38		
New London	IX 33		
Sachem's Head	XI 00		
New Haven	XI 16		
Bridgport	XI 11		
Sheffield Island	X 58		
Huntington Bay	X 51		
Great Captain's Island	XI 1		
Oyster Bay	XI 7		
Sand's Point	XI 13		
New Rochelle	XI 22		
Throg's Neck	XI 20		

TABLE No. 3:

Showing the direction of the current at its greatest velocity, or the set and maximum rate of the ebb and flood stream. (The greatest velocity occurs nearly midway between the slack-water. The stations in this and the other tables are numbered as on the published charts.)

Stations No. 45 to No. 20 were occupied by Lieutenant J. R. Goldsborough, U. S. Navy, in 1846; and No. 20 to No. 9 were occupied by Lieutenant J. R. Goldsborough, U. S. Navy, in 1847. Stations near 42 and 41 were re-occupied in 1848 by Lieutenant J. R. Goldsborough, U. S. Navy.

EASTERN SERIES.

	Ebb stream.		Flood stream.	
No.	Greatest velocity—miles per hour.	Direction.	Greatest velocity—miles per hour.	Direction.
45	2.1	S. 22°E.	2.1	N. 11°W.
44	2.4	S. 43 E.	1.3	N. 53 W.
43	2.8	N. 68 E.	1.6	N. 17 W.
42	1.1	S. 61 E.	1.2	S. 82 W.
41	1.9	S. 50 E.	2.0	N. 51 W.
40	1.9	N. 86 E.	1.4	N. 84 W.
39	1.0	N. 59 E.	0.8	S. 82 W.
38	1.3	N. 58 E.	1.0	S. 78 W.
37	2.0	N. 84 E.	2.0	N. 81 W.
36	4.5*	S. 56 E.	4.7†	N. 78 W.
35	1.9	S. 77 E.	1.6	N. 55 W.
34	2.8	S. 67 E.	2.1	N. 53 W.
33	2.7	N. 70 E.	2.6	S. 73 W.
32	2.5	S. 71 E.	1.8	W.
31	1.7	S. 80 E.	1.8	S. 86 W.
30	2.0	N. 52 E.	1.4	S. 53 W.
29	1.5	S. 81 E.	1.5	N. 78 W.
28	1.6	S. 83 E.	1.4	N. 76 W.
27	1.5	S. 67 E.	1.2	W.
26	2.0	S. 76 E.	1.9	N. 84 W.
25	0.8	N. 70 E.	0.6	S. 71 W.
24	1.5	N. 76 E.	1.5	N. 63 W.
23	2.1	N. 64 E.	1.8	S. 80 W.
22	1.8	N. 88 E.	2.2	N. 84 W.
21	2.2	S. 84 E.	2.1	S. 71 W.
20	2.2	N. 77 E.	1.9	S. 81 W.
19	1.3	N. 73 E.	1.2	S. 62 W.
18	1.5	N. 58 E.	1.4	S. 33 W.
17	0.8	N. 62 E.	1.0	S. 64 W.
16	1.2	N. 68 E.	1.2	S. 76 W.
15	1.1	N. 75 E.	1.3	S. 46 W.
14	0.6	N. 50 E.	0.6	S. 42 W.
13	0.7	N. 35 .	0.6	S. 58 W.
12	0.9	N. 34 E.	0.6	S. 25 W.
11	1.0	N. 14 E.	0.5	S. 26 W.
10	0.9	N. 45 E.	0.5	S. 15 W.
9	1.0	N. 28 E.	0.7	S. 25 W.

* 3.0, observations in 1848.—Lieut. J. R. G.

† 2.4, observations in 1848.—Lieut. J. R. G

WESTERN SERIES.

Greatest velocity observed at the stations between Throg's Neck and Governor's Island.

Stations No. 8 to No. 1 were occupied by Lieutenant J. R. Goldsborough, U. S. Navy, in 1846; and No. 1 to No. 9 were occupied by Lieutenant Charles H. Davis, U. S. Navy, in 1845.

No.	Ebb.	Flood.
8	Missing.	....
7	1.1	1.5
6	1.0	1.3
5	1.0	0.5
4	1.0	0.6
3	1.0	1.4
2	Missing.	....
1	2.7	2.9
1	4.6	5.9
2	2.7	4.2
3	2.8	2.4
4	2.6	1.2
5	4.0	2.2
6	1.0	0.7
7	2.2	3.9
8	4.7	4.2
9	3.7	3.2

Greatest velocity and corresponding direction in New York bay and harbor, observed by Lieutenant Charles H. Davis, in 1844.

No.	No. of published chart.	Ebb.		Flood.	
		Greatest velocity.	Direction.	Greatest velocity.	Direction.
1	1	1.0	S. 47° E.	0.9	N. 32° W.
2	2	1.5	S. 50 E.	0.5	N. 36 W.
3	3[1]	2.5	S. 73 E.	1.3	N. 61 W.
4	3[2]	2.5	S. 49 E.	1.5	N. 49 W.
5	4	1.5	N. 51 E.	1.7	N. 76 W.
6	5	1.0	S. 66 E.	1.2	S. 87 W.
7	1	2.9	N. 74 E.	2.0	N. 71 W.
8	2	2.0	S. 51 E.	1.8	N. 62 W.
9	3	2.2	S. 71 E.	1.6	N. 8 W.
10	4	1.8	S. 67 E.	1.8	S. 78 W.
11	5	1.4	S. 53 E.	2.0	S. 31 W.
12	6	2.1	S. 60 E.	1.7	N. 55 W.
13	7	2.4	S. 34 E.	1.8	N. 52 W.
14	8	2.5	S. 15 E.	1.4	N. 26 W.
15	9	3.0	S. 44 W.	1.8	N. 47 E.
16	10	3.0	S. 47 W.	2.0	N. 47 E.
17	11	2.4	S. 30 W.	1.8	N. 20 E.
18	12	3.7	S. 56 W.	3.0	N. 68 E.
19	1	2.4	S. 25 E.	2.0	N. 20 W.
20	2	2.3	S. 58 E.	1.8	N. 58 W.
21	3	2.8	S. 75 E.	1.5	N. 20 W.

TABLE No. 4.

Luni-current interval for the middle of slack-water after high water stand, or for the beginning of the ebb or outgoing stream.

EASTERN PART OF THE SOUND—1846–'47.

Station.	Mean luni-current interval.	No. of observat'ns.	Luni-current interval of stations in or near the channel.	Current establishment or means.
No. 45	11*h*. 38*m*.	3	11*h*. 38*m*.	XI*h*. 33*m*., eastern entrance of sound.
44	11 16	2	11 16	
43	11 42	2	11 42	
42	11 16	2	11 16	
41	9 59	3	....	
40	11 14	3	11 14	
39	9 53	3	....	
38	10 17	2	....	
37	10 00	2	....	
36	12 20	2	12 20	
35	11 02	3	....	
34	11 45	2	11 45	
33	11 15	2	11 15	
32	10 04	1		
31	10 03	3		
30	12 00	2	12 00	XII*h*. 00*m*., middle part of sound.
29	10 11	2	....	
28	12 09	2	12 09	
27	11 05	3	....	
26	11 22	3	....	
25	11 52	2	11 52	
24	10 58	2	....	
23	12 04	3	12 04	
22	10 56	1	10 56	
21	12 30	3	12 30	
20	12 20	3	12 20	
19	12 47	3	12 47	XII*h*. 38*m*., western part of sound.
18	12 55	2	12 55	
17	12 49	3	12 49	
16	11 54	2	11 54	
15	12 00	3	12 00	
14	11 48	2	11 48	
13	13 48	2	13 48	
12	12 44	3	12 44	
11	12 42	3	12 42	
10	12 46	3	12 46	
9	8 0	3	....	Rejected.

WESTERN PART NEW YORK BAY AND CHANNEL—1844.

Station.	Luni-current interval.	Same for stations in the channel.	
No. 1	7*h*. 40*m*.	7*h*. 40*m*.	Mean VIII*h*. 20*m*. 12 stations of 1845 give VIII *h*. 18*m*.
2	7 56	7 56	
3	6 51 ?	Rejected.	
4	8 50	8 50	
5	7 58	7 58	
6	6 39 ?	Rejected.	
7	8 30	8 30	
8	8 15	8 15	
9	7 55 ?	7 55	
10	8 19	8 19	
11	9 03	9 03	
12	9 18	9 18	
13	9 18		
14	8 16		
15	9 10		
16	9 38		
17	9 38		
18	10 00		
19	8 39	8 39	
20	7 53	7 53	
21	8 03	8 03	

NEW YORK HARBOR.

1844. Luni-current interval from three stations, 9*h*. 29*m*.
1845. " " " 9 22

HELL-GATE, 1845.—Observed by Lieut. Charles H. Davis, U. S. Navy.

Station.	Luni-current interval.	Mean.
1	10*h*. 00*m*.	IX*h*. 33*m*.
2	10 18	
3	9 36	
4	9 26	
5	9 28	
6	9 38	
7	9 15	
8	9 07	
9	9 09	
1st. in 1846.	9 31	

BETWEEN HELL-GATE AND THROG'S NECK, 1846.—Observed by Lieut. J. R. Goldsborough, U. S. N.

Station.	Luni-current interval.	Mean.
1	10*h*. 28*m*.	X*h*. 41*m*.
2	10 50	
3	11 08	
4	10 35	
5	10 25	

TABLE No. 5.

Duration (mean) of the ebb and flood stream, from the middle of one slack-water to the middle of the next, and of slack-water.

LONG ISLAND SOUND.

No.	Ebb.	Flood.	Slack-water.
45	6h. 35m.	6h. 55m.	15m.
44	6 35	6 05	5
43	6 50	6 02	0
42	5 50	6 25	10
	6 15	5 52	In 1848, 7
41	6 22	5 55	0
	5 17	6 45	In 1848, 10
40	6 45	5 57	5
39	6 10	6 12	20
38	5 10	6 42	7
37	6 37	6 35	0
36	6 37	6 25	0
	6 29	5 52	In 1848, 3
35	6 20	5 57	5
34	6 42	5 55	0
33	6 25	5 55	7
32	8 10	4 10	0
31	6 13	5 40	0
30	6 22	6 17	0
29	6 47	5 40	5
28	6 50	5 25	5
27	6 25	6 02	0
26	7 15	6 15	10
25	6 20	5 55	0
24	6 30	5 47	10
23	6 47	5 52	0
22	6 35	6 10	5
21	6 45	6 30	5
20	6 47	6 45	2
19	5 35	5 42	7
18	6 42	5 57	10
17	4 57	7 42	0
16	6 32	6 12	0
15	5 00	6 40	12
14	6 35	5 07	45
13	6 17	5 27	20
12	6 37	4 37	45
11	7 35	5 05	5
10	6 25	5 30	12
9	6 45	5 55	10

NOTE.—The duration of ebb or flood differs as much as three quarters of an hour in successive tides; but ordinarily not more than ten or twenty minutes.

BETWEEN THROG'S NECK AND GOVERNOR'S ISLAND.

Stations No. 8 to No. 1 were observed by Lieut. J. R. Goldsborough, U. S. N., in 1846; and No. 1 to No. 9, by Lieut Charles H. Davis, U. S. N., in 1845.

No.	Ebb.	Flood.	Slack-water.
8	......	......	......
7	5*h*. 55*m*.	7*h*. 15*m*.	0*m*.
6	6 10	6 00	5
5	5 52	6 25	5
4	......	6 20	10
3	5 55	6 40	10
2	......	......	......
1	6 10	6 35	0
1	6 00	5 50	3
2	6 00	6 05	2
3	6 00	5 55	......
4	6 00	6 10	20
5	6 00	6 00	......
6	6 10	5 50	25
7	5 55	6 00	0
8	6 00	6 00	......
9	5 50	6 09	......

NEW YORK BAY AND HARBOR.

The observations are made in such a manner as to give no duration of ebb, flood, and slack-water, which, together, should be more than 12 hours. Finding it about 10 hours, it is evident that the observations do not extend from slack-water to slack-water.

TABLE No. 6.

Showing the irregularity in the luni-current intervals on successive tides.

LONG ISLAND SOUND—1846–'47.

No. of stations.	Luni-current intervals.			Means.
45	11*h*. 20*m*.	10*h*. 53*m*.	12*h*. 42*m*.	11*h*. 38*m*.
41	10 36	9 52	9 28	9 59
40	10 45	11 06	11 51	11 14
39	9 29	9 28	10 41	9 53
35	10 57	11 08	10 59	11 02
31	10 18	10 28	9 22	10 03
29	10 01	10 13	10 25	10 11
27	11 00	11 10	11 05	11 05
26	10 27	12 40	11 00	11 22
23	12 02	11 39	12 30	12 04
21	11 34	12 31	13 23	12 30
20	11 09	12 16	13 34	12 20
17	12 26	12 59	13 02	12 49
15	12 56	12 59	12 06	12 00
12	13 17	12 01	12 55	12 44
11	12 13	12 44	13 08	12 42
10	12 27	12 41	13 10	12 46
7	9 43	9 52	11 40	10 25
6	10 24	10 18	11 02	10 35
3	10 01	10 28	10 55	10 28
1	9 10	9 28	9 55	9 31

APPENDIX No. 51.

Tide Tables for the Coast of the United States.

The following tables contain the revised data for the principal tidal elements of a number of points on the coast of the United States, with additions to the tables published last year, furnished by the discussions of the tidal observations. They are selected from a large number of results obtained in the progress of the Coast Survey, only those stations being reported, as a general rule, where the observations extended through at least two lunations.

EXPLANATION OF THE TABLES.

Table I gives a list of the stations, beginning at the north and east, and following the coast south and west. The first three columns of this table need no explanation.

The fourth gives the mean interval between the time of the moon's transit and the time of high water. This is also called the "corrected establishment" of a place. Navigators are in the habit of using the term "time of high water at full and change of moon," but this is not equivalent to the mean interval on our coast, where the tide follows two days after the transit of the moon by which it is produced. On the Western coast, however, the mean interval appears to coincide with the interval at full and change.

The fifth column gives the difference between the greatest and least intervals.

Table II will show at what age of the moon these occur.

The sixth column gives the mean rise and fall, or range of the tide.

The seventh gives the same for spring tides, and the eighth for neap tides.

The ninth column gives the mean duration of the flood or rise of the tide, and the tenth the mean duration of the ebb or fall of the tide. Both are reckoned from the middle of one stand to the middle of the next.

The eleventh column gives the mean duration of the stand, also sometimes called slack-water, although the latter term is more usually applied to the cessation of the tidal current than to the cessation of the vertical rise or fall of the surface of the water.

Table II gives the interval between the time of the moon's transit and the time of the high water for different ages of the moon. The hour of the moon's transit is in the first column, and each subsequent column gives the interval referred to for the place named at the head of the column.

This table results from applying the correction for half-monthly inequality to the mean interval of Table I.

Table III gives the changes of height of high and low water for the different ages of the moon. The times of transit are, as in Table II, in the first column, and the names of the places to which the table applies at the head of the successive columns.

Under the heading of each place four columns are given. The first shows the rise of high water above mean low water, at the several ages of the moon.

This column gives the addition to be made to a chart upon which the soundings are reduced to mean low water, to obtain the depths at high water, at any period of the lunar month.

The second column under the head of each place shows the height of high water above mean low water of spring tides, and gives the means of finding the depths at high water upon charts of which the soundings have been reduced to the mean low water of spring tides. The third column shows how to reduce depths given at mean low water to the low water of the day, and the fourth column how to reduce depths given at mean low water of spring tides, to the low water of the day.

This table is obtained from applying the half-monthly inequality of heights of high and low water, respectively, to the mean heights of mean high and low water, and to the mean heights of high and low water of spring tides.

Table IV gives the rise or fall of the tide at several stations in the Gulf of Mexico.

On this part of the coast the tides present the following peculiarities: When the moon's declination is zero, or nearly so, there are two small, irregular tides in twenty-four hours; when the moon's declination is greatest, there is generally but one tide in twenty-four hours.

Between these two periods there are sometimes two very small tides of unequal height. This inequality often amounts to one foot in the height of low water. In the height of high water, however, the inequality rarely exceeds four or five inches, and more generally manifests itself by the tide standing at about the same height for several hours.

When the time of greatest declination of the moon occurs at full or change, the rise and fall are greatest. When the moon's declination is zero in the first or last quarter, the rise and fall are least.

Tables V, VI, VII, VIII, IX, and X, refer to places at which the difference in interval and height of A. M. and P. M. tides, or the diurnal inequality in time and height, is large. Tables V and VII are for Key West, and the others for San Francisco.

Table V gives the interval between the moon's transit and the time of high water for each hour of transit, and for each day from the maximum declination of the moon to the zero of declination. At this latter period the diurnal inequality vanishes. The intervals corresponding to the superior transits, and north declinations and inferior transits, and south declinations, are given in the first half of the table, and those for superior transits and south declinations, and for inferior transits and north declinations, in the second half.

This table is made by applying the correction for the half-monthly inequality to the mean interval, and by applying to the numbers thus found the corrections for the daily inequality, with their proper signs.

The times of both upper and lower culminations of the moon, are given in the United States Nautical Almanac.

Table VI gives the height of high water at Key West above mean low water of spring tides, for every hour of transit, and for each day from the maximum of the moon's declination. As in Table V, the moon's age is in the first column, and the number of days from the greatest declination is at the head of each successive column. One-half of the table applies to upper transits and north declinations, and to lower transits and south declinations; and the other half to upper transits and south declinations, and lower transits and north declinations.

Tables VII and VIII are the corresponding ones for San Francisco, and are similarly arranged. The heights in Table VIII are given above the *lowest* low water of the day at *spring* tides.

Tables IX and X are similar ones for the time and height of *low* water at San Francisco. Table XI gives the proportionate rise or fall of the tide before or after high water, during successive half hours, for spring and neap tides at New York and Old Point Comfort.

Table XII gives a description of the bench-marks to which the heights of the tides have been referred, at some of the more important ports.

TABLE I.

General Tide Table for the coast of the United States.

Station.	Locality.	State.	Interval between time of moon's transit and time of high water. Mean.	Interval between time of moon's transit and time of high water. Difference between greatest and least.	Rise and fall. Mean.	Rise and fall. Spring.	Rise and fall. Neap.	Mean duration. Flood.	Mean duration. Ebb.	Mean duration. Stand.
Coast from Portland to New York.			h. m.	h. m.	Feet.	Feet.	Feet.	h. m.	h. m.	h. m.
Portland	Atlantic wharf	Me	11 25	0 44	8.8	10.0	7.6	6 14	6 12	0 20
Portsmouth	Fort Constitution	N. H	11 23	0 53	8.6	9.8	7.2	6 22	6 07	0 21
Newburyport	Custom-house wharf	Mass	11 22	0 50	7.8	9.1	6.6	5 16	7 09	0 24
Salem		do	11 13	0 50	9.2	10.6	7.6	6 19	6 06	0 06
Boston Light		do	11 12	0 35	9.3	10.9	8.1	6 20	6 06	0 15
Boston	Charlestown dry-dock	do	11 22	0 44	10.0	11.3	8.5	6 16	6 18	0 09
Nantucket	Commercial wharf	do	12 24	0 37	3.1	3.6	2.6	6 23	5 44	0 09
Edgartown	Light-house pier	do	12 16	....	2.0	2.5	1.6	6 51	5 29	0 24
Holmes' Hole		do	11 43	0 31	1.7	1.8	1.3	6 41	5 21	0 12
Tarpaulin Cove		do	8 04	0 49	2.4	2.6	2.0	6 09	6 17	0 34
Wood's Hole	North side	do	8 06	....	3.9	....	....	6 31	5 51	
Wood's Hole	South side	do	8 56	....	1.5	....	....	6 03	6 22	
Bird Island Light	Buzzard's bay	do	7 59	0 45	4.4	5.3	3.5	6 51	5 58	
New Bedford Harbor	Dumpling Rock	do	7 59	0 41	3.8	4.6	2.8	6 50	5 33	0 42
Newport	Fort Adams	R. I	7 45	0 24	3.9	4.6	3.1	6 21	6 03	0 23
Point Judith		do	7 32	0 46	3.1	3.7	2.6	6 12	6 10	1 00
Montauk Point	Long Island	N. Y	8 10	1 42	2.0	2.5	1.4	6 13	6 11	
Sandy Hook		N. J	7 29	0 47	4.8	5.6	4.0	6 10	6 15	0 16
New York	Governor's island	N. Y	8 13	0 46	4.3	5.4	3.4	6 00	6 25	0 28
Long Island Sound.										
Watch Hill		R. I	9 00	0 23	2.7	3.1	2.4	6 35	5 56	0 14
Stonington		Conn	9 07	0 30	2.3	3.4	2.1	6 15	6 10	0 25
Little Gull Island		N. Y	9 38	1 07	2.5	2.9	2.3	6 01	6 21	0 37
New London		Conn	9 28	0 52	2.6	3.1	2.1	5 56	6 26	0 22
New Haven		do	11 16	1 08	5.8	6.6	5.1	6 24	6 05	
Bridgeport		do	11 11	1 03	6.5	8.0	4.7	6 01	6 07	
Oyster Bay, Long Island		N. Y	11 07	0 51	7.3	9.2	5.4	6 08	6 24	
Sand's Point		do	11 13	0 31	7.7	8.9	6.4	5 55	6 30	0 14
New Rochelle		do	11 22	0 32	7.6	8.6	6.6	5 51	6 35	0 12
Throg's Neck		do	11 20	0 39	7.3	9.2	6.1	5 50	6 33	0 43
Coast of New Jersey.										
Cold Spring inlet		N. J	7 32	0 51	4.4	5.4	3.6	6 08	6 18	
Cape May	Landing	do	8 19	0 47	4.8	6.0	4.3	6 11	6 15	0 20
Delaware bay and river.										
Delaware Breakwater		Del	8 00	0 50	3.5	4.5	3.0	6 15	6 06	0 26
Higbies	Near Cape May	N. J	8 33	0 43	4.9	6.2	3.9	6 26	6 00	
Egg Island Light		do	9 04	0 51	6.0	7.0	5.1	5 52	6 27	
Mahon's Ditch		Del	9 52	1 18	5.9	6.9	5.0	6 11	6 11	
New Castle		do	11 53	....	6.5	6.9	6.6	5 06	6 43	0 47
Philadelphia	Navy yard	Pa	13 15	0 54	6.1	7.0	5.2	4 51	7 05	
Philadelphia	Walnut street wharf	do	13 21	0 42	5.9	6.6	5.1	4 52	7 06	
Chesapeake bay.										
Old Point Comfort		Va	8 17	0 50	2.5	3.0	2.0	6 01	6 25	
Point Lookout		Md	12 58	0 45	1.4	1.9	0.7	5 59	6 19	0 35
Annapolis	Taylor's wharf	do	16 38	0 40	0.9	1.0	0.8	6 11	6 15	0 34
Bodkin Light		do	17 42	0 48	1.0	1.3	0.8	5 23	7 05	
Baltimore	Jackson's wharf	do	18 33	0 13	1.3	1.5	0.9	5 51	6 33	
James river	City Point	Va	14 14	....	2.6	....	....	5 28	6 52	0 40
Richmond	Rockett's wharf	do	16 28	....	2.9	....	....	4 52	7 34	
Coast of North Carolina, South Carolina, Georgia, and Florida.										
Hatteras inlet		N. C	7 04	0 57	2.0	2.2	1.8	6 07	6 07	0 50
Beaufort	Fort Macon	do	7 26	0 59	2.8	3.3	2.2	6 11	6 10	0 42
Smithville	Barracks wharf	do	7 19	0 47	4.5	5.5	3.8	6 01	6 26	0 26
Charleston	Castle Pinckney	S. C	7 13	0 36	5.3	6.3	4.6	6 33	6 09	0 33
Savannah river	Fort Pulaski	Ga	7 20	0 41	7.0	8.0	5.9	5 49	6 35	0 26
Savannah city	Dry-dock wharf	do	8 13	0 51	6.5	7.6	5.5	5 04	7 22	0 14
St. Augustine	Wharf	Fla	8 20	0 43	4.2	4.7	3.5	6 07	6 19	0 35
Cape Florida		do	8 31	0 51	1.5	1.7	1.2	6 00	6 25	0 44
Sand Key		do	8 40	[illegible]	1.2	2.0	0.6	6 31	5 55	0 13
Key West	Fort Taylor	do	9 22	[illegible]	1.4	2.3	0.7	6 59	5 25	0 12
Tampa Bay	Egmont Key	do	11 21	[illegible]	1.4	1.7	1.0			
Cedar Keys	Depot Key	do	13 15	1 55	2.5	2.8	1.8	6 12	6 13	
Western coast.										
San Diego	La Playa	Cal	9 50	1 45	3.7	5.0	2.3	6 22	6 00	0 30
San Pedro		do	9 45	1 48	3.9	4.7	2.2	6 18	6 05	0 30
San Luis Obispo		do	10 12	2 27	3.7	5.2	2.4	6 37	5 50	
Monterey	Custom house wharf	do	10 28	0 49	3.4	4.3	2.5	6 31	6 02	0 35
San Francisco	North beach	do	12 12	1 04	3.6	4.3	2.8	6 39	5 51	0 34
Astoria		Or. Ter	12 48	1 13	6.1	7.3	4.5	6 03	6 28	0 33

TABLE II,

Giving the mean interval between the time of moon's transit and the time of high water for every hour of moon's transit.

Time of moon's transit.	Boston, Mass.	New York, N. Y.	Philadelphia, Pa.	Old Point, Va.	Baltimore, Md.	Smithville, S. C.	Charleston, S. C.	Fort Pulaski, Savannah river, Ga.	Key West, Fla.	San Francisco, Cal.
h.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
0	11 38	8 20	1 31	8 33	6 47	7 26	7 38	7 30	9 26	12 11
1	11 28	8 15	1 25	8 21	6 37	7 16	7 28	7 19	9 12	11 59
2	11 20	8 06	1 18	8 09	6 26	7 09	7 16	7 11	9 00	11 47
3	11 13	7 55	1 11	8 00	6 17	7 04	7 07	7 06	8 51	11 39
4	11 07	7 52	1 06	7 52	6 11	7 02	7 00	7 04	8 49	11 44
5	11 06	7 53	1 00	7 48	6 10	7 04	6 58	7 04	8 57	12 01
6	11 13	7 59	0 59	7 53	6 19	7 09	7 01	7 08	9 17	12 17
7	11 25	8 11	1 07	8 07	6 32	7 17	7 10	7 16	9 39	12 29
8	11 38	8 23	1 23	8 24	6 44	7 28	7 28	7 28	9 52	12 40
9	11 47	8 32	1 34	8 40	6 52	7 37	7 42	7 39	9 56	12 42
10	11 49	8 35	1 42	8 48	6 53	7 40	7 48	7 43	9 51	12 36
11	11 47	8 31	1 41	8 46	6 50	7 36	7 46	7 37	9 39	12 23

TABLE III,

Giving the height of high and low water at the different hours of moon's transit.

Time of moon's transit.	BOSTON, MASSACHUSETTS.				NEW YORK.			
	Rise of high water from mean		Fluctuation of low water from mean		Rise of high water from mean		Fluctuation of low water from mean	
	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.
Hours.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	10.6	11.3	Sub...0.6	Add..0.1	4.5	4.9	Sub...0.4	Add....0.0
1	10.6	11.3	0.7	0.0	4.5	4.9	0.4	0.0
2	10.5	11.2	0.6	0.1	4.4	4.8	0.3	0.1
3	10.3	11.0	0.3	0.4	4.2	4.6	0.1	0.3
4	10.0	10.7	0.0	0.7	4.0	4.4	Add..0.1	0.5
5	9.7	10.4	Add..0.5	1.2	3.8	4.2	0.3	0.7
6	9.4	10.1	0.7	1.4	3.7	4.1	0.5	0.9
7	9.3	10.0	0.8	1.5	3.7	4.1	0.4	0.8
8	9.5	10.2	0.6	1.3	3.8	4.2	0.3	0.7
9	9.7	10.4	0.3	1.0	4.0	4.4	0.0	0.4
10	10.0	10.7	Sub...0.0	0.6	4.3	4.7	Sub...0.2	0.2
11	10.3	11.0	0.4	0.3	4.5	4.9	0.3	0.1

TABLE III—Continued.

Time of moon's transit.	PHILADELPHIA.				OLD POINT COMFORT, VIRGINIA.			
	Rise of high water from mean		Fluctuation of low water from mean		Rise of high water from mean		Fluctuation of low water from mean	
	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.
Hours.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	6.2	6.3	0.0	Add ..0.1	2.6	2.9	Sub...0.2	Add 0.0
1	6.4	6.5	0.0	0.0	2.7	3.0	0.2	0.0
2	6.5	6.6	Sub...0.1	0.0	2.7	2.9	0.2	0.1
3	6.5	6.6	0.1	0.0	2.6	2.8	0.0	0.3
4	6.4	6.5	0.0	0.0	2.4	2.7	Add ..0.1	0.4
5	6.2	6.3	0.0	0.1	2.3	2.6	0.2	0.5
6	5.9	6.0	Add ..0.1	0.2	2.2	2.5	0.3	0.5
7	5.6	5.7	0.2	0.3	2.3	2.5	0.3	0.5
8	5.3	5.4	0.1	0.1	2.4	2.6	0.1	0.4
9	5.4	5.5	0.0	0.1	2.5	2.8	Sub...0.0	0.2
10	5.7	5.8	Sub...0.1	0.0	2.7	2.9	0.1	0.1
11	6.0	6.1	0.1	0.0	2.8	3.0	0.2	0.0

TABLE III—Continued.

Time of moon's transit.	BALTIMORE, MARYLAND.				SMITHVILLE, NORTH CAROLINA.			
	Rise of high water from mean		Fluctuation of low water from mean		Rise of high water from mean		Fluctuation of low water from mean	
	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.
Hours.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	1.4	1.6	Sub...0.1	Add ..0.1	4.8	5.1	Sub...0.4	Add 0.0
1	1.4	1.6	0.1	0.1	4.8	5.0	0.3	0.0
2	1.3	1.5	0.2	0.0	4.7	5.0	0.2	0.1
3	1.3	1.5	0.2	0.0	4.5	4.8	0.1	0.3
4	1.2	1.4	0.1	0.0	4.4	4.7	Add ..0.1	0.5
5	1.1	1.3	0.0	0.2	4.3	4.6	0.3	0.6
6	1.1	1.3	Add ..0.2	0.3	4.2	4.5	0.3	0.7
7	1.1	1.3	0.2	0.4	4.1	4.4	0.3	0.7
8	1.2	1.4	0.2	0.4	4.2	4.5	0.2	0.6
9	1.3	1.5	0.1	0.3	4.3	4.6	0.1	0.4
10	1.4	1.6	0.0	0.2	4.6	4.9	Sub...0.1	0.2
11	1.4	1.6	0.0	0.2	4.7	5.0	0.2	0.1

TABLE III—Continued.

Time of moon's transit.	CHARLESTON, SOUTH CAROLINA.				FORT PULASKI, SAVANNAH RIVER, GEORGIA.			
	Rise of high water from mean		Fluctuation of low water from mean		Rise of high water from mean		Fluctuation of low water from mean	
	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.
Hours.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	5.4	5.7	Sub...0.3	Add ..0.0	7.4	7.8	Sub...0.4	Add 0.0
1	5.4	5.7	0.3	0.0	7.4	7.9	0.5	0.0
2	5.4	5.7	0.2	0.1	7.3	7.7	0.3	0.1
3	5.3	5.6	0.1	0.2	7.0	7.5	0.1	0.4
4	5.2	5.5	0.0	0.3	6.7	7.2	Add ..0.2	0.7
5	5.1	5.4	Add ..0.1	0.4	6.5	7.0	0.4	0.9
6	5.0	5.3	0.2	0.5	6.4	6.8	0.6	1.0
7	4.9	5.2	0.2	0.5	6.5	6.9	0.5	0.9
8	5.0	5.3	0.2	0.5	6.7	7.1	0.3	0.7
9	5.1	5.4	0.2	0.4	6.9	7.4	0.0	0.5
10	5.3	5.6	0.1	0.0	7.0	7.6	Sub...0.2	0.2
11	5.4	5.3	0.0	0.2	7.2	7.8	0.4	0.0

TABLE III—Continued.

Time of moon's transit.	KEY WEST, FLORIDA.				SAN FRANCISCO, CALIFORNIA.			
	Rise of high water from mean		Fluctuation of low water from mean		Rise of high water from mean		Fluctuation of low water from mean	
	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.	Low water.	Low water spring tides.
Hours.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	1.4	1.6	Sub...0.1	Add ..0.0	4.0	4.4	Sub...0.5	Add 0.0
1	1.4	1.6	0.1	0.0	3.7	4.1	0.2	0.3
2	1.4	1.5	0.1	0.0	3.6	4.1	0.1	0.4
3	1.3	1.5	0.0	0.1	3.5	4.0	Add ..0.0	0.5
4	1.2	1.4	Add ..0.1	0.2	3.3	3.8	0.2	0.7
5	1.1	1.3	0.1	0.3	3.1	3.6	0.4	0.9
6	1.1	1.3	0.2	0.3	3.1	3.6	0.4	0.9
7	1.1	1.3	0.2	0.3	3.3	3.7	0.3	0.7
8	1.2	1.3	0.1	0.2	3.5	3.9	0.1	0.5
9	1.3	1.4	0.0	0.2	3.6	4.1	Sub...0.1	0.3
10	1.3	1.5	Sub...0.1	0.1	3.8	4.2	0.1	0.2
11	1.4	1.6	0.1	0.0	3.8	4.3	0.3	0.1

TABLE IV,

Giving the rise and fall of tide at several stations in the Gulf of Mexico.

Stations.	Mean rise and fall of tide.				
	Mean.	At moon's greatest decl'n.	At moon's least decl'n.	At sun's equinox.	At sun's solstice.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
St. George's island, Fla	1.1	1.8	0.6		
Pensacola, Fla	1.0	1.5	0.4		
Fort Morgan, Mobile bay, Ala	1.0	1.5	0.4	0.8	1.5
Cat island, Miss	1.3	1.9	0.6	1.2	1.6
Southwest Pass, La	1.1	1.4	0.5		
Dernière island, La	1.4	2.2	0.7		
Calcasieu, La.*	1.5				
Galveston, Texas	1.1	1.6	0.8	0.8	1.2
Aransas, Texas	1.1	1.8	0.6		
Brazos Santiago, Texas	0.9	1.2	0.5		

* At Calcasieu, La., the tide flows and ebbs twice a day, and the greater and lesser rise and fall occur at the ordinary epochs of spring and neap tides—the former amounting to 1.9 ft., the latter to 1.1 ft.

TABLE V,

Giving the interval between the time of moon's transit and the time of high water at Key West, for every hour of moon's transit, and every day reckoning from moon's greatest declination.

Moon's transit.	Upper transit and north declination. Lower transit and south declination.								Moon's transit.	Upper transit and south declination. Lower transit and north declination.							
	0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d		0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d
H.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*H.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
0	10 12	10 9	10 3	9 56	9 47	9 38	9 32	9 26	0	8 40	8 43	8 49	8 56	9 5	9 14	9 20	9 26
1	9 58	9 55	9 49	9 42	9 33	9 24	9 18	9 12	1	8 26	8 29	8 35	8 42	8 51	9 0	9 6	9 12
2	9 46	9 43	9 37	9 30	9 21	9 12	9 6	9 0	2	8 14	8 17	8 23	8 30	8 39	8 48	8 54	9 0
3	9 37	9 34	9 28	9 21	9 12	9 3	8 57	8 51	3	8 5	8 8	8 14	8 21	8 30	8 39	8 45	8 51
4	9 35	9 32	9 26	9 19	9 10	9 1	8 55	8 49	4	8 3	8 6	8 12	8 19	8 28	8 37	8 43	8 49
5	9 43	9 40	9 34	9 27	9 18	9 9	9 3	8 57	5	8 11	8 14	8 20	8 27	8 36	8 45	8 51	8 57
6	10 3	10 0	9 54	9 47	9 38	9 29	9 23	9 17	6	8 31	8 34	8 40	8 47	8 56	9 5	9 11	9 17
7	10 25	10 22	10 16	10 9	10 0	9 51	9 45	9 39	7	8 53	8 56	9 2	9 9	9 18	9 27	9 33	9 39
8	10 38	10 35	10 29	10 22	10 13	10 4	9 58	9 52	8	9 6	9 9	9 15	9 22	9 31	9 40	9 46	9 52
9	10 42	10 39	10 33	10 26	10 17	10 8	10 2	9 56	9	9 10	9 13	9 19	9 26	9 35	9 44	9 50	9 56
10	10 37	10 34	10 28	10 21	10 12	10 3	9 57	9 51	10	9 5	9 8	9 14	9 21	9 30	9 39	9 45	9 51
11	10 25	10 22	10 16	10 9	10 0	9 51	9 45	9 39	11	8 53	8 56	9 2	9 9	9 18	9 27	9 33	9 39

TABLE VI,

Giving the height of high water above low water spring tides at Key West, Florida, for every hour of moon's transit, and for every day, reckoned from moon's greatest declination.

Moon's transit.	Upper transit and north declination. Lower transit and south declination.								Moon's transit.	Upper transit and south declination. Lower transit and north declination.							
	0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d		0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d
H.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*H.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	0	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.6
1	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5
2	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	2	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5
3	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	3	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5
4	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	4	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.4
5	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	5	1.7	1.7	1.6	1.6	1.5	1.5	1.4	1.3
6	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.2	6	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.2
7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.2	7	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.2
8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	8	1.7	1.7	1.6	1.6	1.5	1.5	1.4	1.3
9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	9	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.4
10	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	10	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5
11	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	11	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5

TABLE VII,

Giving the interval between the time of moon's transit and the time of high water at San Francisco for every hour of moon's transit, and for every day, reckoned from moon's greatest declination.

Moon's transit.	Upper transit and north declination. Lower transit and south declination.								Moon's transit.	Upper transit and south declination. Lower transit and north declination.							
	0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ		0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ
H.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*H.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
0	11 11	11 14	11 19	11 26	11 34	11 44	11 57	12 11	0	13 11	13 8	13 3	12 56	12 48	12 38	12 25	12 11
1	10 59	11 2	11 7	11 14	11 22	11 32	11 45	11 59	1	12 59	12 56	12 51	12 44	12 36	12 26	12 13	11 59
2	10 47	10 50	10 55	11 2	11 10	11 20	11 33	11 47	2	12 47	12 44	12 39	12 32	12 24	12 14	12 1	11 47
3	10 39	10 42	10 47	10 54	11 2	11 12	11 25	11 39	3	12 39	12 36	12 31	12 24	12 16	12 6	11 53	11 39
4	10 44	10 47	10 52	10 59	11 7	11 17	11 30	11 44	4	12 44	12 41	12 36	12 29	12 21	12 11	11 58	11 44
5	11 1	11 4	11 9	11 16	11 24	11 34	11 47	12 1	5	13 1	12 58	12 53	12 46	12 38	12 28	12 15	12 1
6	11 17	11 20	11 25	11 32	11 40	11 50	12 3	12 17	6	13 17	13 14	13 9	13 2	12 54	12 44	12 31	12 17
7	11 29	11 32	11 37	11 44	11 52	12 2	12 15	12 29	7	13 29	13 26	13 21	13 14	13 6	12 56	12 43	12 29
8	11 40	11 43	11 48	11 55	12 3	12 13	12 26	12 40	8	13 40	13 37	13 32	13 25	13 17	13 7	12 54	12 40
9	11 42	11 45	11 50	11 57	12 5	12 15	12 28	12 42	9	13 42	13 39	13 34	13 27	13 19	13 9	12 56	12 42
10	11 36	11 39	11 44	11 51	11 59	12 9	12 22	12 36	10	13 36	13 33	13 28	13 21	13 13	13 3	12 50	12 36
11	11 23	11 26	11 31	11 38	11 46	11 56	12 9	12 23	11	13 23	13 20	13 15	13 8	13 0	12 50	12 37	12 23

TABLE VIII,

Giving the heights for high water above the lowest low water of the day at spring tides at San Francisco, for every hour of moon's transit, and for every day, reckoned from moon's greatest declination.

Moon's transit.	Upper transit and north declination. Lower transit and south declination.								Moon's transit.	Upper transit and south declination. Lower transit and north declination.							
	0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ		0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ
H.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*H.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	7.2	7.1	7.1	7.0	6 9	6.7	6.4	6.2	0	5.2	5.3	5.3	5.4	5.5	5.7	6.0	6.2
1	7.1	7.0	7.0	6.9	6.8	6.6	6.3	6.1	1	5.1	5.2	5.2	5.3	5.4	5.6	5.9	6.1
2	7.0	6.9	6.9	6.8	6.7	6 5	6.2	6.0	2	5.0	5.1	5.1	5.2	5.3	5.5	5.8	6.0
3	6.8	6.7	6.7	6.6	6.5	6.3	6.0	5.8	3	4.8	4.9	4.9	5.0	5.1	5.3	5.6	5.8
4	6.6	6.5	6.5	6.4	6.3	6.1	5.8	5.6	4	4.6	4.7	4.7	4.8	4.9	5.1	5.4	5.6
5	6.5	6.4	6.4	6.3	6.2	6.0	5.7	5.5	5	4.5	4.6	4.6	4.7	4.8	5.0	5.3	5.5
6	6.5	6.4	6.4	6.3	6.2	6.0	5.7	5.5	6	4.5	4 6	4.6	4.7	4.8	5.0	5.3	5.5
7	6.6	6.5	6.5	6.4	6.3	6.1	5.8	5.6	7	4.6	4.7	4.7	4.8	4.9	5.1	5.4	5.6
8	6.7	6.6	6.6	6.5	6.4	6.2	5.9	5.7	8	4.7	4.8	4.8	4.9	5.0	5.2	5.5	5.7
9	6.9	6.8	6.8	6.7	6.6	6.4	6.1	5.9	9	4.9	5.0	5.0	5.1	5.2	5.4	5.7	5.9
10	7.1	7.0	7.0	6.9	6 8	6.6	6.3	6.1	10	5.1	5.2	5.2	5.3	5.4	5 6	5.9	6.1
11	7.3	7.2	7.2	7.1	7.0	6.8	6.5	6.3	11	5.3	5.4	5.4	5.5	5.6	5.8	6.1	6.3

TABLE IX,

Giving the interval between the time of moon's transit and the time of low water at San Francisco, California, for every hour of moon's transit, and for every day, reckoning from moon's greatest declination.

Moon's transit.	Upper transit and north declination. Lower transit and south declination.								Moon's transit.	Upper transit and south declination. Lower transit and north declination.							
	0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ		0ᵈ	1ᵈ	2ᵈ	3ᵈ	4ᵈ	5ᵈ	6ᵈ	7ᵈ
h.	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*	*h. m.*
0	18 36	18 35	18 33	18 30	18 26	18 18	18 10	17 58	0	17 20	17 21	17 23	17 26	17 30	17 38	17 46	17 58
1	18 26	18 25	18 23	18 20	18 16	18 8	18 0	17 48	1	17 10	17 11	17 13	17 16	17 20	17 28	17 36	17 48
2	18 13	18 12	18 10	18 7	18 3	17 55	17 47	17 35	2	16 57	16 58	17 0	17 3	17 7	17 15	17 23	17 35
3	18 8	18 7	18 5	18 2	17 58	17 50	17 42	17 30	3	16 52	16 53	16 55	16 58	17 2	17 10	17 18	17 30
4	18 15	18 14	18 12	18 9	18 5	17 57	17 49	17 37	4	16 59	17 0	17 2	17 5	17 9	17 17	17 25	17 37
5	18 29	18 28	18 26	18 23	18 19	18 11	18 3	17 51	5	17 13	17 14	17 16	17 19	17 23	17 31	17 39	17 51
6	18 48	18 47	18 45	18 42	18 38	18 30	18 22	18 10	6	17 32	17 33	17 35	17 38	17 42	17 50	17 58	18 10
7	19 1	19 0	18 58	18 55	18 51	18 43	18 35	18 23	7	17 45	17 46	17 48	17 51	17 55	18 3	18 11	18 23
8	19 8	19 7	19 5	19 2	18 58	18 50	18 42	18 30	8	17 52	17 53	17 55	17 58	18 2	18 10	18 18	18 30
9	19 7	19 6	19 4	19 1	18 57	18 49	18 41	18 29	9	17 51	17 52	17 54	17 57	18 1	18 9	18 17	18 29
10	18 59	18 58	18 56	18 53	18 49	18 41	18 33	18 21	10	17 43	17 44	17 46	17 49	17 53	18 1	18 9	18 21
11	18 48	18 47	18 45	18 42	18 38	18 30	18 22	18 10	11	17 32	17 33	17 35	17 38	17 42	17 50	17 58	18 10

TABLE X,

Giving the heights of low water above the lowest low water of day at spring tides at San Francisco, for every hour of moon's transit, and for every day, reckoned from moon's greatest declination.

Moon's transit.	Upper transit and south declination. Lower transit and north declination.								Moon's transit.	Upper transit and north declination. Lower transit and south declination.							
	0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d		0^d	1^d	2^d	3^d	4^d	5^d	6^d	7^d
H.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*H.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	3.8	3.7	3.6	3.3	3.0	2.7	2.3	1.9	0	0.0	0.1	0.2	0.5	0.8	1.1	1.5	1.9
1	3.9	3.8	3.7	3.4	3.1	2.8	2.4	2.0	1	0.1	0.2	0.3	0.6	0.9	1.2	1.6	2.0
2	4.0	3.9	3.8	3.5	3.2	2.9	2.5	2.1	2	0.2	0.3	0.4	0.7	1.0	1.3	1.7	2.1
3	4.1	4.0	3.9	3.6	3.3	3.0	2.6	2.2	3	0.3	0.4	0.5	0.8	1.1	1.4	1.8	2.2
4	4.4	4.3	4.2	3.9	3.6	3.3	2.9	2.5	4	0.6	0.7	0.8	1.1	1.4	1.7	2.1	2.5
5	4.5	4.4	4.3	4.0	3.7	3.4	3.0	2.6	5	0.7	0.8	0.9	1.2	1.5	1.8	2.2	2.6
6	4.6	4.5	4.4	4.1	3.8	3.5	3.1	2.7	6	0.8	0.9	1.0	1.3	1.6	1.9	2.3	2.7
7	4.4	4.3	4.2	3.9	3.6	3.3	2.9	2.5	7	0.6	0.7	0.8	1.1	1.4	1.7	2.1	2.5
8	4.2	4.1	4.0	3.7	3.4	3.1	2.7	2.3	8	0.4	0.5	0.6	0.9	1.2	1.5	1.9	2.3
9	4.0	3.9	3.8	3.5	3.2	2.9	2.5	2.1	9	0.2	0.3	0.4	0.7	1 0	1.3	1.7	2.1
10	3.9	3.8	3.7	3.4	3.1	2.8	2.4	2.0	10	0.1	0.2	0.3	0.6	0.9	1.2	1.6	2.0
11	3.8	3.7	3.6	3.3	3.0	2.7	2.3	1.9	11	0.0	0.1	0.2	0.5	0.8	1.1	1.5	1.9

TABLE XI,

Giving the height of the tide for every half hour before or after high water, the total range being equal to 1

Hours before or after high water.	New York.		Old Point Comfort.	
	Spring tides.	Neap tides.	Spring tides.	Neap tides.
h. m.				
0 00	1.00	1.00	1.00	1.00
0 30	0.98	0.98	0.98	0.98
1 00	0.94	0.93	0.95	0.94
1 30	0.89	0.86	0.88	0.87
2 00	0.80	0.72	0.80	0.78
2 30	0.72	0.59	0.70	0.68
3 00	0.60	0.45	0.59	0.57
3 30	0.49	0.31	0.49	0.44
4 00	0.39	0.19	0.37	0.34
4 30	0.28	0.10	0.26	0.22
5 00	0.18	0.02	0.17	0.13
5 30	0.09	0.00	0.08	0.05
6 00	0.05	....	0.03	0.01
6 30	0.00	....	0.00	0.00

TABLE XII.

Description of Bench-marks.

Stations.	Description.	Height above mean low water.
		Feet.
Portsmouth, N. H........	(Fort Constitution.) The bench-mark is a cross in head of copper bolt, driven into the solid rock, nearly in a line between outer end of wharf and north side of sallyport, near northwest corner of fort..........................	14.60
Boston..................	(Charlestown dry dock.) Top of stone wall corresponding to division 30 feet of tide-gauge, which is designated by copper figures set in the stone.....	14.76
New York...............	(Fort Columbus, Governor's island.) The bench-mark is the lower edge of a straight line cut in a stone wall at the head of the wooden wharf on Governor's island. The letters U. S. C. S. are cut in the same stone............	14.51
Old Point Comfort, Va...	(Fort Monroe.) The bench-mark is a line cut in the wall of the light-house, southwest side, one foot from the ground..............................	11.00

TABLE XII.—Continued.

Stations.	Description.	Height above mean low water.
		Feet.
Smithville, N. C.	(Barracks wharf, Fort Johnson.) The bench-mark is the top of a granite post sunk in the ground at foot of first ramp	9.17
Charleston, S. C.	(Castle Pinckney.) The bench-mark is the outer and lower edge of embrasure of gun No. 3	10.13
Savannah river	(Fort Pulaski, Cockspur island.) The bench-mark is the coping of the north-east wharf, and is designated by five copper nails driven into it	9.24
Savannah city	(Dry dock wharf) The coping of the wharf serves as a bench-mark, and is designated by five copper nails	8.66
Key West	(Fort Taylor.) The top of the north end of the cistern wall	9.56
Southwest Pass, La.	(East Bayou, Pilot village.) The tide-gauge was in front of the house of the late Henry Fox. The bench-mark is a cedar post six feet long, encased in a copper tube marked "*U. S. Coast Survey, 1853.*" It is set into the ground five feet from the northwest corner of the house, and reaches two feet above the ground. The top (not the rim of the copper tube) is the point of reference	2.11
	There is also a circle of copper nails, with one in the centre, on the north-west corner of the house, and a similar one on the left-hand upright at the entrance of the gallery. The centre nails of those two circles are on the same level, and their height above mean low water is	6.57
Dernière Isle, La.	The tide-gauge was placed in the mouth of a small bay on the north side of the island, one-fourth of a mile from the west end, called Racoon Point. Two cedar posts are set in the ground, on an east and west line, ten feet apart, and are marked with copper nails six inches below the top. These nails are above mean low water	2.47
Galveston, Texas	The lower edge of a copper plate one and a half inches square, nailed to a corner post of a warehouse adjoining Doswell's wharf	1.24
Brazos Santiago, Texas	The tide-gauge was placed at the end of the small wharf belonging to the United States Quartermaster's Department, in the harbor of Brazos Santiago. Two palmetto posts are set in the ground, respectively, 130 and 136 feet distant from the tide-gauge, in a southeast direction. Each of them has a four-inch iron spike, surrounded by copper nails, driven into it on the west-southwest side, which is the point of reference	4.50

APPENDIX No. 52.

Letter from Mr. Douglass Dummett, transmitting the card of a current bottle put over by Lieut. Comg. B. F. Sands, U. S. Surveying Steamer "Walker," south of Mobile Bay, and found near Mosquito inlet, eastern coast of Florida. Also, card put over by Lieut. Comg. T. A. Craven, U. S. Surveying Steamer "Corwin," fourteen miles from Cape Florida light, and found by Mr. John Adams near Jupiter inlet.

NEW SMYRNA, FLA., *June* 10, 1854.

MY DEAR SIR: At the request of Lieut. Sands, I enclose you a card which I found in a bottle about five miles south of Mosquito inlet, on the 6th ultimo. Having passed the same place on the 2d, and not seeing any bottle, I presume it must have come on shore between those dates.

With much respect, I am your obedient servant,

DOUGLASS DUMMETT.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

U. S. COAST SURVEY.—A. D. BACHE, Superintendent.

U. S. STEAMER "WALKER."

April 8, 1854.

Latitude..28° 57′ N.
Longitude..88 15 W.

The finder of this bottle will please enclose this paper to Professor A. D. Bache, Superintendent U. S. Coast Survey, Washington city, D. C., informing him of the place where and time when found.

B. F. SANDS,
Lieut. Commanding.

U. S. COAST SURVEY STEAMER "CORWIN."

POSITION No. 1.

June the 8th, 1854.—Cape Florida light bearing, per compass, WSW., distant 14 miles.

Air temperature, 79°.5; surface water, 81°.0; temperature 500 fathoms, 49°.0.

The finder of this will confer a favor by forwarding to

Prof. A. D. BACHE,
U. S. Coast Survey,
Washington, D. C.

"Taken up by John Adams on the Florida coast, near Jupiter inlet, the 14th Nov., 1853."

APPENDIX No. 53.

Description of a tide-gauge used at stations on the open seacoast, and in situations exposed to strong currents: By Henry Mitchell, Sub-Assistant U. S. Coast Survey. (See Sketch K.)

a a, is a tube of iron, or heavy copper, of from three to five inches bore, passing through the ring of an anchor at *b*, and screwed into the sand by an attached auger, *c*.

d, a screw band, to which is attached the apex of a tripod of iron rods, secured at the base to the anchors *e, f, g*.

h, the top of the pipe, and the reading point of the gauge.

i, a rod attached to the float, rising and falling within the pipe.

j k, a sheet of iron or copper bent nearly round the gauge, fastened by screw-bands at *u*, and serving to protect the float-rod from wind and sea.

Instead of screwing the pipe into the bottom by the auger, it would be equally secure to connect it to the ring of an anchor by a joint. The joint, in this case, must turn at right-angles to the shank of the anchor, in order that the gauge may be plumbed after being set up. Two holes, one-eighth of an inch each, are sufficient to let in the water; but others should be made, and covered by bands of canvass, to serve in case the first should be stopped.

To set up gauge.—The operation of setting up a gauge, of the form described, requires a surf-boat and four men, in moderate weather. The four anchors, with buoys attached to crowns, should first be carried off just beyond the breakers, and dropped in one to two fathoms water, in the vicinity of the spot fixed upon for the gauge. The gauge should then be taken off, one of the anchors raised astern of the boat, the pipe passed through the ring, and the anchor let down to the bottom of the sea. The pipe is then screwed into the sand by a hand-spike passed through a twist of rope; or, if fast to the anchor-ring by a joint, the pipe should be supported by a buoy. Each of the three other anchors is then raised in turn and the iron rods made fast to the rings, after which the anchors are lowered to their final positions. Each rod is then fastened by a chain to the screw-band at high-water line, and the gauge plumbed. The float and rod are of the form generally used in box-gauges.

During these operations, the surf-boat should be kept steady by an anchor, and a line to the shore; but in a heavy swell, or strong current, the whole should be done as quickly as possible, as it is very difficult to avoid drifting, and sometimes the apparatus becomes loaded with sea-weed, and difficult to manage.

Observing.—The observer stands upon the beach and reads the graduation on the rod by the aid of a spy-glass. At night, the rod is illuminated by a lantern of the usual form, furnished with a tin reflector, drawn off by lines passing through a pulley at the gauge. A tight wire, fastened at one end to the gauge, and at the other to an elevated point on shore, is necessary for the lantern to slide upon.

APPENDIX No. 54.

Letter from Lieutenant Commanding T. A. Craven, U. S. N., assistant in the Coast Survey, to the Superintendent, in relation to a specimen-box for bringing up the bottom in deep-sea soundings, with a description and drawings.

U. S. SURVEYING STEAMER "CORWIN,"
Penobscot Bay, October 16, 1854.

DEAR SIR: As requested, I send you drawings of the sounding specimen-box, invented by me, for bringing up the bottom from great depths. I have used it with great success in sounding from the vessel, while not in motion, at depths varying from fifty fathoms to four hundred fathoms.

As the lead descends, the upward pressure of the water against the projecting lip of the valve forces it up to the stops; when it strikes bottom, the valve, of its own weight, will fall to its seat, and in hauling it up, the pressure is so great that nothing can escape.

I do not think the instrument entirely suitable for sounding in shoal water from a vessel going at moderate speed; and, although it will bring up bottom while running lines, it cannot constantly be depended upon, and I do not recommend it for that purpose, but for sounding at depths of twenty-five fathoms, and below, it is the only instrument I have found to be of service.

It will be observed that no current of water can flow into or through this box; and the greater the speed of hauling up, the more effectually is the valve closed.

Very respectfully, your obedient servant,

T. AUGS. CRAVEN,
Lieutenant U. S. N., Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

EXPLANATION OF FIGURES.

Figure No. 1, *Front elevation.*—A A A, the frame in which the box is secured.
C, the valve, which closes with an air-tight joint, covering the top of the box.
D, the shaft, which is inserted into the lead its entire length, and secured by a key through the eye, *e.*
d d, are two stops let into the sides of the frame to prevent the valve from rising too far.

The frame is of wrought iron, the box of brass.

Figure No. 2, *Side elevation.*—A A, the frame; B, the box.
C, valve, raised as far as the stops permit.
D, lugs, in which the valve hinges.
a a, screws which secure the box in the frame.
f, a groove in bottom of frame for an arming of tallow.
E, the shaft.

Figure No. 3, *Section through S*—Exhibits the capacity and thickness of the box, with valve closed; the valve has a lip projecting an eighth of an inch, so that the pressure of water, in descent, may take hold of and force it up to the stops.

The general form of the box is that of a mortising chisel; and with a fifty-pound lead attached, it easily penetrates the bottom.

APPENDIX No. 55.

Letter of Assistant J. E. Hilgard, on the action of sea-water upon metals used in the construction of instruments, and on magnetic needles.

Dear Sir: The recent disaster of the United States schooner Phoenix, gave occasion to some observations on the action of sea-water upon the metals used in the construction of instruments, which convey some useful indications and deserve to be placed on record.

A number of valuable instruments were on board when the vessel sunk, and remained submerged in about five fathoms of water for three weeks, when the vessel was raised.

On examining the instruments I found them much less damaged than I had anticipated. The hold of the vessel was filled with black mud and sand, and a very offensive smell prevailed, indicating the presence of sulphuretted hydrogen, which is confirmed by the fact, well known to mariners, that black mud cleans the chain cables; that is to say, it causes the rust to scale off—a marked effect of certain sulphurets.

The silver parts of the instruments were blackened, but the black film could be polished off without sensible injury to the graduation.

Brass parts that had been previously tarnished presented a bronzed appearance, while bright brass only became slightly reddish, some of the zinc being probably decomposed.

Steel, wherever exposed, was very much rusted; many of the smaller parts were entirely rusted away. The axes, however, and the close fitting parts, were well preserved.

German silver, an alloy of copper and nickel, was not tarnished in the least degree, nor did it become so when afterwards exposed to the air without being cleaned with fresh water. It is much to be recommended for clamp and tangent screws, springs, and other working parts of instruments which require hardness and elasticity, and are frequently exposed to the action of the salt spray when used on the beach.

The shellac varnish used as coating for the instruments proved to be a great protection.

A marked contrast was exhibited by the condition of some magnetic needles, part of which were kept in small zinc cases, while others were in a wooden case. The latter were very nearly destroyed by rust, while the former, owing to the galvanic action produced between the zinc and steel by the pressure of the sea-water, were preserved perfectly bright, a thin, white coating of zinc being deposited on them, which was readily rubbed off.

A singular circumstance was noticed in the case of the two magnetic dipping-needles packed in wood, which, however trivial it may appear, nevertheless indicates some action which remains to be explained. These needles were of the ordinary form, and were packed side by side, the axles of both being nearly in a right line. The adjoining pivots were distant about ⅛ inch, and were, in a great measure, preserved from rust, while the exterior pivots were entirely gone.

APPENDIX No. 56.

Letter from George Mathiot, Esq., containing a detailed description of his self-sustaining voltaic battery.

WASHINGTON, *November* 12, 1854.

DEAR SIR: Captain Benham has communicated your request that I would prepare a description of my self-sustaining voltaic battery, with your favorable opinion of its usefulness, and reference to the judgment of Dr. Gould of a similar tenor.

Many inquiries have been made in regard to the principles of construction of the battery, with commendation of its working properties, and I have even received large commercial orders for its construction, which, of course, I could not execute, so that, up to this time, a few sets only have been made for use in government works. I now give a thorough description of the battery, and of the principles on which its action depends, hoping that thereby the recent important applications of voltaic currents may be facilitated through my labors.

The first forms of the voltaic battery were so expensive and cumbrous, and withal so uncertain and fleeting in action, that the idea of applying galvanic currents to the great business affairs of life would certainly have gained nothing more than a smile from even the most sanguine philosopher. But, from the continued researches of electro-chemists, the world has now the benefit of electro-metallurgy and the electric telegraph.

The batteries now employed are uncertain to a considerable degree, and require constant attention. Any consideration, therefore, tending to the improvement of the instrument, so as to avoid the necessity for frequent attention, cannot but be appreciated at this time, when the world is asking science for a telegraph across the Atlantic, and we are looking for a line from the Pacific to the Mississippi, on which there must needs be many stations or relays of batteries, that from the uninhabited state of the country cannot be constantly attended or even frequently visited.

The construction which I have devised will, I think, obviate many of the difficulties attending telegraphing, and the principles of electro-chemistry, and even experience, justify me in saying that batteries may be constructed to be buried in the earth or sunken in the sea, which will certainly and uniformly continue in action for very long periods, even for a hundred years.

In this battery there is no new element, neither is the form such as to attract the attention in respect to anything in it materially different from the batteries now in use. It is only in all the parts being constructed with rigid adherence to the principles of electro-chemistry that its peculiarity consists, and therefore a consideration of the principles is necessary to its appreciation.

A charged voltaic battery may be considered as a factory of electrical power, just as a charged and ignited furnace is a factory of heat, and similarly in both cases the rapidity with which the fuel is consumed, and the steadiness of action, will depend on the arrangement of the parts. A furnace in action consumes the fuel; whether the generated caloric be applied to use or suffered to run waste, the chemical affinity will sooner or later consume the fuel; and though the action may be diminished to some extent by cutting off some of the conditions of combustion, the extent of that action will depend on the construction of the furnace. If a furnace could be made so that we might draw off the requisite amount of caloric to boil a pound of water just as it might be required, and retain the residue until we again had occasion to use fire, then such a furnace would be a storehouse of caloric, just as a granary is a storehouse of grain from which we draw a supply, and keep the residue in store.

The same remark will apply to the battery; once changed, the chemical affinity consumes the material sooner or later, usefully or not, and we can entirely arrest action only by unloading. Much indeed can be done by modifying the conditions of action, but, as in the furnace, all will depend on the construction.

To make a battery which can keep the action in reserve, is the problem of a depot of electricity.

The uncontrollable nature of the voltaic conditions, I conceive, was the cause why batteries have not hitherto been constructed with reference to the *whole amount* of force, as well as to the *strength* or rate of working.

Previous to my own efforts I know of no attempts at putting a quantity of galvanic material in store ready for action just when required.

A cell of the reservoir battery is in form a four-sided prism of stone-ware, eight inches long, three inches wide, and ten inches deep.

On the side, at the depth of three inches, is formed a trough or tray, an inch wide and half an inch deep, running the length of the side. This tray is made with the jars.

It is indispensable that the jars should be completely water-tight, but they are difficult to obtain; and thus far I have had none which have given full satisfaction. The best were of chemical stone-ware, but only half of them were water-proof. A coat of glazing cannot be depended upon for sealing, as in vessels for culinary and table purposes, as sulphate of zinc penetrates even the beautiful stone-ware called "granite."

When unable to obtain good rectangular jars, I have used cylindrical glass jars, and formed the tray with cement on a plate of glass or gutta-percha, a little less in width than the inner diameter of the vessel. The plate can be kept from moving by projecting jogs, which catch on the edge of the vessel. The plate, tray, and jogs can easily be moulded in one piece in glass.

The conducting plate of the battery is of the platinized silver introduced by Mr. SMEE; but the mode of preparing it is different. I first puncture it closely with a square-pointed awl. The holes should not be cut with a punch, which removes the metal, but formed by pushing the metal up in bars, like those on the common tin grater. In this way none of the surface is lost, and both sides of the silver are rendered efficient to a single surface of zinc. After the plate has been punctured, it should be well cleaned, and then electroplated until the deposite begins to roughen; this very much improves the stability of the plate, and greatly augments the extent of surface. The cyanides should then be well washed away with hot water, and the plate be platinized. I find that the platinizing is very durable, if the arrangements for depositing the platinum are made so that the bright metallic platinum shall first be deposited, and the amorphous form (black deposites) gradually succeed it. The reguline deposite of platinum can readily be obtained by using a mixture of chloride of platinum and chloride of sodium, (instead of the acid solution of chloride of platinum recommended for obtaining the black powder,) with a train of small batteries and a platinum electrode.

The conducting plate is attached to a square bar of lead nine inches long, and five-eighths of an inch across the sides. The bar rests on the top of the jar, and is kept from moving horizontally by studs near the ends. At the distance of an inch and a half from each end of the bar is a pendant an inch long, and of nearly the same section as the bar. The plate is attached to the bar by sawing a slit a third of an inch deep in each pendant, in the direction of the length of the bar, inserting the silver in the slit, and thoroughly closing down the lead on the plate. This is conveniently done by biting the pendant in the jaws of a common bench-vice. In the side of the bar, near the middle, is screwed a thick copper wire, which projects out horizontally two inches and a quarter, and then drops three inches and an eighth. Into the end of this wire is tapped a piece of platinum wire, which is left projecting about an eighth of an inch. Every part of the copper-wire should be thoroughly coated with cement or encased with a glass tube, or the vertical part may be encased with glass and the horizontal with cement; but when glass is used, it should be cemented on so as to exclude entirely the liquid of the battery, thus preventing its contact with the copper. If cement alone is used, the wire should first be wrapped, otherwise the cement is liable to become detached, as it does not hold so well to the copper as it does to the wrapping.

The zinc plates of the battery should be ¼th of an inch thick, and of the length of the inside of the jar or tray. The zinc should be well amalgamated, and then placed in the jar with the edge resting in the tray, and the tray filled with mercury. The plate is secured in place by its length and by the encased wire from the adjacent cell, which hinder it from falling forward.

But the terminal zinc must be secured by a wire similarly encased and tipped with platinum to dip into its mercury tray, and then bent down against the outside of the jar to a glass or iron cup containing mercury, for continuing the circuit.

The wire from the terminal silver should dip into a similar cup. If, then, the conductor which continues the circuit be encased and tipped with platinum, the current may be led off from any portion of the train by inserting the conductor into the mercury tray.

The jars are charged with a mixture of one part of sulphuric acid, and six parts of water These proportions are calculated for dissolving all the zinc and all the sulphate formed, and leaving a slight excess of acid and water.

When the mixture of acid and water is made, it should be allowed to get cold before it is put into the jars, if the silvers are to be put in, as a hot solution of sulphuric acid would act on the silver, and dissolve a portion, which, though very small, would ruin both the silver and the zinc plates, as will presently be made to appear.

Lastly, the silver plates should never be put into the acid when the zincs are not in, as in that case the silver, not being enfilmed by hydrogen, would be in danger from the acid.

To hinder evaporation from the jars, the battery is placed in a box made with a double rim on the lid so as to form a deep trough or recess, into which the walls of the box go when the lid is put on. When the battery is to remain a long time without attention, the box should be completely air-tight.

I have devised no special plan for hindering the evaporation, for the particular circumstances in which the battery is placed will cause the rate of evaporation to be great or small: thus, when the battery is exposed to frequent changes of temperature, the loss from the jars will be great, (even though a box is used) if the air can flow in and out. But when the battery can be placed in a vault or cellar having a uniform temperature, and not subjected to frequent changes of air, then no box will be required, if the battery can be filled up every few months. When a vault cannot be had, a heap of earth over the box will greatly hinder changes of temperature and evaporation. Only let it be remembered that the jars should be kept full, either by refilling or by hindering evaporation.

The form of battery described above has advantages over all others in simplicity and cheapness, as well as certainty and economy of action. Its riddance of the usual appliances for making *contact*, such as binding screws, clamps, and soldered joints, so expensive in manufacture, and yet so very uncertain in use, will certainly commend it to every one who knows the endless trouble which invariably attends the use of these joinings.

How often has a lecture been spoiled because there was a bad contact which could not be detected; and how often do we hear of a whole day being lost in telegraphic operations, from the nitric acid having eaten off the solder which joined a platinum to a zinc in the Grove's battery. Moreover, we have no residues of the zincs—no necessity for re-amalgamation.

To show all the advantages of the arrangements described, for maintaining the conditions of voltaic action, would be to take a full view of the theory of the generation and diffusion of voltaic electricity, which would be impossible in this communication. Yet, to set these advantages in some light, I will take but a glance at the voltaic action.

The universal feature of a voltaic combination is that of three substances in a series, in which the two extreme bodies have dissimilar properties with respect to the intermediate, which is a compound body, so constituted that one of its components can be eliminated by one of the extreme bodies, and the other component by the other extreme body. In all useful batteries, one of the extreme bodies is zinc; the other, some less oxidable metal; and the intermediate, water, or water with some acid, generally the sulphuric. The relations and actions of these three substances will embrace all that relates to the generation of the voltaic current.

We will suppose that the function of the zinc is to disturb the electrical equilibrium, by combining with the oxygen of the water, (or, if we consider the electrolyte as sulphate of hydrogen, the action will be the same,) that the function of the water is to transmit the disturbance by a wave of decomposition and recomposition, and that the function of the less oxidable plate (the conducting plate) is to produce equilibrium, by eliminating hydrogen from the electrolyte.

The chemical affinity generates the electricity by the combination of the zinc with the oxygen and the decomposition of the water. Therefore the amount of electricity, and the consequent tension which the affinity can generate in a given time, will depend on the favorable circumstances for chemical action, such as the presence of acid to dissolve the oxide of zinc, which otherwise would soon exclude the electrolyte by encrusting the zinc; the presence of water to dissolve the sulphate of zinc; temperature affecting the solvent capacity of the water, and the reaction of the tension against the affinity.

When a battery is first charged, all the conditions are prime; from this there is a decline by several ways to the point of no action. The decline may result from a changing of the electrolyte or of the conducting plate. The character of the change, and the rapidity of decline, will depend wholly on the construction of the battery. The construction may be such that the action will wholly cease before even a small portion of the material is consumed. When the zinc plate of a battery is placed in such a situation that the generated sulphate of zinc cannot flow away, as when the plate is placed at the bottom (horizontally) of the jar, and the arrangements are made such that the quantity of electricity, and the consequent formation of zinc salt, shall exceed the rate at which the diffusion of the salt can take place, the zinc plate will soon become coated with a crop of crystals. As the cessation of action here is visibly due to exclusion of the excitant, it follows that in whatever position the zinc plate is placed, just in proportion as the sulphate of zinc excludes the excitant, will the capacity of the chemical affinity to generate the electrical tension decrease.

Many plans for removing the sulphate of zinc from the cell have been devised. The most of these have been based upon the idea that the sulphate by its superior gravity would subside and saturate the lower parts of the solution. I have tested the value of this idea by the following method: Vessels 38 inches deep were filled with solutions of the sulphate of various degrees of saturation; then, after letting the solutions repose for several days at a uniform temperature, I drew off a portion of the liquid at the bottom, and a portion from the depth of three inches from the top, and in no case found a difference of density to produce more than one degree of Baumé's hydrometer. But I have found that even a saturated solution will always be considerably deficient *just at the top*, provided that it is not subjected to agitation. By this I learned that a *calm solution cannot be saturated on the top*. On this basis I formerly, in conjunction with Mr. J. Green, the well known maker of philosophical apparatus, constructed batteries with the zinc arranged horizontally within half an inch of the top of the liquid. These horizontal batteries required perishable mechanical contrivances for keeping the plates in position which would quite unfit them for telegraphic operations, though I still consider them superior to all others for electrotyping. By the action of these horizontal batteries we found that the grains of salt were deposited in crystals, at the bottom, while the top of the solution remained unsaturated.

From a single cell of these horizontal batteries, which held four gallons, and was only eight inches deep, I have frequently taken 2½ gallons of crystals of sulphate of zinc. I have sought to make use of these advantages about the top of the solution, in the construction of the reservoir battery, as far as practicable, with simplicity of construction.

From what is said above concerning the horizontal battery, will be seen the advantage of using in the reservoir a long, narrow plate of zinc, with the length horizontal. This also has an advantage in regard to the mercury keeping the plate always well amalgamated from not having a great height to climb.

In all other batteries, the important principle of the subsidence of the salt has been wholly overlooked; for although it has been proposed to draw off the saturated solution from the bottom, while fresh excitant was supplied at the top, yet the plates have invariably been placed with their lengths vertical. The self-amalgamation of the zinc has been introduced not merely with reference to the saving of labor and mercury, but with reference to the continued action of the battery. This mode of re-amalgamating appears somewhat specious at first; but soon the question arises, how far can this mercury creep up the plate and efficiently amalgamate it? This will depend on the quality of the zinc, as will appear from a consideration of the uses of amalgamation.

All commercial zinc contains mechanical impurities, such as charcoal, stones, &c., and is alloyed with various metals, but chiefly with iron. As the action of the solvent reduces the surface and leaves the impurities projecting, they are placed in situation to form voltaic circles having the least possible resistance—which is being most favorably disposed for action. Every particle of foreign matter on the zinc surface acts as a conducting plate to it, evolving hydrogen from the electrolyte, and most rapidly consuming both the zinc and the solvent.

If now the zinc plate is mercurialized, the ernormous cohesive force of the mercury causes it to contract over the particles of carbon, iron, &c., and the surface of the plate is made homogeneous, and consequently, as the particles which evolved the hydrogen are now excluded from the electrolyte, their action on it ceases. The mercury itself, if more strongly charged with zinc in one place than in another, might evolve the hydrogen; but fortunately having a most perfect polish, it binds the hydrogen firmly to it. This action of the polished metal we will consider presently.

But as the consumption of the zinc goes on, the impurities accumulate on the surface, and project so far that the mercury cannot envelope them; hence the efficacy of the amalgamation at any place will depend on the amount of limpid mercury at that place, and the amount of the impurities to be covered. So I find that with the ordinary English and New Jersey zinc, the solution of twenty-five grains from a square inch of the surface (a depth of $\frac{1}{69}$th of an inch) will leave the impurities projecting so far that the quantity of mercury which can adhere to the zinc when in a vertical position, cannot prevent violent chemical action in the minute galvanic circles. But the zinc known in commerce as the "Musselman's" is so easily protected that I find the corrosion may go the depth of $\frac{1}{4}$th of an inch, and the mercury still be efficient when flooded over the surface. Here, then, is the answer to the question as to how far the zinc plate may be protected or efficiently amalgamated by standing it in a flood of mercury. If the plate is not to be dissolved to a very great depth, the good commercial zinc will be sufficiently protected; but for a longer time the zinc should be redistilled, and for a very long time nothing but chemically pure zinc should be employed. Practically I find that the "Musselman's" answers well for one year.

From what has been said concerning the action of the impurities of the zinc, it will be perceived that if any carbonaceous matter falls on the battery, it may attach itself to the zinc, and thus rapidly destroy the voltaic conditions by consuming the materials; since the evolution of hydrogen would continue while there remained zinc to be oxidized, acid to dissolve the oxide, and water to dissolve the salt. This shows the necessity of a box to prevent currents of air from sweeping over the battery; for even the dust which subsides from the atmosphere, may set up the destructive action.

From the same kind of reasoning, it is obvious that the presence of the least particle of any salt reducible by zinc or by hydrogen should be avoided; and such a salt coming in contact with the zinc, would instantly form a conducting plate. If we would avoid every risk of this destructive action, the fixtures of the battery must not be made of a metal which can form a soluble salt with sulphuric acid.

I will have occasion to refer again to the employment of the oxidable metals for the battery fixtures; then I will merely state that I have found by experience that even silver is unsuitable, for when I employed a silver bar and silver pendants to hold the conducting plate, sulphate of silver was formed.

We now come to the consideration of the most delicate part of the battery—the conducting plate. The function of this plate is solely the elimination of the hydrogen of the electrolyte. The plate, indeed, does conduct the positive electricity from the electrolyte. But by the chemical theory of the voltaic generation, *the elimination of the hydrogen from the electrolyte is the conduction of the positive electricity; and the conduction of the positive electricity is the elimination of the hydrogen*—the one is inseparable from the other, conduction and decomposition being *identical* in an electrolyte.

By this it will appear that the liberated hydrogen should not be suffered to adhere to the conducting plate, for the gas being a very bad conductor, it will resist conduction, and consequently chemical action.

The office of this part of the battery has generally been considered a mystery, being subject to very great and sudden changes, which being unaccountable by mere inspection, were attributed to occult power called the "electro-motive force." But certainly rational investigation can refer all the battery changes to known forces. By late investigations we know that the gases adhere to, and condense on, all solid bodies. If the attraction between a sheet of metal and a molecule of gas is regulated by those same laws which govern the planetary masses, then we can easily conceive that the more definite the plane of attraction, the more strongly will the molecule be drawn, and consequently the denser and higher will be the adhering layer of gas. And, by the same laws, we can see that an indefinite plane will act with opposing forces, as we see in the deviation of the plummet in the vicinity of mountains; as we see in the perturbation of the planets; and as we suppose when a body descends toward the centre of the earth from the surface. The former of these conditions is fulfilled when the surface is polished; the latter when it is rough or unpolished.

We can conceive the mounts of the roughness to rise so high above the plane of maximum force, that the adhesion to the prominences will be almost destroyed. And we can conceive the mounts to react so much against the pits that the plane of attraction shall be nearly or quite destroyed. We can conceive of a surface thrown into such fine points and recesses that a molecule of gas might float in equilibrium in the cavities, or adhere with the least determination to the prominences. Hence the great advantage of the deposite of finely divided metal.

A surface atomically rough will hold only an atmosphere of the least possible height and density. But this is not attainable. We get the nearest approximation to an atomic roughness when a surface has been covered with amorphous metal by electro deposition. Then it may be said to be rough or unpolished to the greatest degree for that metal.

Could we view such a surface, or rather I should say want of surface, we doubtless should find it many thousand fold more rugged, uneven, and porous, than the common sponge.

The various metals let go the hydrogen in the voltaic circuit with very different degrees of readiness. From the observations, I conclude that the attraction of the various metals for the gas is directly as their specific gravities. All the less dense metals decompose water, (evolve hydrogen.) Sodium and potassium evolve the gas in torrents. The base metals proper have less action on water, and a stronger attraction for the gas. The noble metals hold the gas very firmly, and are without action on water.

The order in respect to evolution is the reverse in respect to gravity; and the order in respect to gravity is consequently the reverse of the order of fitness for a conducting plate in respect to the evolution of hydrogen. Platinum, gold, and lead, hold the gas very hard. When polished plates of these metals are used, the hydrogen adheres in large bubbles, which very slowly creep up the plate. Mercury I do not compare, because its mechanical form is the best possible for adhesion; but could we but polish the solid noble metals as perfectly as the atomic polish of the mercury, I have no doubt but that the mercury, according to its density, would follow after gold. Silver answers better than the other noble metals. Experiment has not enabled me to decide that copper is better than silver, but I am much inclined to consider the copper as best. Iron is decidedly better than any metal above it in density, and requires no special preparation to make it evolve freely. Zinc is so prone to evolution that it is with difficulty that the hydrogen can be made to adhere. The metals of the alkalies cannot be investigated with hydrogen like the denser. A mere particle of zinc will coat a surface of copper or iron with hydrogen, and protect it from oxidation forever; but as soon as potassium or sodium is deposited, it is instantly re-combined with oxygen, because it cannot be quoted with hydrogen. Here I may remark that the newly reported aluminum which is said to have the nobility of silver, with the density of only 2.5, ought, by the above views, to make a most admirable conducting plate.

By the above view, the adhesion of hydrogen is very nearly the reverse of the affinity for oxygen. Here we find silver with a medium adhesion and a low affinity. This at once indicates that it is the metal which will be generally used for making batteries. Iron, which is the most oxidable metal that can be employed for conducting plates, has a very low adhesion, and fortunately a mechanical advantage from its ever-fibrous or granular form, which greatly increases its fitness for evolution. Could it remain as iron in the battery, it would probably be all we should ever desire, though it acts vigorously when newly cleaned—its affinity for oxygen soon makes it worthless. This objection holds not only for iron, but for some kinds of batteries holds even against silver, and we are sent at last to the more noble metals.

The difference between gold and platinum in respect to the adhesion, and also in respect to the liability to chemical change, is so small as to make the employment of one or the other merely a question of economy. But there is another property—one which quickly determines the preference; this is the capability of being put in the best mechanical form for non-adhesion, or making the closest approximation to atomic roughness.

Of all the metals, platinum has the greatest tendency to the amorphous state, (excepting its relatives, rhodium, indium, &c.) I do not remember having seen that its crystal has ever yet been determined. Not so with gold; its crystalline tendency is so strong, that it aggregates so much in precipitation, even from extremely dilute solutions, that the deposite has a decided yellowish tinge, and the slightest pressure makes the deposite conglomerate. I here need scarcely remind you of Wollaston's tedious process for metallizing spongy platinum.

If the above views of the nature of the adhesion are correct, then it follows that the surface of the conducting-plate should be amorphous platinum, and nothing but amorphous platinum; and consequently, if we wish our battery to *retain* its capacity to remove the hydrogen from the electrolyte, which, let it be borne in mind, is the capacity to conduct electricity, then there should not be the remotest liability of the amorphous platinum to have a deposite of any other metal, or any oxide formed on it.

On this consideration I have carefully avoided using any reducible base metal about the battery, in such way that its salt might get into the cell. I have before shown what would be the consequences of this on the zinc plate, and equally injurious would be its action on the conducting plate, whether it were deposited on it as metal or as oxide. In either case the hydrogen would adhere, the conduction resistance would be increased, the tension would rise proportionally and react against the affinity; the chemical action, the soul of the battery, would proportionately decline. That the mutations of this battery from adhering coats of hydrogen, metals, or oxides, on the conducting plate, are attributed to *conduction resistance*. I shall expect to be regarded by the advocates of electro-polar forces as wholly untenable, and the resistance to be considered as incompetent to produce the effect. But that the gas resists is indisputable, and that it adheres to the conducting plate is equally indisputable, for we know that the very clods of the fields attract and condense the gases; and is it not, therefore, but as fair an inference that it adheres somewhat to dense metallic plates? The thickness of the adhering film may be extremely small, but its resistance may be quite considerable, for the resistance of airs is almost incomparable to that of metals. We know that a battery has penetrated over 3,000 miles of iron wire, and when a battery of 2,000 pairs had the poles parted only the least distance that could be manipulated, then the galvanic action could not be exhibited.

It remains now only to notice the electrolytic changes with reference to continued action. The generated sulphate of zinc alters the conditions of action, not only by saturating the acid and water, but the dissolved sulphate itself is an electrolyte, and therefore may coat the conducting plate with zinc, and deteriorate it just as was shown would result from the salts of the other base metals. Fortunately, there is not so much danger of the plate becoming wholly coated with zinc as with the other base metals, for the deposited zinc is rapidly removed by its great tendency to become salt, in which it is assisted by the close proximity of the uncoated portions of conducting plate, forming good local circles with it. Should there be no portions of the plate bare to reduce the counter-tension generated by the resolution of the deposited zinc, then we should have the tension acting against the battery current. This probably can never happen, yet the plate is often made nearly inefficient by the reduced zinc, when the acid is mostly saturated.

The acidulated water or sulphate of hydrogen is electrolyzed by a far less tension than decomposes sulphate of zinc; it is only, therefore, when the quantity of sulphate of hydrogen becomes proportionately small, and causes the tension to rise by its increased resistance, that the sulphate of zinc is decomposed.

But it is unquestionable that that force which is the result of the combination of the elements of sulphate of zinc, cannot of itself undo that combination; yet while the battery is working, zinc is constantly being deposited and re-dissolved. In considering this action of the galvanic current which is apparently so anomalous to the exhibition of every other known force, I have concluded that we should look for some additional force acting conjointly with the current, rather than for a moment admit the absurdity of an "electromotive force," with its supposed capacity of acting infinitely without expending itself. Such an additional force I conceive can be found in the attraction of the matter of the conducting plate for the heavy element of the electrolyte.

If the conditions under which the deposition of the zinc takes place be considered, it must appear that it is the attraction which makes the determination. In the first place the deposition is nothing when the proportion of sulphate of zinc about the plate is small in comparison to the sulphate of hydrogen; but as the proportion of sulphate of zinc increases, the deposition of it begins to show itself, until it becomes very copious in a nearly saturated solution. The supposition I have made is, that the deposition is effected by the conjunction of the attraction with the current or electrical tension; consequently the deposition can only take place when the tension is so high that the addition of the attraction enables it to overcome the affinity. This exactly conforms to the conditions; the good conducting sulphate of hydrogen being removed, the bad conducting solution of zinc will cause the tension to rise. I cannot now go into the discussion of the specific weights of the elements of the two electrolytes, to show that that attraction will act in the same direction with the electric tension. It is at once evident that if we admit that the matter of the plate attracts the elements or atoms—and what physicist at this day would think of denying it?—then it follows that altering the aggregation of the surface of the plate will diminish that attraction, just as it diminishes the adhesion of the hydrogen; yet, as the molecule of zinc is so much heavier than the hydrogen atom, the disturbed aggregation should extend much deeper into the plate for destroying the attraction for the zinc than is merely required for preventing the adhesion of the gas. On these principles I have made the conducting plate, with the disintegrated state of the surface extended to the greatest depth admitting of the requisite mechanical durability, for which the plate is electro-plated to the beginning of roughness before putting on the coating of platinum.

I have sought to describe the peculiarities of this battery, by exhibiting the actions of the various parts, and the principles which guide me in their construction. These principles, I acknowledge, are new in their application to the galvanic phenomena. I have only to say for them, that they are the acknowledged principles of matter and motion, and consequently the principles of universal nature. But it may be that my solutions are wrong, and that further research will not sustain the views; yet, I ask for them a trial as to their conformity with the admitted solutions of the great multitude of natural phenomena. Thus we know that oxygen is condensed with a force of nearly a thousand atmospheres on spongy platinum; and does not geometry show us that if the disintegrated mass attract thus strongly, the solid surface will attract enormously? and if oxygen is so strongly attracted by the solid surface, then why may it not attract hydrogen, which is only sixteen times lighter, sufficiently to condense a layer which the battery liquid cannot displace because it is denser than the liquid? I must here ask that I may not be misunderstood by supposing that I refer to the bubbles of gas which adhere to smooth surfaces by the superincumbent pressure. Geometry, indeed, shows us that these bubbles are dispersed by a rough surface, but it also shows that these bubbles are hemispheres, and therefore that they cannot entirely prevent contact of the plate and liquid.

That the deposition of the zinc, also, should be referred to the attraction of the plate, is that which the universal principle of attraction demands. Why not admit that that attractive force which we know exists in all things, concurs with the electrical tension to produce this, when we are constantly seeing the greatest anomalies produced by concurring forces? Thus we *know* that the affinity of copper for oxygen, at low temperatures, is superior to that of hydrogen; yet, when a piece of coal is saturated with hydrogen and immersed in a solution of sulphate of copper, the hydrogen is oxidyzed and copper reduced, simply because the attraction of the coal for the copper, added to the affinity of the hydrogen for oxygen, make a united force superior to the affinity of copper for oxygen. Here we have a voltaic circle composed of coal, sulphate of copper, and hydrogen, which becomes active by the help of attraction, and is enabled to decompose an electrolyte whose affinities are even *stronger* than those of the produced electrolyte.

I has been considered as the standing miracle of electricity, and the unanswerable argument against the chemical theory of electrical excitation, that a battery will work on a neutral solution of sulphate of zinc, and deposite zinc on the conducting plate; for, say the advocates of the electro-motive force, the force is greater than the affinity of zinc for the negative element, for, after overcoming the conduction resistance, it is still enabled to separate zinc from the negative element. But there is a little experiment which shows conclusively that it is the state of the surface of the conducting plate which determines the electrolysis, and not a supposed electrical condition involved in the nature of the substance of the plate.

Let a battery of several pairs be connected with a pair of large platinum electrodes, in a solution of sulphate of zinc, containing a little free acid—or a single battery may be used if an electrode of zinc is used to receive the oxygen,—then, if the platinum electrode be well polished, zinc will be rapidly deposited on it, and there will be no hydrogen given off; then let the deposited zinc be dissolved off, and the platinum electrode roughened with emery and well platinized, and then restored to its former connection with the battery; now, the same battery, with the same solutions and electrodes, will chiefly electrolize the sulphate of hydrogen; there will be very little zinc deposited, but the hydrogen will fly off in copious streams.

As the reservoir battery is designed chiefly for telegraphs, I may, with propriety, before closing, say a few words relative to the quantity of electricity required to work a telegraph. I have measured the quantity of the current on some lines by interposing voltametres in the circuit.

The quantity near the battery is very great compared with the quantity on the part remote from the battery, for the insulation is always imperfect; and of the whole quantity that leaves the battery, only a small proportion reaches the remoter part. But to get all the waste included in my measurement, I measured near the battery, and found when the line was in good working order, the *quantity* of the electricity was that represented by the solution of one grain of zinc per hour. Sometimes the line would work well with much less than a grain; and often after the batteries had been recently charged, the quantity was ten grains; but mostly, when the line was in fine order, the quantity was about the grain.

Supposing the current to be on about seven hours per day, (which I think comes near the time,) then one pound of zinc will supply all the electricity used in 1,000 days, or, say three years of business days. From this it will appear that my idea of a battery to serve 100 years is, at least, not so extravagant as to be without some show of probability. Such a battery would require zincs of only 33 pounds weight, or (allowing for some local action, as there is some always carried on, even by the mercury) say 50 pounds, which is a cube of less than six inches square.

I have lately had a fair opportunity of knowing the value of this battery. In May last, I charged six cells, which were put in a box in the upper laboratory, to be used in the experiments on photographic engraving. The battery has since been in almost daily use for gilding deep-sea thermometers, or other instruments, or else in the experiments. During the six months which have elapsed, it has been used probably 2,000 times, in which there was nothing more required to get the current than to complete the circuit. During the intensely hot spell of the past summer, I three times added a little water to supply the loss from evaporation, and these were the only times the box was opened.

Very respectfully, and obediently, your servant,

GEORGE MATHIOT.

Prof. A. D. Bache,
Superintendent U. S. Coast Survey.

APPENDIX No. 57.

Report on Engraving in relation to the Coast Survey. By Lieutenant E. B. Hunt, Corps of Engineers U. S. Army, and assistant U. S. Coast Survey.

Tarrytown, N. Y., *September* 21, 1854.

Sir: In proceeding to execute your instructions of September 2, directing me to prepare a report on "engraving as executed in the Coast Survey Office," I shall assume that your wishes will best be answered by such a treatment of the whole subject as will exhibit it in all its essential bearings. Recognising in engraving an art of the highest and most influential character, not less than a practical handicraft of a strictly manual nature, I should esteem it an ill-judged narrowness here to pass unnoticed those fundamental generalities, ever most prone to escape from sight. At present it will doubtless be advisable to avoid unfolding in detail the mere routine and mechanical dexterities of this profession; dexterities practised only by those who have devoted patient years to its acquisition. The art and practice of engraving in the Coast Survey Office being my subject, I shall consider it in reference to its office organization, history, and administration, to its artistic and technical aspects, and to its prospects.

That policy which has given origin and support to the system of operations embraced under the name of the Coast Survey has two definite aims of peculiar importance. First, it aims at a connected system of geodetic, topographical, and hydrographic observations, fitted for bringing to light all such general and local facts of configuration of the coast as are important to navigation, commerce, and local interests or improvements. Secondly, it aims to present in the most correct, useful, and popular form, the delineations, discoveries, and developments resulting from this system of field observations. The various operations of the survey fall into two great classes in conformity with these specified objects, being either, 1st, *field-work;* or, 2d, *office-work.* In the first is embraced the series of reconnaissance, astronomical, magnetic, trigonometrical, topographical, hydrographic, tidal, and current observations, all of which, as they are made, are duly entered in their appropriate records ; and thus the field-work has produced that aggregate of note-books and sheets, topographical and hydrographic, which constitutes the office archives. The class of office-work embraces all the operations by which this mass of materials is wrought over and elaborated to the final forms of publication, whether as maps, charts, reports, or results. The crude observations require to be reduced and discussed in the computing division to deduce latitudes, longitudes, azimuths, distances, and tidal results, and each hydrographic party plots its own soundings in the office. The drawing division expends, on the materials thus supplied, all the resources of graphic art in producing, as connectedly as possible, pictorial representations of the combined geodetic, topographical, and hydrographic results for each locality in turn. The engraving division has for its specific office to form for the printer's use, of the drawings thus made, an enduring record in copper-plates, as also of the tide-tables, sailing directions, and descriptive notes, furnished with, or aside from, the drawings; it has, indeed, to assemble, arrange, and engrave all the elements of perfect maps and charts. The electrotypist next takes a relief-cast, or *alto,* and from this as many identical copper-plate copies, or *bassos,* as may be required. The printer goes on to print from these bassos whatever stock of impressions, on paper, may be needed to meet the demands of commerce, navigation, and local interests, as indicated by the requisitions of the local sale-agents, and the orders for distribution established by law. All these operations, while proceeding under their own special directions, are kept co-ordinated and in due relations by a general direction. It may thus be seen, that while the field-operations produce the raw materials of geography and hydrography, the office-operations are applied to the manufacture, from these materials, of faithful maps and charts, to meet the national demand. The principles and economy of a manufacturing art and establishment will, therefore, be found to apply to the direction and execution of the office-operations. In this manufacturing organization, the engraving division enters as a subordinate but essential component, requiring to be maintained not only in healthful operation within itself, but also in adequate and just relations with the co-ordinate divisions, and with the amount of field-work to be published.

The organic form under which the engraving division is now established has resulted from experience of what is needed, and from the progressive expansion of the engraving operations consequent on the extension of field-work into each of the eleven sections of our coast. On reverting to the date of your entrance on the superintendency, but slight traces of the present condition of office-engraving are met. In 1843 three engravers were employed, but only three sheets of maps had been published up to 1844. An accumulation of nearly ten years of back-work was then to be engraved, and great efforts were required to bring up these arrears, without permitting the new work to fall behind; efforts which cannot even yet be relaxed. It was necessary to augment the force of engravers, to arrange and systematize the work on hand, to provide for its distribution according to the capacities of individual engravers, to determine the fitness of engravers out of the office properly to execute plates by contract, to make from time to time such contract arrangements, to study and analyze prices for each species of work, and, in general, to exercise forethought, vigilance, and administrative capacity in giving organized efficiency to the work of engraving. While very much of this burden fell on yourself and the assistants in charge of the office, (successively Captain Eakin, Captain Humphreys, Major Stevens, and Captain Benham,) it was a source of special congratulation that, from 1844 to 1846, the fine tase and excellent capacities of Assistant Farley, and from 1847 to 1850 the graphic skill and faithful services of Assistant Fairfax, were available for the more immediate charge and the detailed administration of engraving matters. The style and usages of the engraving division, as now established, bear strong traces of Captain Humphrey's close investigations and judicious electicism. The style of view and topographical engraving which has been so successfully adopted for the Western coast reconnaissance-maps, is in great part a monument of Mr. McCoy's artistic felicity, and of the vigorous grappling with new problems which distinguished the office career of Major Stevens. The skill of Siebert, Rollé, Dankworth, Knight, McCoy, and other engravers, has risen to meet the emergencies and demands which frequently occur in the expanding work of the Survey, and it is due to them that practice has been so close a follower of the instructions and conditions under which they have worked. It would be an unjust omission here not to notice that many perfections of detail, and especially the general harmonizing of styles, are due to your own frequent room-inspections of engraving in progress during your first years of superintendence, and, more recently, to your critical examinations of, and comments on, the quarterly file of proofs, and such special proofs as have presented open questions. It is also but just to remark that, at a time when arrears of engraving hung so heavily on the office, the availability for contract-engraving on several small harbor plates, of the skill combined in Sherman and Smith's establishment, was truly a kindness of fortune.

A candid retrospection over the office map engraving certainly affords much reason for congratulation by reason of its aggregate onward progress. The entire range of map and chart publication furnished at first no satisfactory model for imitation, but it was then alike essential to push rapidly forward the work in hand, and, in so doing, to develop a more perfect and finished model of chart-work than had anywhere been produced. In both these respects, just grounds for satisfaction exist, and it is not too much to claim a higher finish and more perfect elaboration for the best Coast Survey charts than is exhibited in any others of which we have any knowledge.

In the early days of the office organization, the drawing and engraving needed no separation, and you placed them first, in 1844, under Mr. Farley's charge. This was the beginning of an organization which has grown with the growth of the work, and which has required yearly division and subdivision to adapt it to the present expansion of the work.

The engraving division, as at present constituted, is under the charge of Lieut. J. C. Clark, U. S. A., with a clerical assistant, and embraces seven regular engravers, (of whom four or five are first-class artists,) six apprentices in various stages of training, and indirectly two standing employés on contract work, with several others, who, from time to time, are employed on jobs or rates, as circumstances require. Ten of these are topographical engravers or apprentices, and five are letterers. It is very desirable somewhat to increase the first-class force, but so great is the demand in this country for skilful engravers in the bank-note and book-illustration departments, and so small relatively is that for superior topographical engravers, that the best talent is absorbed mainly in the former channels, leaving it a difficult matter to procure satisfactory artists in the number desired for the office-work. It is hence quite important to keep each engraver steadily at work in his highest style, and with this view, to arrange the work as long beforehand as practicable. During Captain Humphrey's office administration, the burden of definitely arranging work lay chiefly on him, and his arrangements were carried out by Mr. Farley and Mr. Fairfax. Under Major Stevens the same practice prevailed, especially after the transfer of Mr. Fairfax to the drawing division, and continued in a diminishing degree during the few months in which I had charge of the engraving division, as also through the subsequent period of Mr. Tinkham's occupancy of that position. After Mr. Tinkham's resignation, the brief terms of service by Captain Gibson, myself, and Captain Oakes, with Mr. Tennent to aid in details, were marked by no great change of administrative arrangement; and now, under Lieut. Clark, the direction involves the same free consultation with the assistant in charge of the office on all essential points. I cannot but remark here on the great disadvantage arising from the changes which have so frequently been found necessary in the charge of the engraving division. This results in a sad loss of experience and knowledge, and in the unsteady application of the engravers' powers; both of which seriously retard and impair the work executed. It is not easy to sum up the amount of special knowledge which a chief of engraving should possess, for on him depend not only the proper distribution of current work and all the detailed arrangements for its execution, but also it is chiefly from him that improved styles, methods, and regulations must be expected to proceed, as certainly by him they must all be tested. On him, too, rests a great responsibility for giving to the apprentices a right training, both as young engravers and as young men, and it is by him that a general spirit of activity and intelligence must be communicated to those under his charge. The position should be one of great labor, and is one worthy to call forth the powers of a vigorous mind, filled with deep faith in progress everywhere, and most of all in this very art of engraving.

In passing to the consideration of engraving as a branch of the fine arts, and of map engraving as involving its own distinctive artistic principles, it is evident that only the most practical views of the case can be ventured on. To omit this higher phase of the subject, would be a most unpardonable omission, because map engraving is peculiarly prone to sink to the level of merely mechanical routine work; a deplorable lapse, which can only end in a dry, cold, insignificance of style, alike degrading to the artist and subversive of the art. In most branches of practical art, the exercise of fancy, the culture of idealism, and the spiritual significance of the subjects treated, suffice to keep alive the artist's interior powers; but engraving, especially when the subjects are inanimate and wanting in aerial perspective, has a constantly operative tendency to obliterate from the engraver's mind all active conceptions of such truths and principles as transcend the petty dexterities of execution. At Dusseldorf, the *gerne* and *ideal* schools of painting co-exist in powerful competitive action. Each most happily reacts on the other, for the idealists infuse somewhat of their poetic mysticism into the too rigid imitative delineators, while the stern truth of the *gerne* artists chastens extravagance and unnatural fantasies from the canvass of the introspective idealists. But no Dusseldorf is possible for the topographical engraver. If he be not wholly and conscientiously *gerne* in his art, he must be a moral culprit, falsifying the natural subject which he is called upon literally to render. Ideal topography or hydrography is a criminal counterfeit. Neither has he depth of aerial perspective to stimulate his study of nature, or to habituate him to that subtle perception of effects desired and attained, which becomes like an added sense to the landscape engraver. Hence he is too prone to assume that topography has no elements of a fine art, and to rest content with neat and dexterous execution; a conclusion equally false and unfortunate.

No man can be a first-class topographical engraver who is destitute of the essential qualities of an artist, as, of course, none but a genuine artist can do even tolerable justice to the various headland and harbor views required on the series of charts. The engraver who ignores art can only accumulate topographical lines and dots in spiritless ranks by literal copyism from his drawing, or in unreasoning conformity to conventional rules. But it is the engraver's duty to rise above his model in the elements of expression, and to render nature with a fidelity and spirit such as no mere system can teach. Ruskin has expended a vast affluence of argument and eloquence in maintaining the need of minute fidelity to the very species of rocks and trees in landscape painting; not by literal delineation, but by the clear display of whatever constitutes the prime characteristics of each species. If such adherence to fact is justly demanded in landscape art, where fancy is permitted so much scope, and where the variations of composition demanded by taste are confessedly legitimate, how much more is the topographer bound to present the real specific character of the various species of hills, fields, trees, coasts, &c., which he is called upon to represent. How fine a sense of natural truth and characteristic attributes should be exacted from him who is to express enduringly in copper the rocky shores of New England, the clay banks of the Chesapeake, the sand beaches of the Carolinas, and the bluff headlands of our Pacific sea-margin. All this burden of high fidelity cannot justly be thrown on the drawing division, for no engraver is a thoroughly good topographical artist who cannot lend a still superior grace and fidelity of manner, a purer and finer tone of execution, even to the exquisite drawings of Fairfax, McClery, and Welch, or to the softly bold hills of Lambert and Herbst. The dry-point of Siebert, and the etching-needle of McCoy, have an art power which no drawing-pen possesses; nor would any written exemplar of lettering have guided Knight in the execution of such letter bodies as those on the lower Delaware sheet. While no zeal in perfecting the drawings should on any account be abated, it is a truth which cannot be safely forgotten, that our map engravers must themselves, through artist culture and persistent effort, vindicate their rightful claims to fellowship with the noble art brotherhood.

Three distinct elements of delineation require to be combined by the topographical engraver: 1st. The outlines, or horizontal configuration, embracing all boundary lines of fields, roads, streams, coast, houses, &c., which must be accurately traced and transferred to the plate by the aid of projecting or locating squares. 2d. The undulations of ground or surface fluctuations must be represented by horizontal curves called contours, or by the lines of steepest descent called hachures. 3d. The indications of fields, grass, marsh, mud, sand, forest, &c., are to be added in such a manner as to exhibit the entire occupancy of the ground. The lettering should, if possible, always intervene between the outlines and hachureing; a step embracing the title, sailing directions, notes, soundings and bottoms, with all names of objects and localities. Placing lettering on hachured and surface indicated work risks the harmony of effect, and it is quite essential to introduce soundings, &c., before sanding. Besides, the letterer's gauge-lines must be burnished or coaled out at an essential sacrifice of depth in any previous topographical work over which they extend. The system of hachures employed in the office is a modification of Lehman's, and the light is assumed as vertical. Though an oblique light would give stronger hill effects, and more aerial perspective, its advantages are partial, and involve a sacrifice of that strict equity which distinguishes an orthographic light, and which a true artist can combine with excellent slope and shade expression. The description and history of the modified Lehman style used in the Coast Survey belong rather to that of the drawing than of the engraving division.

A question of great importance, and one not lightly to be answered, here occurs, concerning the proper policy for the office to adopt relative to specializing the styles and capacities of the individual engravers. It is characteristic of the ruder stages of all arts and manufactures that a single hand has manifold functions. Each progressive step narrows the sphere of individual action, and concentrates a more undivided attention on the narrowed field. The individual thus becomes merged in a train of processes to which he contributes but his humble mite; thus the lofty and generalizing, but somewhat rude, spirit is bowed to the mechanical, petty perfection of one idea. The good result is mechanical perfection and facility; the bad is mannerism and narrowed individual capacity. Thus, in engraving, Mr. Wilson Lowry, of London, invented the engraver's ruling machine, which was applied to ruling skies. As a consequence, I understand that nearly all the machine sky-ruling executed in London is done at a single establishment. The result is that London plates exhibit a mechanical perfection and softness in the skies which is an unceasing wonder. But, on the other hand, a mannerism, the most obvious, runs through them all, and wearies the eye with iteration interminable. Apparently, the sky rulers have reduced sky-ruling to a system, convenient in practice, giving great delicacy in execution, and only marred by its resulting monotony and non-conformity with the endless variety in the sky itself. So in the topographical work of the Coast Survey Office, the channel lies between Scylla and Charybdis. To give one engraver a great variety of work lowers his mechanical mastery of each species, while too long concentration on one species tends to sink the artist in the mechanic, and to form a manner no longer pliant with the varying characteristics of our kaleidoscopic coast. It is a well settled fact in general that the same artist should not be both a topographical and a letter engraver. But it is not so clear that one should do hills only, another sand only, another only fields, woods, and cities, and another only views. The exigencies of current work do much towards the practical regulation of this matter, but it is also, in part, an open, a free question. In view of the great value of improvements in style, and of the necessity of expanding individual capacities for this purpose, it seems desirable to have each topographical engraver practised in all branches of topography. Nor am I at all persuaded, that on the whole, and for a life-time, an engraver will the more excel in hachureing by being always restricted to that branch. The whole engraver is needed as a basis for the best hachureing artist. Besides, mannerism, even of the highest order, is a sad penalty, which waits with unrelenting punctuality on an excessive and sustained subdivision of work, and when its hold is once fastened-on the office, release will be indeed a forlorn hope. Timely caution is wisdom. It is a grateful reflection, that despite the routine and mechanical tendencies of the graver and needle in these elaborate days, genius has immortal rights, now as ever. Though the powerful handling of Albert Durer aud Raimondi, the strength, the freedom, the boldness of the renowned old Italian, German, and French masters of engraving, must be in part ascribed to the enthusiasm of the poetic or heroic age of this art; yet much was due to their individual genius, and genius still retains its old prerogative, now as then impressing its own splendors on its products.

The office history of a chart plate, from beginning to end, may be thus summed up. The project and complete drawing of a chart being received in the engraving rooms from the drawing division, the first step is to have a plate cut out of the desired size; this is done in the electrotype rooms, where the blank copper for this purpose is kept. This copper is usually planished and polished by Mr. Burdett, of Baltimore, of sizes ordered from the office, the size for large charts being given exactly, while other large plates are also ordered for cutting up. The planished copper is carefully inspected by an engraver and the electrotypist, to insure its being of good quality, well planished, and free from flaws and ash-holes. Some plates of electrotype copper are used. It is quite certain that all may thus be made of the quality desired, and every way as good as the planished plates. When the plate is cut out, and its edges smoothed, it is sent to the drawing division to have the neat lines and the projection of parallels and meridians, or the transfer squares, drawn on it, by which to lay down the tracing from the drawing. If convenient, the neat lines, border, and scales may then be engraved. With a point, the engraver traces the outlines of the drawing on a sheet of fish glue, or on tracing paper, with a pencil, a square at a time. The fish-glue lines are filled with plumbago, and a coat of wax is flashed over the surface of the heated plate. The tracing being accurately reversed on the wax-coat by aid of the squares, the plumbago is made to adhere to the wax by rubbing the back or going over the lines of the tracing. Detaching the tracing, the engraver, with a point, draws all the lines through the wax lightly in the copper. Removing the wax, he next proceeds with a graver or dry-point to cut the outlines firmly in the plate, hill-contours or other auxiliary lines excepted. In the French Survey, the outlines and contours are transferred from the plane-table sheets to the copper-plates by means of the pantograph, but the variety of scales and the combination of sheets in reducing, make this plan far less available for the Coast Survey. The next step is to pass the plate to the letterer, who executes the title, sailing directions, notes, tide-tables, soundings and bottoms, latitudes and longitudes, magnetic variations, and the general lettering of places, objects, points, &c., as far as the material warrants, when the plate is returned to the topographical engraver, who, with the drawing and plane-table sheet before him, proceeds to cut in the hachures, along and perpendicular to the traced contours, these contours alone sufficing for some engravers, who find the hachures of the drawing quite unnecessary. The indications of woods, marsh, mud, grass, tilled fields, dry sand, rocks, &c., are next added. The wet sanding, dotted in, relative to the selected curves of depth, must then be executed, if it has not been sooner done. Views of headlands and harbor entrances following next in order, are chiefly etched in, the graver being used for finishing, and the ruling-machine, with a diamond point, for water and sky. The supplementary lettering is completed, and the whole work verified to correct errors, discover deficiencies, and remedy petty faults of style or work. The seal and verification, price, presentation sentence, artists' names, &c., are added, and on final approval by the Superintendent the plate is considered done. During all this time frequent proofs are taken, on which the work is freely examined. Erasures are often made with the burnisher and scraper, and when it is necessary to restore the plane face thus hollowed out, the plate is beaten up from the back by laying its face on an anvil. The burr made by the graver and point is removed by the scraper and by coaling.

The finished plate is then electrotyped or put in alto as soon as possible, no unnecessary impressions being taken prior to that step. From the electrotype duplicates or bassos the printer proceeds to print the number required, leaving the original intact. In cases where extensive erasures are to be made, it is cheaper to make an alto, erase the relief lines from it, and then take a basso for the new work, than it is to erase on the original, beat up, and restore injured work. By aid of the electrotype process, also, plates are extended to receive additional work; large plates are subdivided, executed in parts, and then rejoined, to facilitate or hasten the work on them; views are taken from one plate and inserted into another, and blank copper-plates are made of any desired quality.

The lettering of maps and charts is a process of the utmost importance, both to their utility and their beauty. Indeed, no other class of engraved subjects is so dependent on the taste and skill of the letterer as these are, and more especially the charts. The expression of good topography will be almost ruined by the contiguity of lettering, either graceless in itself, or inharmonious with the other work. In charts, the title, the names, sailing directions, notes, tide tables, scales, soundings, and bottoms, make up so large a portion of the engraved matter, that a lack of success in this branch cannot fail to ruin the appearance of the whole chart. Nor is this success easily commanded. It requires from the letterer not only a graceful formation of the letter, but an artistic appreciation of the effects due to the distribution and spacing of letter sizes, words, and bodies of lettering. To preserve the balance of a sheet, to give to each part its due prominence and no more, to arrange titles tastefully, and to give names due relief and due subordination, are essentials demanding the endowments and eye of an artist. Though called the most mechanical branch of engraving practice, truly good lettering is no mere journeywork. The formation of letters should be graceful, their lines geometrical, their size true to the prescribed gauge-lines, and each letter should in all places be consistent with itself, its neighbors, and the style to which it belongs. The adoption of the plain English letter in the office, and the entire rejection of all fancy styles and flourishes, has been a great safeguard against errors, and has produced a single and essentially homogeneous style in all the office charts. Yet it is astonishing to what an extent effects can be varied within these restrictions, even in plain bodies of stump of the same gauge, simply by varying the light and heavy strokes, by opening or closing the letter extensions, and by changing the slight elements of letter formation. The effect of different scales on lettering is an element too much overlooked. In engraving soundings, bottoms, and currents, clearness is absolutely essential, as also is their accurate transfer. The style of figures ought to be such as not to prejudice the subsequent sanding, and the selection of soundings such as duly to fill and yet not to overcrowd the water-spaces. Letter work is peculiarly adapted to contract execution, as well-established rates for each species of letter can be readily applied, and as good letterers out of the office are less rare than good topographical engravers. The French *Depôt de la guerre* has laid down detailed instructions for lettering maps. (Memorial Topographique et Militaire, No. 5.)

The lettering now in use was thoroughly studied by the superintendent, by Capt. Humphreys, and Assistant John Farley. The skill of Messrs. Dankworth and Knight was taxed for the forms of the letters; rules were laid down and specimens prepared for guidance in the various cases which could occur. The large letters of the titles have always been deemed the least satisfactory of these results.

The proofs, during the progress of a plate, are of great importance in regulating its style of work, and in preparing corrections and additions. The files of these, kept in the engraving division, make a complete exhibit of the progress of each plate, and contain much of the original matter. On the quarterly files of proofs is recorded a full statement of the work during the quarter on each plate, by whom done, how applied, its cost and character. A ledger-book of plates, some few gaps excepted, gives the detailed history of each plate. Much material has accumulated, showing the cost of each kind of work on different scales, which is used as a basis for estimates in making contracts. It is highly desirable to give greater accuracy and compass to these analyses of cost; but this can only be done satisfactorily by giving special attention to the subject during a considerable period, in which a steady and laborious administration of the division shall prevail. The daily reports of occupation, the monthly reports and projects of the division, the quarterly files, report, and project, and the yearly report and project, form the chief administrative papers, and, with the vouchers for payments, are duly filed. Files of business letters, standing orders, map projects, and cases of the materials and instruments used by the engravers, are kept in the division chief's room. The charge of papers, the preparation and distribution of work, the inspection of it when done, its verification, the preparation of pay vouchers, the charge of apprentices, the study of and reports on subjects relating to engraving, and the division operations—these duties exact close and vigorous application from the head of this important division. To make each engraver's work tell to the utmost, to bring forward the apprentices well and judiciously, to judge character and capacities aright, to be alert for what is new and well-versed in what is old, are among the difficult requisites appertaining to this position.

A detailed *technical* consideration of the several styles and processes of engraving would require too great an extension of this report, and is moreover quite unnecessary, as full information thereon can be found in various treatises on the arts in several encyclopedias, and especially in Perrot's excellent *Manual du Graveur*, in the *Roret* series. The technical details will also be found to constitute the portion of knowledge which is most especially the common stock among intelligent engravers. In the Coast Survey Office no use has yet been made of wood engraving, mezzotint, chalk engraving, engraving in colors, zincography or steel engraving, and the use of lithography has been restricted chiefly to the annual report sketches. Wood engraving is not likely to be resorted to unless it be for some mechanical drawings in the report, for which it may prove useful, as a means of economy, in printing large editions without transfers on stone. As woodcuts work with the letter-press directly, they should, when equally appropriate, be used for large editions in preference to any basso style of printing. Mezzotint is quite impossible in the office so long as the present topographical system prevails. Aquatint has only been used in a single instance, partly because aquatint is wholly unfit for transfers on stone. It is not likely to be of service so long as copper-plates are used, as it gives too few impressions. Should hill shading ever be tried instead of hachures, this process would deserve cultivation, for analogous cases of its successful use are frequent in physical geography. It is my impression that it has been tried for hill shading in the ordnance survey office, at the time when the medal ruling-machine was made to engrave hill models, and other topographical experiments were undertaken. There is in the West Point library an extensive atlas, in which the hills are shaded, I presume, with lithographic crayons. Chalk engraving, engraving in colors, the Baxter process, zylography, the cerographic process, the anastatic process, chromolithography, lithographic crayon, or two crayons, and many more processes, which are useful in their own spheres, are in nowise likely to become of service in the Coast Survey Office. Zincography, as it now exists in this country, is entirely too coarse for office use; but in France it stands much higher, and I have been told that original drawings are transferred to zinc with great success in Prussia. Lithographic autography is not, however, in such a condition in this country as to make resort to it advisable. For engraving in relief, wood, zinc, lithographic stone, copper, and steel, have been used with various degrees of success; boxwood being far the most employed. The material used at the Smithsonian Institution for stereotyping seems to possess some remarkable capacities for this purpose, if I may judge from some sketches of promising aspect thus produced. Relief engraving is certainly of far greater prospective value than depressed or basso engraving, because of its indefinite capacity of being cheaply printed on the power-press, as is well illustrated by the 135,000 impressions regularly worked from the pages of Harper's Magazine. Each page of this publication is electrotyped, a copper film coating type and woodcuts alike, and type metal is melted into the back of the copper shell to give it the required thickness: thus both woodcuts and type are converted into a relief copper-plate, from which the prints are worked off. For office purposes, none of the relief printing processes seem yet to be applicable, though it is possible they may be so in the future. Whether it will in any case be advisable to have engraving done on stone for the office can scarcely now be asserted; for while work can be done on stone in a passable style, it is not now customary so to do it, and hence it would now be inexpedient to try engraving on stone, except it be for work on a larger scale than is customary in the office, or economical in the printing. I have elsewhere treated the subject of lithographic transfers. (Coast Survey Report, 1853.)

A question of considerable importance is sometimes raised, relative to the substitution of steel for copper plates in the office engraving. The advantages of such a change would be an increased durability of the plates, and a saving of electrotype duplication; the disadvantages, greater cost in the first instance, and less facility for erasures. Though the cost of engraving a subject in steel with the graver and dry-point certainly exceeds that of doing the same on copper by a very essential fraction, this fraction seems to be a progressively diminishing one, and so far as etching is concerned, has no existence. But the great mass of the work now done on the office plates is done with the tools, and etching has led only a precarious existence there. It has only been used for the views and reconnaissance topography, many of the views even not having been etched. The introduction of steel would naturally bring with it a great increase of etching; but still the graver would have much to do in finishing and harmonizing the etched work. The avoidance of electrotype duplication would, it seems to me, be a very questionable advantage; for without it the original plates can never be sufficiently safe against accidents. Even with steel plates, duplication would appear essential for security. Again it would be in practice a serious drawback that steel is less fitted for erasure and beating up, since a very great amount of erasure is now required by errors and revisions of field and office work, and by new data and surveys. On the whole, the objections to a change from copper to steel seems quite to outweigh its advantages, aside from all consideration of the temporary inconveniences incident to such a step.

Stippling, as generally understood, can scarcely be said to form a part of the office-work, though this includes a remarkably great amount of sanding, which is in fact a peculiar stippling. Although generally done with the tool, it is in some cases etched, and this, too, with fine effect. Whether the office sanding could not be done, at least in part, by other and more advantageous means than those now employed, is a question well worthy to be entertained. So great is its amount that improvement here would tell largely on the general style and economy of engraving. The roulette style of work seems to me worthy a rigorous and impartial trial, with a view to test its adaptedness for chart sanding; at least that of the lower style, such as is used in the sketches. The French have long used the roulette for the delicate species of work in imitation of crayon drawing, for which the full set of roulettes used amounts to about forty. Stippling with the graver and dry-point has, in the hands of Ryland and other English artists, achieved such success, that it seems but a reasonable anticipation to expect from the roulette a satisfactory and economical style of sanding, which can also be printed by transfer. It is an instrument requiring skill in its use to insure success; but, fortunately, Mr. Dougal, of Washington, possesses this essential to a degree indicating him as one fit to try such an experiment.

The graver, the dry-point, and the etching-needle are so familiar to all who are conversant with engraving, and are used in the office in modes so little peculiar, as to demand no special notice. I might remark that the etching topography of McCoy has sometimes made me call in question the preponderance of graver and dry-point work; but the exquisite hill work of Siebert is always a powerful vindicator of the cutting-tools. Yet there is a freedom of movement in the etching-needle which nothing else can give, and which bears one back in thought to Albert Durer, Rembrant, Van Dyck, and Salvator Rosa, fluently expressing the noble conceptions of genius through this humble but honored medium.

Permanently to maintain the engraving division in a state of healthy and progressive action, demands an earnest care and solicitude respecting the education of those composing it. Even the most proficient have need to be constantly advancing themselves in their knowledge and practice of this art, so narrow as a mere handicraft, but so boundless in its capacities and relations. As the older engravers pass from the stage, the younger ones must rise to their places and achieve an equal proficiency. But merely to remain stationary is not enough in this case; progress is needed from year to year, and progress can only come as a reward for well-directed efforts. It is only by superior education, concurring with favoring opportunities, that a steady, forward impulse can be communicated to an art peculiarly prone to inertness. The apprentices must be formed by appropriate educational appliances to that mature and living mastery of their vocation which we see exemplified in those now grown veterans in its exercise. Natural capacities must exist to be trained, and deliberate means must second nature, as preliminaries to any good result. Not alone by slight-of-hand, or the soulless dexterities of long practice, can an apprentice become a true engraver; but a full comprehension of the means, scope, and spirit of his art must go before success. A taste chastened and matured, an eye trained and sensitive, a zeal earnest and not purely mercenary, a mind active and observant, a culture liberal and appropriate, a patient and industrious schooling in practice, and, above all, high-toned character: these are among the elements which need to concur in an apprentice who is to rise into the first rank of engravers, and give new development to the resources of his profession. To continue importing all the best office engravers from Europe is a very unsatisfactory policy; to procure men trained to the higher styles of office-work from the workshops of our country is now impossible, and it only remains to form apprentices by such an education as shall give their natural talents the desired direction and unfolding. Here is no place to discuss the special means of culture most proper to this end, or whether the present methods are the best. Suffice it now to indicate the absolute importance of giving to them the utmost attainable efficiency.

The introduction of apprentices into the office seems to have resulted from some such reflection on your part in 1845, when Messrs. Ruth and Petit were first thus employed.

To forecast *the future of engraving*, and especially that of maps, is neither imperative nor possible. It is well, however, clearly to realize that such a future is coming, and that it can scarcely be a reproduction of the present.

Maso Finiguerra gave definite form to his discovery of printing from plate engravings in the middle of the fifteenth century. Since then many minds of excellent capacity, and not a few of exalted genius, have expended their earnest efforts in the practice and promotion of etching and tool engraving. Yet this four hundred years of labor and hope, left to the last few years manifold discoveries in this very field. Perkins, of Boston, who made steel engraving a possible art, died hardly two years since, and wood engraving owes to an American of this century the introduction of boxwood, and its consequent astonishing expansion. Scientific topography has no splendid antique heraldry, but its pedigree embraces the rude scrawls of the savage in the sand, the strange caricatures of the old geographers, the charts of Mercator, the Atlas Homanni, the maps of Tardieu, Cassini, Arrowsmith, &c., not to dwell on the woodcut maps of the Chinese, older and more self-conceited than all. From these there has, during the last half century, been a rapid progress to the contoured and hachured maps of the various national trigonometrical surveys still advancing. The rude, fantastic, grossly erroneous configuration, the silent blankness, the absurd *papillæ* mountain ranges, the set wrigglings of rivers, the giant forests stocked with visible lions and alligators, the huge *terræ incognitæ,* and the high-wrought illuminations on corners and margins: these all belong to a historic yesterday, and linger on maps of our own country, published long subsequent to the dawn of our nationality.

When we inspect a finished Coast Survey map, it is quite impossible that we should bear in mind through what a singular chain of progression, through what slow and laborious dawnings of truths now elementary and seemingly self-evident, through what difficulties of the engraving art, and what absurdities, incongruities, and incapacities of delineation, the laborious product of to-day has descended from the uncouth handicraft of Munster, Ortelius, Meyer, and Mercator. Ere another century shall have passed, some critic of antiquarian bias may possibly comment on the Coast Survey Eastern Series, on comparing it with a corresponding issue of his own day, as we now do on comparing the old and new maps of Switzerland, or the Cassini and *Depôt de la Guerre* maps of France. New arts of engraving may so expand the present possibilities in map production, that genius, glorying in its new enlargement, shall outdo immeasurably its own antecedents. Why may not such anticipations find their realization here, in the country, of all, grandest in its geography and most inventive in its capacity? Why not, possibly, in the progress of this very survey, which has already done its part towards this end, directly by fostering topographical skill, and indirectly by its electrotype discoveries, which have diffused the cost of engraving over an indefinite number of unimpaired impressions?

One needs but to observe the intense activity of investigation and invention now at work on engraving and printing processes, and to recall the vast contributions of resource which science has of late bestowed towards their ends, to be assured that many new arts of pictorial reproduction will soon be busily promoting the public good. The name of Daguerre still lingers in our ears as almost that of a living man. Yet, well nigh in every town, in every city-street, are daguerreotype saloons, and scarcely a family is without its invaluable store of daguerreotypes. Photography has grown into a science, and has its treatises and journals, which are constantly teeming with new processes. The younger Niepce, not content with reflected honors, in 1847 announced a process for making drawings engrave themselves. Probably heliographic engraving owes its origin to him, and his process has given ample promise of success, as was placed in evidence before your eyes by a print which the distinguished inventor furnished, over a year since, to the Scientific American. The names of Donne, Talbot, and Claudet, are already associated with processes of this nature, and many other less prominent investigators have also borne part. It is announced in Moigno's Cosmos of May 26, 1854, that Baldus has completely succeeded in a new and easy process of heliographic engraving. A photograph of any subject is taken and made to engrave itself by the action of light; the details are not given. The time is teeming with such announcements. Fortunately, Mr. Mathiot, no remiss sentinel, is on the lookout for all such prizes, being himself in the full tide of like experiments, and destined, I trust, to complete success. What he has already done gives assurance that he will bear an honored part in the great revolution of art which seems to be portending. Whether when heliography becomes an established art, the engravers will find their occupation gone, is an inquiry which can safely be postponed until they are in less active demand that at present.

A few years since, anastatic printing was much discussed, and fears of counterfeits only kept pace with the expectations of very cheap *fac simile* reprints from all old and new books. The hopes, fears, and excitement, almost the name, have died away. It remains a fact, however, that Appleton, of New York, is now extensively re-printing large line engravings from English and other foreign proofs without re-engraving; and though the re-prints are inferior in quality, they still have an essential fidelity. Scarcely a week since, a new process or art, called homœography, was heralded, claiming to be a revolution as sweeping as anastatic printing was to have been; and for this art the world is indebted to M. Boyer, a French chemist. It stereotypes by producing re-prints from stone cheaply and quickly.

It duplicates engraved prints with entire facility, and promises vastly. Probably it will perform something, and in some way become really useful. It is quite certain that books cannot be re-printed from stone cheaply in considerable editions. Engraved prints can now be re-produced and multiplied in various mechanical ways and without re-engraving. What is to come is beyond conjecture, but I do not believe the electrotype art of renewing plates will soon be superseded.

I cannot here omit to mention the strikingly beautiful results afforded by a process, some two years old, called "nature printing." Such perfect and delicate rendering of leaves in their details of frame-work and veinings, as this process gives for those of appropriate texture, I have never before seen. By a strong pressure the leaf is rolled into a soft metal plate, and thus imprints or fossilizes itself. From this plate impressions are obtained, which, when well colored, rival even the exquisite photographs of natural history specimens lately published in Paris by Blanquart Evrard. The photographs and nature prints are sold at rates not higher than corresponding prints of other kinds, if such there be. Subjects like Algæ, (Smithsonian Contributions, Harvey,) if sufficiently firm, would, I presume, find nature printing their best interpreter, as, in the Paris photographs, the Crustacea of the Museum have lost nothing in fidelity and gained much in beauty.

It is not alone from new engraving processes, a few only of which I have now mentioned, that the style of maps may be expected to undergo change. It is by no means certain that the prevailing system of topography will be immortal. This subject would hardly belong in a report on engraving, were it not that the powers of the engraving arts enter as a most essential element in fixing the system of topography. The method of hachures has some radical faults, which make its perpetuity only desirable in case nothing better can be substituted. The extent to which it sacrifices the distinctness of the contour lines will, as contours become more universal in surveys, be felt as a growing objection. When the engineer needs to use the horizontal curves of a locality, he will most emphatically prefer a system which gives them plainly, to this system of hachures, among which the tracing of contours is a task always troublesome and never quite certain in its results. Hachure engraving is so expensive that a cheaper substitute is quite desirable. It seems by no means impossible that ere long some cheap, clear, expressive and tasteful system of hill delineation may supersede hachures with great advantage. There are now at the Crystal Palace, New York, specimens of topography by Mr. James Duncan, England, in a style which he calls *triotinto*, and in which the hill problem seems to be well apprehended. The contours are drawn in a clear delicate line, very similar to that of the medal ruling-machine. These, alone, would give a very satisfactory relief to the hills, as was well known from the experiments on that style, except in the liability to an entire inversion of elevations and depressions, and in a certain hardness of look. But in the specimens referred to, shading under an oblique light is used to add to the relief, and it also gives softness and pictorial expression. This shading is executed by some means undescribed, but which seems to be the roulette or stippling. The specimens are evidently early attempts in a new style, but experience would undoubtedly so far improve the execution exhibited, as to bring the results at last fully to equal or excel the best hachured work. The indications of woods, houses, &c., rest on the stippled ground with no less distinctness than on hachures. It is possible that even aquatint shades on full contours might be advantageously resorted to. This subject is one of leading importance; and sudden changes, for reasons not thoroughly considered, ought strongly to be resisted. But something better than Lehman's system, or any modification of it, seems abstractly very possible, and is being daily rendered more possible in practice by the progress of engraving arts. The combination of contours and dot hill-shading may or may not be a better system. It is not amiss to canvass closely all such ideas and processes; for if improvement is to come, with its sequences of superior results and economical practice, it must be by full, fair, hopeful, and thoroughly critical trial of well-considered candidate systems.

This report is but an imperfect and fragmentary exhibit of a subject not less interesting than extensive. The pictorial arts are among the most powerful ministers to human enjoyment and instruction, and have even now attained a wondrous multiplicity of power and form. What the printing-press does for the written idea, engraving art does for the formal and pictorial. In view of the fruitfulness in contributions, especially to photographic and printing processes, which each passing year displays, hope becomes the mandate of inductive reason.

I have the honor to be, very truly, yours, &c.,

E. B. HUNT,
Lieut. Corps of Engineers, Assist. U. S. C. S.

Professor A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 58.

Letter from F. M. W. Thacher, Esq., and others, of Edgartown, Massachusetts, to Lieut. Comg. H. S. Stellwagen, U. S. Navy, assistant in the Coast Survey, acknowledging the efficient aid rendered by the officers and crew of the steamer Bibb in relieving the brig B. M. Prescott.

EDGARTOWN, *September* 16, 1854.

SIR: We desire to make our warm acknowledgments for the efficient aid rendered by you and the officers and crew of the U. S. steamer Bibb, under your command, in relieving from her perilous situation on Cape Poge, and in bringing safely into this port in tow of the steamer, the brig B. M. Prescott.

In making this acknowledgment, alike due to your courtesy and promptness, we take great pleasure, and, as an act of simple justice, request you to transmit a copy of this communication to the department.

With much consideration, we are your very obedient servants,

F. M. W. THACHER,
Special Agent, and in behalf of Philadelphia underwriters and insurers of cargo.
ABRAHAM OSBORNE,
Agent New York and Boston Insurance Companies.
Captain JAMES C. HIPSON.

H. S. STELLWAGEN, Esq.,
Lieut. Comg. U. S. Steamer Bibb.

APPENDIX No. 59.

Extracts from letters of Assistant F. H. Gerdes to the Superintendent, in relation to the stranding of the schooner "Gerdes," in a hurricane near Fourchon Pass, Gulf of Mexico, on the night of March 30, 1854.

APRIL 7, 1854.

DEAR SIR: Mr. Oltmanns, who had come up in a lugger, reported, immediately on my arrival, that the "*Gerdes*" struck during a sweeping hurricane from the south and south-east, in the night, between the 30th and 31st of March, on the coast east of Bayou Lafourche. * * * * * * * * *

I started immediately in an open boat by way of Isle Dernière, and reached the schooner just in time to assist in the final arrangements for her present safety.

The instruments, charts, and journals, had been safely landed and secured under the direction of Mr. Oltmanns, on the morning of the 31st. All the chronometers, however, had lost their rate.

A short time previous I had directed sailingmaster McNeil, an able and experienced seaman and navigator, to take the "*Gerdes*" from Mississippi sound to Atchafalaya bay, and to await me at Point au Fer. I was meanwhile engaged in a reconnaissance of certain parts of the interior, not included in last season's work.

From his report and concurrent information, it appears that the vessel left Mississippi sound on the 29th of March, and on the following morning, off Pass à Loutre, encountered a strong gale which carried away her main gaff; that at 5 p. m. she made the Southwest Pass, bearing north, distant five miles. The weather being then moderate, her course was laid, steering west by south, for Ship Island channel, so as to give the land a berth of twenty miles. At 8 o'clock it commenced to blow strongly from SE. and E., and the night was so dark that the main-mast could not be seen from the wheel. At 11.30 p. m., by a flash of lightning, breakers were seen close under her lee, and before the helm was fairly down she had struck with tremendous force, and the sea commenced washing over her some ten feet high. The spoon-drift at the same time prevented all sight or hearing; within three hours a current quite contrary to the ordinary direction had swept the vessel from her course, *the whole distance of her offing*. At daylight she was found to be nearly a mile west of Fourchon Pass, close to the beach, with only six inches of water under her bows and four feet astern.

I attach no blame whatever to the party in charge of the vessel at the time of this disaster, she being on her proper course and carrying such sail as could be brought to bear; moreover, the soundings taken were nearly all of the same character. The entire darkness and the impossibility of hearing the breaking of the sea against the wind, in connection with the sudden and powerful counteraction of current, satisfy me that no agencies not actually brought into requisition could have availed for avoiding the disaster.

After discharging all the ballast, water-casks, provisions, and, in short, everything movable, the schooner was finally relieved from her perilous condition, but with the loss of boat, swept from its lashings on deck, the anchors, both quarter-deck stern-houses, part of starboard rail, and rudder.

Sailingmaster McNeil having shipped a temporary rudder, succeeded in passing the schooner without injury over the second bar, on which was found only three feet of water. She was safely anchored in the Bayou on the 15th of April.

At the scene of the disaster the Captain of the Racoon Point light-ship was detained four days by the weather, and rendered us all the assistance in his power. He deserves much credit for his kindness and good will.

Very respectfully, your most obedient servant,

F. H. GERDES.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 60.

Letter from Assistant George Davidson, relative to the wrecking on the bar of Tomales bay, California, of the vessel carrying instruments and camp equipage in charge of Sub-Assistant James S. Lawson.

SAN FRANCISCO, CAL., *December* 15, 1853.

DEAR SIR: I have just received a letter from Mr. Lawson, per express from Tomales bay, in which he tells me of the wreck on the bar of the bay of the vessel upon which the party went up. With the whale-boat, and by the exertions of the party, he succeeded in first saving all the instruments, and then most of the camp equipage and stores. The vessel went to pieces in a few hours.

He launched his boat in the middle of the breakers on the bar, and made three or four trips to the vessel through them. At the last one, the vessel rolled over and carried the whale-boat and all in it under, but, most unaccountably, the crew escaped.

The foresight, activity, and fearlessness of Mr. Lawson, deserve the highest praise. He is now at work.

Very respectfully, yours,

GEORGE DAVIDSON.

Professor A. D. BACHE,
Superintendent Coast Survey.

APPENDIX No. 61.

Letter from Lieut. Comg. James Alden, U. S. Navy, assistant in the Coast Survey, detailing the search made, at the request of the owner, for the steamer Sea Bird, disabled near Point Año Nuevo, by an accident to her machinery.

U. S. SURVEYING STEAMER ACTIVE,
San Francisco, May 16, 1854.

DEAR SIR: I have respectfully to report that we have just returned to this anchorage, after an anxious, but, I am happy to say, a successful search for the steamer Sea Bird. Her machinery it appears broke down on the 7th instant near Point Año Nuevo, rendering her entirely unmanageable; the same day a boat landed from her at Monterey, with a messenger who travelled overland to San José, and from thence telegraphed the information to this place, which was received on the morning of the 8th, the day after the accident, stating also that she required immediate assistance; whereupon her owner, Capt. Wright, called upon me, and stated that he had used every exertion to obtain a steamer to go after her, but that the delay in getting one ready he feared would be fatal to the Sea Bird; I of course consented to go, and at meridian, in less than two hours from the time the news reached me, we were outside of the heads. The same evening at 8 o'clock we arrived at Monterey, and the next day, Tuesday, continued the search as far south as San Simeon, where it was thought she would certainly be found. After remaining at that point all night, during which time we communicated with San Luis Obispo, (which is some thirty-five miles further to leeward) by an overland messenger, I concluded we must have passed the object of our search on our way down, and determined to retrace our steps. The weather was clear and pleasant, but we returned to Monterey with no tidings of the missing vessel. Here we were told that she had on board at least one hundred souls, including passengers and crew; and this information, although it could not stimulate us to any greater exertion for their rescue than had already been put forth, decided me not to give up the search while the least hope remained; so, with but little delay at Monterey, we again turned our course to the south, and on Friday, the 12th instant, we discovered the object of our search at anchor under Point Conception, in an indentation of the coast, near a small place called on the charts "Coxo," which she had managed to reach after great risk and exertion, by drifting and sailing for the most part *stern* foremost, as it was found almost impossible to get her before the wind. She had drifted two hundred miles during the time we were looking for her. The damage to her machinery was occasioned by the breaking of the strap which confines the piston-rod to the cross-head, the piston coming down with force enough to crush the lower part of the cylinder. We found the vessel tight and stanch; and no one being inclined to leave her, at 11 o'clock the same evening we took her in tow, and reached this place without accident this morning, stopping at San Luis Obispo six hours, in a blow, and as many hours at Monterey for fuel on our way up.

With great respect, I am, very truly, your obedient servant,

JAMES ALDEN,
Lieut. Comg. U. S. N., Assistant U. S. Coast Survey.

Professer A. D. BACHE,
Superintendent U. S. Coast Survey, Washington.

APPENDIX No. 62.

Letter from the Superintendent to Commodore Joseph Smith, U. S. N., chief of Bureau of Yards and Docks, transmitting the acknowledgments of Lieut. Comg. James Alden, U. S. N., assistant in the Coast Survey, for facilities afforded in docking the surveying steamer "Active" at the dry dock in California.

COAST SURVEY OFFICE, *January* 12, 1854.

SIR: I have the pleasure to enclose, herewith, a communication addressed to yourself from Lieut. Comg. James Alden, U. S. N., assistant in the Coast Survey, in acknowledgment of the politeness and facilities afforded him by Mr. Dean, and others, connected with the dry dock in California, in docking the U. S. surveying steamer Active, under his command.

In forwarding the enclosed, I would take the opportunity to add my own to the acknowledgments of Lieut. Comg. Alden.

Very respectfully, yours, &c.,

A. D. BACHE, *Superintendent.*

Com. JOSEPH SMITH, U. S. N.,
Bureau of Navy Yards and Docks.

U. S. SURVEYING STEAMER ACTIVE, BENICIA, *December* 15, 1853.

DEAR SIR: In the performance of an agreeable duty, I would beg leave, through you, to tender my acknowledgments to Mr. Dean, the agent, and to those gentlemen connected with him here, at the dry dock, for their polite attention, and facilities afforded us in docking this vessel. She was taken out of the water and put in again without the slightest accident, everything working to a charm.

I examined, with much pleasure, the whole work, and it appears to have been done in a thorough, substantial, workmanlike manner, reflecting great credit upon every one who has had anything to do with it.

The building of that noble structure by the general government, and the wise arrangement that makes it open to all, must, I am sure, be appreciated by every one interested in the commercial prosperity of this flourishing State.

With great respect, I am your obedient servant,

JAMES ALDEN,
Lieut. Comg. U. S. N.

Com. JOSEPH SMITH, U. S. N.,
Chief of Bureau of Yards and Docks, Washington.

APPENDIX No. 63.

Recommendations in regard to Aids to Navigation made in reports to the Superintendent.

Section.	Object.	By whom recommended.	Date of report, &c.
I.	Buoy on the sunken ledge, near Hog island, Eggemoggin reach, Maine.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported October 28, 1854. Referred to Light-house Board November 4, 1854.
	Buoy to mark the Half-tide ledge, near Eggemoggin reach, Maine.	Lieut Comg. T. A. Craven, U. S. N., assistant.	Reported October 28, 1854. Referred to Light-house Board November 4, 1854.
	Buoy to mark a rock half a mile southeast of Fisherman's ledge, near Kennebunk pier-head, Maine.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported October 28, 1854. Referred to Light-house Board February 22, 1855.
	Light to be discontinued at Dice's Head, coast of Maine.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported October 28, 1854. Referred to Light house Board November 4, 1854.
	Light-boat and fog-bell on Alden's reef, Portland harbor, Maine.	Lieut. Comg. M. Woodhull, U. S. N., assistant.	Reported January 17, 1854. Referred to Light-house Board January 18, 1854.
	Buoy on Davis' ledge, near Minot's, entrance to Boston harbor.	Commander C. H. Davis, U. S. N., late hydrographic chief U. S. Coast Survey.	Referred to Light-house Board November 10, 1854.
	Pier on ledge near Annisquam harbor, Mass., and beacon at outer extremity.	Lieut. Comg. M. Woodhull, U. S. N., assistant.	Reported January 6, 1854.
	Positions for buoys in Nantucket sound.	Lieut. Comg. M. Woodhull, U. S. N., assistant.	Marked on chart accompanying report made October 18, 1854.
	Positions of buoy-boats on Nantucket shoals, and north end of Great Rip.	Lieut. Comg. H. S. Stellwagen, U. S. N , assistant.	Reported May 15, 1854.

Recommendations in regard to Aids to Navigation—Continued.

Section.	Object.	By whom recommended.	Date of report, &c.
II.	Additional beacon on Romer shoal, entrance to New York harbor.	Lieut. Comg. M. Woodhull, U. S. N., assistant.	Referred to Light-house Board January 14, 1854.
VI.	A third-class light at Indian River inlet, coast of Florida.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported October 11, 1854. Referred to Light-house Board October 14, 1854.
	A third-class light in latitude 26° 45′ E., coast of Florida, south of Jupiter inlet.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported October 11, 1854. Referred to Light-house Board October 14, 1854.
	Screw-pile beacon and two buoys at entrance to Turtle harbor, Florida reef.	Lieut. Comg. T. A. Craven, U. S. N., assistant.	Reported September 20, 1854. Referred to Light-house Board September 26, 1854.
VIII.	Light at east side of entrance to Fourchon Pass, Louisiana.	Assistant F. H. Gerdes	Reported July 1, 1854.
IX.	Landmarks on Padre island, coast of Texas.	Assistant W. E. Greenwell...	Reported June 21, 1854.
X. XI.	Año Nuevo and Santa Cruz, California, examined for light-house site.	Lieutenants Comg. Jas. Alden and T. H. Stevens, U. S. N., and assistant A. M. Harrison.	Referred to Light-house Board January 17, and February 16, 1854
	Anacapa examined for light-house site.	Lieut. Comg. T. H. Stevens, U. S. N., assistant.	Reported September 21, 1854. Referred to Light-house Board November 1, 1854.

APPENDIX No. 64.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, transmitting report of Lieut. Comg. M. Woodhull, U. S. N., assistant in the Coast Survey, in reference to the location of a light-boat and fog-bell in the vicinity of Alden's reef, Portland harbor, Maine.

COAST SURVEY OFFICE, *January* 18, 1854.

SIR: I have the honor to transmit, herewith, a report from Lieut. Comg. M. Woodhull, U. S. N., assistant in the Coast Survey, upon the result of his survey of Alden's reef, Portland harbor, Maine, and recommending as a guard against this, and other reefs in its vicinity, the location of a light-boat, provided with a fog-bell to warn vessels in foggy weather, when the light cannot be seen.

I concur in the recommendations of Lieut. Comg. Woodhull, made in the enclosed report, and would respectfully request that it be forwarded, for their consideration, to the Light-house Board.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE, *Secretary of the Treasury.*

COAST SURVEY OFFICE, WASHINGTON, *January* 17, 1854.

DEAR SIR: I have received your letter of January 13, making certain inquiries, for the use of the "Light-house Board," in relation to Alden's reef, off Portland harbor, to which I have the honor, herewith, to reply.

The position of the reef is as follows: It lies about N. E. and S. W., and by compass the north light on Cape Elizabeth bears from it N. W. by W., distant three miles; barn on Richmond's island W., distant four miles and a half; Portland light N. N. W. ¼ W., distant six miles and a quarter; Wood Island light S. W. by W. ¼ W., distant about fourteen miles.

The reef, as near as I can judge by my measurements, is about nine hundred and fifty feet long, and two hundred and fifty feet in width. Its shoalest part is on the west side, and through its centre from north to south the water is quite deep; which circumstance doubtless gave rise to the belief that there were *two* distinct rocks or ledges. which supposition, I think, is entirely disproved by my recent survey. The rock, as it is called, but which, more properly, should be considered a reef, is of immense dimensions, extremely irregular in form, having shoal projections on it from four and a half feet to twenty-four feet, low water. I discovered but one nubble with four and a half feet water on it, one with six feet, several with eight feet, and a very considerable number of shoal spots with eleven, twelve, thirteen, fourteen, fifteen, &c., feet, (all estimated at low water.)

The reef lies immediately in the way of all navigation, and particularly of vessels bound for the westward, or of those coming from the harbor of refuge at Richmond's island. I consider this "the great danger," in approaching Portland harbor; and the *key* to the lesser ones of the "Hue and Cry," "Old Anthony," and "Taylor's" reefs. It is the cause of much anxiety and care to the navigator; and one that is avoided with the greatest difficulty in thick weather, and during the prevalence of the terrible easterly storms, by which the coast of Maine is so frequently visited.

Portland is fast becoming, through the enterprise and intelligence of its "commercial men," a port of the first importance to the United States. There has already been established a line of steamers between it and Liverpool, and other lines of steamers communicating with foreign ports are projected. The exports and imports are large and daily increasing, and everything is tending to cause it to be, at no very distant day, the third, if not the second, commercial emporium of the country. The harbor is second to none I am acquainted with, for safety, capacity, depth of water, and facility for ingress and egress; and there is none, I believe, that has received so little aid from the government, towards its improvement, guides to navigation, &c.

I have given my especial attention to the best method of providing some guard for Alden's reef, and the neighboring reefs. I have considered fully all the plans now in use, and have arrived at the opinion that the cheapest, and most efficient, would be a "light-ship," moored near the south side of the rock: the vessel to be provided with a good "bell," to be used in thick weather; a bell that could be heard at a distance of four miles would be a timely notice to the navigator of his locality. I would reccommend, in connection with this matter, that the bell now at Cape Elizabeth be replaced by a steam-whistle, to guard against confounding it and the bell at the light-ship. If this arrangement is approved and carried out, the navigator would, in all phases of the weather, be instantly and truly informed of his position, and thereby be enabled to avoid, with certainty, all danger.

As I have been asked the question whether a beacon would answer the purpose required, I would state, as my decided opinion, that a beacon would answer but indifferently, as it would only be a guide during day-light and clear weather, for which the less expensive "spar-buoy" would answer equally well and be of as little use during thick weather. I may be mistaken in my judgment, but I have endeavored candidly to state my convictions, and therefore recommend that a light-ship be placed at or near Alden's reef, as the best, cheapest, and most efficient aid that could be rendered under the peculiar circumstances of the case.

All of which is respectfully submitted by yours, truly, &c.,

M. WOODHULL,
Lieut. Comg., and Assistant U. S. Coast Survey.

Prof. A. D. Bache,
Superintendent U. S. Coast Survey.

APPENDIX No. 65.

Letter from the Superintendent to the Secretary of the Treasury, in relation to an additional beacon for Romer shoal.

Coast Survey Office,
January 14, 1854.

Sir: I have the honor to transmit, for the information of the Light-house Board, a copy of a re-survey which has been made of Romer shoal, New York harbor, to ascertain if any and what changes had occurred there, and in the vicinity, since the previous survey, and to exhibit precisely the present condition of the shoal, and the Swash channel.

Lieutenant Woodhull, U. S. N., assistant in the Coast Survey, by whom the hydrographic survey was made, reports that there is special necessity for an additional beacon, to be placed at the extreme seaward limit of the shoal, and in the position marked *a* on the chart, in about twenty feet water.

Lieutenant Woodhull calls attention to the fact, that the iron beacon, from its improper location, cannot serve as a guide to vessels either entering or leaving the harbor, and to the absolute necessity for placing the iron beacon exactly where the shoal terminates, notwithstanding the cost which may be incurred by its erection in deep water, and the difficulty of protecting it from the ice.

In these views I concur, and would recommend the construction of a new beacon in the place proposed by Lieutenant Woodhull.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 66.

Letter from the Superintendent to the Secretary of the Treasury, communicating the report of Lieut. T. H. Stevens, U. S. N., assistant in the Coast Survey, upon an examination of the island of Anacapa, California, for the selection of a site for a light-house.

COAST SURVEY STATION, NEAR CAMDEN, ME.,
November 1, 1854.

SIR: I have the honor to transmit, with my approval, a report of Lieut. Comg. T. H. Stevens, assistant in the Coast Survey, on the examination of the site for a light-house on Anacapa island, coast of California, and on the necessity for a light at that point, and would respectfully request that the report and accompanying sketch may be sent to the Light-house Board.

Very respectfully, yours, &c.,

A. D. BACHE, *Superintendent.*

Hon. P. G. WASHINGTON,
Acting Secretary of the Treasury.

SAN FRANCISCO, CAL., *September* 21, 1854.

SIR: I have to report that, in compliance with instructions, I have made an examination of the island of Anacapa, with a view to the selection of a site for a light-house, and find that the part of the island suitable for this purpose, being the eastern portion, is a mass of rock of volcanic formation, about ninety feet in height, perpendicular on every face, and with an ascent inaccessible by any natural means.

The island of Anacapa, so called, is composed of three parts, connected by a broken reef of rocks, the eastern portion being the most northern; the whole approaching the form of a crescent. The best anchorage is off the east end of the middle part, near the wreck of the Winfield Scott, in eleven fathoms water, an eighth of a mile from the shore. The water is bold on every side of the island, increasing rapidly in depth, so that a quarter of a mile from shore you run into twenty fathoms. The bottom is hard, and mixed with sand and corals.

Considering the location of a light-house at this point as impracticable without very great expense, which the interests of commerce do not now demand, for the reason that the coasting trade always keeps the main land aboard, and that the ocean steamers use altogether the passage between Santa Cruz and Santa Rosa, both in going and coming, I would respectfully report against the establishment of a light at this point, which could not be erected without a great outlay of means, and could not be kept going unless at considerable expense, as the island is destitute of wood, water, or even sufficient arable land for the support of a single family.

The loss of the "Scott," which first seems to have attracted attention to this point as a necessary one for the establishment of a light, was one of those unaccountable accidents which sometimes befal the most capable officers; but as the line of steamers to which she belonged now use a different route, and as they are the only ones that could be benefited, the necessity for its erection no longer exists.

I enclose, herewith, a sketch of the island, drawn by Mr. McMurtrie.

Respectfully, yours,

T. H. STEVENS,
Lieut. Comg. U. S. S. Schooner Ewing.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 67.

Letters from the Superintendent to the Secretary of the Treasury, communicating the results of examinations made by Lieuts. Comg. James Alden and T. H. Stevens, U. S. N., assistants in the Coast Survey, and by Assistant A. M. Harrison, with reference to a light-house at Point Año Nuevo, or at Santa Cruz, California.

COAST SURVEY OFFICE, *January* 17, 1854.

SIR: I have the honor to transmit, herewith, for the Light-house Board, the report of Lieut. Comg. James Alden, U. S. N., assistant in the Coast Survey, upon the examination of Año Nuevo and Santa Cruz, California, with reference to the location of a light-house, made according to request, under the law.

* * * * * * * *

Very respectfully, yours, &c.,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE, *Secretary of the Treasury.*

U. S. SURVEYING STEAMER ACTIVE,
Benicia, December 15, 1853.

DEAR SIR: I send herewith Lieut. Comg. Stevens' report of the work executed by him, and also his report in relation to the light at Año Nuevo.

I concur with him fully in what he says in regard to the necessity of a light at that point rather than at Santa Cruz.

* * * * * * * *

Respectfully, I am, your obedient servant,

JAMES ALDEN,
Lieut. Comg. U. S. N. and Assist. U. S. Coast Survey.

Prof. A. D. BACHE,
Supt. U. S. Coast Survey, Washington, D. C.

U. S. S. SCHOONER EWING, SAN FRANCISCO,
December 10, 1853.

SIR: After examining the two points of Año Nuevo and Santa Cruz, with a view to the selection of a site for a light-house, I have, for several reasons, given the preference to the former as the most important point for this purpose.

In the first place, I consider it, from its character, an extremely dangerous point, and it should, therefore, have a light upon it for the purpose of warning the mariner of approaching danger. It possesses all the requisites, from its proximity to Santa Cruz, for a guide to that harbor; it would prove of advantage to vessels employed in the coasting trade; and as it is frequently the first land made by vessels coming from distant ports, its importance is manifest in this connection. For these reasons, and from the fact that a light-house at Santa Cruz would only serve a local trade, I respectfully recommend the establishment of a light at Año Nuevo as of far greater importance.

In regard to the location of the proposed site at Año Nuevo, I would recommend the island, or sĕn, which consists of a sloping ledge of rocks, covered with a stratum of yellow clay about four feet thick, which is also covered with a mound of sand about thirty feet high, the whole above high water, and rising in the neighborhood of fifty-five feet. For a suitable foundation it would be necessary to remove the sand as deep as to the clay. The island has an area of about a fifty-seventh of a mile, and can be reached from the main shore in moderate weather and at low tide.

The sector of visibility to seaward from this point, exclusive of Monterey bay, is 180°, inclusive 200°. A light-house forty feet high above the surface, erected at Island signal, could be seen at a distance of eighteen nautical miles from a ship's deck, say 13 feet high.

Respectfully, your obedient servant,

T. H. STEVENS, *Lieut. Commanding.*

Lieut. Comg. JAMES ALDEN, U. S. N.,
Chief of the Hydrographic party on the Western coast.

COAST SURVEY OFFICE, *February* 16, 1854.

SIR: I have the honor to transmit, for the Light-house Board, additional information in regard to a light-house near Santa Cruz, California, in a report from Assistant A. M. Harrison, of the Coast Survey, and in two tracings of topographical maps—one of the coast near Santa Cruz, and the other of Point Año Nuevo.

Should the Light-house Board hereafter determine to erect a local light at Santa Cruz, the map will be of service to them in fixing the site.

Mr. Harrison concurs with Lieut. Stevens in recommending the placing of a seacoast light at Año Nuevo—a question, however, which the Board will probably decide from more general considerations in regard to the lighting of the Western coast than have entered into the views of either of these officers. I have abstained, on this account, from expressing concurrence in their recommendation.

When the time may come for placing a light on Año Nuevo, it may be well to consider the reasons assigned by Mr. Harrison for preferring the site marked *a* on his map, to that marked *b* recommended by Lieut. Stevens. In my judgment, however, the advantage of placing the light on the extremity of the point is sufficient to counterbalance the objections stated by Mr. Harrison, and I therefore express a preference for the site recommended by Lieut. Stevens, and marked *b* on Mr. Harrison's map.

Yours, respectfully,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE, *Secretary of the Treasury.*

SANTA CRUZ, CALIFORNIA, *December* 30, 1853.

DEAR SIR: Accompanying this report please find two topographical maps, one of Santa Cruz and one of Point Año Nuevo—scale $\frac{1}{10000}$.

Agreeably to instructions, I have examined and surveyed the coast between the two above-mentioned places, and would recommend Point Año Nuevo as the most suitable site for a light-house.

Should it, however, still be deemed advisable to build the light-house at Santa Cruz, the point marked (*a*) upon the map is the one recommended. It has as a foundation a substratum of hard rock, covered for several feet with firm earth. It is thirty feet in height, and the light from a lantern forty feet high, placed there, could be seen at a distance of fifteen and two-tenths statute miles from a ship's deck, say ten feet high. The sector of visibility to seaward from this position, exclusive of Monterey bay, would be about 130°;

inclusive, 200°. But it is my opinion that Point Año Nuevo possesses all the requisites as a site for a guide to Santa Cruz harbor, and would also prove of advantage to vessels in the coasting trade. This point once made, it becomes a matter of little difficulty to reach Santa Cruz; and vessels from the northward, bound to Monterey, and even up and down the coast, would find a light here very serviceable, while one at Point Santa Cruz would avail them but little, if any at all.

It is also, sometimes, the point first made by vessels from distant ports bound to San Francisco; and when this occurs at night, a light would be very useful. Respecting the exact location of the proposed site upon Point Año Nuevo, the two positions (*a*), (*b*), marked upon the map are submitted, although the point marked (*a*) is the one I deem preferable; (*b*) is located upon a small island, and the only advantage to be obtained here is the greater angle of visibility it commands to seaward.

The island consists of a sloping ledge of rocks, covered with a stratum of yellow clay, about four feet thick, which is also covered with a mound of sand about thirty feet high, the whole above high-water mark being in the neighborhood of fifty-five feet. For a suitable foundation, it would of course be necessary to remove the sand at least as far as the clay. The island has an area of about the $\frac{1}{57}$th part of a square mile, and cannot be reached from the main shore except at low tide, and in calm weather.

We were delayed nearly a week in the month of September, waiting for an opportunity to get upon it, in order to survey it.

In consideration of these facts, I think that the loss in the number of degrees of horizontal visibility which would be commanded by a light placed upon the island, is more than compensated by the increased elevation, firm foundation without removing the earth, and accessibility, at all times, of the position marked (*a*.)

Between this position and the extremity of the point, the ground slopes gradually to the southward for a distance of nine hundred metres, and is then thrown into a succession of rolling hills of shifting sand, varying from twenty to one hundred feet in height.

Point (*a*) is one hundred and six feet high by level. The sector of visibility to seaward from this point, exclusive of Monterey bay, is 155°; inclusive, 168°.

A light-house forty-feet high erected at point (*a*) could be seen at a distance of twenty and one-tenth statute miles from a ship's deck, say ten feet high.

I was assisted in my surveys by Mr. Johnson.

Respectfully submitted:

A. M. HARRISON,
Assistant U. S. Coast Survey.

Professor A. D. Bache,
Superintendent U. S. Coast Survey, Washington, D. C.

APPENDIX No. 68.

Results of examinations for sites of light-houses, beacons, buoys, &c., referred to the Superintendent of the Coast Survey by the Secretary of the Treasury, at the request of the Light-house Board, in accordance with the laws of March 3, 1851, *and August* 31, 1852.

Sect'n.	Locality.	Object.	By whom examined.	Report of Superintendent.
I	Eastern extremity of Eggemoggin Reach, coast of Maine.	Examination and reconnaissance for lt.-house.	Lieut. Comg. Craven	Site on south bluff of Hog island recommended November 4, 1854. (Appendix No. 69.)
	Entrance to thoroughfare at Isle au Haut, Maine.	Examination for light-house.	Lieut. Comg. Craven	Site on dry ledge near Spoon island recommended November 4, 1854.) Appendix No. 69.)
	Southern island, Tenant's harbor, Maine.	Examination for light-house.	Lieut. Comg. Craven	Recommended November 4, 1854. (Appendix No. 69.)
	Noddle's island, entrance to harbor of Castine and Brookville, Maine.	Examination for light-house.	Lieut. Comg. Craven.....	Recommended November 4, 1854. (Appendix No. 69.)

Results of examinations for sites of light-houses, beacons, buoys, &c.—Continued.

Sect'n.	Locality.	Object.	By whom examined.	Report of Superintendent.
I	Dry Point, on Lineken's Neck, Maine.	Examination for light-house.	Lieut. Comg. Craven	Recommended November 4, 1854. (Appendix No. 69.)
	Wood island, Maine	Examination for light-house.	Lieut. Comg. Craven	(Reported Feb. 22, 1855.)
	Pier head at Kennebunk harbor, Maine.	Examination for light-house.	Lieut. Comg. Craven	(Recommended February 22, 1855.)
	Nubble, Cape Neddick, York harbor, Maine.	Examination for light-house.	Lieut. Comg. Woodhull..	Reported March 16, 1854. (Appendix No. 70.)
	Point of Rocks, Westport, Massachusetts.	Examination for light-house and keeper's house.	Lieut. Comg. Stellwagen .	Light-boat south of "Hen and Chickens" recommended December 4, 1854. (Appendix No. 71.)
II	Pine island, Fisher's Island sound, Connecticut.	Examination for position of fog-signal.	Lieut. Comg. Stellwagen .	Recommended December 2, 1854. (Appendix No. 72.)
	Niantic, Long Island sound, Connecticut.	Examination for light-house.	Lieut. Comg. Stellwagen.	Reported December 4, 1854. (Appendix No. 71.)
	Black Point, between Connecticut river and New London.	Examination for light-house.	Lieut. Comg. Stellwagen.	Harbor-light recommended December 4, 1854. (Appendix No. 71.)
	End of breakwater at Southport, Connecticut.	Examination for harbor light.	Lieut. Comg. Stellwagen.	Reported December 4, 1854. (Appendix No. 71.)
	Race Point, Fisher's island, Long Island sound, New York.	Examination for light-house.	Lieut. Comg. Stellwagen.	Recommended December 4, 1854. (Appendix No. 71.)
	Horton's Point, Long Island sound, New York.	Examination for light-house.	Lieut. Comg. Stellwagen .	Recommended December 4, 1854. (Appendix No. 71.)
	Absecom bar, coast of New Jersey.	Examination for bell-buoy.	Lieut. Comg. Woodhull..	(Recommended February 12, 1855.)
	Bowers' Beach, between Murderkill and Jones' creeks, Delaware bay, Delaware.	Examination for light-house.	Lieut. Comg. Woodhull..	(Recommended February 12, 1855.)
	Mouth of Old Duck creek, Delaware bay, Delaware.	Examination for light-house.	Lieut. Comg. Woodhull..	(Recommended February 12, 1855.)
VI	Coffin's Patches, on Florida reef.	Reconnaissance for light-house.	Lieut. Comg. Craven	Light on Sombrero key recommended June 30, 1854. (Appendix No. 73.)
VIII	Entrance to Vermilion bay, Louisiana.	Examination to discontinue light.	Lieut. Comg. Sands	(Reported Jan. 31, 1855.)
	Mouth of Calcasieu river, Louisiana.	Examination for light-house.	Lieut. Comg. Sands	(Reported Feb. 2, 1855.)
IX	Galliuipper Point, Lavacca bay, Texas.	Examination for light-house.	Lieut. Comg. De Haven. (Instructions issued.)	
X, XI	Harbor of Santa Barbara, California.	Examination for harbor-light.	Lieuts. Comg. Alden and Stevens.	(Recommended February 5, 1855.)
	Anacapa, or Santa Cruz island, California.	Examination for light-house.	Lieuts. Comg. Alden and Stevens.	Reported Nov. 1, 1854. Recommended Feb. 5, 1855.)
	Harbor of Santa Cruz, bay of Monterey, California.	Examination for light-house.	Lieuts. Comg. Alden and Stevens.	(Recommended February 5, 1855.)
	Harbor of San Pedro, California.	Examination for harbor-light.	Lieuts. Comg. Alden and Stevens.	(Recommended February 5, 1855.)
	Point Lobos, California	Examination for light-house.	Lieuts. Comg. Alden and Stevens. (Instructed.)	
	Punta de los Reyes, California.	Examination for light-house.	Lieuts. Comg. Alden and Stevens.)	(Recommended February 5, 1855.)
	Umquah, Oregon Territory.	Examination for light-house.	Lieut. Comg. Alden. (Instructions issued.)	
	Cape Shoalwater, Washington Territory.	Examination for light-house.	Lieut. Comg. Alden. (Instructions issued.)	
	New Dungeness, Washington Territory.	Examination for light-house.	Lieut. Comg. Alden. (Instructions issued.)	
	Blunt's or Smith's island, Straits of Fuca, Washington Territory.	Examination for light-house.	Lieut. Comg. Alden	(Recommended February 5, 1855.)

APPENDIX No. 69.

Letter from the Superintendent to the Secretary of the Treasury, enclosing extracts from the report of Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, on the examination of sites for light-houses on the coast of Maine.

COAST SURVEY STATION, NEAR CAMDEN, MAINE,
November 4, 1854.

SIR: I have the honor to transmit to the department, to be forwarded to the Light-house Board, extracts from the report of Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey, on the examinations made by him, under my instructions, of the sites for light-houses at Castine, Eggemoggin reach, Isle au Haut, Tenant's harbor, and Damariscotta river, all between the Kennebec river and Mt. Desert bay, Maine.

These are a part of the examinations desired by the Light-house Board, and directed, by your letter of September 8, to be made under the law.

A chart of a reconnaissance of Eggemoggin reach, by Lieut. Comg. Craven, is preparing, and will be sent soon to the department.

I concur with Lieut. Comg. Craven in the recommendations made in his report, and now communicated, and feel it my duty to express to the department the gratification which his promptness in the discharge of this duty has given me.

Very respectfully, yours,
A. D. BACHE, *Superintendent.*

Hon. P. G. WASHINGTON,
Acting Secretary of the Treasury.

COAST SURVEY STEAMER CORWIN,
Portland, October 28, 1854.

SIR: In compliance with your instructions of 13th September, I have visited and examined the proposed sites of light-houses on this coast, viz: 1. Castine; 2. Eggemoggin reach; 3. Isle au Haut; 4. Tenant's harbor; 5. Damariscotta river. * * *

I. *Noddle's Island, Castine.*—I am of opinion that the light-house on Dice's Head is of no use to the harbor of Castine. Southeast from the light-house lies a ledge called "Otter Rock," nearly midway in the entrance of the harbor, the channel lying between Otter Rock and Noddle's island, the shores of which are very bold. From Noddle's island the course is east-northeast, which carries clear of Hosmer's Rock. Vessels entering at night have great difficulty in making Noddle's island, as it is low and covered by the higher land back of it, and a light on Noddle's island would make the approach to the harbor easy and safe at all times, and guide vessels past both the ledges named; and, in my opinion, the light on Dice's Head might be discontinued, as the light on Noddle's island would serve all the purposes of bay navigation.

II. *Eggemoggin Reach.*—The light for the eastern entrance to the reach should be located on the south bluff of Hog island. In the accompanying sketch of the entrance to the reach, I have indicated the site selected by the letters L H, and a circle *in red.* The bluff is elevated, and the channel very bold. The channel from the eastward lies between "Mahony" and "Smutty Nose," two small islets lying south (nearly) of Harbor island. The light on Hog island would show over Harbor island, and guide vessels through this great thoroughfare, and to vessels coming in from the south the light should be brought to bear north, when they may run for it and avoid the dangerous ledge off Green island, and also a sunken rock lying S. by W. ¾ W. from light-house, distant half a mile from Hog island. I recommend that this rock, bare only at very low tides, be marked by a buoy. Its position is not well known, and it has brought up several vessels. The water is deep around it.

There is a second rock, "awash" at lowest tides, nearly south of it, about forty metres distant, and a buoy on this, also, would mark the "Half-tide ledge," which bears from the rocks NW. ¾ W., distant one-fourth of a mile.

III. The Isle au Haut Thoroughfare is not a thoroughfare in the common acceptation of the term, but the passage between Kimball's island and Isle au Haut. The northern entrance is bare at low water, but the southern part deepens to a snug harbor, called the

"Isle au Haut Thoroughfare." This harbor is much resorted to by the fishing fleets as a harbor of refuge. It is open to the SW., and the light on Saddle Back ledge, about six miles distant, shows fair into the harbor; and I think no other is needed, but would recommend, instead of a light-house at the thoroughfare, that one be placed on the dry ledge lying NE. by N. from the easternmost of the Spoon islands, distant about half a mile, where it would be a guide to coasters bound up Jericho bay, (the sheet of water lying between Isle au Haut and Marshall's island.) It would connect with the light on Mount Desert Rock, and warn vessels of the proximity of several dangerous ledges—especially the fatal "Black Ledges," which lie nearly four miles E. by S. from the northern part of Isle au Haut, and which have proved very sadly disastrous to vessels caught here in bad weather. A light on the ledge named would also connect with that for Eggemoggin reach, and be an important aid to navigation.

IV. *Tenant's Harbor.*—A light is much needed at this place. It is a harbor of refuge of much resort, and the town of St. George has some trade. The light-house should be on the northeastern point of Southern island, the island forming the south side of the entrance. The harbor is small but well sheltered, and to the many vessels trading to the Penobscot, is an important place of refuge in bad weather. Some disasters have occurred to those trying to reach it in the dark. A light of the smallest class will answer the purpose.

V. *Dry Point, Damariscotta river.*—A light is quite necessary at this place, both as an aid to vessels bound through Fisherman's Island sound, and to those entering the river. The entrance to the Damariscotta is about three-fourths of a mile wide, and a blind one. There is a bad ledge making off from the south point of Horse island, but on the Dry Point side the shores are bold, giving ten fathoms within eighty yards of the shore. Dry Point is very low and rocky, and cannot be got hold of at night, as vessels fear to enter. The approaches are easy and safe from the south, and with a light it would be accessible at all times. The commercial advantages of the river are such as to require this indispensable aid to navigation.

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Very respectfully, your obedient servant,

T. AUGS. CRAVEN,
Lieut. Comg., Assistant Coast Survey.

Prof. A. D. BACHE,
Superintendent U. S. Coast Survey.

APPENDIX No. 70.

Letter from the Superintendent to the Secretary of the Treasury, communicating the result of an examination made by Lieut. Comg. M. Woodhull, U. S. N., assistant in the Coast Survey, in reference to a light for the Nubble of Cape Neddick, York harbor, Maine.

COAST SURVEY OFFICE, *March* 16, 1854.

SIR: I would respectfully request you to inform the Light-house Board, that after a thorough hydrographic survey of York harbor, Maine, the map of which has already been sent to the Board, and an examination of it in reference to the question whether or not a light-house should be placed there, Lieut. Comg. Maxwell Woodhull (the officer charged with that duty) has come to the conclusion that no light-house is necessary.

* * * * * * * * *

Yours, respectfully,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

APPENDIX No. 71.

Letter from the Superintendent, transmitting extracts from the report of Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, on the examination of sites for light-houses on the coast of Massachusetts, Connecticut, and New York.

NEW YORK, *December* 4, 1854.

SIR: I have the honor to forward the report of Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, of the examination of sites for light-houses at Westport, Massachusetts, and Niantic, Black Point, Southport, Fisher's island, and Horton's Point, Long Island sound, under my instructions and by direction of the Treasury Department, on the application of the Light-house Board.

I concur with Lieut. Comg. Stellwagen in his conclusions, reserving the consideration of the class of light to be determined by the Light-house Board, as also the suggestion in regard to a light-boat off the entrance to Westport.

I would respectfully request that this report may be transmitted to the Light-house Board.

Very respectfully, yours,

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. JAMES GUTHRIE,
Secretary of the Treasury.

Extract from the report of Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, on the examination of sites for light-houses at Westport, Massachusetts, Niantic, Black Point, and Southport, Connecticut; and at Race Point and Horton's Point, New York.

COAST SURVEY STEAMER "BIBB,"
New London, November 22, 1854.

SIR: I have to report the result of the examinations of the following localities for sites for light-houses, as desired, under the law, by the Light-house Board, according to your instructions of the 2d instant.

1. *Westport*, Massachusetts. The entrance to the river leading to this town is marked on the west side by a rocky point called "West Head," which rises moderately from the water until it attains an elevation of about seventy-five feet, at about four hundred feet from the point. This is the site which has been suggested for a light-house, and is marked on the accompanying tracing (No. 1) with a circle in *red.* The advantages of having a light-house on that point are, I think, inconsiderable, as the river is very narrow, shallow, and crooked, and can scarcely be navigated except with fair wind and tide, and by large vessels only at hight water. Its great intricacy, want of depth, and average width, (about one-eighth of a mile,) will be perceived by glancing at the chart; and though it is said some eighteen small whaling barques, &c., and about twenty fishing schooners and smacks, belong to the port, it has been very rarely attempted to carry a square-rigged vessel in or out at night, and this could seldom be done under the most favorable circumstances with the assistance of a light. Its service would be confined to a few small schooners and fishing smacks, with very skilful local pilots on board. Vessels rarely make for the outer harbor, or bay, for refuge from northerly winds, as several dangerous rocks lie in it. Its eastern boundary is formed by Gooseberry neck, and the dangerous ledges extending south from that point; and to clear these, a light on "West Head" would render but little aid.

In lieu, therefore, of a light-house at Westport, I would respectfully recommend that a light-boat be placed a little to the southward of the series of rocks known as the "Hen and Chickens," "Old and Young Cocks," &c., extending nearly due south from Gooseberry neck, and in the position marked in *red* on the accompanying tracing. This would serve as a mark to clear all the rocks, to shape a course for Westport, and to show the entrance into Buzzard's bay, indicating the fair way to New Bedford, and towns to the eastward; and to Newport, New London, &c., to the westward, thus serving a triple purpose and accomplishing all that can be done for Westport, while serving as a guide to vessels running east or west. The light-boat would serve a most important purpose in pointing out the perilous rocks and ledges near which it should be placed, and on which many vessels have been lost.

I think that a light-boat, in the position marked, would confer a great benefit upon a large portion of the mercantile community, and that it is much demanded by a consideration of their wants.

2. I am of opinion that there is but little necessity for a light at or near *Niantic*, Connecticut. The proposed position lies some five or six miles up Niantic creek, and the light would be seen by only a few small vessels trading up the river for produce, and to Millstone Point for stone. The trade is too limited to demand the expense and care which would be incurred in the erection of a light-house.

3. A light-house on *Black Point*, Connecticut, is scarcely needed. This point forms the western cape of Niantic river, and very little local trade is carried on; the commerce of the river being limited to a few traders in market produce, and to carrying stone from the opposite cape called Millstone Point. It is not called for by the passers through Long Island sound, as the lights at Saybrook and New London, and the light-boat on Bartlett's reef, are all in sight from it. A harbor-light might be of service to vessels wishing to anchor under the land from a northerly blow, or with a head tide to be out of the track of steamers. Should anything be erected, I would recommend a "harbor light" as a guide to the anchorage, to be placed at a point in the position marked by a circle in *red* on the accompanying tracing, (No. 3,) at some sixty or eighty feet from the edge of the bank, which rises about fifteen feet above the water. The top soil is good, lying in masses of rock which crop through the ground to the surface, at the spot indicated on the tracing.

4. The trade of Southport, Connecticut, is carried on with eight small vessels belonging there, and a few occasionally looking in from neighboring towns, and it is very small. The channel is so shallow that our boat grounded at the outer pier, and could not get within two hundred yards of the breakwater, there being less than a foot of water with the tide not quite out. None but vessels of light draught can enter, and such only at or near high water. I think a light is not called for by interests sufficiently large to warrant the expense of its erection and maintenance.

5. The examination of Fisher's island, N. Y., shows that a light-house at *Race Point* would materially benefit the large commerce constantly passing through Long Island sound, and between Gull island and Fisher's island.

In view of the limited amount of appropriation, a site was selected near the house erected for the government life-boat, at the southwestern extremity of Fisher's island, called "Race Point," which is indicated on the accompanying chart (No. 5) by a small circle in *red*. Were it not for the expense it would be highly preferable to erect a substantial structure on Race Rock itself, (which is very dangerous,) lying nearly a half mile southwest from Race Point, and having four feet water over it at low tide.

The light at this point should be a second-class seacoast French light, as it will be at a narrow gate of the sound, and should revolve, showing alternate flashes of red and white to distinguish it clearly from Watch Hill revolving light, and from Gull island, Plumb island, and several other fixed lights near it. Too much cannot be done for the safety of the already immense and constantly increasing fleets of vessels passing through the sound in all seasons, and in all weathers. The spot indicated is twelve or fifteen feet above the water, and on a rocky foundation.

6. On *Horton's Point*, Long Island sound, N. Y., a light would be highly beneficial in thick weather, particularly to steamers, which seldom anchor or lie by; and it would help to fill the long gap on the Long Island shore between Old Field light and Plumb island, a distance of over forty miles, at present without a light.

The site selected is marked with a small circle in *red* on the accompanying chart, (No. 6,) and is some eighty feet from the edge of a bluff, elevated about seventy-five feet above the water, and near its most prominent point composed of very large masses of rock filled in with gravel and sand, and covered with a thin rich soil. A second-class seacoast light, illuminating about 230°, is recommended; and if possible, with the amount appropriated, it should be constructed to revolve, in order to distinguish it from those adjacent, which are nearly all fixed lights.

The foregoing conclusions are the results of careful investigation, and diligent inquiry among the best informed residents in each vicinity, captains of steamers, pilots, &c., &c., and will, I trust, be found satisfactory.

Very respectfully, yours, &c.,

H. S. STELLWAGEN, U. S. N.,

Lieut. Comg., Assistant in Coast Survey.

Prof. A. D. BACHE,

Superintendent U. S. Coast Survey.

APPENDIX No. 72.

Letter from the Superintendent of the Coast Survey to the Secretary of the Treasury, transmitting the report of Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey, upon the examination of Pine island and vicinity, Fisher's Island sound, with reference to the placing of a fog-signal there.

NEW YORK, *December* 2, 1854.

SIR: I have the honor to transmit, with my approval, the report of an examination of Pine island and its vicinity, Fisher's Island sound, in reference to the expediency of placing a fog-signal there. The report is by Lieut. Comg. H. S. Stellwagen, U. S. N., assistant in the Coast Survey. I concur in his conclusions, and would respectfully request that a copy of the report, and of this letter, may be forwarded to the Light-house Board, at whose request, under your instructions, the examination was made.

Very respectfully, yours,

A. D. BACHE, *Superintendent.*

Hon. JAMES GUTHRIE,

Secretary of the Treasury.

COAST SURVEY STEAMER "BIBB,"

Philadelphia, December 1, 1854.

SIR: In obedience to your instructions, I have made a careful examination of Pine island and several points of land at the entrance to New London, Conn., and have to report that in my opinion a fog-signal in that vicinity would be of great utility to the numerous vessels trading there, among which are several steamboats daily carrying a vast number of passengers; and also to many coasters that seek at times, as a place of refuge, the harbor of New London, which is one of the best we possess on the Atlantic coast of the United States.

It could be advantageously placed either at the light-house at Eastport, or at the southern extremity of Pine island. The former might be least expensive, as the keeper of the light could attend it for a small extra compensation, but Pine island would be the best to warn vessels of the proximity of "Black Ledge," a very dangerous reef of rocks lying south of it, and would also serve very well to indicate the course into the harbor. By using a fog-trumpet it could always be easily distinguished from the signal at the North Dumpling, which is a bell; so that their being near each other would be rather an advantage, as, should both be heard at once, the sounds would be distinct, and the directions would the better determine the position of the vessel.

Pine island is of small extent; has several houses on it; and the southern end terminates in a point which is about twenty-five feet above the water, and is composed of large masses of rock with a light covering of soil.

To inform myself on the subject of the various sorts of alarms applicable to the contemplated purpose, I inspected the whistle and trumpet, with steam-engine, machinery, and air-pumps, which are near New London light-house, but not in use. I also examined the apparatus invented by Mr. Daboll, which has a weight and pulley as the motive power for working the air-pumps, and a very ingenious pendulum clock movement to regulate the frequency and duration of the blast of the whistle or of a trumpet, and think that possibly, with some slight modification, it will be found better adapted for the purpose than any other instrument yet invented. I hope a trial will cause the erection of them at all the dangerous points along the coast.

Very respectfully, your obedient servant,

H. S. STELLWAGEN,
Lieut. Comg., and Assistant Coast Survey.

Prof. A. D. Bache,
Superintendent U. S. Coast Survey.

APPENDIX No. 73.

Correspondence with the Secretary of the Light-house Board, Lieut. T. A. Jenkins, in relation to the reconnaissance of Coffin's Patches. (See Sketch F.)

Treasury Department,
Office Light-house Board, April 13, 1854.

Dear Sir: I enclose herewith a copy of a letter from Lieut. G. G. Meade on the subject of a hydrographic reconnaissance of Coffin's Patches, on the Florida reefs, and have to request to be informed if it will be in the power of the Superintendent to direct the officer charged with hydrographical operations on that coast to comply with the request of Lieut. Meade this season, and also if it will be necessary to request the Hon. Secretary of the Treasury to address the Superintendent on the subject.

Very respectfully, your obedient servant,

THORNTON A. JENKINS,
Secretary.

Capt. H. W. Benham,
U. S. Engineers, assistant in charge of Coast Survey Office.

Philadelphia, *February* 21, 1854.

Sir: It is extremely desirable that there should be a "hydrographic reconnaissance" made of that portion of the Florida reef known as the "Coffin's Patches."

The examinations made by me last summer, though satisfactory, so far as concerns solving the question of the character of the foundation of the proposed light-house, yet, from want of time and means, these examinations were not sufficiently extended to authorize the definitive selection of a site for the structure.

Knowing the promptitude of the Superintendent of the Coast Survey in responding to all calls upon his department for the advancement of the public interests, and in view of the efficiently organized hydrographic party now on the reef, it has occurred to me that a reconnaissance of these shoals might be ordered by him, which, while it would furnish us with desired information, would not be valueless in the future operations of the survey itself.

For the purpose of selecting a site, this reconnaissance need be only of the most general character. What I wish to know is, the number and relative positions of the different shoals or spots constituting the Patches, and the general depth of water on each, together with the position of some known object on the shore.

The great desideratum is to ascertain the position of that shoal which is the most protected from the gulf-wave, where the stability of the structure would be the least endangered.

If the Board should concur with me in these views, I would ask that an application be made to the Superintendent of the Coast Survey to have such a reconnaissance made if convenient.

Very respectfully, your obedient servant,

GEO. G. MEADE,
Lieut. Topographical Engineers.

Capt. E. L. F. Hardcastle, U. S. A.,
Engineer Secretary of Light-house Board, Washington, D. C.

COAST SURVEY OFFICE, *April* 17, 1854.

DEAR SIR: I have received your letter, dated 13th instant, enclosing a copy of a letter from Lieut. G. G. Meade, in relation to a hydrographic reconnaissance of "Coffin's Patches," on the Florida reefs.

I will at once direct the reconnaissance, but fear that my instructions may not reach Lieut. Comg. Craven in time to obtain the information immediately.

Yours respectfully,

A. D. BACHE, *Superintendent.*

Lieut. T. A. JENKINS, U. S. N.,
Secretary Light-house Board.

COAST SURVEY OFFICE, *June* 30, 1854.

SIR: In compliance with your request, a hydrographic reconnaissance has been made of Coffin's Patches, founded on the triangulation of Lieut. James Totten, U. S. A., assistant in the Coast Survey, by Lieut. Comg. T. A. Craven, U. S. N., assistant in the Coast Survey. I send a tracing of his chart.

In his report upon the work, Lieut. Comg. Craven says: "With regard to the erection of a light-house on these shoals, I do not think the position eligible. Vessels bound through the Florida straits generally try to 'make,' or do 'make,' *Sombrero key*, which is about ten miles to the southward and westward of Coffin's Patches. A light on Sombrero key would guide vessels clear of the Patches, and could be made a more permanent work."

Yours respectfully,

A. D. BACHE, *Superintendent.*

Lieut. T. A. JENKINS, U. S. N.,
Secretary Light-house Board.

NOTE.—Appendix No. 23, or the Table of Depths, is for the present withdrawn, to be revised or extended.

CONSOLIDATED ALPHABETICAL INDEX

OF THE

TEN ANNUAL COAST SURVEY REPORTS,

FROM 1844 TO 1853, INCLUSIVE.

PREPARED BY LIEUT. E. B. HUNT.

[The first annual report of progress made by the present Superintendent was that for 1844. This Index, with that for this volume, and the Sketch Index, will supply references for all the matter in the Annual Coast Survey Reports published since 1844. In addition, there are various special reports not here referred to.]

Reports for—

1844:	28th	Congress,	2d session,	Ex. Doc.,	Senate	No. 16,	Ho. of Reps. No. 25.
1845:	29th	"	1st "	" "	"	No. 13,	" No. 38.
1846:	29th	"	2d "	" "	"	No. 3,	" No. 6.
1847:	30th	"	1st "	" "	"	No. 6,	" No. —.
1848:	30th	"	2d "	" "	"	No. 1,	" No. 13.
1849:	31st	"	1st "	" "	"	No. 5,	" No. 14.
1850:	31st	"	2d "	" "	"	No. 7,	" No. 12.
1851:	32d	"	1st "	" "	"	No. 3,	" No. 1.
1852:	32d	"	2d "	" "	"	No. 58,	" No. 2.
1853:	33d	"	1st "	" "	"	No. 14,	" No. 12.

A.

C.

F.

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J.

M.

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CONSOLIDATED INDEX

OF

SKETCHES EMBRACED IN THE ANNUAL COAST SURVEY REPORTS FROM 1844 TO 1853, INCLUSIVE.

PREPARED BY LIEUT. E. B. HUNT.

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- 1844: Triangulation, &c., in southeast part of Massachusetts, (A.)
- 1845: Triangulation, &c., in east part of Massachusetts, (A.)
- 1846: East part of Massachusetts and southeast of New Hampshire, (A.)
- 1847: Embraces Mount Pleasant, (A.)
- 1848: Embraces Mount Pleasant; new plate, (A.)
- 1849: Embraces Passadumkeag, (A.)
- 1850: Embraces Passadumkeag, (A.)
- 1851: New plate $\frac{1}{400000}$, full details, (A.)
- 1852: Ditto, (A.)
- 1853: Ditto, extended in sub-sketch, (A.)

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Alden's Rock: Hydrographic sketch, 1853, (A, No. 2.)

Boston Harbor survey:
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- 1848: Triangulation, sheets, outlines, and currents, (A *bis.*)
- 1851: Ebb-current chart, showing course and velocity, (A, No. 3.)

Minot's Ledge: Chart and sections, 1853, (A, No. 3.)

Nantucket Shoals:
- 1846: Davis' New South shoal, hydrographic sketch, (No. 8.)
- 1848: New and Old South shoals, hydrographic sketch, (A *tris.*)
- 1850: Davis' South shoal and other dangers, new plate, (A, No. 3.)
- 1851: Davis' South shoal and other dangers, new plate, (A, No. 2.)
- 1852: Davis' South shoal and other dangers, (A, No. 2,) (and A, sub-sketch.)
- 1853: Davis' South shoal and other dangers, (A, No. 4.)

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Sow and Pigs Reef: Sketch chart, views, 1853, (A, No. 5.)

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- 1846: Reconnaissance in New Jersey, (C.)
- 1847: A section outline, (B.)
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- 1849: Ditto, (B.)
- 1850: Ditto, (B.)
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- 1848: (B *tris.*)

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Beacon Range Sites, New York harbor: Elm-tree and Point Comfort, 1851, (B, No. 5.)
Romer and Flynn's Shoals, New York bay: Sketch chart, 1853, (B, No. 2.)
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- 1851: New survey and new plate, (B, No. 4.)
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- 1847: Sketch with buoy locations, (B, *bis.*)
- 1848: Sketch with buoy locations, (B, *bis.*)

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- 1845: Delaware and Chesapeake connection, triangulation, and sheets, (B.)
- 1846: From Point-no-Point northwards, (C.)
- 1847: Ditto, and including Eastern Shore, (C.)
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- 1849: Down to the Rappahannock and Chincoteague, (C.)
- 1850: Includes entire Chesapeake and coast to Beach inlet, (C.)
- 1851: Includes entire section $\frac{1}{100000}$, (C.)
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- 1852: Delaware and Maryland, and part of Virginia, (C, No. 3.)
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Wachapreague, Machipongo, and Metomkin inlets: Sketch chart, 1853, (C, No. 3.)
Chesapeake entrance: Reconnaissance chart, 1851, (C, No. 2.)
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- 1849: Albemarle and its tributaries, (D.)
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- 1850: Preliminary sketch chart, (D, No. 4.)
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New River and Bar: Reconnaissance chart, 1852, (D, No. 4.)

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1852: Sketch of progress; Cape Fear and vicinity to New river, (D, No. 2.)
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1850: Base and triangulation, North and South Edisto rivers, (E, No. 2.)
1851: Progress sketch, North and South Edisto rivers and St. Helena sound, (E, No. 3.)
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Musquito Inlet: Reconnaissance chart 1851, (F, No. 3.)

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Cape Florida: Proposed base, 1850, (F, No. 4.)

Cape Sable: Proposed base, 1850, (F, No. 3.)

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1851: Grand bay, including Horn Island Pass, entrance, (H. No. 7.)
1852: Sketch chart, (H. No. 4)
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National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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