REPORT OF THE SUPERINTENDENT

OF THE

U.S. COAST AND GEODETIC SURVEY

SHOWING

THE PROGRESS OF THE WORK

FROM

JULY 1, 1900, TO JUNE 30, 1901.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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LETTER

FROM

THE SECRETARY OF THE TREASURY

TRANSMITTING

The Report of the Superintendent of the United States Coast and Geodetic Survey.

TREASURY DEPARTMENT, OFFICE OF THE SECRETARY,
Washington, D. C., December 6, 1901.

SIR: In compliance with the requirements of section 4690, Revised Statutes, I have the honor to transmit herewith, for the information of Congress, a Report transmitted to this Department by Mr. O. H. Tittmann, Superintendent of the Coast and Geodetic Survey, showing the progress made in that work during the fiscal year ended June 30, 1901. It is accompanied by maps illustrating the general advance in the operations of the Survey up to that date.

Respectfully,

L. J. GAGE, *Secretary.*

The PRESIDENT OF THE SENATE.

LETTER

FROM THE

SUPERINTENDENT OF THE UNITED STATES COAST AND GEODETIC SURVEY

SUBMITTING THE

Annual Report for the fiscal year ended June 30, 1901.

UNITED STATES COAST AND GEODETIC SURVEY,
Washington, D. C., December 3, 1901.

SIR: In conformity with law and with the regulations of the Treasury Department, I have the honor to submit herewith, for transmission to Congress, the Annual Report of progress in the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901. It is accompanied by maps illustrating the general advance in the field work of the Survey up to that date.

Respectfully,

O. H. TITTMANN,
Superintendent.

The Honorable the SECRETARY OF THE TREASURY.

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O. H. TITTMANN, *Assistant Superintendent*, July 1 to Nov. 30.
FRANK WALLEY PERKINS, *Assistant Superintendent*, Feb. 11 to June 30.

OFFICE OF THE SUPERINTENDENT.

Frank Walley Perkins, *Executive Officer*, Oct. 19 to Feb. 10.
D. B. Wainwright, *Assistant*, July 1 to Oct. 19.
W. B. Chilton, *Clerk*.
H. M. Fitch, *Confidential Clerk*.

Dr. Henry Smith Pritchett served as Superintendent from July 1 to November 30, on which date his resignation took effect. He left the service to accept the position of president of the Massachusetts Institute of Technology.

THE WORK OF THE YEAR.

A notable event during the year was the inauguration of the survey of the coasts of the Philippine Islands.

Acting upon the information obtained by an officer of the Survey sent to the islands for the purpose of reporting upon existing conditions, an assistant of the Coast and Geodetic Survey was sent to Manila with authority to organize a suboffice and establish the necessary facilities for preparing the data obtained by the surveying parties in the field for immediate publication in the form of preliminary charts.

The Director of Coast Surveys in the Philippine Islands was also authorized to publish Notices to Mariners and all information useful to mariners as soon as practicable.

A small body of trained officers was assigned to duty in this region and the existing conditions made it desirable to adopt the plan of making detached harbor surveys at all important places as the first step in carrying out the plan of the survey.

A report of the results accomplished during the year will be found in Appendix No. 1 to this Report.

From the foundation of the Bureau of Weights and Measures, in 1831, the Superintendent of the Coast and Geodetic Survey has been charged with the custody of the standard weights and measures of the United States. The constantly increasing demands upon the Bureau and the necessity for increased facilities and equipment induced Congress to establish the National Bureau of Standards by a law which was approved March 3, 1901, but did not become fully operative until after the close of the fiscal year. A more detailed reference to this subject will be found in the report of the Office of Standard Weights and Measures.

On March 13, 1901, the necessary connections between triangulation in widely separated localities having been made and the computations being sufficiently advanced to afford the basis for such decision, the Coast and Geodetic Survey adopted a standard datum, to be known as the "U. S. Standard Datum," to which all geographic positions throughout the United States will be reduced, whenever possible, as rapidly as practicable, so as to make such positions strictly comparable in all portions of the country.

In October, 1900, a notable publication was issued by the Survey under the title of "The Transcontinental Triangulation and American Arc of the Parallel."

The Hon. Lyman J. Gage, Secretary of the Treasury, honored the Survey in authorizing the publication of the following, over his signature, as the preface to the volume:

> The volume which is here presented to the scientific world contains the results of the most extensive piece of geodetic work attempted by any nation, a geodetic triangulation across the continent and the resulting arc of the parallel. This work has been conducted with the greatest care, and many improvements in the means of observation have marked its progress.
>
> In presenting this complete record of a great undertaking, carried through by a bureau of the Treasury Department, the executive officers of the Department feel that it will prove a contribution to the science of the world worthy of the United States.

The preparation of another important contribution to the subject of geodesy was completed during the year under the title of "The Eastern Oblique Arc of the United States," and contains the discussion of an oblique arc extending from Maine to Louisiana.

The act of Congress making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1901, approved June 6, 1900, contained an item of appropriation for all necessary employees to man and equip the vessels of the Coast and Geodetic Survey. This legislation involved a radical change in the organization of the parties afloat, as the vessels of the Survey were manned with enlisted men of the Navy.

The change was anticipated and had been prepared for as far as it was in the power of the Survey to make such preparations in advance of the date, July 1, 1900, when the law authorizing it went into effect. On July 1 some of the vessels were en route to Alaska and others were returning from Porto Rico, and consequently the transfer from the naval to a civil basis could not be effected on that date. The plan agreed upon was that all the crews were to remain under their naval enlistment until such time as each ship should reach a home port, when the transfer would be made as soon as practicable, and that the Survey should repay to the Navy Department all of the expense incurred after July 1. This plan was carried out and the crew of the last vessel from Alaska was transferred in November and the records of all the men under naval enlistment were closed in the following month.

The constant changes of the coast line and of the depths in rivers, harbors, and ocean bars, the increase in the draft of ships, the new features continually added by commercial and other developments make it necessary to resurvey many parts of the coast at intervals more or less frequent.

In the Eastern Division, hydrographic work was done on the coasts of Massachusetts, Connecticut, Delaware, North Carolina, South Carolina, Georgia, and Florida; topographic work in Maine, New Hampshire, Connecticut, New York, Maryland, and

South Carolina; triangulation in Massachusetts, New Hampshire, Florida, Georgia, and Maine; elevations were determined by leveling in South Carolina, Kentucky, Tennessee, and Alabama, and magnetic work was done in North Carolina, Maryland, District of Columbia, Pennsylvania, Illinois, Kentucky, Virginia, Tennessee, Mississippi, Indiana, Michigan, and Ohio. A permanent magnetic observatory was established at Cheltenham, Md., to be used as a base station. A continuous tide record was obtained at New York, Philadelphia, Washington, and Fernandina.

In the Middle Division, the triangulation was extended along the ninety-eighth meridian in Nebraska and Kansas; nine base lines were measured in Nebraska, Kansas, Oklahoma Territory, and Texas, with primary accuracy and unrivaled speed and economy, and magnetic observations were made in Louisiana, Texas, Arkansas, Missouri, Kansas, Nebraska, Iowa, Minnesota, and South Dakota.

In the Western Division, triangulation, topographic, and hydrographic work was done in Oregon and Washington. A continuous tide record was obtained at San Francisco, Cal., and at Seattle, Wash., and a speed trial course was established in the Santa Barbara Channel. Magnetic observations were made in Washington and Oregon.

In Alaska, surveys were made along the coast of Seward Peninsula, including Port Clarence and Norton Sound. The survey of Prince William Sound was continued, and toward the end of the year the important work of surveying the principal passes through the Aleutian Islands into Bering Sea was begun, as well as the survey of Icy Straits and Cross Sound.

In Porto Rico, hydrographic work was continued in the harbors and bays and off shore. The triangulation around the island and topographic surveys of the shore line were continued. The topographic survey of Vieques Island was completed.

In the Hawaiian Islands, the work of separating the records relating to the Coast Survey from the Land Office records was begun, and also the compilation of a list of the geographic names used in the islands.

In the Philippine Islands, astronomic observations were made at fourteen stations, and the longitude, latitude, and azimuth determined. Magnetic observations were also made at these stations and tide observations were made at ten different places. Three charts and three notices to mariners were issued. Six additional charts (four from Coast and Geodetic Survey work and two Spanish charts needing republication with additions) were ready for publication on July 1. A steamer was purchased by the Philippine Commission for the use of the Coast and Geodetic Survey, and money was appropriated by the Commission to repair and equip this vessel.

MAGNETIC SURVEY.

The determination of the magnetic elements was made in 340 different localities, embracing 376 stations (65 of which were in localities previously occupied) distributed over 31 States and Territories, from Maryland to Alaska, including the Hawaiian Islands, the Philippines, Porto Rico, and British Columbia, and the local disturbances affecting the mariner's compass in the waters along the coast of southeast Alaska were examined.

The principal magnetic observatory or base station at Cheltenham, Md., 16 miles southeast of Washington, was completed, the instruments were installed and photographic records of the magnetic variations were obtained after April, 1901. A photographic self-recording instrument was installed in an extemporized building at Baldwin, Kans., and records of the magnetic variations were obtained after August, 1900.

Declination variations were observed in an extemporized building at Sitka, Alaska, after October, 1900, and special simultaneous magnetic observations were made by all the magnetic parties at various times and especially in connection with the total solar eclipse May 17 and 18.

In addition to their regular work, these observatories will cooperate, at the formal request of the German Government, with the international magnetic work to be carried out during the time of the Antarctic expeditions which have been sent out from Germany and Great Britain.

COAST PILOTS.

Owing to the Spanish war, officers engaged in the preparation of the Coast Pilots were detached, the work was interrupted, and some time was required to reorganize this special branch of the service.

During the fiscal year, the Coast Pilot relating to southeast Alaska was thoroughly revised in the field and prepared for the printer. The field revision of the Coast Pilot between San Diego and San Francisco was completed and new editions of sections relating to the Atlantic coast were published and the revision and issue of other numbers is progressing as fast as the available force will permit.

INTERNATIONAL LATITUDE SERVICE.

Satisfactory results have been obtained at the astronomical observatories maintained under the direction of the Survey at international expense at Gaithersburg, Md., and Ukiah, Cal., for the purpose of determining the variation of latitude.

SPECIAL WORK.

Speed trial courses for the use of ships and torpedo boats were established in Delaware and Chesapeake bays, and the Santa Barbara Channel course was extended.

One officer of the Survey continued to serve as a member of the Mississippi River Commission, another was sent to the meeting of the International Geodetic Association held at Paris, France, in September, 1900, as the representative of the United States, and others investigated the methods of making hydrographic surveys and the printing of charts in foreign countries. In the demarkation of the provisional boundary between Alaska and British Columbia, one officer acted as commissioner and another as engineer on the part of the United States. Two officers of the Survey were appointed by the United States Supreme Court as members of a commission to retrace and mark the boundary line between the States of Virginia and Tennessee, and one officer was engaged on the resurvey of Mason and Dixon's Line under an assignment requested by a commission of the States of Maryland and Pennsylvania.

One officer completed the connection of gravity stations in the United States and Europe and another had charge of the Survey Exhibit at the Pan-American Exposition in Buffalo, N. Y.

Details in regard to the field work of the year will be found in Appendix No. 1 to this Report.

The appropriations made for the U. S. Coast and Geodetic Survey on account of the fiscal year of 1901 amounted to $902,830. Of this amount $10,885 was for the use of the Office of Standard Weights and Measures, which by later legislation has been merged into the National Bureau of Standards. Sixty thousand dollars was for the rebuilding of the U. S. Coast and Geodetic Survey steamer *A. D. Bache*, and the sum of $20,000 for the building of a small steamer, while $210,245 was for the pay of the officers and men of the Coast and Geodetic Survey vessels, and $54,600 for repairs of vessels. For Office expenses, including the purchase of new engraving machines, the sum of $38,000 was provided, and the remainder of the appropriation was about equally divided between party expenses and salaries.

The statement of the expenditures during the fiscal year is given on pp. 24–51.

I. OFFICE OF ASSISTANT IN CHARGE.

ANDREW BRAID, *Assistant in Charge*.

The usual work in the Office was continued.

The work of reducing the geographic positions in southeast Alaska to a uniform standard was almost completed. The computation of more than 1 000 miles of precise leveling lines was made.

A United States Standard Datum, to which all connected geographic positions are to be reduced, was adopted and the positions of the primary points along the thirty-ninth parallel triangulation along the eastern oblique arc and along the western oblique arc were reduced to this datum before the close of the fiscal year. The discussion of "The eastern oblique arc of the United States" was completed and submitted for publication.

Bulletin No. 41, "The magnetic survey of North Carolina," was prepared for publication. The preparation of a new edition of the Magnetic Declination Tables was begun and the revision of the computation of all magnetic observations previously made by the Survey was undertaken and considerable progress made.

The annual volume of tide tables for the year 1902 was prepared and published with the usual separates for the Atlantic coast and for the Pacific coast. It contains predictions for 70 principal and about 3 000 subordinate stations throughout the world.

Harmonic analysis of several series of tide observations were made, aggregating five years of continuous record. An aggregate of thirty-five years of record from automatic tide gauges was received, examined, and registered.

The drawings for 13 new charts and for 9 new editions of charts were completed.

The copperplates for 7 new charts and 51 new editions of charts were also completed,

Nine hundred and ninety-two plates were corrected for printing, and 75 330 impressions were made from the engraved plates.

A new edition of the Chart Catalogue was prepared, published, and issued. Fifteen new charts published by lithography were issued.

The usual monthly Notices to Mariners were prepared. published, and issued.

An electrical apparatus for indicating changes in water level at any distance from the point of observation was purchased for use in the office of the Philadelphia Maritime Exchange, and the changes and improvements necessary to adapt it for use as a tide indicator were completed.

Details under this head will be found in Appendix No. 2 to this report.

II. OFFICE OF INSPECTOR OF HYDROGRAPHY AND TOPOGRAPHY.

H. G. OGDEN, *Inspector of Hydrography and Topography.*

A.—INSPECTION.

Personnel.

Name.	Occupation.
J. H. Roeth	Clerk.
R. D. Chase	Writer.

The inspection of the field work during the first half of the fiscal year was confined to the personal supervision, by Assistant Ogden, of the operations of the steamer *Endeavor*, Assistant F. A. Young, commanding, engaged upon an examination of the bars and channels in the Delaware River above Bombay Hook. The work involved the determination of the availability of channels that differed about 1 foot in depth.

The duties of the Inspector in the Office were more than usually onerous during the year. The act of Congress making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1901, approved June 6, 1900, contained an item of appropriation for all necessary employees to man and equip the vessels of the Coast and Geodetic Survey. This legislation involved a radical change in the organization of the parties afloat, as the vessels of the Survey were manned with enlisted men of the Navy.

This change was anticipated and had been prepared for as far as it was in the power of the Survey to make such preparations in advance of the date, July 1, 1900, when the law authorizing it went into effect.

On July 1, some of the vessels were en route to Alaska and others were returning from Porto Rico, and consequently the transfer from the naval to a civil basis could not be effected on that date. The plan agreed upon was that all the crews were to remain under their naval enlistment until such time as each ship should reach a home port, when the transfer would be made as soon as practicable and that the Survey should repay to the Navy Department all of the expense incurred after July 1. This plan was carried out and the crew of the last vessel from Alaska was transferred in November and the records of all the men under naval enlistment were closed in the following month.

The successful execution of this plan is largely due to the courteous consideration of Paymaster M. M. Ramsay, U. S. N., and to his clerk, Mr. H. C. Jordan, who remained in charge of the accounts until the final settlement.

The preparation of the necessary rules and forms for the record of the civil crews required by the scheme adopted under the provisions of Treasury Department Circular No. 111, dated July 13, 1900, involved a large amount of labor of an unusual kind, and Assistant Ogden expresses his appreciation of the earnest and efficient work of Mr. J. H. Roeth, clerk, in this connection.

Assistant Ogden sailed from New York on March 2, under instructions to proceed to Porto Rico and inspect the hydrographic and topographic work in progress in that locality. He visited the parties of Assistants Nelson, Flower, Boutelle, and Forney and issued such instructions as were found to be desirable on account of the local conditions and the objects to be accomplished. He sailed from San Juan, P. R., for New York on May 8.

On October 20, 1900, a contract was entered into with the Towsend & Downey Shipbuilding and Repair Company, of New York, to rebuild the steamer *Bache*, and on March 19, 1901, a contract made with the James Reilly Repair and Supply Company for building a small steamer under authority granted by Congress, and work on both these vessels was in progress at the close of the fiscal year.

The special appropriation for repairs to the steamer *Gedney* put the hull of the vessel in first-class condition, and a contract was made for a new boiler for this vessel, to be installed after the return of the ship from work in Alaska during the field season of 1901.

The other vessels of the Survey received repairs during the year as they became necessary and were authorized by the appropriation for that purpose.

The following is a list of the ships in service during the year, with a chronological statement of their changes of station:

STEAMER BACHE:

July 1. At work on Chesapeake Bay, below Potomac River.
August 24. Sailed for Baltimore, Md.
August 25. Arrived at Baltimore, Md.
September 4. Sailed for Barren Island to establish trial course for United States Navy Department.
September 14. Returned to Baltimore, Md.
September 26. Sailed from Baltimore to resume work on Chesapeake Bay.
September 27. Arrived at working grounds.
October 25. Sailed for Baltimore to dock vessel.
October 26. Arrived at Baltimore, Md.
November 14. Sailed for Lower Chesapeake Bay for hydrographic work.
November 14. Arrived at working grounds.
November 28. Returned to Baltimore, Md.
December 17. Sailed for Shooters Island, New York, to be rebuilt.
December 19. Arrived at Shooters Island.
June 30. Still undergoing repairs.

STEAMER BLAKE:

July 1. At St. Thomas, Danish West Indies.
July 3. Sailed from San Juan for examination of Tybee Bar, Georgia.
July 8. Arrived Tybee Roads, Savannah River, Georgia.
July 20. Sailed from Tybee Roads for Baltimore to dock.
July 26. Arrived at Baltimore, Md.
August 5. Sailed from Baltimore for examination of Hatteras Shoals.
August 9. Arrived at Cape Hatteras.
August 30. Sailed for Washington.
September 1. Arrived at Washington, D. C.
September 12. Sailed for Baltimore, Md.
September 13. Arrived at Baltimore, Md.
September 26. Sailed from Baltimore to establish trial course for United States Navy Department at Barren Island.
October 21. Returned to Baltimore, Md.
December 17. Sailed for Dry Tortugas, Fla., for resurvey of that locality.
December 29. Arrived at Dry Tortugas.
June 1. Sailed from Key West for Baltimore, Md.
June 6. Arrived at Baltimore, Md.
June 30. At Baltimore, Md.

SCHOONER EAGRE:

July 1. At Baltimore, Md.
August 5. Sailed for New York for repairs.
August 10. Arrived at New York.
September 17. Proceeded to Irvington on Hudson for resurvey of Hudson River.
November 5. Sailed for Baltimore to prepare for Porto Rico.
November 13. Arrived at Baltimore, Md.
December 3. Sailed from Baltimore for San Juan, P. R.
December 20. Arrived at San Juan, P. R.
June 11. Sailed from San Juan for Baltimore, Md.
June 20. Arrived at Baltimore, Md.
June 30. At Baltimore, Md.

STEAMER ENDEAVOR:

July 1. At work on the Delaware River resurvey with headquarters at Philadelphia, Pa.
November 28. Sailed for Baltimore for repairs.
November 29. Arrived at Baltimore, Md.
March 22. Sailed for working ground in Upper Chesapeake Bay.
April 13. Returned to Baltimore, Md.
June 24. Sailed for working ground in Lower Chesapeake Bay.
June 30. At work in Lower Chesapeake Bay with headquarters at Newport News.

STEAMER GEDNEY:

July 1. At the Puget Sound Naval Station undergoing repairs.
December 8. Sailed for San Francisco, via Seattle.
December 26. Arrived at San Francisco.
January 29. Sailed from San Francisco with Coast Pilot party for points on the coast south of San Francisco.
March 9. Returned to San Francisco.
May 25. Sailed for Seattle on the way to Alaskan working grounds.
May 29. Arrived at Seattle.
June 13. Sailed for working grounds in Icy Straits, Alaska.
June 30. At work in Alaska.

SCHOONER MATCHLESS.

July 1. Engaged on resurvey of Charleston Harbor.
July 28. Sailed for Baltimore, Md.
August 7. Arrived at Baltimore, Md.
October 2. Sailed for New York for repairs.
October 8. Arrived at New York.
December 3. Sailed for Ponce, P. R.
June 8. Sailed from Mayaguez, P. R., for Baltimore, Md.
June 17. Arrived at Baltimore, Md.
June 30. At Baltimore, Md.

STEAMER MCARTHUR:

July 1. At San Francisco.
August 28. Sailed for Seattle to get Coast Pilot party.
September 1. Arrived at Seattle.
September 6. Sailed from Seattle with Coast Pilot party for cruise in southeast Alaska.
November 1. Returned to Seattle.
December 9. Sailed for San Francisco.
December 15. Arrived at San Francisco.
May 4. Sailed for Alaskan working grounds via Seattle.
May 9. Arrived Seattle.
May 16. Sailed for working grounds in Sannak Islands.
June 30. On working ground.

STEAMER PATHFINDER:

July 1. At St. Michael, Alaska.
October 5. Sailed for San Francisco, from Dutch Harbor.
October 14. Arrived San Francisco.
April 18. Sailed for Dutch Harbor via Seattle.
April 25. Arrived Seattle via Port Angeles and Port Stanley.
May 9. Sailed for Dutch Harbor.
May 16. Arrived Dutch Harbor.
June 30. On working grounds at Dutch Harbor.

STEAMER PATTERSON:

July 1. At working grounds in Alaska.
October 20. Sailed from Dutch Harbor for Seattle.
October 29. Arrived at Seattle.
May 16. Sailed from Seattle for Alaskan working grounds.
June 30. On working grounds in Alaska.

B.—COAST PILOT PARTY.

Personnel.

Name.	Occupation.
John Ross	Nautical expert, chief of party.
H. C. Graves	Nautical expert.
H. L. Ford	Do.
Talbot O. Pulizzi	Writer.

The work of the party covered the coast waters of the Atlantic coast, Pacific coast, and the coast and inland passages of southeastern Alaska, the Fox Island Passes, Unalaska Bay, and Bering Sea.

One member of the party was employed in each of the three divisions and was assisted by the others whenever it was necessary to expedite work in any particular locality.

An account of the work in the field will be found under the name of the officer in charge in Appendix No. 1, which contains the details of the field work. The following is an account of the work of compiling, publishing, and issuing the data collected in the field.

Mr. Ross was on field duty November 23 to December 26. Mr. Graves was on field duty July 1 to November 27, and Mr. Ford was on field duty December 15 to July 1.

Capt. E. H. Francis, Alaska pilot, was on temporary duty from January 28 to April 6, assisting in the revision of the third edition of the Alaska Coast Pilot. Mr. W. B. Proctor was temporarily detailed for duty ten days in September in compiling data for use in the preparation of the second edition of United States Coast Pilot, Atlantic Coast, Part VIII.

The usual work of the party in the line of preparing publications for the printer, reading proof, and correcting Coast Pilot volumes to date of issue was executed during the year.

The manuscript for the following publications was sent to the printer on the dates stated:

August 14.—United States Coast Pilot, Atlantic Coast, Part VII, 2d edition.
December 19.—United States Coast Pilot, Atlantic Coast, Part V, reprint and supplement.
March 6.—Bulletin No. 40, 3d edition.
March 22.—United States Coast Pilot, Atlantic Coast, Part VIII, 2d edition.

A leaflet describing the preparation of Coast Pilots and a Notice to Mariners, stating changes in the sailing directions for Delaware River, were prepared for the printer. Specifications for rebuilding the steamer *Bache* and for rebuilding the steamer *Hydrographer* were also prepared.

On June 30 the United States Coast Pilot, Pacific Coast, Alaska, Part I, had been prepared and was ready for the printer.

The following publications, prepared by the Coast Pilot party, were issued during the year:

United States Coast Pilot, Atlantic Coast, Part V (reprint).
United States Coast Pilot, Atlantic Coast, Part VII (2d edition).
United States Coast Pilot, Atlantic Coast, Part VIII (2d edition).
Supplement to United States Coast Pilot, Atlantic Coast, Part V.
Bulletin No. 40. Coast Pilot notes on the Fox Island Passes, Unalaska Bay, Bering Sea, and Arctic Ocean as far as Point Barrow (3d edition).
Leaflet on Coast Pilots for Pan-American Exposition.
Notice to Mariners of changes in Delaware River.

Assistant Ogden expresses his appreciation of the very satisfactory services rendered by the clerks in his office, and the great interest and earnest energy shown by the officers of the Coast Pilot party in the preparation of the work intrusted to them.

III. OFFICE OF INSPECTOR OF GEODETIC WORK.

J. F. HAYFORD, *Inspector of Geodetic Work.*

The inspection of the geodetic work is made, in the main, without leaving the office, in the form of a careful examination of the correspondence and monthly reports from field parties, and of the records and computations received from time to time. The Inspector of Geodetic Work is also the chief of the Computing Division, and is able to utilize as an efficient form of inspection the careful examination to which every record is necessarily subjected when the office computation is being made. The Inspector, therefore, only occasionally finds it necessary to visit parties in the field.

For the purpose of inspecting the operations of the base measuring party at work on the Alice Base Line, in Texas, Assistant Hayford left Washington on December 4 and proceeded to Alice, Tex.

He reached the base line on the 7th and thoroughly inspected all of the operations of the measurement and was much impressed by the skill which had been developed by the party during the season's work.

The plan of operation followed has resulted in very rapid measurement, with an accuracy in the determined length far above the limit absolutely demanded by the triangulation.

Prof. A. E. Burton, of the Massachusetts Institute of Technology, taking advantage of the presence of the Inspector of Geodetic Work at the Alice Base, joined the party on December 8 for the purpose of submitting the tape apparatus constructed by the institute to a practical test in field use. This apparatus has been developed by the students of the institute during the past thirteen years, Messrs. Henry E. Warren and George C. Whipple having taken the principal part in this operation.

Authority was given for this test in order to determine whether this form of apparatus could be used to advantage in measuring any base line which may be required in the work of the Coast and Geodetic Survey. The following is extracted from the report on this test submitted by the Inspector of Geodetic Work:

The important feature of this form of tape apparatus is the device for obtaining the temperature of the tape. The whole length of the 100-meter tape and an approximately equal length of German silver wire form two of the arms of a Wheatstone bridge. The two variable arms of the bridge, together with the telephone which is substituted in the place usually occupied by a galvanometer, and the necessary interrupter, batteries, and connections form the thermophone proper.

The electrical resistance of the steel tape varies more rapidly with a change of temperature than does that of the German silver. The ratio of the resistance of the tape to that of the German silver is therefore the measure of their temperatures; or, with sufficient accuracy, it is a measure of the temperature of the tape, provided the German silver is similarly exposed so as to have approximately the same temperature as the tape. The thermophone dial, over which moves a pointer which indicates the position of the contact point regulating to two variable arms of the bridge, is graduated so as to indicate the temperature of the tape in Fahrenheit degrees. This method of determining the temperature of the tape has three very important advantages over the use of mercurial thermometers either fastened to the tape or swung in the air near it.

1. It determines the actual temperature of the tape regardless of whether the heat reaches the tape in the radiant form or otherwise.

2. The thermophone furnishes an instantaneous determination of the temperature of the tape.

3. The thermophone furnishes a measure of the actual mean temperature of the whole length of the tape.

The apparatus was also tested in Washington, before going to the field, by making repeated readings on a single tape length, extending over many hours of sunshine, shade, and darkness, covering two entire days. The Inspector was much impressed by the desirability of using this apparatus after certain modifications have been made, and commends the various good features combined in it at present.

The Inspector also visited the leveling party at work in Alabama, under charge of Aid W. H. Burger, and found the work progressing in a very satisfactory manner.

IV. OFFICE OF THE INSPECTOR OF MAGNETIC WORK.

L. A. BAUER, *Inspector of Magnetic Work.*

The work of inspection consisted mainly in duties incidental to the supervision of the field work in Terrestrial Magnetism, such as the preparation of the necessary directions and information for the use of the field parties, the critical examination of the records of the magnetic observations made in the field, and the writing of the summaries and reports of progress.

Personal inspection of the field work was made at various times, and during the fall of 1900 an examination of available sites for magnetic observatories in Alaska and in the Hawaiian Islands was made, as described in Appendix No. 1 to this Report.

The entire activity in the field work under the head of Terrestrial Magnetism is briefly summarized in the following table:

Summary of magnetic work executed between July 1, 1900, and June 30, 1901.

State or Territory.	Number of localities.	Number of stations.	Old localities reoccupied.	Declinations observed.	Inclinations observed.	Intensities observed.
Alaska	35	57	12	40	47	27
Arkansas	15	15	1	15	15	15
California	1	1	1	1	1	1
Colorado	9	9	0	9	9	9
District of Columbia	3	3	2	3	2	2
Hawaiian Islands	10	11	2	9	8	5
Illinois	4	4	1	4	4	4
Indiana	16	16	5	16	16	16
Iowa	37	38	4	38	38	38
Kansas	8	8	2	8	8	8
Kentucky	2	2	1	2	2	2
Louisiana	3	3	1	3	2	3
Maryland	7	15	6	15	13	13
Michigan	3	4	2	4	3	3
Minnesota	16	16	4	16	16	16
Mississippi	11	11	3	11	11	11
Missouri	9	9	1	9	9	9
Nebraska	41	42	2	42	41	41
North Carolina	23	23	0	23	23	23
Ohio	10	11	1	11	10	10
Oklahoma	4	4	0	4	4	4
Oregon	1	1	1	1	1	1
Philippine Islands	13	13	0	13	0	0
Porto Rico	16	16	2	16	0	0
Tennessee	1	1	1	1	1	1
Texas	22	22	3	22	22	22
South Dakota	5	5	1	5	5	5
Virginia	10	10	3	10	10	10
Washington	4	5	1	5	5	4
Wisconsin	3	3	2	3	3	3
British Columbia	3	3	0	3	2	0
Total	345	381	65	362	331	306

V. OFFICE OF THE DISBURSING AGENT.

SCOTT NESBIT, *Disbursing Agent.*

Personnel.

Name.	Occupation.
N. G. Henry	Confidential clerk and cashier.
Ida M. Peck	Typewriter and clerk.
Jennie H. Fitch	Clerk.

The disbursement of the funds of the Coast and Geodetic Survey is made not only by payments directly from the Disbursing Agent, but also largely through the medium of its Assistants and other officers, when acting as chiefs of parties. These officers, on approval of the Superintendent, receive advances of public funds from the Disbursing Agent in lump sums, under authority of an Executive order dated March 26, 1886, as follows:

EXECUTIVE MANSION, *Washington, D. C., March 26, 1886.*

Under authority of section 3648 of the Revised Statutes of the United States, permission is hereby given that needful advances of money be made to officers of the Navy detailed to duty as chiefs of parties in the service of the United States Coast and Geodetic Survey, and to all Assistants, Sub-Assistants, and Acting Assistants, or officers of the Coast and Geodetic Survey acting as chiefs of parties and engaged under instructions from the Superintendent of such Survey upon any work or operations of said Survey.

No compensation shall be allowed for the disbursement of any moneys hereby authorized to be advanced, and the officers or persons authorized to receive and disburse moneys so advanced shall be subject to all the terms, provisions, and conditions of law as to the custody, disbursement, and rendering of accounts of public money of the United States.

But no advances of money shall be made to a civilian chief of any party in the service of said United States Coast and Geodetic Survey unless a bond of such civilian officer shall be given in the penal sum of $2 000 with two sureties who shall have qualified in that sum, and which bond shall contain the usual condition of the bond required by law from disbursing agents or clerks, and shall be approved by the Solicitor of the Treasury, and be filed in his office, and shall from time to time be renewed, strengthened, or increased, as the Secretary of the Treasury may direct.

GROVER CLEVELAND.

In conformity to this order there are now 57 officers of this Survey bonded in the sum of $2 000, or more, each. When acting as chiefs of parties these officers receive, from time to time, such advances of public funds from the Disbursing Agent as are required to meet the necessary current expenses of the work in hand.

A ledger account is kept in the office of the Disbursing Agent with each chief of party receiving an advance, each one being charged with all advances made to him, and on the other hand receiving credit for all proper expenditures made by him when presented on regularly supported vouchers, and after such accounts have been audited in the office of the Disbursing Agent and found to be correct. All of these accounts, with their supporting vouchers, are then sent to the First Auditor of the Treasury for examination and audit by him.

This system has met the needs of this service and results, in the main, in economy and good order in its expenditures.

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901.

[Prepared pursuant to the act approved March 3, 1853.]

SALARIES—PAY OF FIELD OFFICERS, 1901.

To whom paid.	Time employed.	Amount.
SUPERINTENDENT.		
Henry S. Pritchett	Five months	$2 078.80
Otto H. Tittmann	Seven months	2 921.20
ASSISTANTS.		
Chas. A. Schott	Ten months and twenty-two days	3 571.40
Aug. F. Rodgers	One year	4 000.00
Otto H. Tittmann	Five months	1 330.45
Andrew Braid	One year	3 107.08
A. T. Mosman	....do	3 000.00
Herbert G. Ogden	....do	3 000.00
Will Ward Duffield	....do	3 000.00
John F. Hayford	....do	3 000.00
W. D. Alexander	Five months	1 241.70
Erasmus D. Preston	One year	2 060.40
Cephas H. Sinclair	....do	2 500.00
William Eimbeck	....do	2 486.42
Frank D. Granger	....do	2 500.00
L. A. Bauer	....do	2 500.00
Herman S. Davis	Thirty days	195.65
Frank Walley Perkins	One year	2 294.59
J. J. Gilbert	....do	2 200.00
Henry L. Marindin	....do	2 200.00
John F. Pratt	....do	2 200.00
Edmund F. Dickins	....do	2 200.00
Dallas B. Wainwright	....do	2 200.00
Isaac Winston	....do	2 086.41
William C. Hodgkins	....do	2 200.00
Philip A. Welker	....do	2 107.59
James B. Baylor	....do	2 000.00
John Nelson	....do	2 000.00
John A. Flemer	Five months (furlough)	....
Fremont Morse	One year	2 000.00
Stehman Forney	....do	2 000.00
Gershom Bradford	....do	2 000.00
Oscar W. Ferguson	....do	2 000.00
John E. McGrath	....do	1 630.42
Edwin Smith	....do	1 630.42
Walter B. Fairfield	....do	1 800.00
W. Irving Vinal	....do	1 800.00
George R. Putnam	....do	1 775.50
Fred A. Young	....do	1 600.00
Ferdinand Westdahl	....do	1 600.00
Homer P. Ritter	....do	1 600.00
John B. Boutelle	....do	1 600.00
E. B. Latham	....do	1 400.00
Robert L. Faris	....do	1 400.00
Charles C. Yates	....do	1 400.00
Geo. L. Flower	....do	1 200.00
Owen B. French	....do	1 200.00
William Bowie	....do	1 200.00
Harry F. Flynn	....do	1 200.00
Frank W. Edmonds	....do	1 200.00
Frank M. Little	....do	1 200.00

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—PAY OF FIELD OFFICERS, 1901—Continued.

To whom paid.	Time employed.	Amount.
ASSISTANTS—continued.		
Hugh C. Denson	Seven months	$687.23
R. B. Derickson	....do	687.23
AIDS.		
Hugh C. Denson	Five months	374.20
R. B. Derickson	....do	374.20
Edgar R. Frisby	Six months and six days	460.10
H. W. Rhôdes	One year	900.00
Benj. E. Tilton	....do	900.00
F. F. Weld	....do	900.00
Gurley S. Phelps	Three months and ten days	197.60
Hugh C. Mitchell	One year	816.90
Clarence W. Noble	Thirteen days	25.41
Frank H. Brundage	One year	805.50
John A. Fleming	....do	816.90
William H. Burger	....do	720.00
B. A. Baird	....do	720.00
Walter C. Dibrell	....do	720.00
Ora Miner Leland	....do	675.05
Thos. E. Vaughn	Thirty days	58.80
John S. Coombs	....do	59.74
M. B. Thornton	....do	59.74
Thos. Nelson Page, jr	....do	60.00
James A. French	One month and five days	70.00
L. L. Jones	Thirty days	56.00
Richard W. Walker	Four months and seventeen days	272.41
W. A. Naghton	Four months and four days	245.60
William E. Parker	Four months and eleven days	264.00
E. Mercer French	Eighteen days	36.00
Ossian E. Carr	Three months and seventeen days	213.01
Geo. E. Selby	Twenty-five days	49.45
John Kenneth Mills	Sixteen days	31.65
Expenditures		112 874.75
Appropriation		116 460.00
Expenditures		112 874.75
Unexpended balance		3 585.25

SALARIES—PAY OF OFFICE FORCE, 1901.

DISBURSING AGENT.		
Scott Nesbit	One year	$2 200.00
CHIEF OF DIVISION OF LIBRARY AND ARCHIVES.		
Edw. L. Burchard	One year	1 800.00
CLERKS.		
William B. Chilton	One year	1 647.44
Nicholas G. Henry	....do	1 650.00

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—PAY OF OFFICE FORCE, 1901—Continued.

To whom paid.	Time employed.	Amount.
CLERKS—continued.		
William C. Maupin	One year	$1 397.29
Adelbert B. Simons	do	1 400.00
J. Henry Roeth	do	1 388.05
Herbert M. Fitch	do	1 393.48
John H. Smoot	do	1 206.52
Eugene B. Wills	do	1 197.21
Ida M. Peck	do	1 195.34
James M. Griffin	do	1 200.00
Geo. A. Fairfield	do	1 200.00
Harlan C. Allen	do	1 200.00
Jennie H. Fitch	do	1 000.00
Alice G. Reville	do	1 000.00
Joseph B. Quinlan	do	998.06
CHART CORRECTORS.		
Henry R. Garland	One year	1 200.00
Lily A. Mapes	do	1 200.00
Mary L. Handlan	do	619.05
Virginia F. Campbell	do	720.00
WRITERS.		
Kate Lawn	One year	898.60
Albert F. Zust	do	900.00
J. H. Millsaps	do	900.00
Archie Upperman	do	800.00
Calvin W. Jones	do	720.00
Eugene Meads	do	720.00
El Bie K. Foltz	do	720.00
William H. Davis	Two months and nineteen days	138.81
Fannie Cox	Thirty days	58.70
E. C. Mewshaw	do	58.70
Geo. H. Draper	One month and twenty-two days	100.00
Arthur S. Barnes	Three months and three days	192.50
Susie C. Mahany	Twenty days	39.56
Mary A. Grant	One year	600.00
BUOY COLORIST.		
A. B. Simons, jr.	One year	669.12
DRAFTSMEN.		
Edwin H. Fowler	One year	2 400.00
Henry Lindenkohl	do	2 196.58
Adolph Lindenkohl	do	2 000.00
William C. Willenbucher	do	1 998.45
Ernest J. Sommer	do	1 800.00
Frank C. Donn	do	1 800.00
David M. Hildreth	do	1 800.00
Charles H. Deetz	do	1 600.00
Edmund P. Ellis	do	1 600.00
John T. Watkins	do	1 400.00
Harlow Bacon	do	1 400.00
James P. Keleher	do	1 199.53

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—PAY OF OFFICE FORCE, 1901—Continued.

To whom paid.	Time employed.	Amount.
DRAFTSMEN—continued.		
Paul Erichsen	One year	$998.83
Williams Welch	Four months and twenty days	388.55
Sully B. Maize	One year	1 000.00
Donald Derickson	Two months	146.73
W. I. Bickford	Two months and nineteen days	198.07
L. A. Waters	Thirty days	73.37
Albert P. Maderia	....do	73.37
John H. Lindsay	....do	73.36
Samuel W. Bogan	....do	64.18
Richard W. Walker	Two months and five days	169.46
J. Newton Baker	Five months and sixteen days	458.33
Chas. H. Hahn	Five months and thirty days	447.50
James W. McGuire	Five months and four days	382.50
Charles Mahon	One year	700.00
COMPUTERS.		
Edward H. Courtenay	One year	2 000.00
Myrick H. Doolittle	....do	1 909.14
Leland P. Shidy	....do	1 800.00
Daniel L. Hazard	....do	1 599.38
Rollin A. Harris	....do	1 600.00
Albert L. Baldwin	....do	1 600.00
John C. Hoyt	....do	1 600.00
Artemas Martin	....do	1 400.00
Lilian Pike	....do	1 199.53
William H. Dennis	....do	1 000.00
Deane S. Bliss	....do	1 000.00
Chas. R. Duvall	....do	1 000.00
COPPERPLATE ENGRAVERS.		
William A. Thompson	One year	2 000.00
Henry M. Knight	....do	2 000.00
Theodore Wasserbach	....do	2 000.00
William H. Davis	....do	1 800.00
Edward H. Sipe	....do	1 800.00
William F. Peabody	....do	1 600.00
Harry L. Thompson	....do	1 600.00
William A. Van Doren	....do	1 400.00
Alfred H. Sefton	....do	1 200.00
Peter H. Geddes	....do	1 200.00
William Mackenzie	....do	1 000.00
Geo. Hergesheimer	....do	1 000.00
Frank G. Wurdemann	....do	900.00
William H. Holmes	....do	900.00
Hugo Franke	....do	900.00
Rowland H. Ford	....do	900.00
Franklin Geoghegan	....do	700.00
PHOTOGRAPHER.		
Cassius F. Blacklidge	Eleven months and fourteen days	1 526.07
ELECTROTYPER AND PHOTOGRAPHER.		
Louis P. Keyser	One year	1 209.77

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—PAY OF OFFICE FORCE, 1901—Continued.

To whom paid.	Time employed.	Amount.
ASSISTANT ELECTROTYPER AND PHOTOGRAPHER.		
Roy Thomas	One year	$676.73
PLATE PRINTERS.		
D. N. Hoover	One year	1 796.74
Eberhard Fordan	....do	1 198.78
Neil Bryant	Ten months and eight days	484.92
Chas. J. Harlow	One year	1 200.00
Chas. F. Locraft	....do	1 200.00
William M. Conn	....do	1 191.04
R. J. Fondren	....do	1 200.00
M. W. Lang	Thirty days	82.42
W. A. Naghton	Eight days	24.73
PLATE PRINTERS' HELPERS.		
Chas. Buckingham	One year	686.42
E. F. Campbell	....do	700.00
Raoul F. Le Mat	....do	682.62
William B. Mehler	Eleven months and fourteen days	667.63
Edwin M. Kline	Ten months and nine days	599.12
INSTRUMENT MAKERS.		
Ernest G. Fischer	One year	1 800.00
Clement Jacomini	....do	1 200.00
Thos. A. Gibson	....do	1 200.00
William R. Whitman	....do	999.32
M. Lauxmann	....do	1 000.00
Ovid St. Marie	Thirteen days	35.71
J. A. Clark	One year	898.16
CARPENTERS.		
Horace O. French	One year	1 200.00
Geo. W. Clarvoe	....do	1 000.00
C. N. Darnall	....do	969.09
WATCHMEN.		
David Parker	One year	880.00
J. W. Drum	....do	880.00
MESSENGERS.		
Thomas McGoines	One year	880.00
Charles Over	....do	820.00
Chas. H. Jones	....do	820.00
William R. McLane	....do	820.00
William H. Butler	....do	820.00
William J. Diercks	....do	700.00
Atrell Richardson	....do	700.00
John W. Hunter	....do	639.35
John H. Brown	Four months and twenty-two days	252.16

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—PAY OF OFFICE FORCE, 1901—Continued.

To whom paid.	Time employed.	Amount.
LABORERS.		
Horace Dyer	One year	$635.80
Frank Thomas	....do	628.72
Harrison Murray	....do	630.00
Hans Bowdwin	....do	630.00
John H. Mason	....do	596.80
Samuel B. Wallace	....do	550.00
Ransom Smart	Eleven months and twenty days	533.59
Charles H. Strothers	Eleven months and eight days	450.23
Virginia McGliney	1 year	365.00
John W. Brown	6 months and 27 days	209.28
Expenditures		140 175.49
Appropriation		141 640.00
Expenditures		140 175.49
Unexpended balance		1 464.51

RECAPITULATION.

Pay of field officers	$112 874.75
Pay of office force	140 175.49
Expenditures	253 050.24
Total sum appropriated for salaries	258 100.00
Total sum expended for salaries	253 050.24
Unexpended balance	5 049.76

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES, 1901.

TIDES, ETC.

To whom paid.	On what account.	Amount.
Geo. W. Clarvoe	Philadelphia tidal	$10.49
E. F. Dickins	Seattle tidal	68.00
Fred A. Kummell	Washington tidal	720.00
F. M. Little	Philadelphia and Fernandina tidal	229.97
H. E. Olsen	Philadelphia tidal	195.61
J. F. Pratt	Seattle tidal	400.00
August F. Rodgers	San Francisco tidal	1 064.09
L. P. Shidy	Washington tidal	58.95
J. G. Spaulding	Fort Hamilton tidal	1 102.23
B. W. Weeks	Fernandina tidal	616.10
Amount disbursed		4 465.44
Railroad account referred to Auditor for settlement		.35
Expenditures		4 465.79
Appropriation		5 000.00
Expenditures		4 465.79
Unexpended balance		534.21

OFFSHORE WORK, ETC.

To whom paid.	On what account.	Amount.
R. D. Chase	Services	$899.65
E. F. Dickins	Coast pilot	62.00
H. L. Ford	Services and travel	1 506.05
H. C. Graves	do	1 907.65
Talbot Pulizzi	Services	1 080.00
John Ross	do	2 100.00
Ferd. Westdahl	Coast pilot	104.55
E. H. Wyvill	Services	1 500.00
Expenditures		9 159.90
Appropriation		10 100.00
Expenditures		9 159.90
Unexpended balance		940.10

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES, 1901—Continued.

STATE SURVEYS, ETC.

To whom paid.	On what account.	Amount.
Adams Express Co	Transportation	$25.42
A L Baldwin	Base measurements	7 052.04
L. A. Bauer	Magnetics	13 082.86
J. B. Baylor	.....do	202.28
Blue Line Transfer Co	Transportation	157.16
Wm. H. Burger	Precise leveling	2 578.76
Chasselon *à Paris*	Magnetic instruments	647.68
W. C. Dibrell	Magnetics	787.90
Harry M. W. Edmonds	Traveling expenses	116.30
O. W. Ferguson	Precise leveling	1 935.74
J. A. Fleming	Magnetics and building observatory	7 560.36
O. B. French	Traveling expenses	77.15
Geo. W. Knox Express Co	Transportation	91.87
F. D. Granger	Triangulation	4 814.74
John F. Hayford	Traveling expenses	150.68
L. G. Jennings	Storage	8.50
F. M. Little	Magnetics	337.90
A. T. Mosman	Triangulation	5 653.97
C. H. Myers	Rent	10.00
J. A. Nicholson & Son	Tents	136.24
S. K. Paul	Services	38.00
Pennsylvania Railroad Co	Transportation	1.49
Henry S. Pritchett	Traveling expenses	100.09
Revenue-Cutter Service	Flags	6.95
Aug. F. Rodgers	Repairing instruments	4.50
C. H. Sinclair	Longitudes	295.69
Ludwig Tesdorpf	Magnetic instruments	528.67
B. A. Thompson	Storage	3.00
Benj. E. Tilton	Precise leveling	1 582.48
Otto Toepfer	Magnetic instruments	1 521.64
United States Express Co	Transportation	21.81
Wm. Weinrich, jr	.....do	1.75
Isaac Winston	Storage	36.00
Amount disbursed		49 569.62
Railroad accounts referred to Auditor for settlement		350.31
Expenditures		49 919.93
Appropriation		50 000.00
Expenditures		49 919.93
Unexpended balance		80.07

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES, 1901—Continued.

NAVY TRAVEL, ETC.

To whom paid.	On what account.	Amount.
J. B. Boutelle	Traveling expenses	$6.85
F. W. Edmonds	Special survey	346.16
W. B. Fairfield	....do	960.85
J. F. Hayford	Traveling expenses	8.25
G. S. Lewis	....do	37.20
W. I. Vinal	Special surveys	931.12
P. A. Walker	Traveling expenses	30.30
Charles C. Yates	Special survey	449.75
Amount disbursed		2 770.48
Railroad accounts referred to Auditor for settlement		81.94
Account settled by Auditor for work done at Port Royal naval station		35.31
Expenditures		2 887.73
Appropriation		3 400.00
Expenditures		2 887.73
Unexpended balance		512.27

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
Adams Express Co	Transportation	$1.25
Wm. W. Cloud	Notary fees	7.50
R. L. Faris	Traveling expenses	63.54
E. G. Fischer	....do	6.06
E. H. Fowler	Commutation of subsistance	77.50
N. G. Henry	Notary fee	.50
Geo. W. Knox Express Co	Transportation	4.69
F. M. Little	Establishing compass ranges	84.00
John Ross	Traveling expenses	36.45
D. B. Wainwright	....do	15.41
Isaac Winston	Commutation and traveling expenses	217.80
Chas. C. Yates	Traveling expenses	138.84
Expenditures		653.54
Appropriation		4 000.00
Expenditures		653.54
Unexpended balance		3 346.46

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES, 1901—Continued.

RECAPITULATION.

[Showing expenditures in gross by sub-items.]

On what account.	Amount.
Tides, etc	$4 465.44
Offshore work, etc	9 159.90
State surveys, etc	49 569.62
Navy travel, etc	2 770.48
Objects not named	653.54
Amount disbursed	66 618.98
Railroad accounts referred to Auditor for settlement	432.60
Account settled by Auditor for work done at Port Royal naval station	35.31
Expenditures	67 086.89
Appropriation	72 500.00
Expenditures	67 086.89
Unexpended balance	5 413.11

CLASSIFICATION OF EXPENDITURES FOR PARTY EXPENSES, 1901.

On what account.	Amount.
Tidal operations	$4 465.79
Coast pilot	9 159.90
Triangulation	10 866.12
Geographical positions	372.84
Magnetics (including observatories)	24 867.84
Base measurements	7 668.65
Precise leveling	6 144.48
Special surveys	2 723.19
Traveling expenses, transportation, etc	818.08
Total	67 086.89

REPAIRS OF VESSELS, 1901.

To whom paid.	On what account.	Amount.
C. V. Archambault	Steamer Gedney	$50.00
Atlantic Iron Works Co	Steamer Blake	372.88
Baltimore Marine Railway Machine and Boiler Works.	Steamer Endeavor	2 005.35
C. F. Bennett	Launch Rudy	60.01
Ernest Betz	....do	39.00
J. B. Boutelle	Schooner Eagre and Launch Inspector	860.75
E. F. Dickins	Steamer Gedney	554.75
G. L. Flower	Schooner Matchless	88.26
Forsberg & Murray	Launch Rudy	53.09
Gas Engine and Power Co. and Chas. L. Seabury Co., Consolidated.	Repairs of launch	388.45

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

REPAIRS OF VESSELS, 1901—Continued.

To whom paid.	On what account.	Amount.
J. J. Gilbert	Steamer Pathfinder	$3 890.00
Wm. Gokey & Son	Schooners Matchless and Eagre	7 830.02
W. C. Hodgkins	Steamer Blake	34.77
John M. Rodgers Boat, Gauge, and Drill Works.	Steamer McArthur	300.92
S. R. Karr & Co	Steamer Blake	180.00
H. G. Ogden	Traveling expenses and schooner Transit.	126.51
J. F. Pratt	Steamer Patterson	1 247.20
Roberts Safety Water Tube Boiler Co.	Schooner Eagre	572.15
J. H. Roeth	Traveling expenses	2.30
John Ross	Schooner Eagre	16.55
Spedden Shipbuilding Co	Steamer Gedney	2.00
W. I. Vinal	Steamer Bache and schooner Matchless	72.27
P. A. Welker	Steamers Blake and Bache	2 107.64
Ferdinand Westdahl	Steamer McArthur	2 547.61
Wm. E. Woodall & Co	Steamer Blake and schooners Matchless and Eagre.	1 737.54
Fred. A. Young	Steamer Endeavor	639.27
Amount disbursed		25 779.29
Account settled by Auditor for repairs to steamer Gedney		15 655.12
Expenditures		41 434.41
Appropriation		54 600.00
Expenditures		41 434.41
Unexpended balance		13 165.59

CLASSIFICATION OF EXPENDITURES FOR REPAIRS OF VESSELS.

Name of vessel.	Amount.
Steamer Bache	$92.36
Steamer Blake	3 372.72
Schooner Eagre	6 081.87
Steamer Endeavor	2 644.62
Steamer Gedney	16 261.87
Schooner Matchless	4 031.92
Steamer McArthur	2 848.53
Steamer Pathfinder	3 890.00
Steamer Patterson	1 247.20
Schooner Transit	30.00
Steam and naphtha launches	834.51
Traveling expenses of inspection officers	98.81
Total	41 434.41

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PUBLISHING OBSERVATIONS, 1901.

To whom paid.	On what account.	Amount.
Arthur F. Belitz	Services	$1 000.00
Expenditures		1 000.00
Appropriation		1 000.00
Expenditures		1 000.00

GENERAL EXPENSES, 1901.

To whom paid.	On what account.	Amount.
Adams Express Co	Transportation	$43.00
A. Lietz Co	Repairs to instruments	50.00
American Arithmometer Co	Adding machine	350.00
American Ice Co	Ice	267.45
American Journal of Science	Subscriptions	6.00
American Mason Safety Tread Co	Repairs	156.73
American Steel and Copper Plate Co	Engraving supplies, etc	35.00
R. P. Andrews & Co., Incorporated	Stationery, photograph supplies, etc	22.00
A. Angelowitz	Instrument shop	4.15
E. & H. T. Anthony	Copper and photograph supplies	44.98
R. Carter Ballantyne	Stationery, chart paper, etc	70.58
Wm. Ballantyne & Sons	Books and stationery	18.52
D. Ballauf	Contingencies	3.50
Barber & Ross	do	10.20
L. A. Bauer	Books	49.73
Arthur Baumgarten	Stationery	39.99
Bausch & Lomb Optical Co	Photograph supplies	5.63
Anna Beckman	Contingencies	8.90
Benedict & Burnham Manufacturing Co.	Instrument shop, etc	306.38
C. L. Burger & Sons	Instruments	719.35
John Bliss & Co	Books and charts	48.10
Blue Line Transfer Co	Transportation	7.15
Blum Bros	Contingencies	92.28
H. Bosswell & Co	Repairs	141.00
R. R. Bowker	Subscription	5.00
W. Andrew Boyd	Books	25.00
C. S. Braisted	Stationery	8.82
Brentanos	Books	.25
R. M. Brown	Carpenter shop	.93
J. H. Bunnell & Co	Contingencies	5.04
Bureau of Engraving and Printing	Printing supplies	1 236.31
D. E. Burton	Carpenter shop	19.35
M. P. Bush	Contingencies	24.56
C. A. Woolsey Paint and Color Co	Carpenter shop, etc	6.66
R. P. Clarke Co	Printing supplies, etc	550.57
Clendenin Bros	Copper	325.34
James Connor	Office horse	34.89
M. G. Copeland & Co	Contingencies	2.75
H. S. Crocker Co	Books	5.00
Joseph L. Crupper	Contingencies	23.25
John B. Daish	Fuel	1 047.75
Dennison Manufacturing Co	Stationery	2.25

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1901—Continued.

To whom paid.	On what account.	Amount.
Thomas A. Dobyns	Contingencies	$0.60
Dodd, Meade & Co	Books	5.95
P. Dougherty	Office horse	150.00
Dulin & Martin Co	Contingencies	1.20
M. Du Perow	Instrument shop, etc	18.65
C. R. Edmonston	Contingencies	15.80
Eimer & Amend	Instrument shop and photograph supplies	12.66
Elliott Electric Blue Print Co	Drawing division and photograph supplies	39.17
E. Morrison Paper Co	Chart paper, etc	1 260.29
Geo. T. Ennis & Co	Instrument shop	150.78
John B. Espey	Instrument and carpenter shops	316.85
Evening Star Newspaper Co	Advertising	3.30
Felt & Tarrant Manufacturing Co	Stationery, etc	50.95
Geo. W. Knox Express Co	Transportation	59.08
Gerstenderfer Bros	Carpenter shop	13.85
Henry F. Getz	Repairs	102.25
Chas. U. Gibson	do	13.00
Z. D. Gillman	Photograph supplies, etc	179.43
Jas. D. Goldsmith	Contingencies	3.50
Andrew B. Graham	Photolithographing	2 249.46
L. M. Graham	Repairs, etc	17.00
Henry J. Green	Instruments	62.00
Hanlan & Goodman	Carpenter shop	1.85
Harris & Shafer Co	Instruments	134.40
Louis Hartig	Carpenter shop, etc	3.78
Harvard University	Subscriptions	2.00
G. Hasler	Instruments	109.17
Jeremiah Hawkins	Extra labor	600.00
Hellman Oil Co	Contingencies	6.00
Mrs. A. Hellmuth	Washing	160.80
G. N. Henderson	Extra labor	600.00
J. W. Hurley	Repairs	978.00
J. Hillengass	do	200.00
H. E. Hooper	Book	8.75
N. Humphrey	Contingencies	1.30
Elwood Ivins	Instrument shop	11.29
James H. Johnson	Repairs, etc	226.00
Jones & Laughlin, Limited	Instrument shop	.93
Jordan & Christie	Contingencies	7.00
M. E. Kahler	Instruments and instrument shop	155.50
S. Kann, Sons & Co	Contingencies	42.68
C. Ashton Kay	Instruments	38.00
Thos. Keely	Contingencies	6.00
Keuffel & Esser Co	Drawing division, photograph supplies, etc	681.14
Richard L. Lamb	Instrument shop	27.00
James B. Lambie	Instrument and carpenter shops, etc	90.76
Lansburgh & Bro	Contingencies	138.48
Nanny D. Lee	do	.75
Lemcke & Buechner	Books and subscriptions	115.61
Arthur Leslie	Repairs, etc	30.00
Library Bureau	Stationery, etc	177.94
Melville Lindsay	Photograph supplies	17.39
T. L. Lindsay	Contingencies	.50
Mrs. M. E. Little	Office furniture, etc	20.25
W. H. Lowdermilk & Co	Books and subscriptions	97.70
Lufton Rule Co	Instrument shop	15.00
Lutz & Co	Office horse and wagon	51.60
Mackall Bros	Electric supplies, etc	201.41

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1901—Continued.

To whom paid.	On what account.	Amount.
E. W. Mackintosh	Stationery, etc	$13.05
W. E. Maloney	Repairs	110.00
Matthiessen & Hegeler Zinc Co	Zinc	163.79
F. P. May & Co	Carpenter shop, etc	11.00
McDermott Carriage Co	Office wagon	3.00
James H. McGill	Instrument shop and drayage	18.70
W. H. Mehler	Repairs	43.50
Geo. Meier & Co	Printing supplies	1.50
F. H. Melville	Stationery	1.41
A. A. Meredith	Extra labor	154.84
Chas. E. Miller & Bro	Contingencies	27.35
Francis Miller	Carpenter shop, etc	210.32
Moore Bros	Contingencies	.50
F. J. Monrote	Instruments and repairs	19.75
W. B. Moses & Sons	Office furniture, etc	721.18
C. A. Muddiman & Co	Repairs	2.00
Multiscope and Film Co	Photograph supplies	39.35
P. Munn & Co	Books and subscriptions	9.00
C. A. Murdock & Co	Stationery	5.40
N. Murray	Subscriptions	7.50
Geo. F. Muth & Co	Drawing and printing supplies and carpenter shop.	633.36
J. M. Myers	Stationery	90.00
National Electric Supply Co	Stationery, etc	10.55
National Mosaic Co	Repairs	144.00
Guy M. Neely	Contingencies	.30
T. S. & J. D. Negus	Instruments	9.00
E. S. Newman	Stationery	2.50
New York Steel and Copper Plate Co	Copper plates	1 282.95
F. E. Okie Co	Printing supplies	12.00
Ottawa Literary and Scientific Society.	Books	1.68
V. L. Ourdan	Engraving machines, etc	6 008.40
John C. Parker	Books and stationery	43.20
Parsons Paper Co	Contingencies	5.40
J. A. Pierpoint	....do	36.92
Chas. S. Platt	Instrument shop	14.79
Postal Telegraph Cable Co	Telegrams	36.54
Postmaster, Washington, D. C	Box rent	16.00
J. D. Potter	Book	5.46
Professional Photograph Publishing Co.	Subscription	1.00
E. J. Pullman	Photograph supplies	1 061.57
G. R. Putnam	Maps	73.38
Queen & Co., Incorporated	Photograph and engraving supplies	61.50
John C. Rau	Repairs, etc	483.41
Reading Paper Mills	Chart paper	2 657.56
Josephine Reed	Extra labor	180.00
Parker G. Reed	Contingencies	3.75
Fred Rees	....do	.88
Hugh Reilly	Carpenter shop	8.98
F. J. Reutlinger	Instrument shop	10.80
Revenue Cutter Service	Flags	42.25
Herbert L. Rice	Book	3.50
E. S. Ritchie & Sons	Instruments	180.00
Rochester Optical and Camera Co	Photograph supplies	.46
Aug. F. Rogers	Suboffice expenses, etc	246.44
Dr. John Rome	Office horse	10.00

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1901—Continued.

To whom paid.	On what account.	Amount.
Rudolph, West & Co	Carpenter shop, etc	$114.18
Julius F. Sachse	Maps	3.00
E. G. Schafer & Co	Repairs, etc	33.81
Schmedtie Bros	Instruments	3.00
Fred A. Schmidt	Drawing and engraving supplies, stationery, etc.	1 838.52
John Sellers & Sons	Instrument shop	30.00
Seth Thomas Clock Co	Instruments	25.20
Chas. W. Sever & Co	Stationery	2.25
B. F. Shaw	Office horse	268.00
Geo. A. Shehan	Carpenter shop	465.22
Shoemaker & Busch	Contingencies	12.98
M. Sickles & Sons	....do	2.95
M. Silverberg & Co	Carpenter shop	27.55
Francis E. Smith	Repairs	18.20
W. A. Smith	Books	1.39
Smithsonian Institution	Transportation exchange	357.85
Soule Photo Co	Photographs	3.33
Standard Oil Co	Contingencies	15.38
Gustav E. Stechert	Books, charts, and subscription	374.93
Sutherland & Carr	Instrument shop, etc	3.75
Guiseppe Tagliabue	Instruments	70.30
The Capital Traction Co	Office travel	51.00
The Chesapeake and Potomac Telephone Co.	Exchange rental and calls	77.23
The Evening Star Newspaper Co	Advertising	3.90
The Fuchs & Lang Manufacturing Co.	Copper	10.20
The Grove Lime and Coal Co	Contingencies	5.80
The J. C. Ergood Co	....do	23.09
The Julius Lansburgh Furniture and Carpet Co.	Office furniture	15.66
The L.A. Starrett Co	Instruments	27.90
The Macmillan Co	Subscriptions	10.00
The McDermott Carriage Co	Office wagon	7.00
The Monumental Label Co	Instrument shop	2.50
The Newberry Library	Books	75.00
The Red "C" Oil Manufacturing Co.	Contingencies	25.70
The Scovell & Adams Co. of New York.	Photograph supplies	276.00
The Shaw-Walker Co	Contingencies	6.91
The Strowger Automatic Telephone Exchange.	Rent of telephones	162.00
The University of Chicago Press	Subscriptions	4.00
The United States Marine-Hospital Service.	Printing supplies	43.37
The Waterproof Paint Co	Contingencies	2.50
The Woolaeger Manufacturing Co	....do	48.75
James S. Topham	Instruments, etc	26.50
R. J. Trostler	Extra labor	216.67
United States Electric Lighting Co	Electricity	221.54
United States Express Co	Transportation	21.40
United States Naval Institute	Subscriptions	3.50
United States Typewriter and Supply Co.	Typewriter	92.25
Chas. C. Van Horn	Contingencies	18.30
W. H. Veerhoff	....do	15.00
Wm. Waple	Extra labor	140.32

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1901—Continued.

To whom paid.	On what account.	Amount.
Wm. H. Warner	Instrument shop	$14.40
John Wanamaker	Books, etc	112.00
Washington Gas Light Co	Gas	774.40
Washington Post Co	Advertising	8.70
J. G. Weide	Contingencies	7.50
Western Electric Co	Instruments	77.00
Western Union Telegraph Co	Telegrams	320.47
The Pratt-Whitney Co	Instrument shop	27.57
Williams, Brown & Earle	Contingencies	28.32
Wyckoff, Seamans & Benedict	Repairs to typewriter	9.70
Yawman & Erb Manufacturing Co.	Contingencies	5.00
Amount disbursed		37 141.60
Accounts for stationery settled by Auditor		671.14
Expenditures		37 812.74
Appropriation		38 000.00
Expenditures		37 812.74
Unexpended balance		187.26

CLASSIFICATION OF EXPENDITURES FOR GENERAL EXPENSES, 1901.

On what account.	Amount.
Instruments and repairs of same	$3 487.98
Instrument shop and carpenter shop	2 044.09
Drawing division	39.18
Books, maps, charts, and subscriptions	832.30
Copper plates and zinc	1 750.82
Chart paper	3 999.87
Engraving, printing, photographing, and electrotyping supplies	4 919.89
Photolithographing and printing from stone and copper	2 238.96
Stationery	1 726.46
Office horse and wagon	515.49
Transportation of instruments and supplies	490.83
Fuel	1 047.75
Gas	774.40
Electricity	221.54
Telegrams	357.01
Ice	267.45
Washing	165.29
Telephones	306.18
Miscellaneous expenses and contingencies of all kinds	1 424.39
Office furniture	576.57
Repairs	2 661.36
Extra labor	1 891.83
Traveling expenses (office)	73.10
Automatic engraving machines	6 000.00
Total	37 812.74

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

SALARIES—OFFICE OF STANDARD WEIGHTS AND MEASURES, 1901.

To whom paid.	Time employed.	Amount.
INSPECTOR OF STANDARDS.		
S. W. Stratton	One year	$2 201.09
ADJUSTER.		
Louis A. Fischer	....do	1 500.00
VERIFIER.		
Frank A. Wolff, jr	....do	1 500.00
MECHANICIAN.		
Otto Storm	....do	1 250.00
WATCHMAN.		
J. A. McDowell	....do	602.50
ASSISTANT MESSENGER.		
George Newman	....do	720.00
ADJUSTER'S HELPERS.		
Walter S. Rich	Two months and thirty days	154.57
Grace Kaiser	Thirty days	58.69
Geo. H. Draper	Two months and twenty-three days	164.28
Samuel W. Bogan	Two months and twenty-eight days	173.74
Expenditures		8 324.87
Appropriation		9 410.00
Expenditures		8 324.87
Unexpended balance		1 085.13

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

CONTINGENT EXPENSES, OFFICE OF STANDARD WEIGHTS AND MEASURES, 1901.

MATERIALS AND APPARATUS AND INCIDENTAL EXPENSES.

To whom paid.	On what account.	Amount.
Arthur H. Thomas Co	Contingencies	$6.00
Brown & Sharps Manufacturing Co	Apparatus	17.45
M. Du Perow	Contingencies	27.27
Louis A. Fischer	Traveling expenses	19.75
George W. Knox Express Co	Transportation	14.80
Z. D. Gilman	Contingencies	4.40
International Bureau of Weights and Measures.	Apparatus	77.69
James B. Lambie	Contingencies	.40
Library Bureau	do	2.25
A. C. McClurg & Co	do	1.85
Chas. E. Miller & Bro	do	1.25
Francis Miller	do	2.70
W. B. Moses & Sons	do	31.00
Postal Telegraph Cable Co	Telegram	.20
R. P. Clarke Co	Contingencies	7.10
Wm. Stocket & Co	do	.90
S. W. Stratton	Traveling expenses	219.50
United States Express Co	Transportation	1.71
The Chespeake and Potomac Telephone Co.	Telephone	.50
Expenditures		436.72
Appropriation		1 475.00
Expenditures		436.72
Unexpended balance		1 038.28

PARTY EXPENSES.

ATLANTIC COAST, ETC.

To whom paid.	On what account.	Amount.
Adams Express Co	Transportation	$72.85
Pedro Alvarez	Services	60.00
Baltimore and Ohio Railroad Co	Transportation	13.02
Baltimore Marine, Railway, Machine and Boiler Works.	Repairs of launches	510.70
D. Bernhardt	Stores for Spy and Quick	12.75
W. H. H. Bixler & Co	Outfit for launches	3.50
Blickensderfer Manufacturing Co	Typewriter	45.00
Blue Line Transfer Co	Transportation	3.96
Wm. H. Bohning	Oil for vessels	1.50
J. B. Boutelle	Combined operations, schooner Eagre	7 172.24
Wm. Bowie	Traveling expenses	2.60
Robert Boyd	Medicines	4.00
Wm. F. Butler	Building whaleboat	290.00
P. B. Castles	Services	463.10
John Clay	Storage	22.71
Capt. J. T. Crabbe, quartermaster, U. S. A.	Forage	90.93

Statement of expenditures of the United States Coast and Geodeti. Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES—Continued.

ATLANTIC COAST, ETC.—Continued.

To whom paid.	On what account.	Amount.
L. P. Delcroix	Freight on launch	$15.00
John W. Dickey	Storage	15.00
M. P. Dimpfel	....do	30.00
John W. Donn	Topography	4 819.24
C. Durm & Son	Storage	205.65
Lewis Ehrman	Water for launches	5.25
Harry Ely	Traveling expenses	7.85
W. B. Fairfield	Triangulation	3 843.19
R. L. Faris	Traveling expenses	24.32
Geo. L. Flower	Combined operations, schooner Matchless.	4 124.34
H. F. Flynn	Traveling expenses	56.65
Forbes Co	Outfit for Eagre and Matchless	211.80
Stehman Forney	Combined operations	5 994.31
O. B. French	Hydrography	1 703.99
Geo. F. Blake Manufacturing Co	Repairing launch	2.10
Geo. W. Knox Express Co	Transportation	3.34
W. F. Glover	Traveling expenses	10.90
Graham's Wharehouses	Storage	9.00
C. L. Green	Traveling expenses	18.55
Chas. E. Hansen	Services	500.75
W. C. Hodgkins	Hydrography	36.59
John Hubert	Oil feeder for launch	2.06
James Clark Co	Repairing launch	18.37
James Reilly Repair and Supply Co.	Outfit for steamer Hydrographer	1 070.75
John L. Martin Co	Storage	7.00
S. M. Johnson & Son	Coal for Hydrographer	60.03
John M. Rodgers Boat, Gauge and Drill Works.	Repairing launches	1 564.86
James J. Lacy & Co	Repairing launch	7.75
E. B. Latham	Topography	103.02
Lebanon Chain Works	Outfit, steamer Hydrographer	233.38
John E. McGrath	Triangulation and topography	2 359.59
James A. McGregor	Traveling expenses	2.75
Mechanical Fabric Co	Outfit, steamer Hydrographer	67.45
T. S. and J. D. Negus	....do	393.50
John Nelson	Triangulation and topography	7 027.42
New York and Porto Rico Steam Ship Co.	Transportation	234.34
H. G. Ogden	Traveling expenses	323.07
Chas. Culliber & Bro	Crating launch	10.00
Pennsylvania Railroad Co	Transportation	32.00
James F. Pfau	Services	182.25
E. D. Preston	Triangulation	712.56
Revenue Cutter Service	Flags and bunting	337.64
Rogers & Curran	Coal for Hydrographer	54.90
John Ross	Hydrography and topography	457.79
C. S. Rossiter & Co	Building dinghy	110.00
J. E. Shepherd	Traveling expenses	45.44
Edwin Smith	Triangulation	260.35
H. S. Smith	Traveling expenses	10.27
V. Sournin	Services	368.51
Spedden Shipbuilding Co	Repairing launch	62.04
Standard Oil Co	Oil for schooner Matchless	119.23
W. Stebbins & Sons	Repairs and outfit for launch	8.86
Stevenson & McGee	Repairing launch	45.00

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES—Continued.

ATLANTIC COAST, ETC.—Continued.

To whom paid.	On what account.	Amount.
C. A. Thompson	Traveling expenses	$3.80
O. H. Tittmann	....do	37.85
United States Express Co	Transportation	7.82
United States Marine Hospital Service.	Medical stores for Matchless	8.13
W. I. Vinal	Combined operations, steamer Bache	4 093.63
D. B. Wainwright	Combined operations	748.62
A. L. Webb	Traveling expenses	18.50
F. F. Weld	Topography	2 230.90
P. A. Welker	Combined operations, steamer Blake	11 831.12
Edwin F. White	Traveling expenses	1.62
Wm. E. Woodall & Co	Storage and repairing boats	254.61
Fred A. Young	Hydrography, steamer Endeavor	4 458.25
Amount disbursed		70 393.71
Railroad accounts referred for settlement		104.90
Accounts for medical stores settled by Auditor		811.77
Expenditures		71 310.38
Balance on hand, report for 1900		64 785.87
Appropriation, sundry civil act March 3, 1901		70 000.00
Repayment from appropriation, pay, etc., of officers and men, vessels Coast Survey, 1901		645.45
Total amount available		135 431.32
Expenditures as above		71 310.38
Present unexpended balance		64 120.94

PACIFIC COAST, ETC.

To whom paid.	On what account.	Amount.
Adams Express Co	Transportation	$74.97
Adams Bros	Outfit	3.00
W. D. Alexander	Combined operations	59.00
American Steel and Wire Co	Sounding wire for Pathfinder	25.50
S. Applegate	Services	500.00
D. Ballauf	Sounding tubes for Patterson	21.00
Blue Line Transfer Co	Transportation	19.00
Wm. H. Burger	Traveling expenses	19.00
H. C. Denson	Combined operations	936.70
E. F. Dickins	....do	6 310.91
F. W. Edmonds	Traveling expenses	38.75
L. H. Emmert	Lumber and hardware	20.75
R. L. Faris	Traveling expenses	108.50
H. L. Ford	Hydrography	444.00
E. H. Francis	Services	360.00
J. J. Gilbert	Combined operations, steamer Pathfinder.	20 872.42
J. Kilpatrick	Storage	34.00
Marine Engine and Machine Co	Outfit, steamer Pathfinder	39.50

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES—Continued.

PACIFIC COAST, ETC.—Continued.

To whom paid.	On what account.	Amount.
H. C. Mitchell	Combined operations	$407.08
Fremont Morse	Topography and hydrography	7 861.25
Ostheimer Bros	Oufit, steamer Pathfinder	260.00
Pennsylvania Railroad Co	Transportation	5.14
J. F. Pratt	Combined operations, Steamer Patterson.	16 321.31
G. R. Putnam	.....do	12 368.48
Revenue-Cutter Service	Hydrography	59.60
H. W. Rhodes	Combined operations	375.30
Homer P. Ritter	.....do	18 501.10
Aug. F. Rodgers	.....do	1 198.14
United States Express Co	Transportation	126.52
Ferdinand Westdahl	Combined operations, Steamer McArthur.	9 654.94
C. C. Yates	Traveling expenses	70.61
Amount disbursed		97 096.47
Railroad accounts referred for settlement		1 295.47
Accounts for medical stores settled by Auditor		858.20
Expenditures		99 250.14
Balance on hand, report for 1900		91 685.28
Appropriation, sundry civil act, Mar. 3, 1901		107 500.00
Repayment from appropriation, Pay, etc., of officers and men, vessels Coast Survey, 1901		3 399.07
Total amount available		202 584.35
Expenditures as above		99 250.14
Present unexpended balance		103 334.21

SPECIAL SURVEYS.

To whom paid.	On what account.	Amount.
O. B. French	Traveling expenses	$16.40
C. H. Sinclair	Northwest Boundary Survey	4 519.58
Amount disbursed		4 535.98
Railroad accounts referred for settlement		224.15
Expenditures		4 760.13
Appropriation, sundry civil act, Mar. 3, 1901		13 400.00
Expenditures as above		4 760.13
Unexpended balance		8 639.87

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES—Continued.

RECAPITULATION.

[Showing expenditures in gross by sub-items.]

On what account.	Amount.
Atlantic coast, etc	$70 393.71
Pacific coast, etc	97 096.47
Special surveys	4 535.98
Amount disbursed	172 026.16
Railroad accounts referred for settlement	1 624.52
Accounts for medical stores settled by Auditor	1 669.97
Expenditures	175 320.65
Balance on hand, report for 1900	156 471 15
Appropriation, sundry civil act, March 3, 1901	190 900.00
Repayment from appropriation, Pay, etc., of officers and men, vessels, Coast Survey, 1901	4 044.52
Total amount available	351 415.67
Expenditures	175 320.65
Present unexpended balance	176 095.02

CLASSIFICATION OF EXPENDITURES FOR PARTY EXPENSES.

Triangulation	$47 145.26
Topography	56 055.18
Hydrography	67 360.08
Astronomic	4 760.13
Total	175 320.65

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PAY, ETC., OF OFFICERS AND MEN, VESSELS, COAST SURVEY, 1901.

PAY OF WATCH OFFICERS.

To whom paid.	Time employed.	Amount.
Charles F. Adae	One year	$1 380.00
Frank H. Ainsworth	....do	1 500.00
William G. Appleton	....do	1 620.00
William M. Atkinson	....do	1 420.00
Byron J. Crowley	Eleven months	1 375.00
John L. Dunn	....do	1 265.00
Arthur H. Dutton	....do	1 540.00
Whitney I. Eisler	One year	1 560.00
Christopher W. Fitzgerald	....do	1 550.00
Lawrence M. Furman	....do	1 500.00
Canon L. Green	....do	1 615.00
William F. Glover	....do	1 615.00
Victor R. Lyle	....do	1 615.00
Charles Lyman	....do	1 495.00
Joseph W. McGrath	Eleven months	1 210.00
William B. Proctor	One year	1 179.67
George F. Thomae	Two months	245.00
Charles A. Thompson	One year	1 435.00
Expenditures		25 119.67
Appropriation		27 500.00
Expenditures		25 119.67
Unexpended balance		2 380.33

PAY OF OFFICERS AND MEN.

To whom paid.	On what account.	Amount.
William Bauman, jr	Pay	$415.16
J. B. Boutelle	Pay rolls, schooner Eagre	11 672.59
Robert Boyd	Pay	35.00
Gershom Bradford, 2d	....do	23.23
E. F. Dickins	Pay rolls, steamer Gedney	12 124.20
Harry M. W. Edmonds	Pay	875.00
George L. Flower	Pay rolls, schooner Matchless	8 051.29
Owen B. French	Pay rolls, steamer Blake	1 241.64
J. J. Gilbert	Pay rolls, steamer Pathfinder	21 362.76
Robert H. Hawkes	Pay	138.39
W. C. Hodgkins	Pay rolls, steamer Blake	763.52
J. G. Maupin	Pay	14.52
Fremont Morse	Pay of deck officer	236.67
John Nelson	Pay	50.00
J. F. Pratt	Pay rolls, steamer Patterson	13 428.41
George R. Putnam	Pay rolls, steamer Research	780.61
Louis C. Ritchie	Pay	795.97
William Sanger	....do	693.00
W. Irving Vinal	Pay rolls, schooners Eagre and Matchless and steamer Bache.	14 301.79
P. A. Welker	Pay rolls, steamers Bache and Blake	20 215.81

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PAY, ETC., OF OFFICERS AND MEN, VESSELS, COAST SURVEY, 1901—Continued.

PAY OF OFFICERS AND MEN—Continued.

To whom paid.	On what account.	Amount.
Ferd. Westdahl	Pay rolls, steamer McArthur	$14 751.39
Fred. A. Young	Pay rolls, steamer Endeavor	12 587.66
Amount disbursed		134 558.61
Account of Matts Solvin, deceased, settled by auditor		16.66
Transferred to appropriation, "Party expenses, Coast and Geodetic Survey," amount expended from that appropriation for pay of officers and men.		4 044.52
Transferred to Navy appropriations amount expended by Paymaster M. M. Ramsey, U. S. N., for pay of officers and men.		30 652.16
Expenditures		169 271.95
Appropriation		182 745.00
Expenditures		169 271.95
Unexpended balance		13 473.05

RECAPITULATION.

Pay of watch officers	$25 119.67
Pay of officers and men	169 271.95
Total expenditures	194 391.62
Total sum appropriated for pay of officers and men	210 245.00
Total sum expended for pay of officers and men	194 391.62
Unexpended balance	15 853.38

STEAMER BACHE, COAST SURVEY.

To whom paid.	On what account.	Amount.
L. B. Friendt	Services and traveling expenses	$2 018.90
Chas. C. Fulton & Co	Advertising	3.90
Journal Newspaper Co	do	5.40
New York Press Co., Limited	do	13.20
Herbert G. Ogden	Traveling expenses	68.25
Edw. L. Peacock	Rebuilding steamer Bache	50.00
The Norfolk Landmark	Advertising	2.73
The Press Company	do	7.20
The Times Company	do	1.95
O. H. Tittmann	Traveling expenses	35.80
Townsend & Downey Shipbuilding and Repair Co.	Rebuilding Bache	32 810.50
Expenditures		35 017.83
Appropriation		60 000.00
Expenditures		35 017.83
Unexpended balance		24 982.17

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

STEAMER FOR COAST SURVEY.

To whom paid.	On what account.	Amount.
James Reilly Repair and Supply Co.	Building steamer Hydrographer	$19 500.00
Appropriation		20 000.00
Expenditures		19 500.00
Unexpended balance		500.00

PARTY EXPENSES, 1899.

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
W. C. Hodgkins	Hydrography, steamer Blake	$11.58
Balance on hand, report for 1900		675.52
Expended since, as above		11.58
Present unexpended balance		663.94

RECAPITULATION.

[Showing expenditures in gross by sub-items.]

Objects not named	$11.58
Balance on hand, report for 1900	2 750.32
Expended since, as above	11.58
Present unexpended balance	2 738.74

CONTINGENT EXPENSES, OFFICE OF STANDARD WEIGHTS AND MEASURES, 1899.

MATERIALS AND APPARATUS AND INCIDENTAL EXPENSES.

To whom paid.	On what account.	Amount.
A. A. Michaelson	Traveling expenses	$336.00
Balance on hand, report for 1900		494.42
Expended since, as above		336.00
Present unexpended balance		158.42

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1899.

To whom paid.	On what account.	Amount.
Western Union Telegraph Co	Telegrams	$3.56
Balance on hand, report for 1900		60.20
Expended since, as above		3.56
Present unexpended balance		56.64

PARTY EXPENSES, 1900.

STATE SURVEYS, ETC.

To whom paid.	On what account	Amount.
Benj. E. Tilton	Leveling	$1.60
United States Express Co	Transportation	.35
Expenditures		1.95
Balance on hand, report for 1900		239.37
Expended since, as above		1.95
Present unexpended balance		237.42

NAVY TRAVEL, ETC.

To whom paid.	On what account.	Amount.
J. F. Pratt	Traveling expenses	$107.25
Balance on hand, report for 1900		250.99
Expended since, as above		107.25
Present unexpended balance		143.74

OBJECTS NOT NAMED.

To whom paid.	On what account.	Amount.
L. B. Friendt	Plans for steamer	$150.00
Balance on hand, report for 1900		675.52
Expended since, as above		150.00
Present unexpended balance		525.52

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

PARTY EXPENSES, 1900—Continued.

RECAPITULATION.

[Showing expenditures in gross by sub-items.]

On what account.	Amount.
State surveys, etc	$1.95
Navy travel, etc	107.25
Objects not named	150.00
Expenditures	259.20
Balance on hand, report for 1900	2 935.50
Expended since, as above	259.20
Present unexpended balance	2 676.30

REPAIRS OF VESSELS, 1900.

To whom paid.	On what account.	Amount.
Moran Bros. Co	Repairs, steamer Patterson	$4 064.00
Amount disbursed		4 064.00
Accounts settled by Auditor for repairs to steamer Gedney		3 300.00
Expenditures		7 364.00
Balance on hand, report for 1900		7 420.51
Expended since, as above		7 364.00
Present unexpended balance		56.51

CONTINGENT EXPENSES, OFFICE OF STANDARD WEIGHTS AND MEASURES, 1900.

MATERIALS AND APPARATUS AND INCIDENTAL EXPENSES.

To whom paid.	On what account.	Amount.
United States Express Co	Transportation	$0.80
Balance on hand, report for 1900		530.82
Expended since, as above		.80
Present unexpended balance		530.02

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

GENERAL EXPENSES, 1900.

To whom paid.	On what account.	Amount.
S. C. Chandler	Books	$5.00
Lemcke & Buechner	Subscription	4.70
John C. Parker	Book	5.00
G. E. Stechert	Books and subscriptions	12.00
The International Arithmachine Co.	Adding machine	36.00
The Macmillan Co	Book	2.50
United States Express Co	Transportation	1.55
Western Union Telegraph Co	Telegrams	5.45
Expenditures		72.20
Balance on hand, report for 1900		402.60
Expenditures since, as above		72.20
Present unexpended balance		330.40

GENERAL RECAPITULATION.

[Showing appropriations and balances for the fiscal year ended June 30, 1901, and for all other accounts included in this report.]

Name of appropriation.	Appropriated.	Expended.	Balances.
Salaries, 1901, sundry civil act, June 6, 1900:			
Pay of field officers	$116 460.00	$112 874.75	$3 585.25
Pay of office force	141 640.00	140 175.49	1 464.51
Party expenses, 1901, sundry civil act, June 6, 1900	72 500.00	67 086.89	5 413.11
Repairs of vessels, 1901: Sundry civil act, June 6, 1900 .... $29,600.00; Deficiency act, March 3, 1901 .... 25,000.00	54 600 00	41 434.41	13 165.59
Publishing observations, 1901, sundry civil act, June 6, 1900	1 000.00	1 000.00	....
General expenses, 1901, sundry civil act, June 6, 1900	38 000.00	37 812.74	187.26
Salaries, Office of Standard Weights and Measures, 1901, legislative act, April 17, 1900	9 410.00	8 324.87	1 085.13
Contingent expenses, Office of Standard Weights and Measures, 1901, legislative act, April 17, 1900	1 475.00	436.72	1 038.28
Party expenses: Balance on hand, report for 1900...... $156,471.15; Sundry civil act, March 3, 1901....... 190,900.00; Repayment from appropriation, "Pay, etc., of officers and men, etc., 1901" 4,044.52	351 415.67	175 320.65	176 095.02
Pay, etc., of officers and men, vessels, Coast Survey, 1901, sundry civil act, June 6, 1900	210 245.00	194 391.62	15 853.38
Steamer Bache, Coast survey, sundry civil act, June 6, 1900	60 000.00	35 017.83	24 982.17
Steamer for Coast Survey, sundry civil act, June 6, 1900	20 000.00	19 500.00	500.00
Party expenses, 1899, balance on hand, report for 1900	2 750.32	11.58	2 738.74
Contingent expenses, Office of Standard Weights and Measures, 1899, balance on hand, report for 1900	494.42	336.00	158.42
General expenses, 1899, balance on hand, report for 1900	60.20	3.56	56.64
Party expenses, 1900, balance on hand, report for 1900	2 935.50	259.20	2 676.30
Pepairs of vessels, 1900, balance on hand, report for 1900	7 420.51	7 364.00	56.51
Contingent expenses, Office of Standard Weights and Measures, 1900, balance on hand, report for 1900	530.82	.80	530.02
General expenses, 1900, balance, on hand, report for 1900	402.60	72.20	330.40
Total	1 091 340.04	841 423.31	249 916.73

Statement of expenditures of the United States Coast and Geodetic Survey for the fiscal year ended June 30, 1901—Continued.

TREASURY DEPARTMENT,
OFFICE OF THE COAST AND GEODETIC SURVEY,
Washington, D. C., December 19, 1901.

I certify that the foregoing statement is a correct exhibit of all expenditures made by me for the United States Coast and Geodetic Survey and for the Office of Standard Weights and Measures, for the fiscal year ended June 30, 1901, and for preceding years, including all accounts paid to the close of business on November 30, 1901.

SCOTT NESBIT,
Disbursing Agent.

Approved:
O. H. TITTMANN,
Superintendent United States Coast and Geodetic Survey.

VI. OFFICE OF EDITOR OF PUBLICATIONS.

E. D. PRESTON, *Editor*, July 1 to Mar. 4.
ISAAC WINSTON, *Editor*, Mar. 5 to June 30.
Arthur F. Belitz, *Stenographer and Typewriter.*

The Annual Report for 1899 was completed under the direction of Assistant Preston, and the proof of Special Publication No. 4, "The Transcontinental Triangulation," was read. The MS. for Special Publication No. 6, "Notes Relative to the Use of Charts," was prepared, sent to the printer, and the proof was read. Progress was made in the preparation of the Annual Report for 1900, but owing to the illness of the editor, Assistant Preston, its completion was delayed.

On assuming the duties of editor on March 5 Assistant Winston found the Annual Report for 1900 still incomplete.

The plan upon which it had been prepared was examined and revised in order to make it accord more nearly with existing conditions, and the preparation of the illustrations was continued until May 15, when the completed MS. was sent to the Public Printer.

In the latter part of May the MS. of a special publication (869 pages) covering the discussion of the eastern oblique arc of the United States, by Assistant Charles A. Schott, was received and prepared for publication, except the illustrations, which were not all completed before June 30.

Abstracts of the reports of field parties for the first half of the fiscal year were prepared for the Annual Report for 1901.

The MS. for all publications of the Survey passes through the office of the editor and the proof is received and sent to the proper division of the office for revision. The Tidal Division reads the proof of the Tide Tables, the Chart Division that of the monthly Notices to Mariners, and the Coast Pilot Party that of the Coast Pilots and Supplements.

The following publications were received and issued during the year:

Tide Tables for 1901.
Tide Tables for 1902.
United States Coast Pilot, Part V (reprint).
United States Coast Pilot, Part VII (2d edition).

United States Coast Pilot, Part VIII (2d edition).
Supplement to United States Coast Pilot, Part V.
Bulletin No. 40, Coast Pilot Notes on Fox Islands, etc. (3d edition).
Bulletin No. 41, Magnetic Survey of North Carolina.
Annual Report of the Superintendent 1899, with Appendices Nos. 3, 4, 5, 6, 7, 8, 9 and 10, also as separates.
Special Publication No. 3. An Atlas of the Philippine Islands.
Special Publication No. 4. The Transcontinental Triangulation.
Special Publication No. 6. Notes Relative to the Use of Charts.
Special Publication No. 6, 2d edition. Notes Relative to the Use of Charts.
Catalogue of Charts, 1900.
Twelve monthly Notices to Mariners.
Fourteen leaflets describing the work of the Coast and Geodetic Survey, for the Pan American Exposition, English edition.

VII. OFFICE OF STANDARD WEIGHTS AND MEASURES.

S. W. STRATTON, *Inspector of Weights and Measures.*

Louis A. Fischer, *Adjuster.*
Frank A. Wolff, jr., *Verifier.*
Otto Storm, *Mechanician.*
W. S. Rich, *Adjuster's Helper.*
Geo. S. Draper, *Stenographer and Typewriter.*
Jas. A. McDowell, *Watchman.*
George Newmann, *Messenger.*

The Office continued under the general direction of the Superintendent, Coast and Geodetic Survey, with Inspector Stratton in immediate charge until June 30, 1901.

During the previous fiscal year an attempt was made to enlarge and reorganize the Office of Standard Weights and Measures in order to meet the constantly increasing demands upon it more efficiently, and the draft of a bill providing for the establishment of a National Standardizing Bureau was submitted to Congress by the Secretary of the Treasury, with an appended statement of the conditions necessitating such legislation. This bill received a favorable report by the House Committee on Coinage, Weights, and Measures, and was under consideration by the Senate Committee on Commerce at the adjournment of the first session of the Fifty-sixth Congress.

A great deal of interest was taken in the measure by manufacturers, scientists, and others throughout the country, and it was favorably considered and passed by Congress in a somewhat modified form, and became a law on March 3, 1901. The act provides that the Office of Standard Weights and Measures shall be known as the National Bureau of Standards, the duties to be as follows:

1. Custody of the Standards.
2. Comparison of the Standards used in scientific investigations, engineering, manufacturing, commercial, and educational institutions with the standards adopted or recognized by the Government.
3. The construction, when necessary, of standards, their multiples and subdivisions.
4. The testing and calibration of standard measuring apparatus.
5. The solution of problems which arise in connection with standards.
6. The determination of physical constants and the properties of materials when such data are of great importance and not to be obtained of sufficient accuracy elsewhere.

The Bureau will exercise its functions for the Government of the United States, for any State or municipal government within the United States, or for any scientific society, educational institution, firm, corporation, or individual within the United States requiring the use of standards or standard measuring apparatus. For all comparisons, calibrations, tests, or investigations, except those performed for the Government of the United States or State governments within the United States, a reasonable fee will be charged. Provision is also made for the purchase of a site, the erection of a suitable laboratory, its equipment with the most improved facilities, and the personnel necessary for the organization of the Bureau.

Although the bill did not become fully operative until July 1, preliminary plans were immediately prepared by the Office of Standard Weights and Measures for carrying out the provisions of the act. This involved the examination of numerous sites, and investigations as to equipment, personnel, and the immediate development of some of the more important lines to be taken up by the new Bureau. Preliminary investigations were made as to the construction and equipment of the more important laboratories of this and other countries, and of the work that must, of necessity, be developed as soon as possible after the organization of the new Bureau. A large number of sites were very carefully inspected with reference to their freedom from mechanical and electrical disturbances and accessibility, in order that a selection might be made as soon as possible after July 1, 1901.

On account of the many requests for information received from Congressional committees and individuals in public and private life, the work of the Office of Standard Weights and Measures was greatly increased. Nevertheless the regular work of the Office was not allowed to suffer, and the usual number of adjustments and verifications of apparatus were made for the Executive Departments, for the States, and for others.

Numerous requests for information concerning the origin and present status of the metric system were received, showing that the country is considering the commercial advantages of the system in its transactions with European and South American nations.

The use of this system in the Philippines, Porto Rico, and Cuba, and the close relations existing between these islands and the United States since the war with Spain, has doubtless much to do with the interest now manifested in the subject.

The division of the work of the Office into two sections was continued during the year.

SECTION I.

The usual number of verifications was made for the Executive Departments, for the State authorities, for manufacturers, and others. In addition, a 5-meter standard was determined for the Japanese Government, a 100-foot steel tape for the chief surveyor of the Straits Settlements, and two 50-meter tapes for the Mexican Government.

The following is a summary of the work done:

59 tapes compared.
18 single weights verified.
13 sets of weights verified.
5 capacity weights verified.
53 thermometers compared.
28 hydrometers verified.
14 leveling rods compared.
6 balances verified.

62 polariscope tubes verified.
1 magnetometer deflection bar compared.
1 5-meter standard compared.
600 sugar flasks graduated and verified.
123 requests for information complied with.

983 Total number of calls.

Section II.

A large portion of the time was devoted to making plans for increasing the range of comparisons and for new lines of work to be undertaken.

A second complete intercomparison of all the resistance standards of the Office, including two new 1-ohm coils, shortly before verified at the P. T. Reichsanstalt, were made during the year, and showed a gratifying constancy of the preliminary standards adopted. With a new intercomparison in contemplation, sufficient information concerning the rate of change of the coils will be at hand to allow suitable corrections to be applied and to enable the Office to guarantee results to within sufficiently small limits of accuracy to meet the most exacting demands, which is at present impossible on account of the absence of such information.

The various resistance boxes of the Office were also recompared and the master standards of a number of manufacturers of scientific apparatus were verified.

APPENDIX No. 1.

REPORT 1901.

DETAILS OF FIELD OPERATIONS.

CONTENTS.

TABULAR INDEX OF FIELD WORK.

EASTERN DIVISION—EAST OF THE MISSISSIPPI RIVER.

1. Maine.
2. New Hampshire.
3. Vermont.
4. Massachusetts.
5. Rhode Island.
6. Connecticut.
7. New York.
8. New Jersey.
9. Pennsylvania.
10. West Virginia.
11. Maryland.
12. District of Columbia.
13. Delaware.
14. Virginia.
15. North Carolina.
16. South Carolina.
17. Georgia.
18. Florida.
19. Michigan.
20. Wisconsin.
21. Illinois.
22. Indiana.
23. Ohio.
24. Kentucky.
25. Tennessee.
26. Alabama.
27. Mississippi.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
1	Magnetic.	Maryland. District of Columbia. Virginia. Michigan. Wisconsin. Illinois. Indiana. Ohio. Kentucky. Tennessee. Mississippi.	Bauer.		70
2	Magnetic.	Maryland. North Carolina.	Baylor.		73
3	Hydrographic. Topographic. Triangulation.	New York.	Boutelle.	Eagre.	74
4	Leveling.	Kentucky. Tennessee. Alabama.	Burger.		75
5	Magnetic.	Pennsylvania. Michigan. Indiana.	Dibrell.		77
6	Topographic. Triangulation.	Maryland.	Donn.		78

EASTERN DIVISION—EAST OF THE MISSISSIPPI RIVER—Continued.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
7	Triangulation.	Maine. New Hampshire. Massachusetts. South Carolina.	Fairfield.		81
8	Direct measurement. Triangulation. Trigonometric leveling.	South Carolina. Georgia.	Fairfield.		82
9	Leveling.	Kentucky. Tennessee. Alabama.	Ferguson.		84
10	Magnetic.	Maryland.	Fleming.		85
11	Hydrographic. Magnetic. Tide. Topographic. Triangulation.	Massachusetts. Georgia. Florida. Illinois.	French.		86
12	Topographic.	Maryland.	Forney.		88
13	Leveling.	District of Columbia.	Hayford.		90
14	Hydrographic. Reconnaissance. Topographic. Triangulation.	North Carolina. Georgia.	Hodgkins.		91
15	Topographic.	Maryland.	Latham.		95
16	Tide.	Pennsylvania. Delaware. North Carolina. Florida.	Little.		96
17	Topographic.	New York.	McGrath.		97
18	Hydrographic. Topographic.	Connecticut.	Marindin.		98
19	Topographic.	Maine. New Hampshire. Maryland.	Nelson.		99

EASTERN DIVISION—EAST OF THE MISSISSIPPI RIVER—Continued.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
20	Hydrographic. Reconnaissance. Topographic. Triangulation.	Massachusetts. Rhode Island. Georgia.	Preston.		101
21	Coast Pilot.	Florida. Alabama. Mississippi. Louisiana.	Ross.		103
22	Longitude.	Wisconsin.	Sinclair.		104
23	Reconnaissance.	Maryland. Virginia.	Smith.		105
24	Tide observations (continuous).	New York. Pennsylvania. District of Columbia. Florida.			106
25	Hydrographic. Leveling. Topographic.	South Carolina.	Vinal.	Matchless.	107
26	Hydrographic. Topographic.	New Jersey.	Vinal.	Bache.	108
27	Topographic. Triangulation.	Delaware. South Carolina.	Wainwright.		110
28	Topographic. Triangulation.	Maryland.	Weld.		111
29	Hydrographic. Special duty. Triangulation.	Maryland.	Welker.	Bache.	112
30	Hydrographic. Special duty. Topographic.	Maryland. Florida.	Welker.	Blake.	115
31	Hydrographic.	South Carolina.	Yates.		118
32	Hydrographic. Triangulation.	Delaware River. Chesapeake Bay.	Young.	Endeavor.	120

MIDDLE DIVISION—BETWEEN THE MISSISSIPPI RIVER AND THE ROCKY MOUNTAINS.

28. Louisiana.
29. Arkansas.
30. Missouri.
31. Iowa.
32. Minnesota.
33. North Dakota.
34. South Dakota.
35. Nebraska.
36. Kansas.
37. Oklahoma.
38. Indian Territory.
39. Texas.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
33	Base measurement.	Nebraska. Kansas. Oklahoma Territory. Texas.	Baldwin.		122
34	Magnetic.	Louisiana. Arkansas. Missouri. Iowa. Minnesota. South Dakota. Nebraska. Kansas. Texas.	Bauer.		124
35	Magnetic.	Kansas. Oklahoma Territory. Texas.	Dibrell.		126
36	Reconnaissance. Triangulation.	Nebraska. South Dakota.	Granger.		127
37	Magnetic.	Texas.	Little.		128
38	Triangulation.	Kansas.	Mosman.		129
39	Coast Pilot.	Louisiana. Texas.	Ross.		131
40	Leveling.	Nebraska. Kansas.	Tilton.		132

WESTERN DIVISION—WEST OF THE ROCKY MOUNTAINS.

40. New Mexico.
41. Arizona.
42. Colorado.
43. Wyoming.
44. Montana.
45. Idaho.
46. Utah.
47. Nevada.
48. California.
49. Oregon.
50. Washington.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
41	Magnetic.	California. Oregon.	Bauer.		133
42	Magnetic.	Washington. Colorado.	Dibrell.		134
43	Coast Pilot.	California.	Dickins.	Gedney.	135
44	Extension of Speed Trial Course.	California.	Edmonds.		136
45	Coast Pilot.	California.	Ford.		137
46	Hydrographic. Reconnaissance. Topographic. Triangulation.	Oregon. Washington.	Morse.		138
47	Charge of Sub-Office. Tide.	California.	Rodgers.		141
48	Astronomic.	Western Division. Northwest Boundary.	Sinclair.		142
49	Hydrographic.	California. Washington.	Westdahl.	McArthur.	144

DIVISION OF ALASKA.

50	Magnetic.	Alaska.	Bauer.		145
51	Reconnaissance.	Alaska.	Dickins.	Gedney.	146
52	Magnetic.	Alaska.	Fleming.		147

DIVISION OF ALASKA—Continued.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
53	Base line. Gravity. Hydrographic. Magnetic. Reconnaissance. Special duty. Tide. Topographic. Triangulation.	Alaska.	Gilbert.	Pathfinder.	148
54	Coast Pilot.	Alaska.	Graves.		152
55	Astronomic. Base line. Hydrographic. Magnetic. Reconnaissance. Tide. Topographic. Triangulation.	Alaska.	Pratt.	Patterson.	153
56	Astronomic. Base line. Hydrographic. Magnetic. Reconnaissance. Topographic. Triangulation.	Alaska.	Ritter.	Taku.	159
57	Base line. Coast Pilot. Reconnaissance. Triangulation.	Alaska.	Westdahl.	McArthur.	161

OUTLYING TERRITORY.

58	Register of Geographic Names. Register of Geographic Positions. Tide.	Hawaii.	Alexander.		163
59	Magnetic.	Hawaii.	Bauer.		164
60	Hydrographic. Reconnaissance. Tide. Topographic. Triangulation.	Porto Rico.	Boutelle.	Eagre.	165

OUTLYING TERRITORY—Continued.

Numerical No.	Character of work.	Locality.	Chief of party.	Name of vessel.	Page.
61	Hydrographic. Tide.	Porto Rico.	Flower.	Matchless.	167
62	Magnetic. Topographic. Triangulation.	Porto Rico.	Forney.		169
63	Base line. Reconnaissance. Triangulation.	Porto Rico.	McGrath.		171
64	Magnetic. Reconnaissance. Topographic. Triangulation.	Porto Rico.	Nelson.		174
65	Collecting information.	Philippine Islands.	Perkins.		176
66	Astronomic. Base line. Hydrographic. Magnetic. Topographic. Triangulation.	Philippine Islands.	Putnam.		177

SPECIAL DUTY.

Character of work.	Name.	Page.
Processes used in production of charts in England and France.	Fowler, E. H.	189
Resurvey of Mason and Dixon's line.	Hodgkins, W. C.	190
Marking the Virginia and Tennessee boundary line.	Hodgkins, W. C. Baylor, J. B.	191
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TECHNICAL INDEX OF FIELD WORK.

DETAILED STATEMENT OF FIELD WORK.

EASTERN DIVISION.

MAGNETIC. | MARYLAND. DISTRICT OF COLUMBIA. VIRGINIA. MICHIGAN. WISCONSIN. ILLINOIS. INDIANA. OHIO. KENTUCKY. TENNESSEE. MISSISSIPPI. | L. A. BAUER.

J. B. BAYLOR, *Assistant.*	May 17–18.
W. M. BROWN, *Magnetic Observer.*	July 1 to Aug. 2.
	Oct. 31 to Jan. 30.
W. G. CADY, *Magnetic Observer.*	Aug. 6 to Sept. 12.
	Nov. 28 to June 30.
C. W. DAWSON, *Recorder.*	July 1 to July 31.
H. M. W. EDMONDS, *Magnetic Observer.*	Apr. 5 to June 16.
C. K. EDMUNDS, *Magnetic Observer.*	Aug. 25 to Sept. 8.
J. A. FLEMING, *Aid.*	Mar. 25 to May 5.
H. F. GLOETZNER, *Recorder.*	July 1 to Sept. 29.
	Nov. 19 to Apr. 15.
D. L. HAZARD, *Computer.*	May 2, 3, 17, and 18.
F. H. LOUD, *Magnetic Observer.*	July 1 to Aug. 5.
J. W. MILLER, Jr., *Magnetic Observer.*	July 1 to Aug. 17.
	Oct. 30 to Nov. 5.
	June 17 to June 30.
R. W. WALKER, *Temporary Aid.*	May 15 to May 21.
R. W. WALKER, *Magnetic Observer.*	June 14 to June 30.
W. F. WALLIS, *Magnetic Observer.*	Dec. 2 to Apr. 12.
	May 24 to June 30.
W. WEINRICH, Jr., *Magnetic Observer.*	July 1 to Aug. 31.
	Dec. 3 to Apr. 10.

The determination of the constants and the comparison of various instruments were made by Assistant Bauer, at the office in Washington, and he also occupied the base station for the magnetic survey of *Maryland*, at Linden, Montgomery County, on three occasions in July, May, and June.

Some special observations were made at Cheltenham, Md., by Assistant J. B. Baylor.

The magnetic elements and bearings of lines were determined for the use of surveyors at the following stations in *Virginia:* Elkton, Front Royal, Luray, Madison, Stanardsville, and Washington, by Magnetic Observer W. M. Brown, July 1 to 12. From July 13 to August 2, and from October 31 to January 31, he was temporarily engaged at Washington, D. C., in reducing field observations and determining constants and comparing instruments. Mr. Brown resigned on February 1.

Magnetic Observer W. G. Cady was on temporary duty at Washington, D. C., from August 6 to September 12 and November 28 to January 7, receiving instructions in magnetic work and determining constants, comparing instruments, and in reducing observations. From October 29 to November 27 he determined the magnetic elements and established meridian lines in *Wisconsin*, at La Crosse, Prairie du Chien, and Madison; in *Illinois*, at Chicago; in *Indiana*, at Michigan City, and in *Michigan*, at Kalamazoo and Detroit. From January 8 to June 30 he was in charge of the magnetic observatory at Cheltenham, Md.

Recorder Dawson assisted Mr. W. M. Brown July 1 to 16, and Assistant L. A. Bauer July 17 to 31.

Magnetic Observer H. M. W. Edmonds was on temporary duty at Washington, D. C., April 5 to 19, receiving instructions in magnetic work. From April 20 to June 16 he was assigned to duty at the magnetic observatory at Cheltenham, Md. On June 17 he started to Sitka, Alaska, to take charge of the magnetic observatory at that place.

Magnetic Observer C. K. Edmunds was on temporary duty at Washington, D. C., August 25 to September 8, making magnetic observations and in making reductions.

Aid J. A. Fleming was stationed at the magnetic observatory at Cheltenham, Md., March 25 to May 5, assisting in the work. He was also engaged in preparing plans for magnetic observatories at Sitka, Alaska, and in the Hawaiian Islands.

Recorder Gloetzner was employed in making observations of the magnetic declination daily, except Sunday, at Gaithersburg, Md., July 1 to 6, August 4 to September 29, and November 19 to April 6. He was temporarily employed at Washington in reducing field work July 7 to August 3, November 16 to 18, and April 7 to 15.

Special observations at Washington, D. C., May 2 to 3, and at Gaithersburg, Md., May 17 to 18, were made by Computer D. L Hazard.

Observations of the declination at Gaithersburg, Md., July 1 to August 5, were made by Magnetic Observer F. H. Loud.

Magnetic Observer J. W. Miller, jr., was engaged in making magnetic observations and determining lines for surveyors' use July 1 to August 17 in *Kentucky*, at Grayson; in *Ohio*, at Portsmouth, Chillicothe, Washington Court-House, Bellefontaine, Marion, Ashland, Akron, Cleveland, Jefferson, and Warren; and in *Virginia*, at Round Hill, Leesburg, Fairfax, and Stafford. He was temporarily employed in Washington, D. C., October 30 to November 5 and on June 17 in reducing field observations. From June 18 to 30 he assisted in the magnetic observatory work at Cheltenham, Md.

Magnetic Observer R. W. Walker assisted in the magnetic observatory work at Cheltenham, Md., May 15 to 21, and from June 14 to 30 he was on temporary duty at Washington, D. C., under instruction in magnetic work.

Magnetic observations were made and meridian lines were established December 2 to 13 in *Illinois*, at Nashville and McLeansboro; in *Indiana*, at Evansville; and in

Kentucky, at Hawesville, by Magnetic Observer W. F. Wallis. From December 21 to February 25 he was on duty at the magnetic observatory at Cheltenham, Md., and from December 17 to 20, February 26 to April 12, and May 24 to June 30 he was on temporary duty at Washington, D. C., determining constants, comparing instruments, and reducing field observations.

Magnetic Observer W. Weinrich, jr., was on temporary duty at Washington, D. C., July 1 to August 8, August 17 to 31, and December 3 to February 21, engaged in receiving instructions in magnetic work and in reducing field observations. From August 9 to 16 he assisted Magnetic Observer J. W. Miller in his work in *Virginia*. He determined the magnetic elements and established meridian lines February 22 to April 10 in *Tennessee*, at Memphis; and in *Mississippi*, at Holly Springs, Oxford, Tupelo West Point, Winona, Yazoo, Jackson, Brookhaven, Forest, Meridian, and Ellisville.

NORTH CAROLINA.

State.	County.	Town.
North Carolina	Alexander	Taylorsville.
Do	Alleghany	Sparta.
Do	Ashe	Jefferson.
Do	Burke	Morganton.
Do	Caldwell	Lenoir.
Do	Camden	Camden.
Do	Caswell	Yanceyville.
Do	Catawba	Newton.
Do	Clay	Hayesville.
Do	Davidson	Lexington.
Do	Davie	Mocksville.
Do	Gaston	Dallas.
Do	Graham	Robbinsville.
Do	Haywood	Waynesville.
Do	Henderson	Hendersonville.
Do	Jones	Trenton.
Do	Mitchell	Bakersville.
Do	Polk	Columbus.
Do	Stanley	Albemarle.
Do	Stokes	Danbury.
Do	Watauga	Boone.
Do	Yadkin	Yadkinville.
Do	Yancey	Burnsville.

On the 1st of July Assistant Baylor was making magnetic observations at Rockville, Md. A meridian line was established and the ends marked with granite monuments.

The magnetic declination was then determined by using a declinometer over this line. Upon the completion of the work Assistant Baylor returned to the Office on July 3. On July 24 he proceeded to North Carolina to complete the magnetic survey of that State, which had been undertaken during the previous fiscal year in cooperation with the State authorities. This work was successfully completed before the close of the fiscal year.

HYDROGRAPHIC.
TOPOGRAPHIC.
TRIANGULATION.

NEW YORK.

J. B. BOUTELLE, Commanding, schooner *Eagre*.

F. M. LITTLE, *Assistant*.
V. R. LYLE, *First Watch Officer*.
J. L. DUNN, *Second Watch Officer*.
W. B. PROCTOR, *Third Watch Officer*.
J. H. ULLRICH, *Assistant Surgeon*.
E. V. MILLER, *Junior Captain's Clerk*.

SUMMARY OF RESULTS.

16 miles shore line surveyed.
7 miles of roads and railroads surveyed.
1 mile of creeks surveyed.
117 miles of sounding lines completed.
3 tide stations established.

From July 1 to August 4 the *Eagre* was at Baltimore, Md., making repairs, and the party was employed in completing the records of the past season's work in Porto Rico. In accordance with instructions, Assistant Boutelle took the vessel to New York for repairs, sailing on the 5th of August and arriving on the 10th. The vessel was placed in the dry dock for repairs, which were completed on September 12.

On September 17 the vessel proceeded to Irvington on the Hudson, and the resurvey of the river at that point was begun. Watch Officer Proctor reported on board on September 19 and Assistant Little on September 29. The triangulation was taken up at the stations Hook Mountain and Pagoda, and extended up the river to Stony Point Light-house.

The hydrographic work was completed from Ardsley and Piermont to a point opposite Hook Mountain.

The topography was extended from Ardsley and Piermont to a point above Tarrytown on the east side and to Nyack on the west side. On the east side the topography extends to the railroad track and on the west side to the road between Piermont and Nyack. The weather was extremely unfavorable for field work on account of fog and rain.

The work for the season closed on November 5, and the vessel sailed for Baltimore, Md., to fit out for work in Porto Rico. The vessel reached Baltimore on November 13.

LEVELING. | KENTUCKY. TENNESSEE. ALABAMA. | WILLIAM H. BURGER.

OVID BELL, *Recorder*.

SUMMARY OF RESULTS.

315 miles completed line.
77 permanent bench marks established.

In order to extend the standard levels of the Survey, Aid W. H. Burger left Washington on July 15 and proceeded to Somerset, Ky., where the arrangements for the season's work were completed and a party was organized. The work began on July 23, and the line of levels was carried southward from Somerset, Ky., along the line of the Cincinnati, New Orleans and Texas Pacific Railway to Harriman Junction, Tenn., and thence eastward along the Southern Railway to Knoxville, Tenn. While engaged in this work very little time was lost on account of bad weather, but the inconvenient schedule of trains used in transporting the party caused some delay. The route passed through a mountainous and sparsely settled portion of Kentucky and Tennessee, and the towns affording accommodations for the party were far apart.

The grades on the railway were heavy, the trestles were long and numerous, and in the first hundred miles of the route the railway passed through 24 tunnels. The topography of the country rendered it impracticable to carry the levels around these tunnels and it was difficult to level through them. Various devices were used to illuminate the leveling rods while at work in the tunnel, and an acetylene gas lamp, such as used on bicycles, was found to be more satisfactory than any other device on dark days and when the tunnels were not straight. In straight tunnels, when the sun was shining, a mirror was placed at each end of the tunnel and the rods were illuminated by reflected sunlight.

From a point near Elverton, Tenn., the levels were carried over a branch line 12 miles long to a triangulation station on Melton Hill.

The levels were connected with bench marks established by the U. S. Geological Survey at Knoxville, and the party then proceeded to Woodville, Ala., under instructions to carry the levels from that point to Birmingham, Ala., via Decatur, Ala.

The route followed the Southern Railway as far as Decatur, where the levels were connected with bench marks established there by the Corps of Engineers, U. S. A. The route then followed the Louisville and Nashville Railway to Birmingham, where connection was made with bench marks established there by the Corps of Engineers, U. S. A., and the work for the season closed on January 12.

The work described above forms a portion of the leveling operations between Cincinnati, Ohio, and Birmingham, Ala., undertaken to connect the elevations determined at the former place by the U. S. Coast and Geodetic Survey with those determined at Knoxville and Chattanooga, Tenn., by the U. S. Geological Survey, and those at Decatur and Birmingham, Ala., determined by the Corps of Engineers, U. S. A.

Stations occupied.

State.	County.	Town.
Pennsylvania	Montgomery	Hatboro.
Indiana	Wayne	Richmond.
Do	Decatur	Greensburg.
Do	Jefferson	Madison.
Do	Orange	Paoli.
Do	Greene	Bloomfield.
Do	Vigo	Terre Haute.
Do	Morgan	Martinsville.
Do	Marion	Indianapolis.
Do	Montgomery	Crawfordsville.
Do	Howard	Kokomo.
Do	Blackford	Hartford City.
Do	Allen	Fort Wayne.
Do	Kosciusko	Warsaw.
Michigan	St. Joseph	Sturgis.
Indiana	do	South Bend.

On July 1 Aid Dibrell, attached to the party of Aid J. A. Fleming, was making magnetic observations at Hatboro, *Pennsylvania*. The observations were completed on July 2, and on July 3 he reported at the Office. On September 4 he started to the field to make magnetic observations in *Indiana* and *Michigan*.

Observations were made to determine the three elements of the earth's magnetism at the fifteen stations named above, and the stations were all marked with a stone post suitably lettered.

On September 29, at Terre Haute, Ind., special declination readings were made at intervals of five minutes throughout the entire day, and the temperature was read and recorded at intervals of fifteen minutes, seventy-fifth meridian time being used. Similar observations were made by other magnetic parties in different parts of the country in execution of a plan to determine the areas over which the diurnal variation of the declination is the same. The work in this Division closed on October 16, and Aid Dibrell started on the 17th to continue his season's work by making observations in the Middle Division.

SUMMARY OF RESULTS JULY 1 TO JANUARY 7.

3 triangulation stations occupied.
103 square miles area of topography.
157 miles shore-line topography.
115 miles roads.
10 miles railroads.

SUMMARY OF RESULTS MAY 6 TO JUNE 30.

Elk Neck.

13 square miles area of topography.
22 miles of roads and railroads.
3 miles of creeks (tidal).

Little Choptank River.

13 square miles area of topography.
35 miles of shore line surveyed.
26 stations occupied and determined.

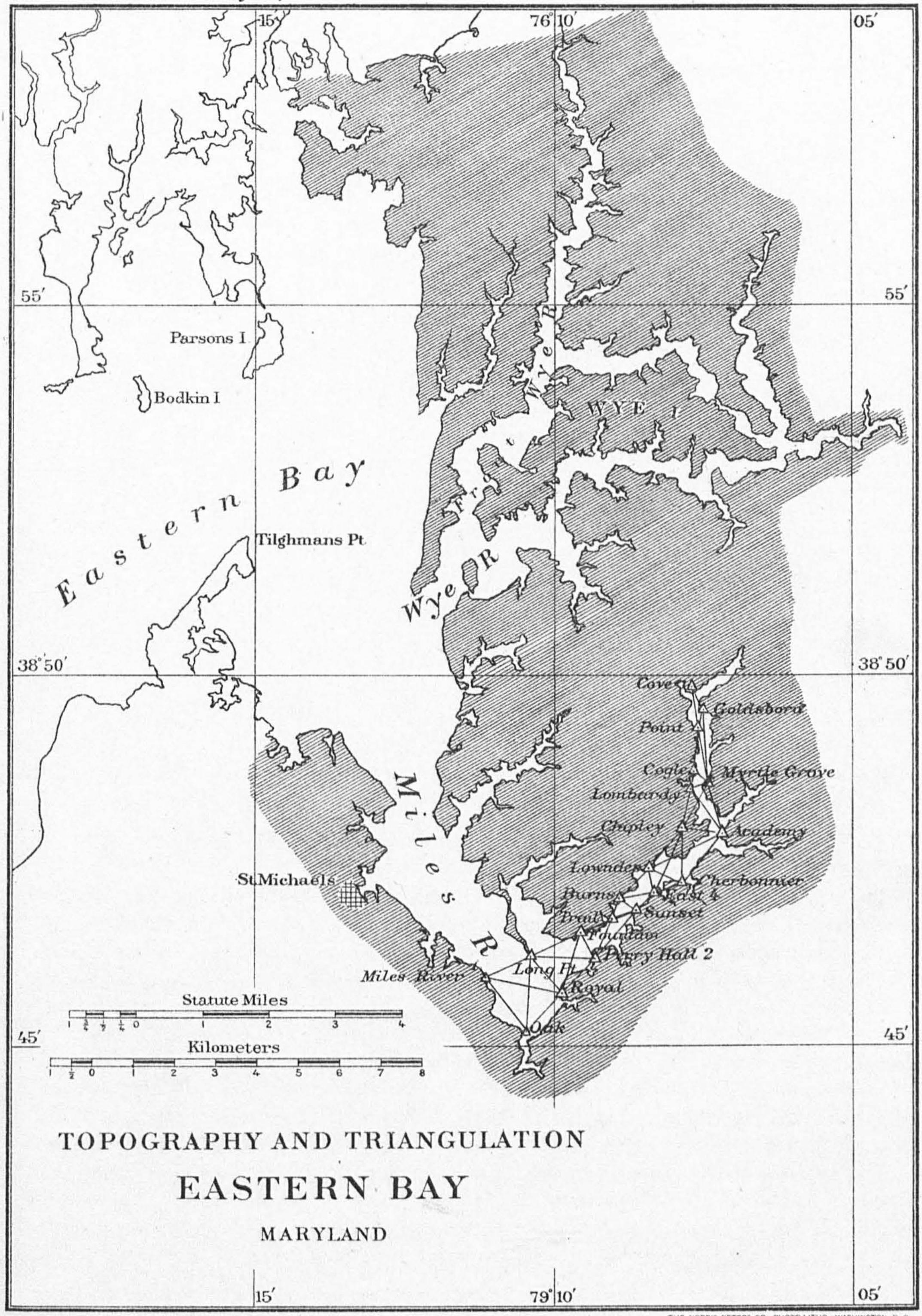
The work begun by Extra Observer Donn during the previous fiscal year was continued by him after July 1.

The triangulation and the shore-line and adjacent details of Miles River, and the several creeks flowing into it from the east, were finished at the end of July, in addition to a large portion of the work on the south side of the river, between McDaniel and Bloomfield, the south margin being the Baltimore, Chesapeake and Atlantic Railroad.

In August all the interior work north of the Miles River and extending to the heads of the creeks flowing into the Back Wye, including the heads of Leeds and Hunting creeks, was completed.

In September the work was advanced in all the branches of the Wye River, from points previously determined from the Eastern Bay and Miles River triangulation. The work in this vicinity was completed, and on October 28 the party moved to Elkton.

The survey of Elk Neck began on November 1. Much delay resulted from the difficulty of landing on the shore from a boat, the eel grass growing in the water covering the approach out to a depth of 6 feet in many places, and while using a team, from the necessity of driving long distances over bad roads to reach portions of the



TOPOGRAPHY AND TRIANGULATION

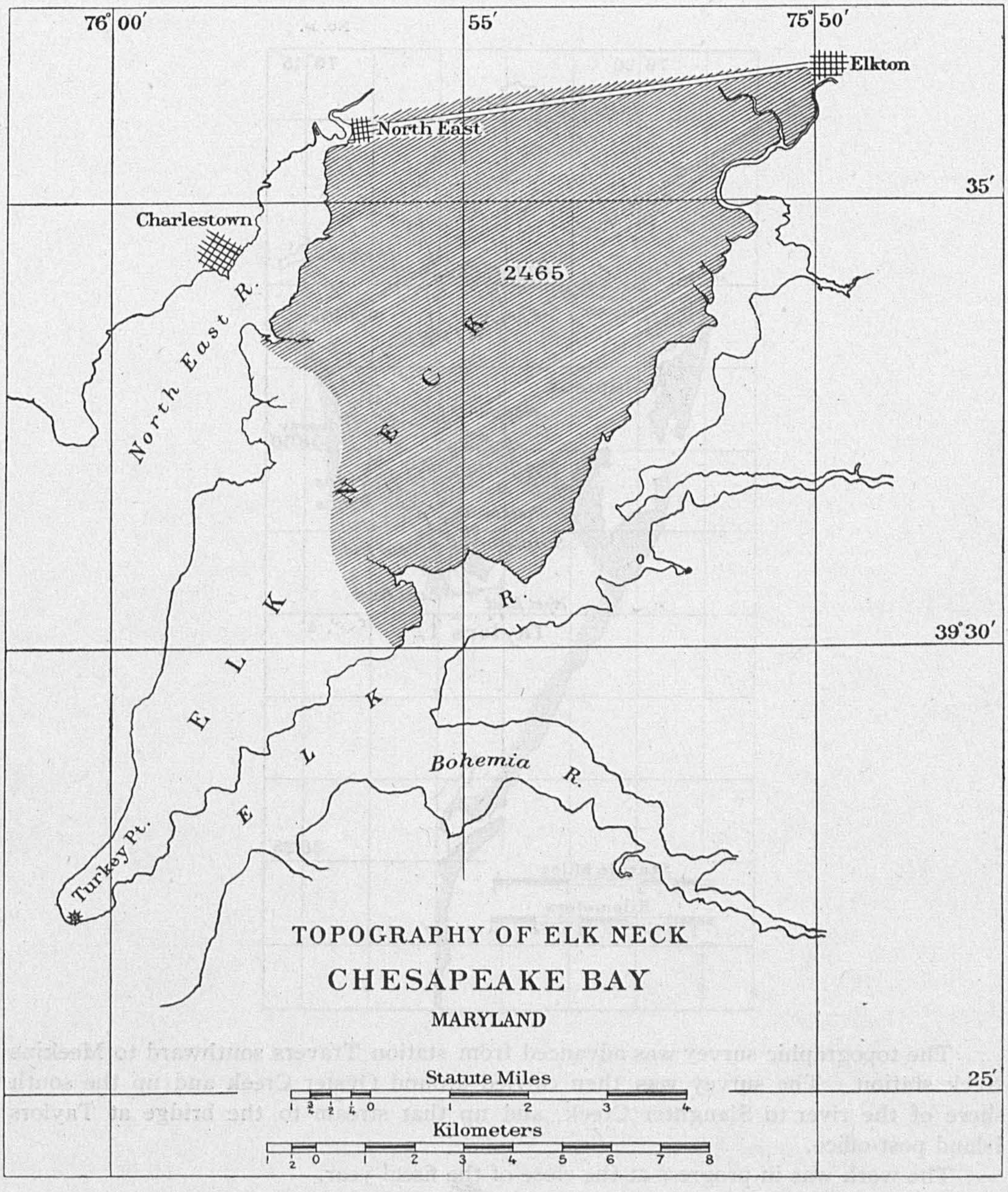
EASTERN BAY

MARYLAND

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

shore line. The work closed on January 7, and Extra Observer Donn was instructed to complete the records and topographic sheets resulting from the season's work in the field.

No. 2.



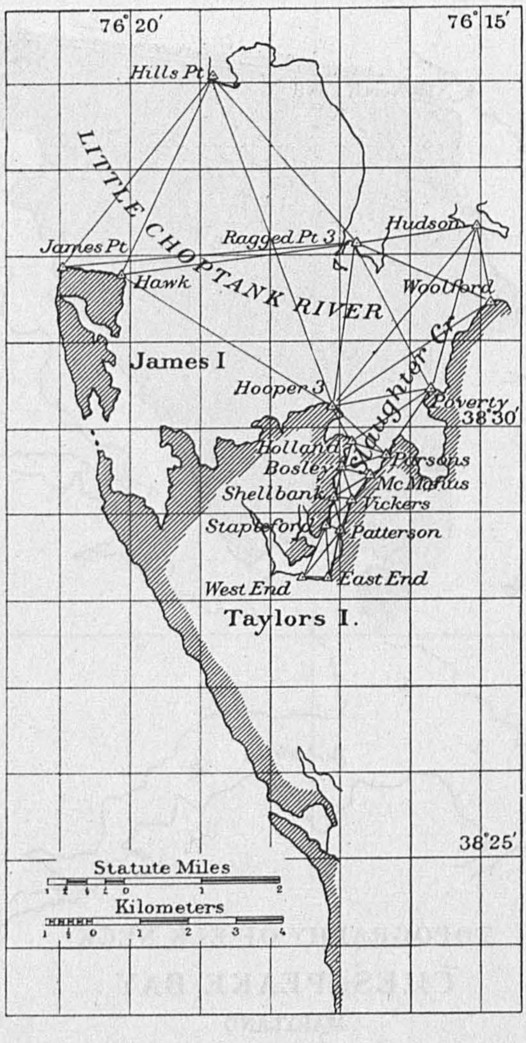
TOPOGRAPHY OF ELK NECK
CHESAPEAKE BAY
MARYLAND

On May 6 he organized a party and resumed topographic work on Elk Neck.

Unfavorable weather prevailed over the greater portion of the month, but in spite of all obstacles the survey was completed on May 31.

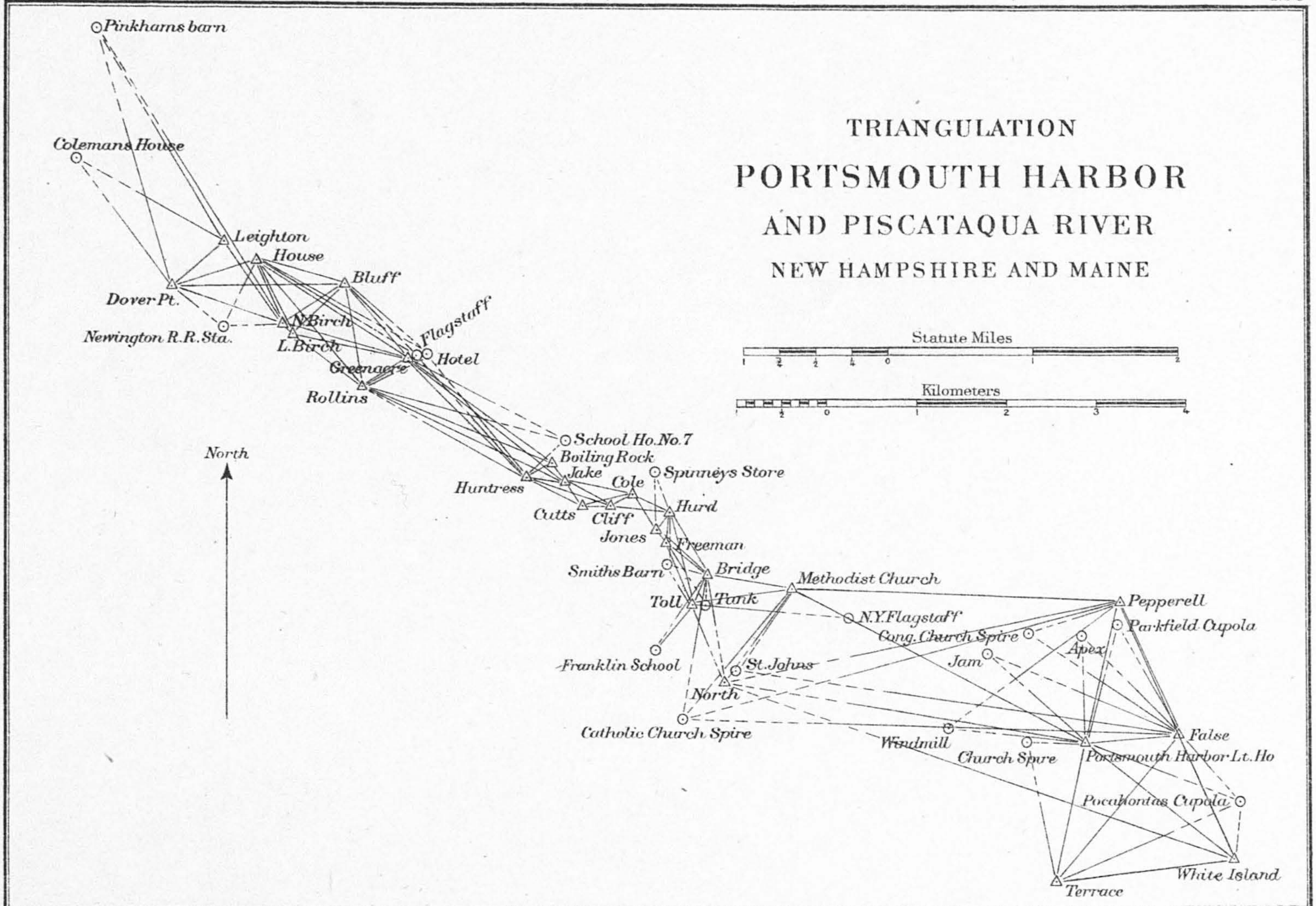
The party then proceeded to Little Choptank River, and began operations in that vicinity on June 4. Two old triangulation stations, James Point and Hills Point, were recovered, signals were erected, and the triangulation was extended as far as the entrance to Hudson Creek on the north side and Woolford Creek on the south side.

No. 2a.



The topographic survey was advanced from station Travers southward to Meekins Neck station. The survey was then carried around Oyster Creek and up the south shore of the river to Slaughter Creek, and up that stream to the bridge at Taylors Island post-office.

The work was in progress at the close of the fiscal year.



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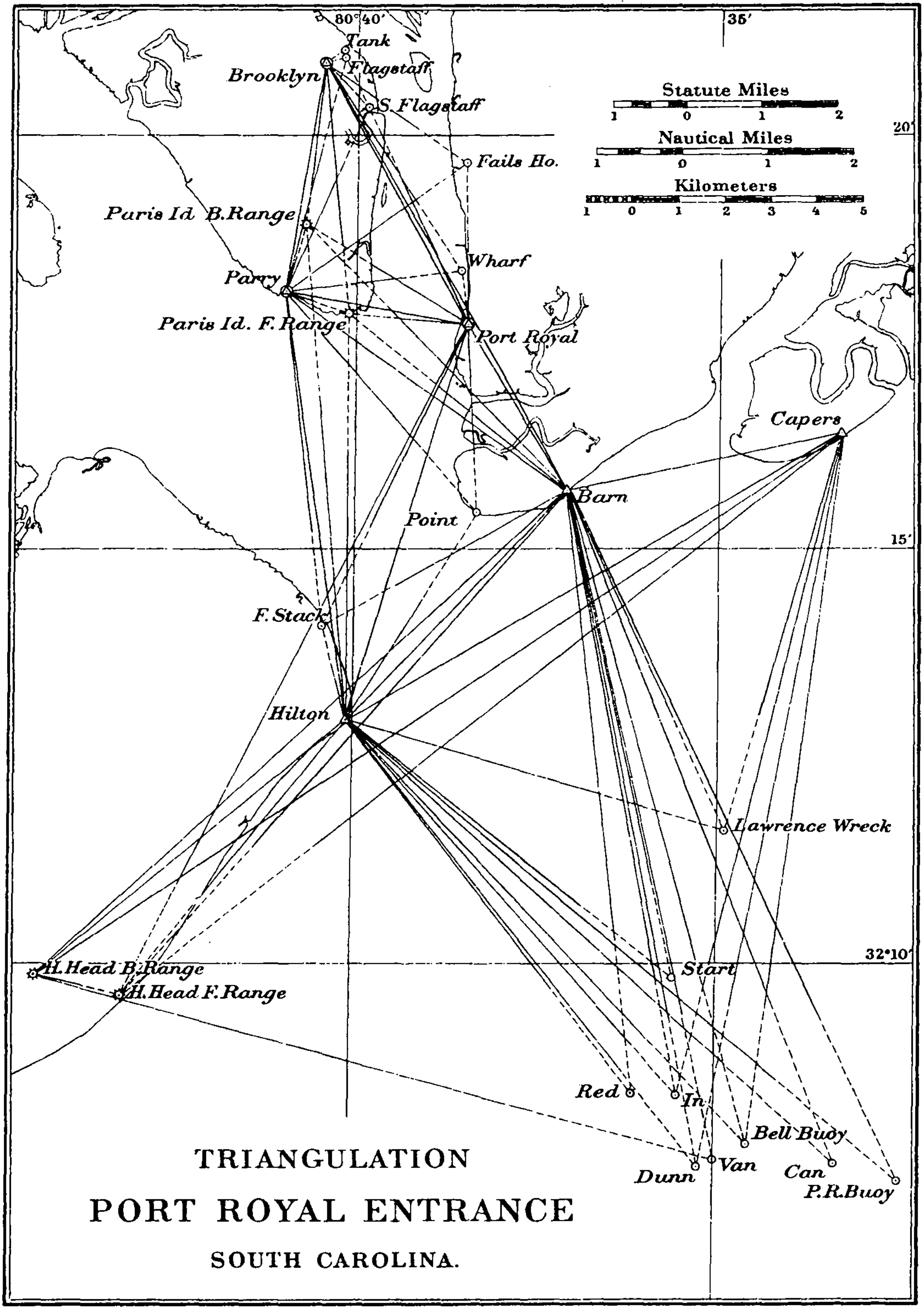


TRIANGULATION

PORT ROYAL ENTRANCE

SOUTH CAROLINA.

THE NORRIS PETERS CO. PHOTO-LITHO., WASHINGTON, D. C.

MAINE.
NEW HAMPSHIRE.
MASSACHUSETTS.
SOUTH CAROLINA.

SUMMARY OF RESULTS.

Maine, New Hampshire, and Massachusetts.

8 old stations recovered.
27 stations occupied.
56 geographic positions determined.

South Carolina.

6 old stations recovered.
7 stations occupied.
27 geographic positions determined.

Under instructions to determine such positions as were required for the topographic work in the vicinity of Portsmouth, N. H., and then to redetermine the position of the Isle of Shoals Light-House, Assistant Fairfield proceeded to that place on July 18.

Operations in the field began on July 20, and on August 23 the geographic position of all the points required for the work had been determined, computed, and furnished to the topographic party.

On August 24 the work of recovering triangulation points began, and continued until three old stations were found undisturbed.

On August 31 Assistant Fairfield went to Isle of Shoals Light-House, and the observations there were made between September 5 and 15. The sea was too rough for him to leave the Light-House until the 20th, when he returned to Portsmouth. Much delay at the next station resulted from unfavorable weather, and the necessary observations were not completed until October 12. On this date he received instructions to close work and report at the office, and immediately proceeded to do so.

On October 25 he proceeded to Beaufort, S. C., under instructions to determine the geographic position of the points required for making a hydrographic survey of the entrance to Port Royal and of the Range Beacons on Hilton Head and Paris Island.

Field operations began on the 27th, and all the necessary observations were completed on December 31. Some of the triangulation points were difficult to reach, and at several of them it was necessary to erect high tripods and scaffolds for observing. Assistant Fairfield makes special mention of the aid rendered and courtesies extended to him by Admiral Sumner and the other naval officers at the Port Royal Naval Station.

SUMMARY OF RESULTS.

32 stations occupied.
34 positions determined.
99 miles tape measurement.
99 miles of leveling (by vertical angles).

Operations began on January 14 under instructions to undertake the connections of the coast triangulation with that in the Blue Ridge Mountains by extending the work from the coast triangulation to Augusta, Ga., and the work was assigned to Assistant Fairfield.

The line Port Royal to Church in the coast triangulation was used as a base for the work, and two other old stations, Parry and Brooklyn, were used in determining the position of a new station, Salt Bridge, on the Charleston and Western Carolina Railroad, a short distance from Beaufort, from which a direct measurement was made along the railroad to a station Beach, near Beach Island, and a short distance from Augusta.

The line was measured along the straight portions of the railroad and prolonged off the track to a junction of the tangents, where a change in direction occurred. The railroad is comparatively straight from Salt Bridge to Allendale, but there are fifteen curves in the next 25 miles, and the tangents range from one-half mile to 6 miles in length.

This condition made it necessary to establish and occupy a large number of stations on this portion of the line. The remainder of the line was measured along a tangent 20 miles long to Beach Island, where final observations were made on June 11.

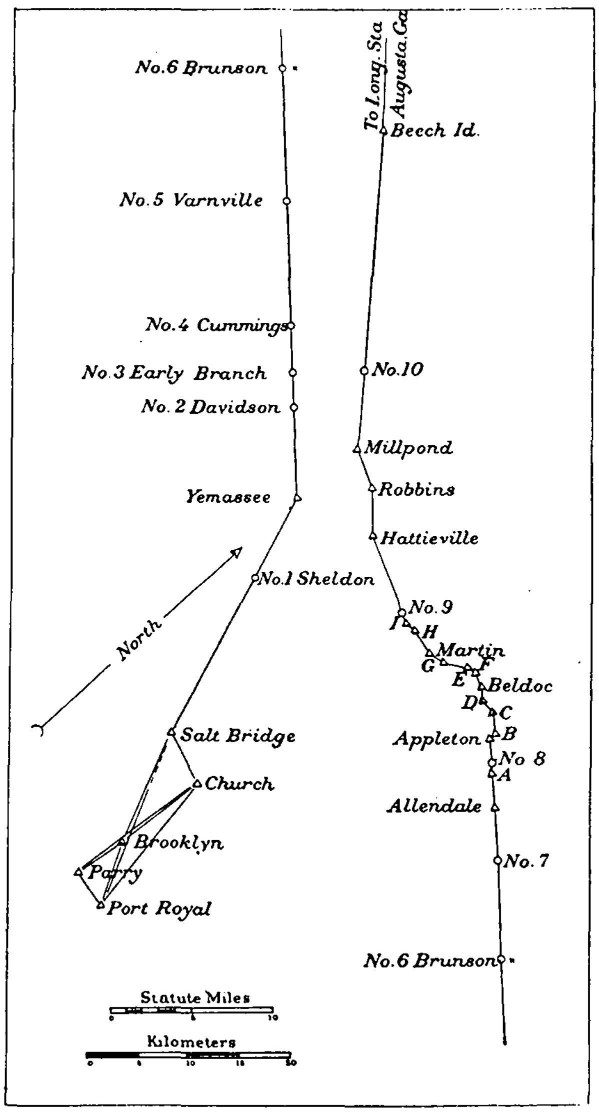
The direct measurement was made with a steel tape lying on top of one of the rails along the straight portions of the railroad track and supported on wooden posts set at intervals of 25 meters when it was necessary to extend the measurement off the track to reach a station placed at the intersection of the two tangents wherever the railroad changed its direction.

The tape measurement began on March 9, and was continued after that date whenever the weather permitted until April 18, when it was completed to Beach Island station.

The measurement was all made at night, except two short tangents which were measured on a cloudy afternoon. The line was measured twice, once in each direction, and the measures were made on different nights. The elevations were determined by measuring double zenith distances on every 200-meter mark on the portion of the line on the railroad, and on the 50-meter marks on the portion not on the track where the tape was supported by the posts. These observations were made while the tape measurement was in progress.

The azimuth was carried from the line Salt Bridge to Church by measuring horizontal angles at all the stations established at the points where the line changed direction and at some interpolated stations on the long tangents. These observations were made in the daytime or at night, as was found most convenient, using heliotropes by day and lamps at night.

No. 5.



Assistant Fairfield expresses his appreciation of the efficient service rendered by Signalman Jasper S. Bilby in performing the duties assigned to him. He also reports the courtesy shown by the authorities of the Atlantic Coast Line Railway in stopping all trains between stations to take on or put off the party in going to and from work.

This was a great convenience and greatly facilitated the work. The operations closed on June 22, and on June 24 Assistant Fairfield reported in person at the Office.

H. A. KELLEY, *Recorder.*

SUMMARY OF RESULTS.

302 miles completed line.
103 permanent bench marks established.

The leveling party in charge of Assistant Ferguson was at work in the field on July 1, extending the standard levels south from Cincinnati, Ohio, and had completed the work as far as Corinth, Ky.

The work was completed to Somerset, Ky., on the 31st of August, and connected with bench marks established at that place by Aid W. H. Burger in starting his leveling work a short time before.

The party then moved forward to Harriman, Tenn., where the necessary bench marks were established from which to carry the line on toward the southern terminus.

The route followed the Cincinnati, New Orleans and Texas Pacific Railway to Chattanooga, Tenn., where the levels were connected with bench marks established at this place by the Corps of Engineers, U. S. A., and by the U. S. Geological Survey.

The levels were then carried along the Memphis and Charleston branch of the Southern Railway to Woodville, Ala., where connection was made with bench marks established by Aid W. H. Burger, from which he started his levels toward Birmingham, Ala.

The work described above forms a portion of the leveling operations betwen Cincinnati, Ohio, and Birmingham, Ala., undertaken to connect the elevations determined at the former place by the U. S. Coast and Geodetic Survey with those determined at Knoxville and Chattanooga, Tenn., by the U. S. Geological Survey, and those at Decatur and Birmingham, Ala., determined by the Corps of Engineers, U. S. A.

After completing the work as far as Woodville, Ala., Assistant Ferguson ran a branch line of levels from that place to determine the elevation of the triangulation station on Gunters Mountain. The field work closed on December 3, and Assistant Ferguson reported at the Office on the 7th.

The preparatory operations leading to the erection of permanent magnetic observatory buildings at Cheltenham, Md., were assigned to Aid Fleming on July 12.

Under the direction of the Inspector of Magnetic Work an examination of the plans and methods of past and existing magnetic observatories was made. The result of his examination indicated the following as the chief requisites desirable in the location and erection of a magnetic observatory.

The selection of a site without local magnetic disturbances, and well removed from all probable future artificial magnetic disturbances; the elimination, in the construction of the buildings, of all materials showing any magnetic properties; the arrangements for absolute and variation instruments to be such that mutual interaction of the different instruments would be inappreciable; the building or buildings for the measurement of absolute values to be so constructed as to admit of a number of simultaneous determinations without danger of appreciable mutual interaction of the magnets of the various instruments; the building for variation observations to be constructed so as to have, without extensive heating, a uniform temperature throughout the year as nearly as possible; the buildings for the variation observatory to have accommodations for at least two sets of instruments, one eye-reading and one self-registering, both rooms to be of sufficient size to meet all reasonable demands.

A site was selected at Cheltenham, Prince George County, Md., and magnetic observations were made in nine places within its limits to determine whether any local magnetic disturbances existed in this vicinity.

The plans were made and the buildings were erected in practical accordance with the requirements mentioned above. The unusual character of the buildings rendered it impracticable to construct them by contract, as all of the bids were in excess of the estimated cost and of the available funds. It was consequently decided to purchase the material and to erect the buildings by hiring the necessary labor.

The work of excavating for the foundations and piers began on September 19, and the buildings were completed and ready for the installation of the instruments on December 22.

HYDROGRAPHIC.	MASSACHUSETTS.	O. B. FRENCH.
MAGNETIC.	GEORGIA.	
TIDE.	FLORIDA.	
TOPOGRAPHIC.	ILLINOIS.	
TRIANGULATION.		

On September 29, Assistant French left Washington for the field, as a member of the party under charge of Assistant C. H. Sinclair, to be engaged in determining the latitude and longitude of the Yerkes Observatory near Chicago.

This work was completed on October 28, and on the 29th Assistant French proceeded to Danville, Ill., under instructions, to determine the magnetic elements, and to establish a meridian line at that place.

This work was completed on November 4, and he proceeded to the Office in Washington, reporting for duty on the 19th.

On March 15 he left Washington under instructions to proceed to Pensacola, Fla., and transfer the schooner *Transit* to Madisonville, La., and to make an inspection of the schooners *Quick* and *Spy* and the naphtha launch which were in charge of a ship keeper at that place. This work was successfully accomplished, and Assistant French proceeded to Darien, Ga., to complete the work assigned to Assistant E. D. Preston, who was relieved some time previously on account of ill health. He reached there on April 1 and immediately began operations for the purpose of determining the geographic position of Sapelo Light-House and other objects near the entrance of Doboy Sound.

The old triangulation stations Spalding (recovered by Assistant Preston), Fox, and Marsh were recovered, utilized, and remarked. Several objects formerly determined as secondary points were also utilized.

A small sloop, hired for the purpose, was used as the means of transportation for two weeks, but it proved unsatisfactory on account of contrary winds, and a small steamer was used during the remainder of the season.

The geographic position of the Light-House was determined and also the position of several old beacons, four range marks set for use in opening a proposed channel through the bar, and several other prominent objects. The unfavorable atmospheric condition caused considerable delay in the progress of the work. After completing this work Assistant French proceeded to Pensacola, Fla., under instructions to make a hydrographic examination of the channel into Pensacola Bay in the vicinity of the point where the U. S. S. *Massachusetts* had grounded.

Deck Officer Roeth, Captain's Clerk Sanger, and a leadsman were ordered to report to him at Pensacola and aid him in the work. Active field operations began on May 1 and ended on May 23.

Three triangulation stations were occupied and the necessary positions determined for use in the hydrographic examination. Lines of soundings were run across the channel at the entrance to Pensacola Bay in several directions.

In addition to this work, lines were run so as to develop the dredged channel through Caucus Shoal and the channel from this shoal to deep water in the bay.

No work could be done on the bar after noon, and usually it was necessary to suspend work at 10 o'clock in the morning on account of rough water caused by wind. Whenever the bar became too rough for the work, the party was employed in topographic and hydrographic work in the bay. The topography of the western end of Santa Rosa Island and around Fort McRae was completed and plotted on the hydrographic sheet. The soundings covered the lower bay west of the navy-yard in a general way to show what changes had occurred since the former survey.

Two tide gauges were established at the entrance of the bay and referred to bench marks previously established in connection with the reduction of soundings to a common plane of reference. Soundings were also made to develop the increase in depth of water near the wharves resulting from the dredging done by the Louisville and Nashville Railroad Company.

As soon as this work was completed, Assistant French disbanded the party and proceeded to Washington, D. C., reaching there on May 25.

He commends the efficient service of Messrs. Sanger, Roeth, and Nelsen.

On May 30 Assistant French left Washington under instructions to make a hydrographic examination of Nantucket Sound in the vicinity of Horse Shoe Shoal, and southwest of this shoal to Great Point.

Through the courtesy of the Chief of the Revenue-Cutter Service, the revenue cutter *Dexter* was detailed to transport the party and the commanding officer was directed to furnish the necessary assistance in preparing for the work.

C. L. Green, first watch officer, William Sanger, captain's clerk, A. C. L. Roeth, deck officer, first class, and Joan Patterson, leadsman, were detached temporarily from the Survey vessels on which they were serving and ordered to report to Assistant French on board the *Dexter*.

The *Dexter* proceeded to Nantucket Sound on June 3 and the work began on the following day. Tide gauges were erected at Nantucket and Edgartown, and tide observations were made at both places during the day for a period of fifteen days.

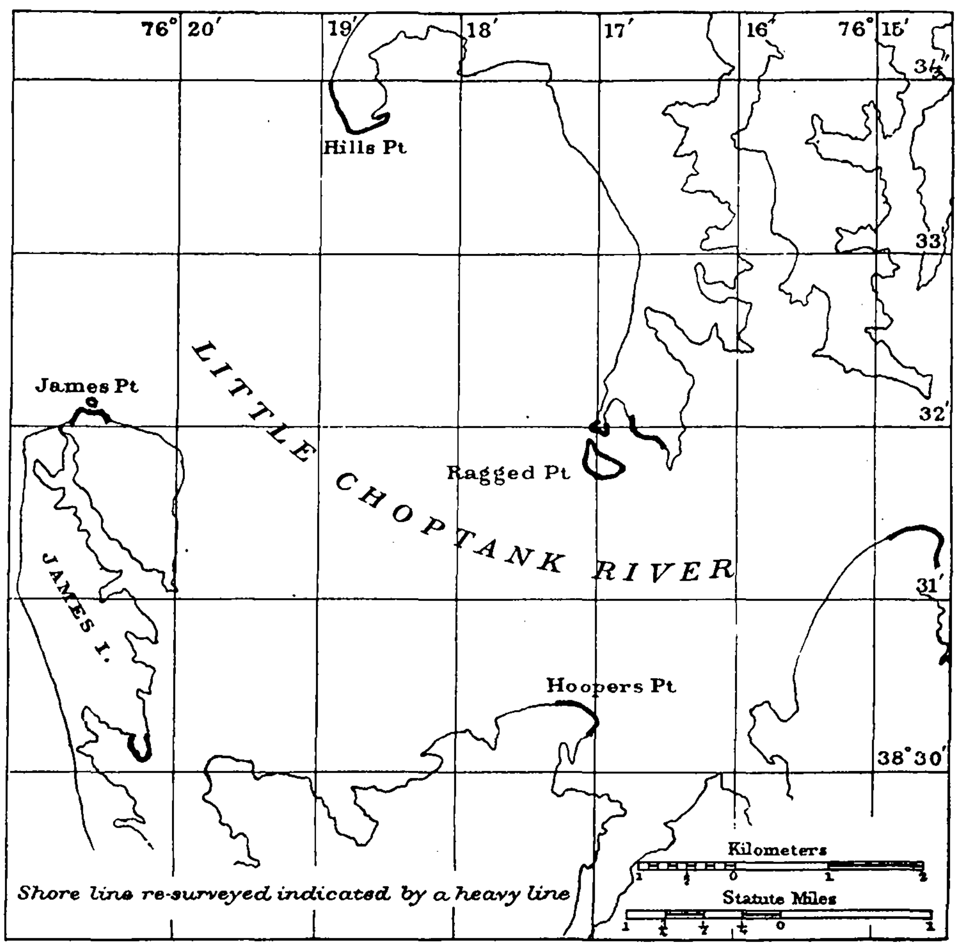
A tide gauge was also erected on Horse Shoe Shoal, and observations were made on it while the soundings were in progress. On June 24 the *Dexter* was required for other duty and the work was suspended. The party was disbanded and the members of it returned to their respective stations. Assistant French proceeded to Washington and reported at the Office on June 25.

His report states that Captain Hand and the officers of the *Dexter* did everything in their power to expedite his operations, and commends them highly for making it possible to accomplish so much in the few days available for the work.

SUMMARY OF RESULTS.

21 square miles area covered.
5 miles of shore line of rivers.

No. 6.



The topographic resurvey of the eastern shore of Chesapeake Bay, from Hills Point, at the mouth of the Little Choptank River, southward, was taken up on August 27 by Assistant Forney.

The party left Washington on the launch *Rudy*, on the date stated, and reached Cambridge, Md., on September 3, having been compelled to stop twice for repairs on the way. Field operations began at once, but owing to the unsatisfactory condition of the launch and the ill-health of the chief, very little work was completed by the party during the season.

Assistant Forney reported himself sick on October 7, and was ordered to close work at once.

The party was disbanded on October 12, and Assistant Forney reported by letter.

In response to a request from Col. Theo. A. Bingham, U. S. A., Superintendent of Public Buildings and Grounds in the District of Columbia, Assistant Hayford was directed to check the elevation of the permament bench mark established by this Survey near the Washington Monument, and to determine the elevation of the four corners of the Washington Monument.

The field work was done on April 1 and 2, by Aid O. E. Carr, under the direction of Assistant Hayford, and indicated no change in the elevation of the bench mark as determined in 1899.

HYDROGRAPHIC. RECONNAISSANCE. TOPOGRAPHIC. TRIANGULATION.	NORTH CAROLINA. GEORGIA.	W. C. HODGKINS, Commanding, steamer *Blake*.

W. F. GLOVER, *First Watch Officer.*
H. C. MITCHELL, *Aid.*
C. A. THOMPSON, *Second Watch Officer.*
L. M. HOPKINS, *Chief Machinist.*
J. A. MCGREGOR, *Chief Yeoman.*
G. E. MARCHAND, *Hospital Steward.*
J. F. PFAU, *Draftsman.*
H. J. ATWELL, *Junior Captain's Clerk.*

SUMMARY OF RESULTS.

Georgia.

20 square miles area of reconnaissance.
6 points selected for stations.
20 square miles area covered by triangulation.
5 stations occupied.
6 geographic positions determined.
9 square miles area covered by soundings.
165 miles of lines sounded.
1 tidal station established.
1 hydrographic sheet finished.
6 miles of shore-line surveyed.
1 topographic sheet finished.

North Carolina.

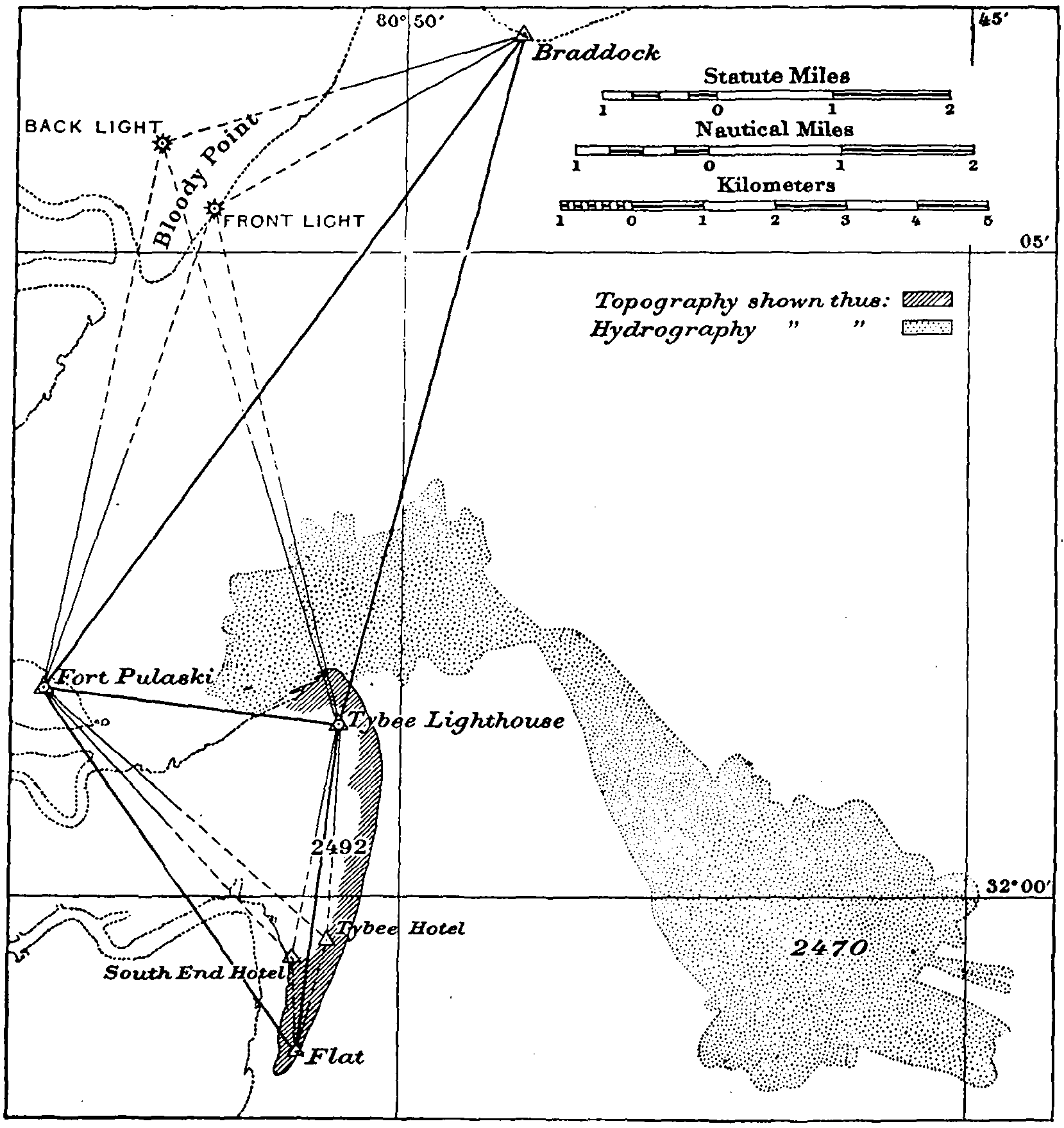
90 square miles area covered by hydrography.
340 miles of lines sounded.
1 773 soundings made.
1 hydrographic sheet completed.

On July 1 the *Blake*, Assistant W. C. Hodgkins, commanding, was at St. Thomas, Danish West Indies, and on the same day sailed to San Juan, P. R. Two days were spent preparing for sea, and on the 3d of July the ship sailed for the Savannah River, Georgia, and reached there on the 9th. The work covered by the statistics given above began on the 10th and was completed on the 20th. The operations included a hydrographic examination of the bar at the entrance to develop the 3-fathom curve on each side of the channel, as far as buoy No. 3, the determination of the position of the range lights on Bloody Point, the southern end of Daufuskie Island, the resurvey of the shore line of the eastern part of Tybee Island, the resurvey of the inner bar at the entrance of the jetties, and the inner anchorage near Fort Screven wharf.

The temperature was very high and the excessive heat caused considerable suffering and delay.

After completing the work in the Savannah River the *Blake* sailed for Norfolk, Va., on July 20 and reached that port on the 23d. Assistant Hodgkins received instructions to proceed as soon as practicable to Cape Hatteras, North Carolina, and make hydrographic examination of the Diamond Shoal off that cape for the purpose of

No. 7.



Entrance Savannah River.

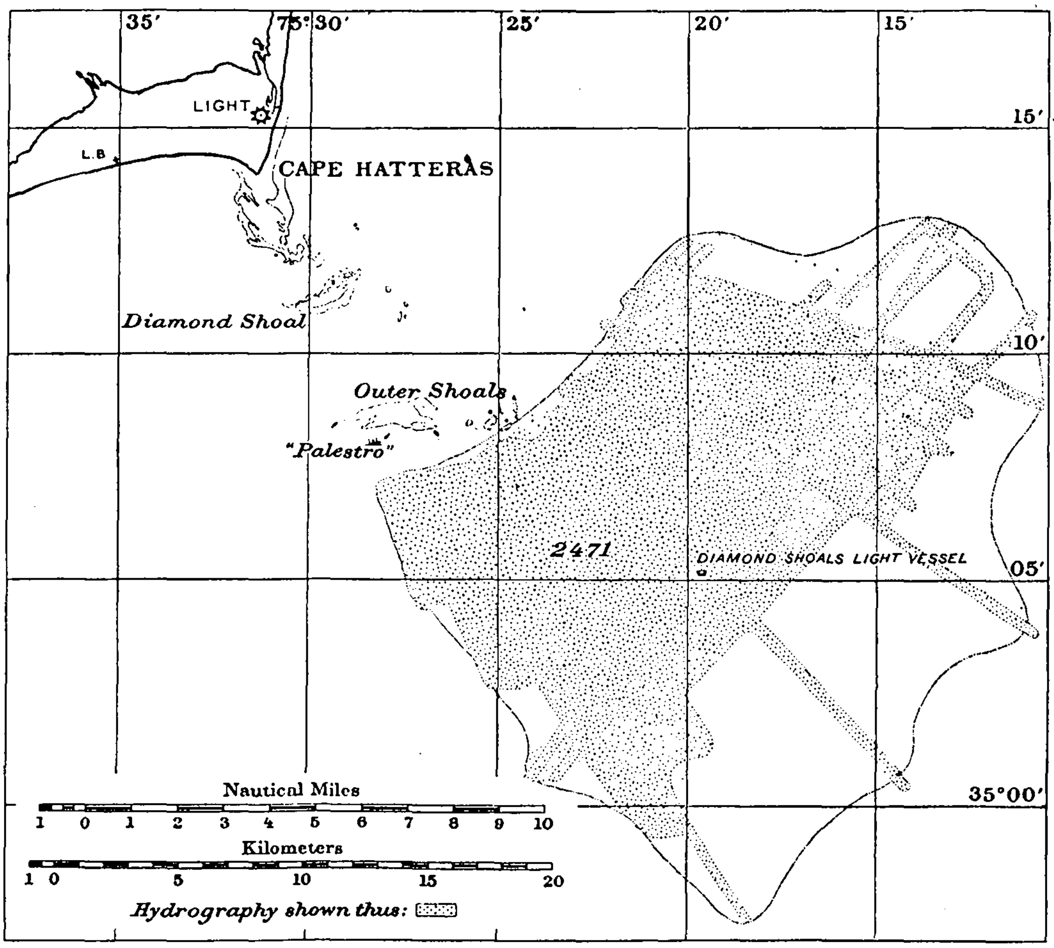
determining its extent and selecting the best anchorage for the new Diamond Shoal lightship. It was impracticable to have the necessary repairs to the ship made at Norfolk without delay and the vessel proceeded to Baltimore, Md., arriving there on July 26.

The repairs were completed on August 1, and on the 5th the vessel sailed for Norfolk, Va., reaching there on the 6th.

The ship was coaled and ready for sea on the 8th, and sailed on that day for Cape Hatteras. After much delay, on account of the dense bank of smoke hanging over the coast and ocean, the *Blake* reached Hatteras Cove on August 9.

Owing to the conformation of the coast and the distance of the work from the shore, the difficulty of accurately locating the ship while sounding would have been great under the best conditions, but this difficulty was vastly increased by the very unfavorable atmospheric conditions which prevailed while the work was in progress.

No. 8.



Authority was granted by the Light House Board to station an observer at Cape Hatteras Light-House and on Diamond Shoal Light-Ship, and to moor the *Blake* to the stern of the Light Ship at night when the weather permitted. The Superintendent of the Life Saving Service gave authority to call on the crew at the Hatteras station for assistance in landing observers, etc., when it did not interfere with the regular duties. The officials of the Weather Service agreed to give prompt notice of the approach of storms. All these were necessary precautions on account of the exposed position of the work and the very dangerous character of this locality in rough weather. Very fortunately, however, no occasion for such a warning arose, the weather during almost the whole month of August being very moderate and the sea very smooth, though the atmospheric conditions were most unfavorable.

The work was successfully completed on August 30, in spite of the difficulties under which it was executed, and gave a very satisfactory delineation of this previously unknown area, and developed the existence of an extensive mud bank, with a little more than 30 fathoms of water on it, in a good position in which to anchor the light-ship.

The work closed on August 30, and the vessel sailed the same day for Norfolk, Va., and reached there on the 31st.

From Norfolk the *Blake* proceeded to Washington, D. C., and was at anchor there from September 1 to 12, when she sailed for Baltimore, arriving there on the following day.

SUMMARY OF RESULTS.

45 square miles area revised.
60 miles of roads revised.

Under instructions to complete the topographic sheet which had been partly finished by Aid Weld during his recent season in the field, by revising the interior topographic work executed many years ago, Assistant Latham left Washington on November 30 and proceeded to Royal Oak, Md.

A party was organized immediately, and the work progressed until December 24, when operations closed, and the party was disbanded.

The shore line and some of the interior work on the sheet had been surveyed by Aid Weld, and Assistant Latham's work consisted in checking the roads and other topographic features as represented in topographic survey made many years ago by sextant angles and sketching.

A summary of the results of this work is given above. Upon the completion of the duty assigned him Assistant Latham returned to Washington and reported in person at the Office on December 26.

DELAWARE.

NORTH CAROLINA.

FLORIDA.

The erection of an automatic tide gauge at Philadelphia, Pa., was in progress on July 1, under the direction of Assistant Little.

This work was completed on July 7, and the gauge was left in charge of Mr. H. E. Olson, tide observer, and Assistant Little proceeded to Washington and reported at the Office on the 8th.

Under instructions to establish deviation range marks on the Delaware Breakwater for the use of vessels in adjusting their compasses, Assistant Little made the preliminary arrangements and left Washington on the 14th, arriving at the breakwater on the 16th.

After this date he was engaged in establishing and marking the position of the range marks on the breakwater and in work connected therewith until December 6, when he left without erecting the range marks, as the result of the delay in their delivery on the breakwater, and reported at the Office on the 7th. On January 18 he started to Fernandina, Fla., under instructions to examine the tide gauge at that place and place it in good order, giving any instructions that might be necessary to the tide observer.

He completed the work at Fernandina, and left on February 15 for Jacksonville, N. C., under instruction to collect the tidal and current data in New River and New River Inlet necessary for the study of the tide in this locality. Four tide gauges were established and observations made during several days, and a portion of the time the observations were also made during the night. The necessary current observations were also made.

The work closed on March 4, and Assistant Little reported at the Office on the 5th.

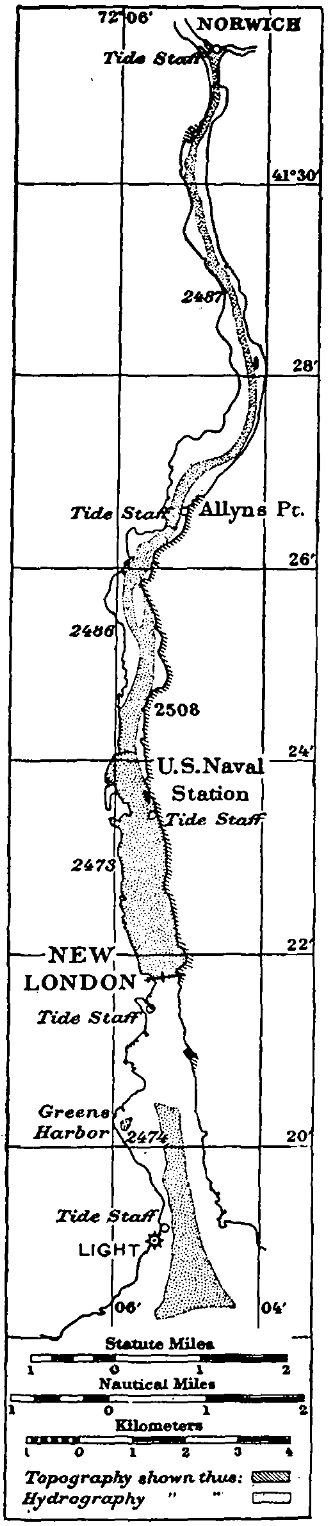
The revision of the topography along the coast of Long Island was taken up in July and the work assigned to Assistant McGrath, who was instructed to note such changes as had taken place since the former topographic survey was made, with particular reference to the construction of wharves, buildings, etc., which should be shown on the charts. The preliminary arrangements were completed and on July 20 he proceeded to Brooklyn, N. Y., and field operations began in the vicinity of that city on July 21. The work progressed without interruption until October 20, when the field operations closed. As many of the old triangulation points were recovered as possible, and from these various objects, including new stations, were located, which served to fix town plans, roads, etc., in position, so that these could be plotted on the old topographic sheets or on new projections.

Numerous field notes and sketches were also made to cover the region examined, and the position of all prominent buildings in the towns was noted on the town plans obtained from the officials of each place.

In this way such work can be done very rapidly, and with the required degree of accuracy. During the season the details were revised on fifty-one topographic sheets, covering the coast of Long Island on the south and east, from Coney Island to Montauk Point.

After closing work Assistant McGrath returned to Washington and reported at the Office on October 22.

No. 9.



Thames River, Connecticut.

HYDROGRAPHIC. CONNECTICUT. HENRY L. MARINDIN.
TOPOGRAPHIC.

F. M. LITTLE, *Assistant.*
F. H. AINSWORTH, *First Watch Officer.*
DYER SMITH, *Recorder.*

SUMMARY OF RESULTS.

2¾	square miles area covered by hydrography.
117	miles of lines sounded.
4	hydrographic sheets completed.
6	miles of shore line of river surveyed.
4	miles of roads surveyed.
1	topographic sheet completed.

The revision of the hydrography and topography on the Thames River, Connecticut, with a determination of the position of the river lights and buoys between New London and Norwich, was taken up in August and the work was assigned to Assistant Marindin.

He left Washington on August 4, and field operations began on the 5th.

The necessary signals were erected, and tide staffs were established at five points in the river.

The hydrographic work above New London includes a resurvey of that part of the Thames River from the railroad bridge at New London to the upper limits of the United States naval station, and from this point to Norwich a hydrographic reconnaissance of the channel in connection with the determination of the position of the range lights and buoys.

The position of the buoys and of 20 range lights was determined by using a plane table and the topographic sheets of the original survey. A resurvey was made locating the shore line and railroad on the left bank of the river between the New London railroad bridge and Allyns Point, by using a plane table.

A hydrographic examination was made of the best channel across the shoal ground situated between the 30-foot contour in the sound at the mouth of the Thames River and the deep hole below the railroad bridge at New London. A weighted rope, 500 feet long, with each end attached to the stern of a tugboat, was dragged along this channel, covering in all a width of about 600 feet, without discovering any obstructions.

An examination was also made to discover a rock reported as an obstruction to navigation in Greens Harbor, a portion of New London Harbor. The rock was dis covered and its position determined.

Upon the completion of the work outlined above, Assistant Marindin closed the field operations on September 24 and reported at the office in Washington on the 25th.

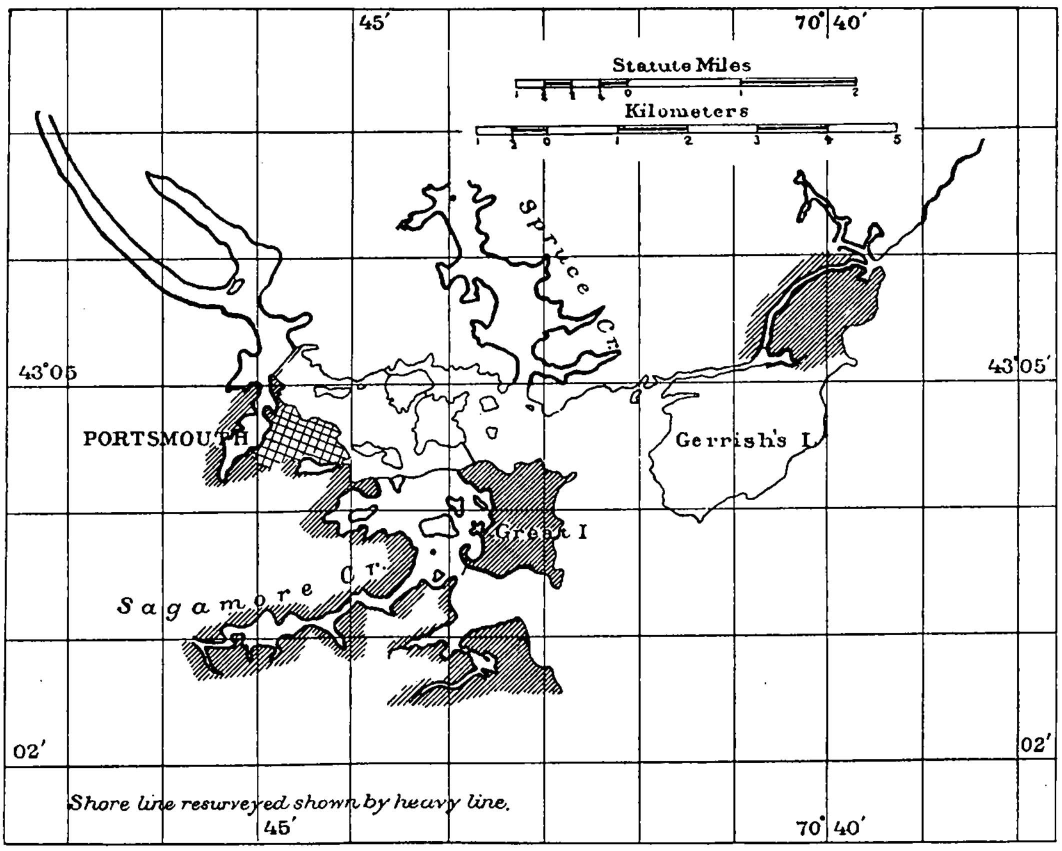
NEW HAMPSHIRE.

MARYLAND.

SUMMARY OF RESULTS.

42 square miles area covered by topography.
15 miles of coast line surveyed.
28 miles of shore line of rivers surveyed.
115 miles of shore line of creeks and ponds and marshes surveyed.
78 miles of railroad.
3 topographic sheets completed.

No. 10.

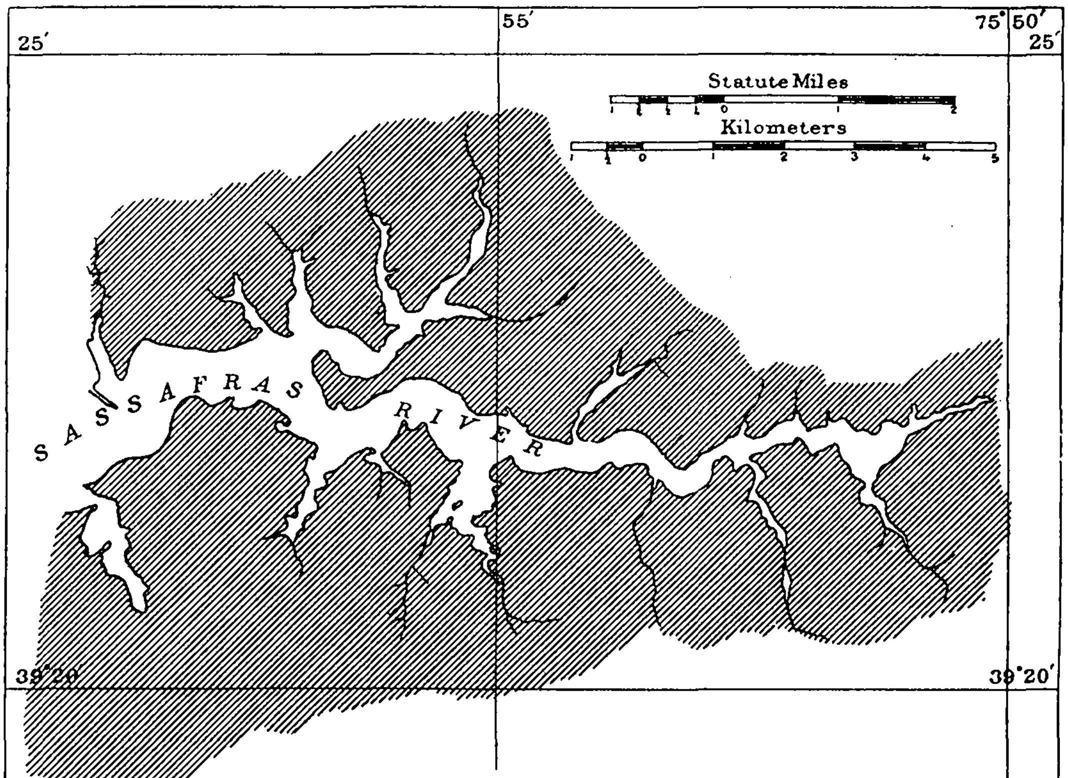


The completion of the topography in the vicinity of Portsmouth, N. H., was taken up in July by Assistant Nelson, and he left Washington on July 13.

The preliminary operations were completed and the plane-table work began on July 19.

On August 24 the survey of the main shore line and the shore line of the rivers, creeks, and ponds, and also the topography within reach from the shore, on the Portsmouth Harbor sheet was completed. The party then moved to Greenacre, Me., and began work on the survey of the shore line and adjacent topography of the Piscataqua River in Maine and New Hampshire, from the Portsmouth bridge to about 4 miles above Dover Point. This work was continued until September 26, when the operations closed

No. 11.



TOPOGRAPHY, SASSAFRAS RIVER, MARYLAND

and Assistant Nelson proceeded to Galena, Md., and on October 2 organized a party under instructions to complete the topographic sheet which he had not been able to complete before the close of his previous season's work in this locality.

The sheet covers the headwaters of the Sassafras River, and was completed on November 30, and the party was disbanded immediately.

Assistant Nelson proceeded to Washington and reported for duty on December 1.

HYDROGRAPHIC.	MASSACHUSETTS.	E. D. PRESTON.
RECONNAISSANCE.	RHODE ISLAND.	
TOPOGRAPHIC.	GEORGIA.	
TRIANGULATION.		

SUMMARY OF RESULTS.

Georgia.

200 square miles area covered by reconnaissance.
12 stations selected.
4 observing tripods and scaffolds built.
15 old stations visited and searched for.
3 old stations recovered.

The examination of the territory included in the current edition of Chart 244, covering the vicinity of Salem, Mass., on which no topography is shown, was assigned to Assistant Preston and he was directed to report what steps should be taken to bring the topography up to date. He was also directed to ascertain whether any existing data could be supplemented by phototopographic methods. He left Washington on October 5; the examination was made as directed, and a report submitted covering all the necessary details.

Five stations were occupied with the phototopographic camera, and 18 negatives obtained which indicate that it is not desirable to use the method for the purpose desired in this region. Ten trigonomic points were visited and the report states their present condition.

The published maps of the region can be relied on to furnish much information which will aid in the compilation of topographic details when a new edition of the chart is prepared.

Assistant Preston proceeded to Providence, R. I., after completing the work in the vicinity of Salem, under instructions to procure data relating to changes in the hydrography of the harbor due to dredging.

Through the kindness of the city engineer, Mr. O. F. Clapp, all necessary information covering this work which was done by the city was obtained and sent to the Office. Mr. Clapp showed a most intelligent interest in the work of the Survey, and furnished data from the records on file in his office of all recent improvements on the water front of the city for use on the new edition of the chart.

Upon the completion of the work at Providence, Assistant Preston proceeded to Newport and made an examination of the changes recently made in certain topographic details on Conanicut Island, which resulted in locating some important roads on the chart of the region.

He reports the kindness and material aid extended to him by Capt. J. P. Cotton, a civil engineer, who is thoroughly informed in regard to the improvements which have been made on the island during recent years, and who furnished such information as was desired. A great many changes have been made on the island, but Assistant Preston bears testimony to the faithful and accurate character of the original topographic work.

After completing this duty, he returned to Washington on November 10.

On January 8 he was again sent to the field under instructions to proceed to Darien, Ga., and organize a party to determine the geographic position of Sapelo Light, and make a trigonometric connection with the special survey made at that point by the Corps of Engineers, U. S. A.

Assistant Preston reached Darien on January 8, and continued field operations until February 22, on which date he was forced to suspend work on account of sickness.

The statistics of the work accomplished are given above.

On November 22 Nautical Expert John Ross left Washington under instructions to make an examination of the principal ports on the Gulf coast of the United States, for the purpose of collecting such information as would be useful in revising the Coast Pilot of this region. He arrived in Pensacola, Fla., on the 24th, and made arrangements to examine the bar off the entrance to the harbor.

The pilots stationed at Warrington offered him the use of their steam tug, and to assist him in any way in their power. This generous offer was accepted, and Mr. Ross proceeded to sound the Caucus Channel. Four lines of soundings were run up and down the channel on ranges, and angles were measured to locate the positions on the ranges. Mr. Ross reports the very valuable assistance rendered him by the pilots.

Dredging operations in the channel were in progress under the direction of an officer of the Corps of Engineers, U. S. A. Mr. Ross proceeded to Mobile, Ala., and to Pascagoula, Miss., where he obtained information covering the vicinity, and reached New Orleans, La., on December 2.

He remained in New Orleans until December 7, collecting information, and during this period visited Gulfport, West End, and Algiers. Mr. Ross left New Orleans for Galveston, Tex., on December 7. and the account of his work during the remainder of the season will be found in the account of the work in the Middle Division.

O. B. FRENCH, *Assistant.*

The determination of the difference in longitude between St. Louis, Mo., and the Yerkes Observatory at Williams Bay, Wis., was undertaken in September, and the work assigned to Assistant Sinclair.

Assistant French was instructed to report to Assistant Sinclair to aid him in this work, and was directed to begin work at St. Louis, while Assistant Sinclair went first to the Yerkes Observatory.

The necessary preparations were completed, and observations were made on October 4.

After making observations and interchanging telegraphic signals on four nights, the observers exchanged stations, and on the 16th observations on four more nights had been made, and the determination of the difference of longitude was thus completed.

After finishing the records and computations, Assistant Sinclair returned to Washington and reported for duty on October 22, leaving Assistant French at the Yerkes Observatory to make observations to determine the latitude of the transit pier. The latitude observations began on October 17 and were completed on the 27th, twenty-five pairs of stars having been observed on six nights.

A topographic reconnaissance of the Potomac River was made by Assistant Smith June 4 to 7 on a trip down the river and back to Washington on a passenger boat.

The positions of piers, wharves, and prominent buildings were plotted approximately when not found on the charts, and notes were made of such facts as would be useful in a resurvey of the river.

On June 15 Assistant Smith left Washington under instructions to take up triangulation work between Washington, D. C., and Mount Vernon, Va.

He made a reconnaissance and selected seven stations to cover the distance indicated. Signals were erected at six stations and the work was in progress at the close of the fiscal year.

TIDE OBSERVATIONS.

NEW YORK.
PENNSYLVANIA.
DISTRICT OF COLUMBIA.
FLORIDA.

Automatic tide gauges were kept in operation throughout the year at the following places:

Fort Hamilton, N. Y., J. G. Spaulding, observer; Philadelphia, Pa., H. E. Olson, observer; Washington, D. C., F. A. Kummel, observer; Fernandina, Fla., B. W. Weeks, observer.

HYDROGRAPHIC.
LEVELING.
TOPOGRAPHIC.

SOUTH CAROLINA.

W. I. VINAL, Commanding,
Schooner *Matchless*.

F. H. AINSWORTH, *First Watch Officer*.
WM. SANGER, *Chief Yeoman*.
JOHN W. CLIFT, *Chief Yeoman*.
GEORGE OLSEN, *Chief Yeoman*.
SWEPSON EARLE, *Yeoman First Class*.
R. McD. MOSER, *Recorder*.

SUMMARY OF RESULTS.

10 square miles area covered by sounding.
89 miles of lines sounded.
1 hydrographic sheet completed.
3 miles of leveling work completed.
2 square miles area covered by topography
20 miles of coast line surveyed.

The schooner *Matchless*, Assistant W. I. Vinal, commanding, reached Charleston, S. C., on June 14. Assistant Vinal was instructed to make a new survey of the old channel entrance to Charleston Harbor, in response to a request from the United States Light House Board, to furnish information upon which any change in existing lights and buoys could be based, or any new ones established could be located. The survey of the old channel was limited by adopting its intersection with the main channel for the northern limit of the work, and the 4-fathom curve to the southward of the bar as the southern limit.

He was also instructed to make a plane-table survey of the outside shore line from Cummings Point southward to the limit of the hydrographic sheet furnished for the work. The geographic positions for this work were determined by a triangulation party and furnished to Assistant Vinal.

The tide gauge established at Fort Sumter was referred to Cummings Point and connected by levels with Charleston Light-House, where a mark was established. A tide staff was attached to the wharf on the north side of Light-House Inlet and referred to the bench mark, to furnish a plane of reference for the soundings.

A plane-table survey was made of the shore line of Morris and Folly islands, from Cummings Point southward to the limit of the hydrographic sheet. The work was completed on July 27, and the *Matchless* sailed for Baltimore on July 28, and reached that place on August 7. The vessel was placed on a dry dock for examination and temporary repairs.

After coming out of the dock, the vessel was anchored off Sea Girt, and the party was engaged in completing the records of field work until September 21, when Assistant Vinal was relieved of the command of the vessel by Assistant George L. Flower.

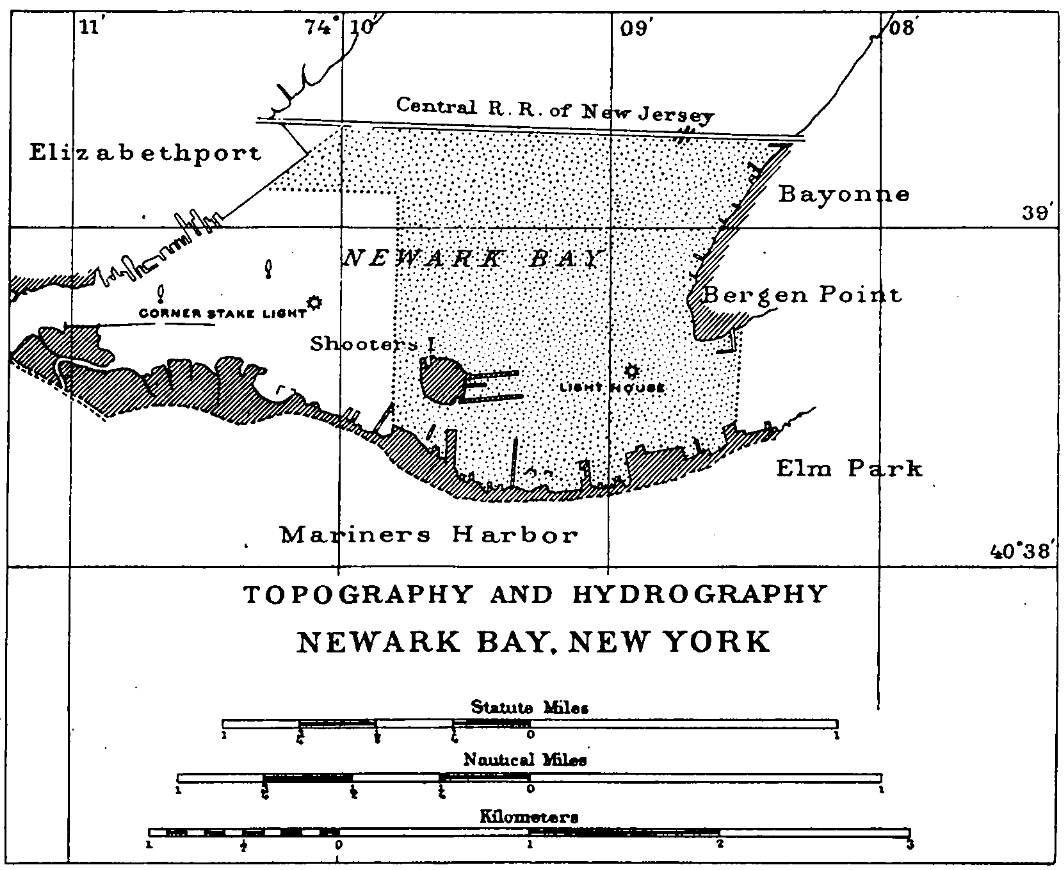
HYDROGRAPHIC. NEW JERSEY. W. I. VINAL, Commanding,
TOPOGRAPHIC. Steamer *Bache*.

C. L. GREEN, *First Watch Officer*.
W. F. GLOVER, *Second Watch Officer*.
J. E. SHEPHERD, *Surgeon*.
H. J. ATWELL, *Junior Captain's Clerk*.

SUMMARY OF RESULTS.

5 square miles area covered by plane-table triangulation.
33 positions determined with the plane table.
1 square mile area covered by topography.
9 miles coast line surveyed.
1 mile of creeks surveyed.
2 miles of road surveyed.
1 square mile area covered by hydrography.
20 miles of lines sounded.
3 tide stations established.

No. 12.



TOPOGRAPHY AND HYDROGRAPHY
NEWARK BAY, NEW YORK

On December 17 the steamer *Bache*, W. I. Vinal, Assistant, Coast and Geodetic Survey, commanding, left Baltimore and arrived at Shooters Island, New York, on the 19th. The ship was placed in the dock of the Townsend and Downey Shipbuilding and Repair Company, who had been awarded the contract for building a new hull, and remained there during the remainder of the fiscal year.

Assistant Vinal continued in command of the ship, with a reduced crew, to care for the Government property and render such assistance as might be in his power to hasten the completion of the new hull.

On April 18 he began the survey of the shore line and the hydrography of lower Newark Bay and Kill von Kull. This work was continued whenever the weather conditions permitted until May 31, when some of the officers were needed for more urgent work, and operations were suspended and not continued until after the close of the fiscal year.

TOPOGRAPHIC. DELAWARE. D. B. WAINWRIGHT.
TRIANGULATION. SOUTH CAROLINA.

B. E. TILTON, *Aid.*

SUMMARY OF RESULTS.

¼ square mile area covered by topography.
1 mile of coast line surveyed.
1 mile of shore line of river surveyed.
2 miles of shore line of creeks surveyed.
2 miles of road surveyed.
1 topographic sheet completed.
1 base line measured with tape.
½ mile of beach measured with tape.
4 square miles area covered by triangulation.
9 stations occupied.
8 geographic positions determined.

An examination to determine the desirability of establishing compass deviation range marks at Delaware Breakwater for the use of vessels in adjusting their compasses was made by Assistant Wainwright July 5 to 7. This work was completed and he returned to the Office and resumed his regular duties.

On October 22 he again left the Office and proceeded to Charleston, S. C., under instructions to organize a party and make a special survey in that vicinity in accordance with a request from the Navy Department for the information of the Naval Board, "organized for the purpose of examining into the expediency of changing the location of the naval station now at Port Royal, S. C., to some point in the State of South Carolina, at or near the city of Charleston." A topographic survey on a large scale was made of the locality known as the Lawton plantation, which is situated on the right bank of the Cooper River, about 6 miles from the custom-house wharf, and extends from Chicora Park southeastward along the river for nearly 1 mile.

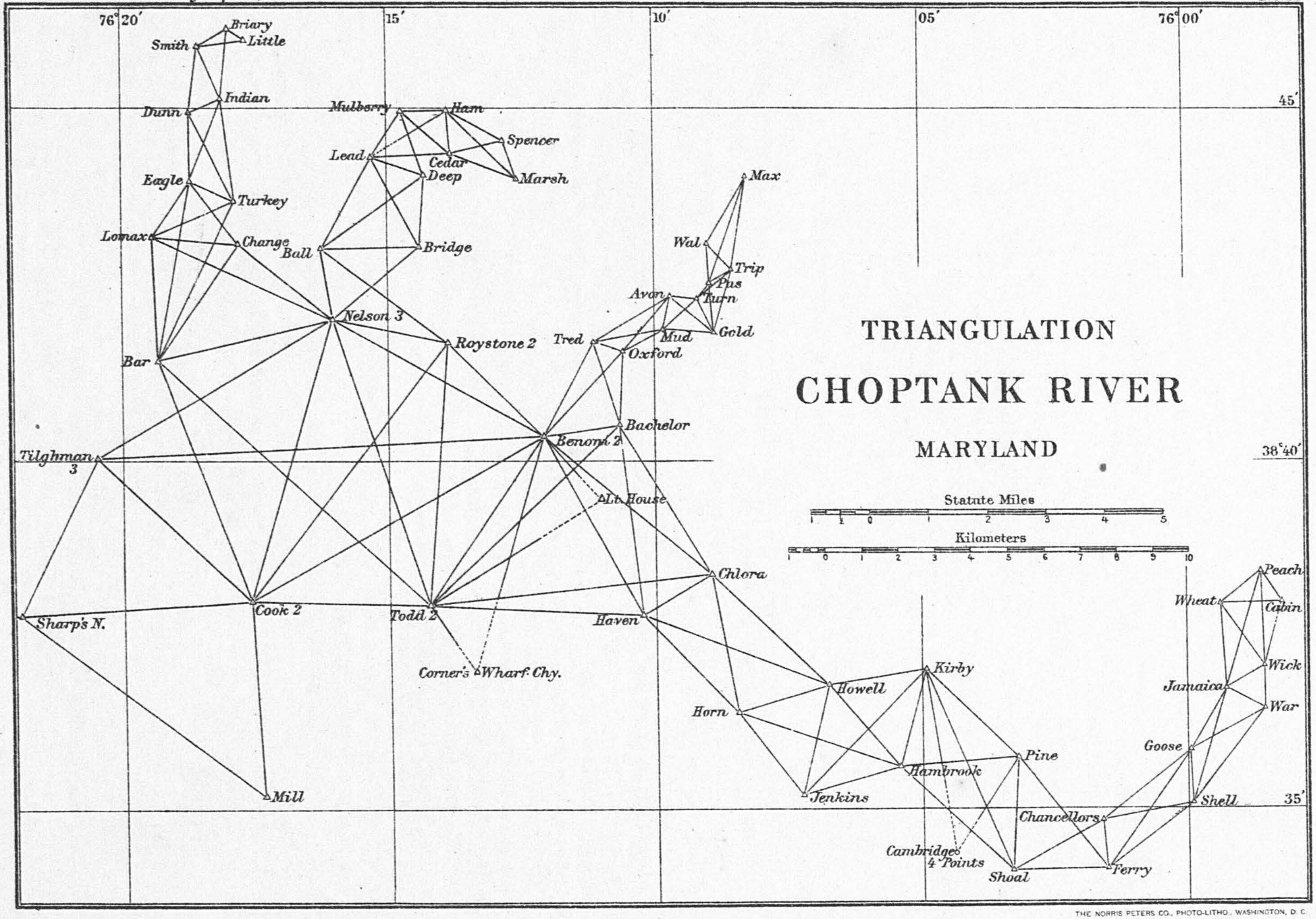
A very small contour interval was adopted as the one most suitable for the topographic work. A number of bench marks were established by spirit leveling and used by the topographer in his work. The plane table and wye level were both used in delineating the details.

The topography was controlled by nine triangulation points, whose positions were determined for this purpose and the determined distances depend on a base line measured twice with a steel tape.

Assistant Wainwright reports that the services of Aid Tilton were particularly valuable, on account of his familiarity with leveling operations, and states that with some additional experience he will become a competent topographer.

He also makes special mention of Mr. R. J. Emory, jr., for the zeal and intelligence with which he executed all the duties assigned to him.

Having completed the work assigned to him, Assistant Wainwright proceeded to Washington and reported for duty at the Office on December 27.



THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

E. B. LATHAM, *Assistant.*

SUMMARY OF RESULTS.

375 miles of shore-line of rivers surveyed.
20 miles of roads surveyed.
2 topographic sheets completed.
54 triangulation stations occupied.
60 geographic positions determined.

The duty of making a resurvey of the Choptank River and tributaries was assigned to Aid Weld, and he left Washington for Tilghman, Md., on July 11.

After some preliminary work he organized a party on July 16 and began at once to erect the signals necessary to extend the triangulation from a line already determined by the Chesapeake Bay triangulation. The naphtha launch assigned to thee us of the party was not ready for use until August 27, and much delay resulted from the use of sailboats previous to that date.

On August 29 a subparty was organized and placed under direction of Assistant Latham, who used a sailboat until October 13, when a launch was available for his use. The triangulation was extended up the Choptank River, to Cabin Creek, 10 miles above Cambridge, Md., and also up the larger tributaries. The shore line was surveyed by using a plane table and such adjacent topography was done as could be easily reached from the shore line.

The survey extends from Force Point, on the Chesapeake Bay, just below Poplar Island, to Hills Point, and then up the Choptank River to Cabin Creek.

A good deal of the interior topography, as shown on the topographic sheets of the former survey, made in 1847, was examined and the changes noted in order to transfer it to the new sheets.

Aid Weld left the work in charge of Assistant Latham on November 15 and proceeded to the Office in Washington.

Aid Weld commends Assistant Latham for his zeal in executing the duties assigned to him.

The work was continued by Assistant Latham until November 21, when he closed work and reported at the Office in Washington on the 22d.

HYDROGRAPHIC. MARYLAND. P. A. WELKER, Commanding,
SPECIAL WORK. Steamer *Bache*.
TRIANGULATION.

G. L. FLOWER, *Assistant*,	July 1 to Sept. 22.
C. L. GREEN, *First Watch Officer*,	July 1 to Dec. 14.
H. C. MITCHELL, *Aid*,	Sept. 22 to Nov. 13.
C. F. ADAE, *Second Watch Officer*,	July 1 to Sept. 18.
W. F. GLOVER, *Second Watch Officer*,	Dec. 4 to Dec. 19.
H. S. SMITH, *Deck Officer, First Class*,	July 1 to Jan. 9.
GEO. OLSEN, *Deck Officer, First Class*,	Sept. 18 to Dec. 3.
J. E. SHEPHERD, *Surgeon*,	July 1 to Dec. 19.
HARRY ELY, *Engineer, Third Class*,	July 1 to Mar. 31.
H. I. MCCREA, *Deck Officer, Third Class*,	July 1 to Nov. 21.
H. J. ATWELL, *Junior Captain's Clerk*,	July 1 to Dec. 19.

On July 1 the steamer *Bache*, P. A. Welker, Assistant, Coast and Geodetic Survey, commanding, was at work in Chesapeake Bay below the mouth of the Potomac River, engaged in executing the triangulation required for the resurvey of the hydrography of this portion of the bay. A reference to the progress in this work before July 1 is contained in the Report for 1900.

It was continued without interruption until July 24, when preparations began to transfer the men on the *Bache* from the Navy pay roll to that of the Coast and Geodetic Survey.

The transfer was completed and the necessary recruits to fill vacancies caused by discharges were secured by August 6, and field work was resumed. On September 4 Lieut. Commander Charles E. Vreeland, U. S. N., member of the Board of Inspection and Survey, Navy Department, was taken on board at Annapolis, Md., for the purpose of making an examination of Chesapeake Bay to the westward of Barren Island, with a view of establishing a trial course, 1 mile long, for torpedo boats. The assignment of the ship for this work was made at the request of the Navy Department. The examination was completed on the 8th and the vessel returned to the lower bay after landing Lieutenant Commander Vreeland at Annapolis.

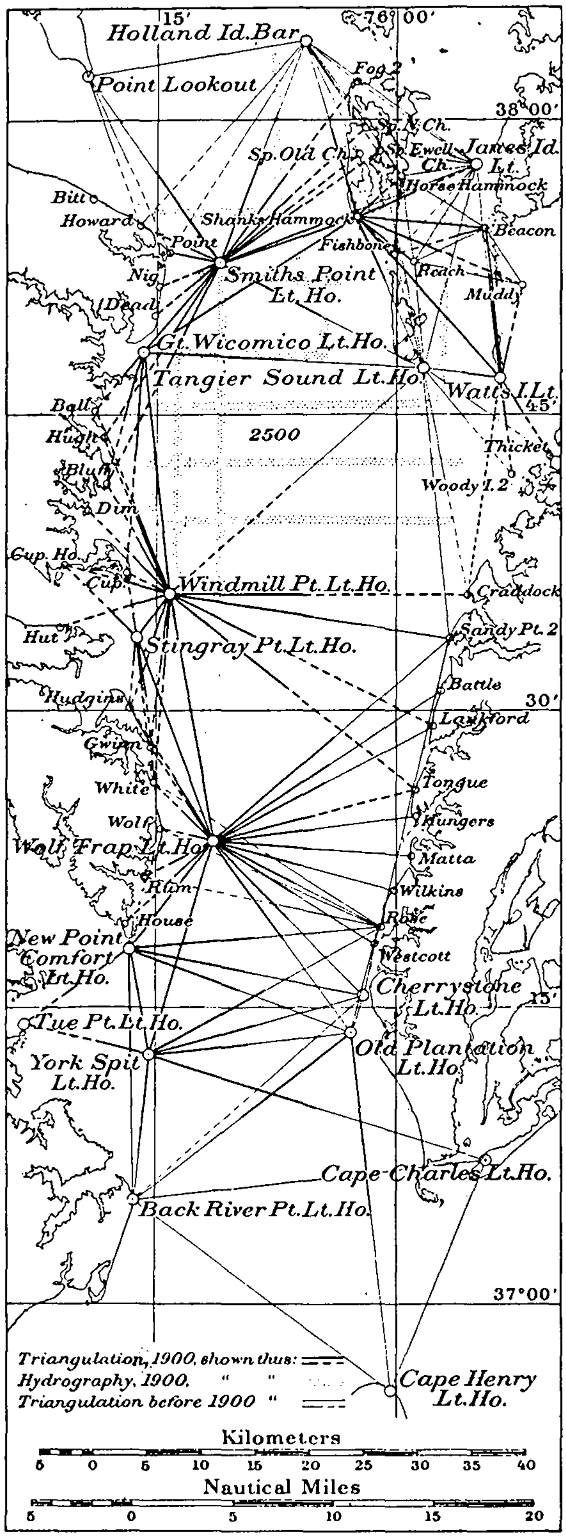
Preparations were made for a change in the command of the ship, and on September 15 Assistant Welker was relieved and ordered to command the steamer *Blake*.

First Watch Officer Green assumed temporary command of the *Bache* on September 15 and remained in command until September 21, when he was relieved by Assistant W. I. Vinal, who took command on that date at Baltimore, Md.

On September 26 the *Bache* left Baltimore, and on the 27th landed H. C. Mitchell, aid, at New Point Comfort light-house to continue the observations at that station.

After repairing the damage to the triangulation signals resulting from a recent storm, the vessel returned to Baltimore and was held open to inspection of bidders for

No. 14



Lower Chesapeake Bay.

the contract to reconstruct the ship, under the authority granted by Congress to do this necessary work, until October 6. Coal and provision were taken on board, and on October 10 the vessel returned to the working ground, where the work was continued until the 25th, when the ship returned to Baltimore to permit measurements, etc., to be made by those wishing to bid on the contract for reconstruction, and was detained there until November 14, when she again returned to the lower bay and resumed active work in the field, which was continued until the 28th, when the work closed and the vessel returned to Baltimore.

On December 17 the *Bache* sailed for New York, and reached Mariner Harbor, Staten Island, on the 19th. The vessel was then placed in the hands of the ship builders who had been awarded the contract to rebuild the ship.

HYDROGRAPHIC. SPECIAL DUTY. TRIANGULATION.	MARYLAND. FLORIDA.	P. A. WELKER, Commanding, Steamer *Blake*.

W. W. DUFFIELD, *Assistant*,	Sept. 24 to Oct. 5.
C. C. YATES, *Assistant*,	Sept. 24 to Oct. 5.
H. F. FLYNN, *Assistant*,	Dec. 14 to Mar. 6.
W. F. GLOVER, *First Watch Officer*,	Sept. 17 to Nov. 30.
C. A. THOMPSON, *First Watch Officer*,	Dec. 1 to June 30.
C. A. THOMPSON, *Second Watch Officer*,	Sept. 17 to Nov. 30.
J. L. DUNN, *Second Watch Officer*,	Dec. 1 to June 30.
J. A. MCGREGOR, *Deck Officer, First Class*,	Sept. 17 to June 30.
R. MCD. MOSER, *Deck Officer, First Class*,	Oct. 14 to Dec. 1.
GEO. OLSEN, *Deck Officer, First Class*,	Dec. 3 to June 30.
L. MCD. HOPKINS, *Chief Engineer, Second Class*,	Sept. 17 to June 30.
G. E. MARCHAND, *Assistant Surgeon*,	Sept. 17 to June 30.
H. J. ATWELL, *Junior Captain's Clerk*,	Sept. 17 to Dec. 11.
P. B. CASTLES, *Draftsman*,	Dec. 15 to June 30.

SUMMARY OF RESULTS.

Maryland.

1 speed trial course established and marked.
4 triangulation stations occupied.
20 geographic positions determined.

Florida.

Triangulation:
48 square miles area covered.
5 stations occupied.
25 geographic positions determined.
Hydrography:
71 square miles area covered.
1 668 miles of lines sounded.
4 sheets completed.
1 tide station established.

On September 17 Assistant Welker assumed command of the *Blake*, relieving Assistant W. C. Hodgkins. The necessary preparations for field work were made and on September 26 the *Blake* left for Baltimore, under instructions to establish a trial course 1 nautical mile in length in the vicinity of Barren Island, in Chesapeake Bay, and this duty was assigned to Assistant C. C. Yates by the commanding officer.

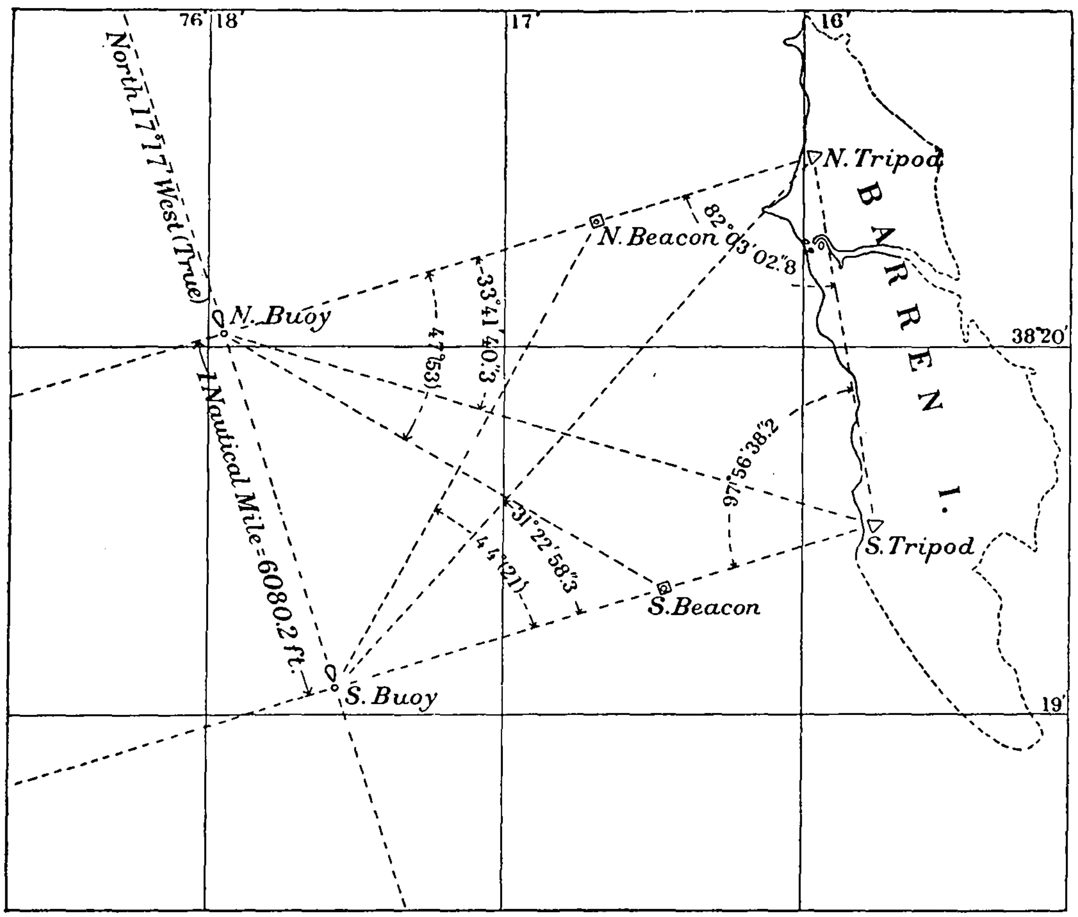
It was found to be impracticable to measure a base line on the island and a nautical mile was determined by triangulation from the line Cedar Point Light, Cove Point Light; this distance having been determined in the triangulation of the bay. The work was checked by introducing Drum Point Light into the scheme as an additional triangulation station.

Ranges were established and on October 5 the vessel returned to Baltimore.

On October 16 the vessel went to Barren Island under instructions to erect two pile beacons as outer range marks. These beacons were completed on October 21, and the vessel again returned to Baltimore.

Assistant Welker testifies to the energy and efficiency displayed by Assistant Yates in executing this duty.

No. 15.

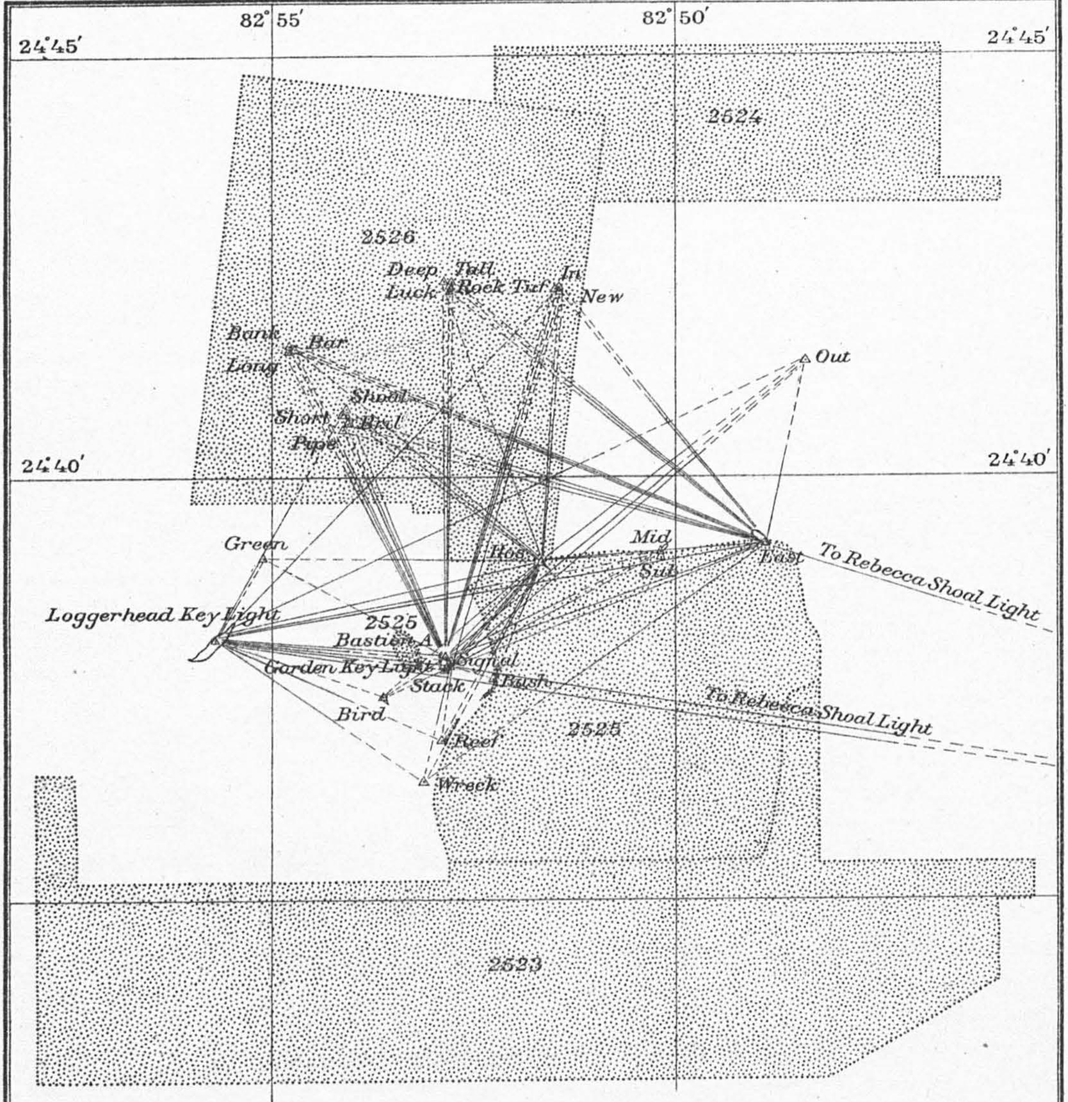


20 Fathom Trial Course, Chesapeake Bay.

Some necessary repairs were made to the vessel and all necessary preparations were made for field work in the Gulf of Mexico.

On December 17 the *Blake* left Baltimore under instructions to make a hydrographic survey in the vicinity of Dry Tortugas, Fla., and reached her destination on the 29th, after several days delay at Key West, to obtain necessary supplies and make some slight repairs to the ship.

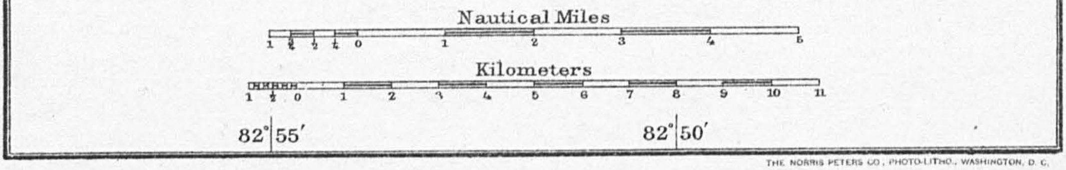
Active field operations began at once, and by January 12 all the necessary signals for use in the hydrographic survey were erected, the observations for their determination



TRIANGULATION AND HYDROGRAPHY

DRY TORTUGAS

FLORIDA



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were in progress, and a sufficient number of positions had been determined to start the hydrographic work. Four signals offshore were found to be necessary and were erected with difficulty in water 6 to 25 feet deep.

The bottom was found to be of a hard, coral formation, and iron pipes could not be pumped down as usual in such cases.

Where the water was less than 12 feet deep a wooden tripod was framed, supported by boats, and lowered into the water with the bottom heavily weighted. A pole with targets attached was secured to the top of this tripod and held in place by guys attached to anchors. In deeper water a gas pipe 2½ inches in diameter, heavily weighted at the bottom, was dropped overboard and secured in an upright position by guys with anchors, as mentioned above, the usual targets being fastened to the top. Three of these signals were destroyed by a gale before serving the purpose for which they were erected, and it was necessary to replace them.

On February 9 Assistant Welker received telegraphic instructions, sent at the request of the Light-House Inspector of this district, directing him to replace the Texas Rock buoy, which had gone adrift and was then stranded in the southeast channel near the entrance. The buoy was recovered on the 11th, but was in such bad condition that it was necessary for the vessel to visit Key West to obtain a new one. The new buoy was placed in position on the 18th, and in executing this work one of the ship's anchors was lost. Two large hydrographic signals were carried away in a heavy squall on the 19th. This squall developed into a violent "norther" during the following night, and five of the signals on the outer reefs were carried away by the heavy sea.

Stormy weather prevailed during the remainder of the month and early part of March, and little progress was made.

On March 9 the vessel sailed for Tampa, Fla., to obtain a steam launch which had been sent by rail to that place for the use of the party. Special arrangements for transporting the launch were made, and it was necessary to wait for favorable weather for the return trip on account of the weight of the launch and the consequent danger of the lashings giving away. These conditions caused so much delay that the launch could not be placed in the water at Dry Tortugas until March 18. Rapid progress was made with the work during the early part of April, but after the 16th the weather was again stormy and more signals were carried away, causing much delay. During May, more progress was made than in the previous three months, and on May 24 the hydrographic survey of all the approaches to Dry Tortugas was completed.

The ship sailed next for Key West towing the launch. The launch was put in proper condition for storage and turned over to the commandant at the United States naval station for safe-keeping. The necessary supplies were taken on board and the *Blake* sailed for Baltimore on June 1 and reached that port on June 6. The rest of the month was spent in putting the ship in condition for work on Nantucket shoals and in making necessary preliminary preparations. Assistant Welker reports that Assistant Flynn performed valuable and efficient service in navigating the ship, in the triangulation and hydrographic work, and in directing the office work of the ward-room officers.

The *Blake* was at Baltimore at the close of the fiscal year.

A. C. L. ROETH, *Deck Officer.*
WM. SANGER, *Captain's Clerk.*

SUMMARY OF RESULTS.

2 square miles area covered.
34 miles of lines sounded.
2 tide stations established.
1 sheet completed.

A hydrographic examination of the bar off the entrance to Port Royal, S. C., to determine whether certain reported changes since the last survey existed in fact was made in December under the direction of Assistant Yates.

The two officers mentioned above and a leadsman were ordered to join the party, and the revenue cutter *Forward* was instructed, through the courtesy of Capt. C. F. Shoemaker, Chief of the Revenue Cutter Service, to take the party on board and to render every possible assistance to Assistant Yates in the prosecution of the work assigned to him.

The work began on December 5 and was continued whenever the weather conditions permitted until it was completed on December 28.

The location of nearly all the signals used in connection with the work had been determined by triangulation from the shore and the location of the other signals was determined by measuring sextant angles on two of the triangulation points.

Tide observations were made at the Port Royal Naval Station and on the bar during all the time that the soundings were being made.

The observations on the bar were made on a tide staff attached to the wreck of a vessel lying about 3 miles inside of the bell buoy.

The plane of reference used for the reduction of the soundings and the time correction for the distance of the water tide staff from the bar were determined from simultaneous tide observations at the outer tide staff and at the Port Royal Naval Station.

All the soundings were obtained with a well-seasoned lead line, which was carefully tested before and after the soundings were made. The leadsman was an expert with many years of experience, and the soundings were made only when the water was smooth. Especial care was taken to determine the height of long ground swells. The examination was made for a special purpose, and consequently no attempt was made to develop anything but the best practicable channel over the bar and the relation of this channel to the buoys in position at the time the work was in progress.

At the beginning of the work it was found that the location of the ranges did not indicate the deepest water over the bar, and it was decided to adopt the channel used by the local pilots as the base for the development of the examination. The location of the pilot's channel was determined by having a pilot, who was selected by the local pilot association, take the vessel four times across the bar through what he considered the deepest water. The position of the vessel was determined at every minute while running these lines, and soundings were made every twenty seconds. The development of this channel did not change the results obtained.

Upon the completion of the work Assistant Yates returned to Washington.

His report expresses his appreciation of the effective aid rendered him by Capt. J. C. Mitchell, First Lieut. F. S. Van Boskerck, jr., and Chief Engineer H. C. Barrows, officers of the cutter *Forward*, and the interest they showed in the work.

HYDROGRAPHIC.	DELAWARE RIVER.	F. A. YOUNG, Commanding,
TRIANGULATION.	CHESAPEAKE BAY.	Steamer *Endeavor*.

July 1 to November 26.

A. L. GREEN, *First Watch Officer.*	
M. F. FLANNERY, *Chief Engineer, Third Class.*	
G. H. PHELPS, *Junior Aid.*	July 1 to Sept. 13.
A. C. L. ROETH, *Deck Officer, First Class.*	
D. B. WAINWRIGHT, *Junior Deck Officer, First Class.*	
WM. BAUMAN, *Junior Captain's Clerk.*	

SUMMARY OF RESULTS—DELAWARE RIVER.

28 square miles area covered by soundings.
370 miles of line sounded.
6 tide stations established.
4 hydrographic sheets completed.
3 triangulation stations occupied.

March 22 to June 30.

M. F. FLANNERY, *Chief Engineer, Third Class*	
A. C. L. ROETH, *Deck Officer, First Class.*	
H. S. SMITH, *Deck Officer, First Class.*	
GERSHOM BRADFORD, *Junior Deck Officer, Third Class.*	June 6 to June 30.
H. J. ATWELL, *Junior Captain's Clerk.*	Mar. 22 to Mar. 30.
WM. SANGER, *Junior Captain's Clerk.*	Apr. 1 to Apr. 26.

SUMMARY OF RESULTS—CHESAPEAKE BAY.

13 signals erected.
29 miles of line sounded.
4 tide stations established.

The steamer *Endeavor*, with Assistant Young in command, was engaged in making hydrographic examinations and surveys in the Delaware River between Chester, Pa., and Bombay Hook from July 1 to November 26. The work involved the determination of the availability of the channels that differed about 1 foot in depth, and resulted in showing that changes in depth had taken place since the previous survey upon which the ranges for the use of shipping were based.

The work was greatly facilitated by the data furnished by Lieut. Col. Charles W. Raymond, Corps of Engineers, U. S. A., in charge of improvements on the river, which included a large number of geographic positions, blue prints of hydrographic surveys, and other information.

The triangulation executed under his direction was connected with the triangulation of the Coast and Geodetic Survey, and can be used in the future as a part of the Survey system.

All recent hydrographic surveys of the Engineers were a guide to the special localities examined and rendered it possible to eliminate large areas from consideration.

Assistant H. G. Ogden, Inspector of Hydrography and Topography, was on board the *Endeavor* during this examination and supervised the operations.

During the season two obstructions to navigation were discovered just off the channel below Pennville by using a long fishing net. This net was weighted and allowed to float downstream, being so arranged that when the bottom caught on any obstruction the float immediately above the object would disappear beneath the surface of the water. The sounding boats followed the net downstream and located the obstructions.

On November 28 the vessel started to Baltimore, Md., via the Delaware and Chesapeak Canal, and reached that place on the 29th.

Assistant Young commends the efficiency displayed by the officers under his command in performing the duties assigned to them.

The *Endeavor* remained at Baltimore from December 5 to March 21, and minor repairs were made to the vessel.

On March 22 Assistant Young left Baltimore under instructions to make a hydrographic examination at the entrance of Sassafras and Elk Rivers in Chesapeake Bay. The necessary signals were erected and tide gauges were established at Pooles Island, Betterton, Reybolds Wharf, and Town Point. Observations of the tide were made by simultaneous readings on the gauges at these stations between March 23 and 28.

The gauges were referred, by spirit leveling, to bench marks established in the previous work, for the purpose of comparing the results with those formerly obtained. On account of unfavorable weather, soundings were made on only four days, but a number of lines were sounded. The soundings at mouth of Sassafras River were referred to tide observations at Betterton, and those at the mouth of Elk River to tide observations at Betterton and at Reybolds Wharf. On April 17 the *Endeavor* returned to Baltimore for additional repairs, which were not completed until June 22. On June 23 the *Endeavor* again left Baltimore, under instructions to continue the hydrographic reconnaissance begun during the preceding fiscal year by Assistant Vinal in Lower Chesapeake Bay.

Thirteen triangulation stations were visited and the signals were repaired.

This work was in progress at the close of the fiscal year.

MIDDLE DIVISION.

BASE MEASUREMENT. NEBRASKA. A. L. BALDWIN.

KANSAS.

OKLAHOMA TERRITORY.

TEXAS.

WILLIAM BOWIE, *Assistant.*
F. H. BRUNDAGE, *Aid.*
O. M. LELAND, *Aid.*
L. A. FISCHER. July 16 to Aug. 12.
L. S. SMITH. July 16 to Aug. 31.
R. S. FERGUSON. Sept. 10 to Jan. 16.

SUMMARY OF RESULTS.

9 base lines measured.

A party was organized under the direction of Computer A. L. Baldwin to measure 9 base lines, distributed along the 98th meridian. These base lines had been located and the ends marked during the progress of the reconnaissance for the triangulation.

The work began on July 16 and the following base lines were measured during the season: Shelton base, near Shelton, Nebr.; Page base, Holt County, Nebr.; Anthony base, Harper County, Kans.; El Reno base, Canadian County, Okla.; Bowie base, Montague and Clay counties, Tex.; Stephenville base, Erath County, Tex.; Lampasas base, Lampasas County, Tex.; Alice base, Nueces County, Tex.; Seguin base, Guadalupe County, Tex.

Five base apparatus were used in measuring each base, two 50-meter tapes, two 100-meter tapes, and the duplex bars.

At the first base a comparator, 100 meters long, was prepared and measured with the standard bar in melting ice. On this comparator each apparatus was standardized before beginning the base measurement. At the last base a comparator was established in a similar manner, and the operation of comparing each apparatus with the standard bar was repeated.

At every base 1 kilometer was measured once with each apparatus as the means of comparison, and one-fifth of the remaining length of the base depends upon measurements made with each apparatus. The portion measured with the duplex bars was remeasured with these bars. A double portion was measured with one 50-meter tape and remeasured with the other, and a double portion was measured with one 100-meter tape and remeasured with the other. This programme was successfully carried out, and on January 16, 1901, six months after the work began, the last comparison was made, after completing the measurement of the last base line, and a notable record in the measurement of base lines for primary triangulation was an accomplished fact.

The nine base lines aggregate 69 kilometers or 43 statute miles in length, and are so widely distributed along the meridian that twenty-six days of the time during the season were necessarily used in moving the party and outfit from base to base.

In addition to the officers, five laborers were used in the measurement.

At the first base advantage was taken of the comparator established there to standardize two 100-meter steel tapes for the Japanese Government, this work being done under the direction of Mr. Louis A. Fischer, adjuster of weights and measures, in the Office of Standard Weights and Measures. At the Anthony base, the party was inspected while at work by Dr. H. S. Pritchett, then Superintendent of the Coast and Geodetic Survey, and at the Alice base Assistant John F. Hayford, Inspector of Geodetic Work, visited the party and inspected all the details of the measurement.

Prof. A. E. Burton, of the Massachusetts Institute of Technology, accompanied Assistant Hayford, and during their stay with the party some field tests were made with thermophone tape apparatus belonging to the institute.

As an instance of the rapidity with which some of the work was done, it may be mentioned that at the Stephenville base, 6.3 kilometers long, the interval between the arrival of the party on the line and the departure therefrom was eleven days, two of which were Sundays, on which no work was done.

Mr. Baldwin reported in person at the office on January 31.

LOUISIANA.
ARKANSAS.
MISSOURI.
IOWA.
MINNESOTA.
SOUTH DAKOTA.
NEBRASKA.
KANSAS.
TEXAS.

W. C. BAUER, *Magnetic Observer.*	July 1 to June 30 (at intervals).
W. M. BROWN, *Magnetic Observer.*	Aug. 5 to Oct. 28.
W. G. CADY, *Magnetic Observer.*	Sept. 12 to Oct. 27.
C. K. EDMUNDS, *Magnetic Observer.*	July 1 to Aug. 21.
F. M. LITTLE, *Assistant.*	Apr. 15 to May 14.
J. W. MILLER, *Magnetic Observer.*	Aug. 21 to Oct. 27.
W. F. WALLIS, *Magnetic Observer.*	July 1 to Dec. 1, Apr. 15 to May 21.
W. WEINRICH, jr., *Magnetic Observer.*	Apr. 11 to June 30.

Magnetic Observer W. C. Bauer assisted in the magnetic observatory work at Baldwin, *Kans.*, July 1 to August 2, and August 17 to 21. From August 3 to 16 he made magnetic observations and established lines for surveyors' use in *Kansas* at Holton and Marysville, and in *Nebraska* at St. Paul and York. From August 22 to June 30 he was in charge of the magnetic observatory at Baldwin, Kans., devoting about ten days each month to observatory work.

Magnetic observations were made and lines for surveyors' use were established August 5 to October 28 in *Nebraska* by Magnetic Observer W. M. Brown at the following places: Albion, Ainsworth, Alliance, Bartlett, Brewster, Bridgeport, Broken Bow, Burwell, Chappell, Gandy, Gering, Harrisburg, Harrison, Hartman, Hewitt, Hyannis, Kennedy, Keystone Ranch, Kimball, Marsland, Merriman, Mullen, Neligh, Newport, Ogallala, Omaha, O'Neill, Seventh Parallel, Rock County, Rushville, School Section No. 36, Schuyler, Sidney, Springview, Thedford, Tryon, and Valentine.

Magnetic Observer W. G. Cady was on duty at the magnetic observatory at Baldwin, *Kans.*, from September 14 to October 15. From October 16 to 27 he assisted Magnetic Observer J. W. Miller at work in *Minnesota*.

Magnetic Observer C. K. Edmunds was in charge of the magnetic observatory at Baldwin, *Kans.*, July 1 to August 21.

Assistant Little was at work in *Texas* under the direction of Megnetic Observer Wallis April 15 to May 14.

Magnetic observations were made and lines for surveyors' use were established by Magnetic Observer J. W. Miller August 22 to October 27 in *Kansas* at Hiawatha; in *Nebraska* at Lincoln; in *South Dakota* at Gettysburg, Huron, Redfield, Sioux Falls, and

Watertown; in *Minnesota* at Alexandria, Benson, Brainerd, Breckenridge, Crookston, Detroit City, Glyndon, Granite Falls, Heron Lake, Lake Benton, Mankato, Mantorville, Minneapolis, St. Cloud, Wadena, and Walker.

Magnetic observations were made and lines for surveyors' use were established by Magnetic Observer W. F. Wallis July 1 to December 1, in *Iowa* at Anamosa, Atlantic, Boone, Burlington, Carroll, Charles City, Cherokee, Corydon, Council Bluffs, Creston, Decorah, Dubuque, Eldora, Emmetsburg, Fairfield, Fonda, Fort Dodge, Garner, Hampton, Hartley, Idagrove, Keokuk, Lancaster, Lemars, Logan, Manchester, Marengo, Menlo, Newton, Northwood, Onawa, Osceola, Oskaloosa, Perkins, Red Oak, Washington, Waterloo, and West Union; in *Nebrasha* at Omaha; in *Missouri* at Chillicothe, Harrisonville, Hermann, Kansas City, Macon, Palmyra, St. Louis, and Sedalia. From November 3 to 16 he was at Baldwin, *Kans.*, comparing his instruments and assisting in the observatory work. He made magnetic observations and established meridian lines April 15 to May 21, in *Texas* at Austin, Belton, Coleman, Groesbeck, Kaufman, Lampasas, and Stephenville, and assisted Magnetic Observer Weinrich at work in *Arkansas*.

Magnetic observations were made and lines for surveyors' use were established by Magnetic Observer W. Weinrich, jr., April 11 to June 30, in *Louisiana* at Alexandria, Columbia, and New Orleans; and in *Arkansas* at Batesville, Camden, Corning, Evening Shade, Jonesboro, Little Rock, Malvern, Monticello, Murfreesboro, Newport, Paragould, Pine Bluff, Searcy, Texarkana, and Walnut Ridge.

OKLAHOMA TERRITORY.

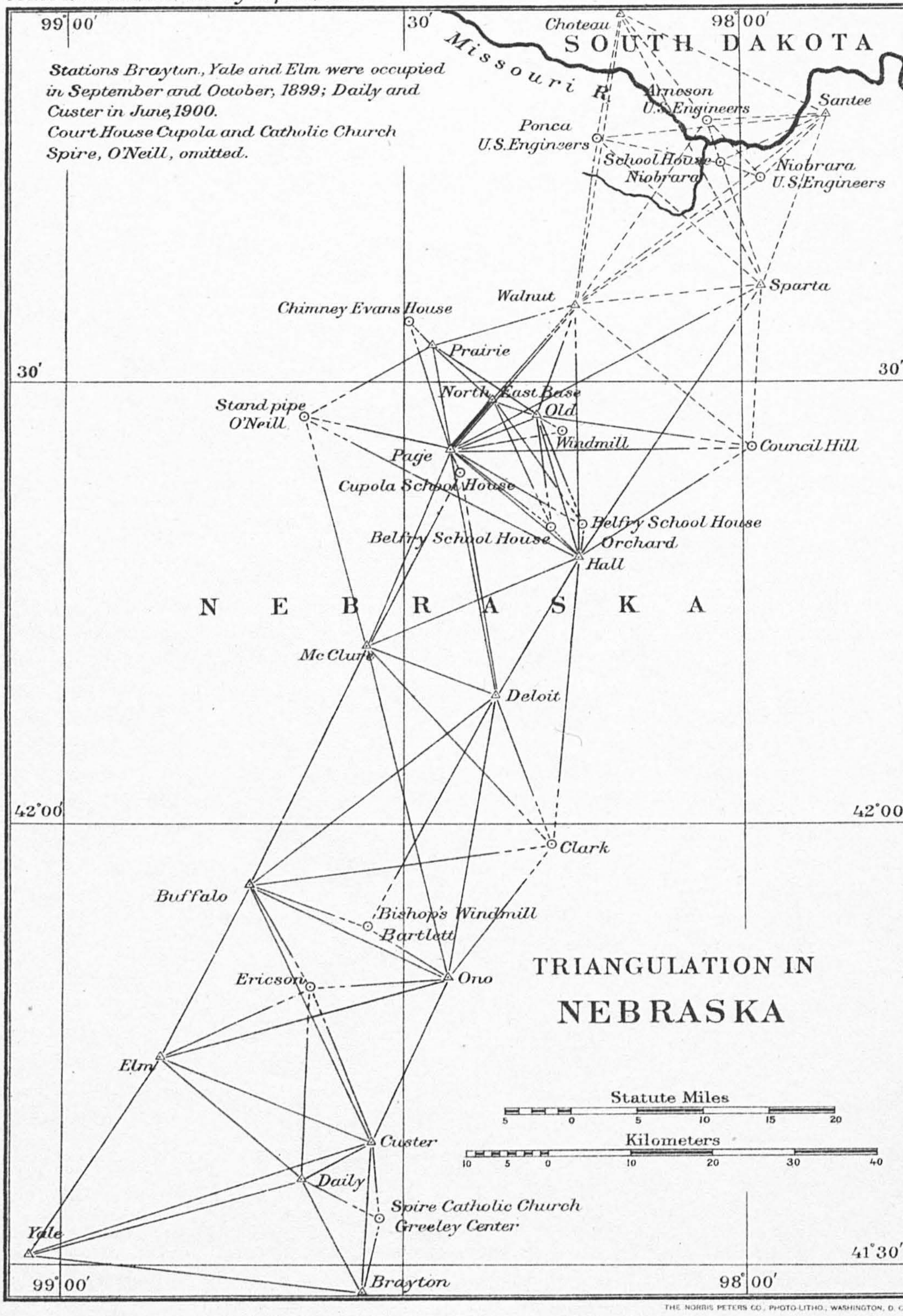
TEXAS.

Stations occupied.

State.	County.	Town.
Kansas	Norton	Richfield.
Do	Stevens	Liberal.
Oklahoma Territory	Beaver	Beaver.
Do	Woodward	Woodward.
Do	Roger Mills	Cheyenne.
Do	Greer	Mangum.
Texas	Wilbarger	Vernon.
Do	Baylor	Seymour.
Do	Stonewall	Aspermont.
Do	Mitchell	Colorado.

Magnetic observations were begun by Aid Dibrell in this division at Richfield, Kans., on November 17. The stations named above were occupied and observations were made to determine the three elements of the earth's magnetism. The stations were marked with stone posts wherever it was practicable to obtain them, and with cedar posts at the other stations.

The work for the season closed on December 19, and Aid Dibrell proceeded to Coleman, Tex., under instructions to store the outfit, and completed this duty on December 22, and then proceeded to Washington, D. C.



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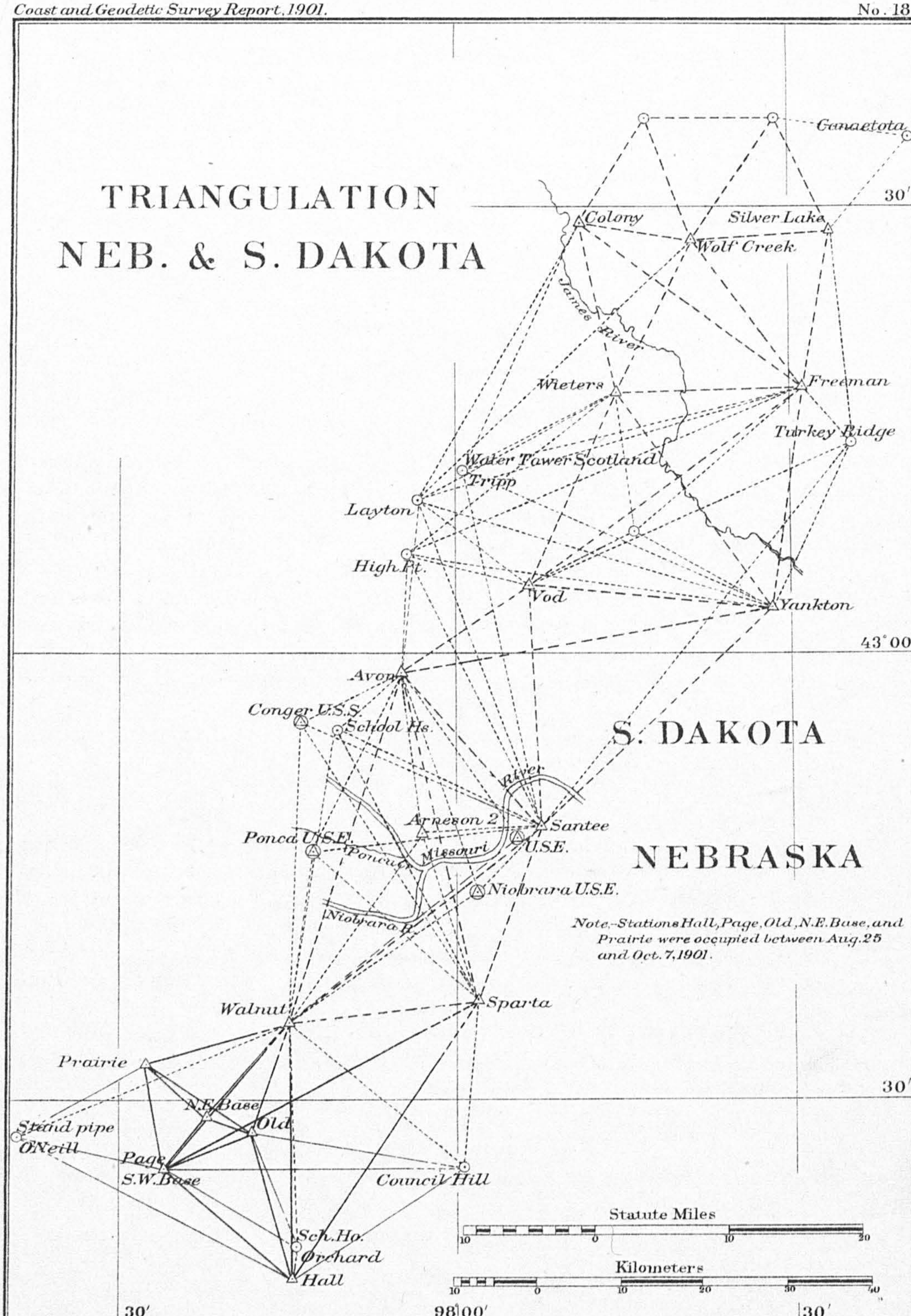

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SUMMARY OF RESULTS.

1 485 square miles area covered by reconnaissance.
10 triangulation stations selected.
9 triangulation stations occupied.
21 geographic positions determined.
958 square miles area covered by triangulation.

The continuation of the triangulation along the ninety-eighth meridian was in progress under the direction of Assistant Granger on July 1 at Ono triangulation station, Wheeler County, Nebr., and the work progressed without serious interruption until the close of observations at station Old, Holt County, Nebr., on October 17. This work is the continuation of Assistant Granger's previous work along this meridian.

The actual time required in making the observations of horizontal and vertical angles at the nine stations occupied was fifty-nine days, or an average of six and one-half days to a station. The number of directions observed at a station ranged from 4 to 8, with an average of 5. After closing observations at station Old, and storing the instruments and outfit at Page, Nebr., Assistant Granger took up the work of reconnaissance northward from the line Walnut to Sparta, and selected two new stations which formed a quadrilateral with the two already named.

Field operations were closed on November 8, and Assistant Granger reported at the Office for duty on November 12.

On April 13, 1901, Assistant Granger left New York for Page, Nebr., under instructions to continue his work of the previous season on the extension of the triangulation along the ninety-eighth meridian northward through Nebraska and South Dakota.

He reached Page on the 15th and immediately prepared for reconnaissance work. He continued the reconnaissance until June 20, when he returned to triangulation point Walnut and prepared to occupy the station.

The observations at this station were in progress at the close of the fiscal year.

Assistant Granger expresses his appreciation of the efficient service rendered by E. E. Torrey, foreman, and D. A. Lewis, driver.

Stations occupied.

State.	County	Town.
Texas	Runnels	Ballinger.
Do	Bandera	Bandera.
Do	McCulloch	Brady.
Do	Coleman	Coleman.
Do	Gillespie	Fredericksburg.
Do	Kerr	Kerrville.
Do	Llano	Llano.
Do	Mason	Mason.
Do	Concho	Paintrock.
Do	Edwards	Rock Springs.
Do	San Saba	San Saba.

The determination of the magnetic elements at a number of places in Texas was assigned to Assistant Little. He began this work on May 15 and continued it during the remainder of the fiscal year.

He used a wagon and team as the means of transportation, and visited those places, which are not easily accessible, as they are away from the railroad.

At each of the stations observations were made to determine the magnetic elements, and a meridan line for surveyors' use was established.

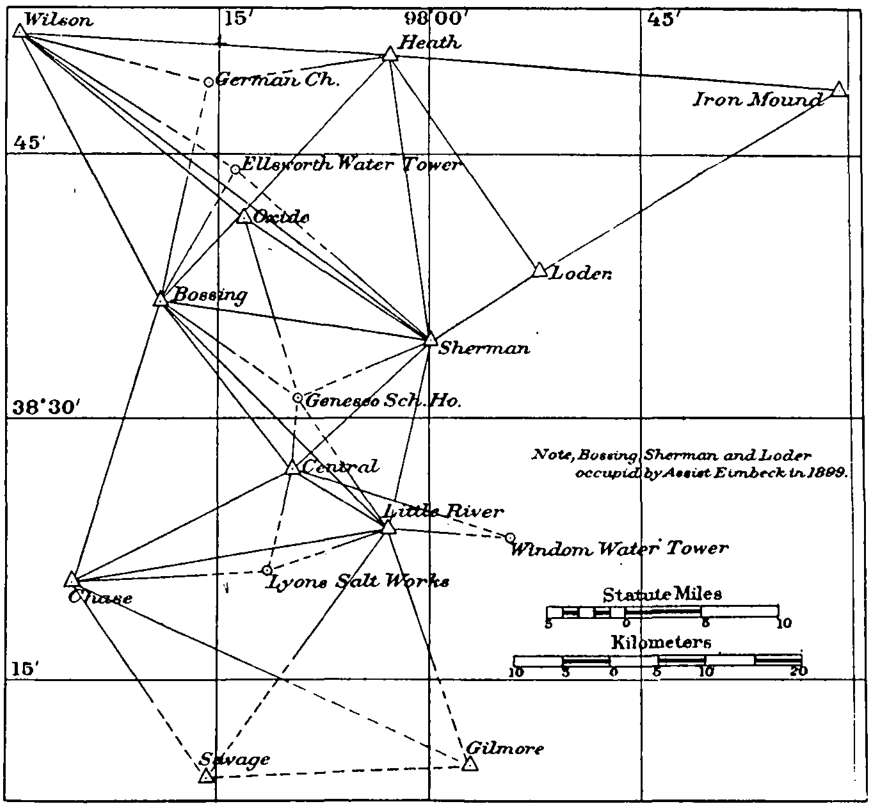
The work was in progress at the close of the fiscal year.

SUMMARY OF RESULTS.

8 stations occupied for horizontal measures.
19 geographic positions determined.
777 square miles area covered by triangulation.

The extension of the triangulation southward, from the transcontinental triangulation, along the ninety-eighth meridian was placed under the direction of Assistant Mosman.

No. 19.



He reached Salina, Kans., on July 7, and preparations for the season's work began immediately and continued until the 22d, when the first observations were made at the station Iron Mound. Stations Heath, Wilson, Central, Little River, and Chase were occupied during the season in the order named, and observations were finished at Chase on October 25.

On October 31 final disposition had been made of the outfit for the winter, and on November 1 Assistant Mosman started to Washington and reported at the Office on the 6th.

Assistant Mosman left Washington on May 17 under instructions to proceed to Sterling, Kans., and resume work on the triangulation along the ninety-eighth meridian in continuation of his work of the previous season.

Signalman Bilby was sent to the field a few days earlier to secure outfit and make necessary preliminary arrangements.

He built tripods and scaffolds at Sunflower, Pretty Prairie, Kingman, and Cheney stations and finished the structure at Arlington.

The scaffolds at Arlington and Kingman stations were extended above the tripod to a height sufficient to allow the heliotropes mounted on top to be seen from other stations, where it would otherwise have been necessary to mount the observing instruments so high above the ground that it would have been dangerous to occupy the stations on account of strong wind when the screens were in place during the observations.

The screens were necessarily used on all scaffolds while observing, as the prevailing wind in this region caused too much vibration of the instruments to permit observations without them.

On June 3 and 4 the camp outfit was moved from storage to Savage Station and the station was ready for observations on the 8th. Strong wind prevented work until June 12 and the observations were completed on the 14th.

It was difficult to procure teams for transportation to Station Gilmore, and this station was not ready to begin observing until the 21st.

Unfavorable weather caused a delay of two days, but the observations were completed on the 25th. More time was lost in finding teams to transport the outfit to Station Partridge, and this station was not ready for observation until June 30.

Harvesting the crops goes on at this season in Kansas and all available transportation and labor are engaged.

At the end of the fiscal year the work was in progress.

In continuation of the work described in the Eastern Division, Nautical Expert Ross left New Orleans on December 7 for Galveston, Tex., visiting Morgan City, Sabine, Rockport, and Aransas Pass en route. While at Sabine he made a trip through the Port Arthur Ship Canal.

He reached Galveston on December 14 and organized a party to make a hydrographic examination of the bar off the entrance to the harbor. In connection with this work, Mr. Ross reports the courtesy extended to him by Capt. C. H. Riché, Corps Engineers, U. S. A., and the valuable assistance rendered by his orders.

He was given every facility to examine the original records of surveys made by the Engineer Corps, and an assistant engineer and several employees were detailed to assist him in making the hydrographic examination of the bar.

The soundings made were more for the purpose of comparison and to note any indication of changes in the buoyed channel which might have occurred during the two months which had elapsed since the survey than to develop the contours of depth over the bar.

The bar buoys were relocated during the progress of the work. The steamer *Pherabe*, of Galveston, was hired and Mr. Ross was fortunate in having a day for the work when there was no sea or swell on the bar, a rare condition at the season of the year.

After completing the duty assigned to him, Mr. Ross returned to Washington on December 26.

KANSAS.

SUMMARY OF RESULTS.

202 miles of levels completed.
44 permanent bench marks established.

The leveling work under the direction of Aid Tilton was in progress on July 1 at Hadir, Nebr., and the party was at work continuing the line of levels between Norfolk and Page, Nebr., as referred to in the Report for 1900. The line was completed to Page and connected with the south end of the Page base line of the triangulation along the ninety-eighth meridian on July 28.

On the same day the party started to Solomon, Kans., to extend the levels south from that place. The route from Solomon to Anthony, Kans., followed the Union Pacific Railway to Salina, over the route of the transcontinental line of levels, thence along a branch of the same road to McPherson, from which place the route followed the Atchison, Topeka and Santa Fé Railway to Anthony, Kans., where the work was closed for the season on October 14.

A branch line was run from Pretty Prairie, Kans., to a point near the selected triangulation station of the same name, and from Kingman, Kans., to a point near the selected triangulation station, also of the same name. As these stations had not been occupied and marked, a stone bench mark was established at the end of each one of these branch lines.

The line was connected with the stone marking the southeast end of the Anthony base line of the triangulation along the ninety-eighth meridian.

Aid Tilton reported in Washington on October 17.

WESTERN DIVISION.

MAGNETIC.	CALIFORNIA. OREGON. WASHINGTON.	L. A. BAUER

W. WEINRICH, Jr., *Magnetic Observer.* Nov. 7 to Nov. 27.

An examination was made on Mount Hamilton, California, by Assistant Bauer, November 2 to 3, to determine whether it was available for a magnetic observatory, and he also determined the magnetic elements.

Magnetic observations were made and lines for surveyors' use were established by Magnetic Observer W. Weinrich, jr., November 7 to 27, in *Washington* at Everett, Mount Vernon, New Whatcom, and Seattle; and in *Oregon* at Portland.

Stations occupied.

State.	County.	Town.
Colorado	Logan	Sterling.
Do	Washington	Akron.
Do	Yuma	Yuma.
Do	Kit Carson	Burlington.
Do	Arapahoe	Gerdts.
Do	Cheyenne	Cheyenne Wells.
Do	Iowa	Sheridan Lake.
Do	Prowers	Lamar.
Do	Baca	Springfield.

Various preliminary arrangements were made and magnetic observations in this division were begun at Sterling by Aid Dibrell on October 29.

While engaged in this work a wagon and horses were used as a means of transportation. The stations named above were occupied and observations were made to determine the elements of terrestrial magnetism. The stations were marked with stone posts wherever it was practicable to obtain them, and with cedar posts at the other stations.

On October 30, at Sterling, special declination readings were made at intervals of five minutes throughout the entire day, and the temperature read and recorded at intervals of fifteen minutes, seventy-fifth meridian time being used. These observations were made by other magnetic parties in different parts of the country in execution of a plan to determine the areas over which the diurnal variation of the declination is the same. The work in this division was closed on the 16th of November.

COAST PILOT. CALIFORNIA. E. F. DICKINS, Commanding, Steamer *Gedney*.

C. W. FITZGERALD, *First Watch Officer.*
J. W. MCGRATH, *Second Watch Officer.*
F. G. CRIST, *Deck Officer, First Class.*
W. W. MARKOE, *Assistant Surgeon.*

On July 1 extensive repairs were being made to the steamer *Gedney* at the Port Orchard Naval Station, Wash. These repairs were completed on December 6, and preparations for a cruise were made at that place and at Seattle.

The vessel sailed for San Francisco, Cal., under the command of E. F. Dickins, Assistant, Coast and Geodetic Survey, on the 17th of December, and reached that port on the 26th, having spent four days at Port Angeles, Wash., waiting for suitable weather to go to sea.

Assistant Dickins immediately began preparations for a cruise along the coast of California, to the southward as far as San Diego, conveying Nautical Expert H. L. Ford, who had been instructed to report on board and to collect all necessary data for the revision of the Coast Pilot volume covering this region. The officers of the ship assisted Mr. Ford in performing the duty assigned to him, and the details of the work accomplished will be found in this Report under the proper heading. The vessel returned to San Francisco and anchored in the harbor on March 9.

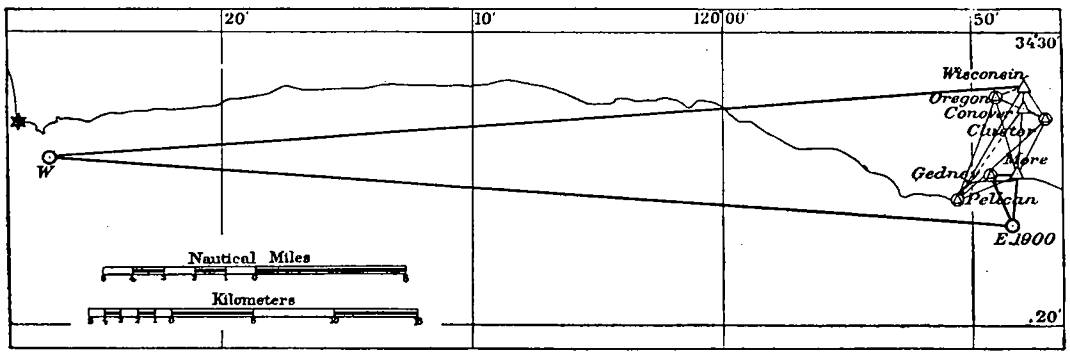
During the voyage the vessel visited all the landings and anchorages of importance along the coast and on the shores of the islands off the coast of southern California.

SANTA BARBARA SPEED-TRIAL COURSE, EXTENSION OF. CALIFORNIA. FRANK W. EDMONDS.

SUMMARY OF RESULTS.

6 triangulation stations occupied.
4 geographic positions determined.
8 square miles area covered by triangulation.

No. 20.



Speed Trial Course. Santa Barbara Channel.

The extension of the Santa Barbara speed-trial course having been requested, Assistant Edmonds was assigned to the work, and on August 23 he proceeded to Santa Barbara, Cal., under instructions to prepare a 32-mile (nautical) speed-trial course in the Santa Barbara channel, for use in the builder's trial of the U. S. S. *Wisconsin*.

Having made all necessary preliminary arrangements, he began field operations on September 3, and the work proceeded without interruption. A distance of 32 nautical miles was determined, and ranges were established marking the ends.

The work was completed on September 21, and on the 22d Assistant Edmonds proceeded to San Francisco, Cal.

A new edition of the Coast Pilot for California, Oregon, and Washington being necessary, Nautical Expert Ford left Washington on December 20, under instructions to proceed to the western coast for the purpose of collecting the information required for the work of revision. Assistant Dickins, commanding the steamer *Gedney*, was directed to take Mr. Ford on board and afford him all necessary assistance in his work. While waiting for the *Gedney* to sail, information was collected in San Francisco.

Mr. Ford reported on board the *Gedney* on January 16, and on the 28th the vessel sailed from San Francisco foi a cruise to the southward to verify the sailing directions and Coast Pilot notes prepared in advance, covering the coast from San Francisco to the Mexican boundary. The ports south of San Francisco were visited, new wharves were located, and all necessary information was collected. The *Gedney* returned to San Francisco on March 9, having completed the necessary work south of that port.

After returning to San Francisco, Mr. Ford was engaged for some time in completing the compilation of the notes made in the field. On May 16 he was detached from the *Gedney*, and established headquarters in San Francisco and prepared to take up the work on the coast north of that port, using local transportation as the best available means of obtaining the desired information.

From May 25 to June 30 the necessary verification of data relating to the coast between San Francisco and Trinidad Head was completed, except for a small part of minor importance immediately to the northward of Point Reyes.

The work was in progress at the close of the fiscal year.

HYDROGRAPHIC. RECONNAISSANCE. TOPOGRAPHIC. TRIANGULATION.	OREGON. WASHINGTON.	FREMONT MORSE.

September 5 to December 7.

B. A. BAIRD, *Aid.*
F. G. CRIST, *Deck Officer.*
J. N. FAHNESTOCK, *Recorder.*

SUMMARY OF RESULTS.

6 square miles area covered by hydrography.
156 miles of lines sounded.
1 hydrographic sheet completed.
5 square miles area covered by topography.
42 miles of shore line of river surveyed.
5 miles of shore line of creeks surveyed.
11 miles of shore line of ponds surveyed.
8 miles of roads surveyed.
1 topographic sheet completed.

April 20 to June 30.

E B. LATHAM, *Assistant.*

SUMMARY OF RESULTS.

36 square miles area covered by reconnaissance.
18 triangulation stations selected.
19 square miles area covered by triangulation.
10 stations occupied.
10 geographic positions determined.
3 square miles area covered by hydrography.
57 miles lines sounded.

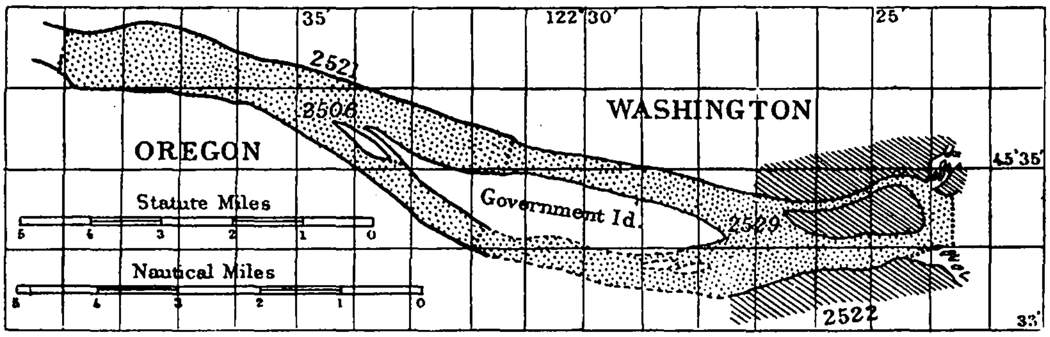
The survey of the Columbia River between Vancouver and the Cascade Locks was assigned to Assistant Morse. He left San Francisco, Cal., on September 5, and proceeded to Portland, Oreg., to organize a party for the work.

On September 20, all the necessary preliminary arrangements having been completed and the party established in camp, the work of recovering old stations and the erection of signals was taken up.

Tide staffs were set up to determine the plane of reference between Vancouver and the Cascade Locks, and the low-water plane established at Vancouver by the Corps of Engineers, U. S. A., during the previous year was adopted for the work. The hydrographic and topographic survey of the Columbia River between Portland and the Cascades proceeded without interruption until December 7, on which date the last soundings for the season were made.

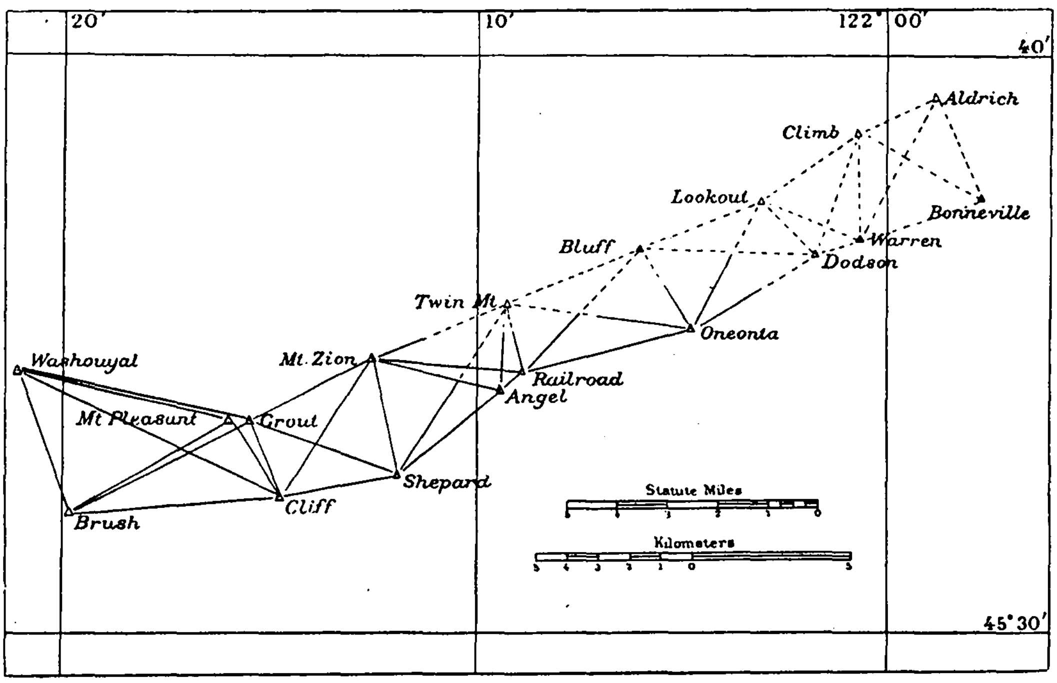
The camp was stored and Assistant Morse proceeded to San Francisco, accompanied by Aid Baird, where they arrived on December 13. He reports the kindness of Capt. William W. Harts, Corps of Engineers, U. S. A., in charge of the work of improving

No. 21.



the Columbia River, in furnishing information relating to the tidal plane previously established at Vancouver and the Cascade Locks, and acknowledges the courtesy and kindness of Mr. W. G. Brown, the overseer of the Cascade Locks, to himself and the members of his party.

No. 22.



Assistant Morse left San Francisco on April 18, under instructions to resume work on the Columbia River and extend the triangulation, topography, and hydrography from the point to which it had been completed during the previous season. He reached

Portland, Oreg., on the 20th, where he organized a party and made all necessary preparations for the season's work. The party left Portland on the 22d and proceeded to Camas, Wash., where camp was pitched and active field operations began immediately. Signals for use in the hydrographic work were erected and soundings were made until May 9, when an unfinished sheet of the previous season was completed.

Assistant Latham reported on April 30 and was assigned immediately to active duty. On May 9 the river was already high and rising rapidly to the regular flood stage caused by melting snow in the mountains, and consequently the hydrography had to be suspended and no topography could be done. Stations were selected for triangulation points and at five of these the necessary observations were made. On June 8 the party moved to Prindle's Landing, where the camp was pitched and the work of reconnaissance was resumed.

By June 27 the scheme had been developed as far as Bonneville, 4 miles below the Cascade Locks.

Three stations were occupied and observations were in progress at the close of the fiscal year.

The Sub-Office of the Survey in San Francisco was continued under the charge of Assistant Rodgers. Numerous duties, largely of a routine character, were assigned to him in connection with this duty. Government property, not needed for immediate use in the field, is stored under his care by the officers from time to time, and the supply is drawn upon by requisition to furnish or complete the outfit of parties going to the field. This property includes instruments as well as camp equipage. In addition to the charge of the Sub-Office, Assistant Rodgers supervised the tide observations at the Presidio Station and kept the tide indicator on Alcatraz Island in order.

Mr. John S. Blough reported to him on October 22 as writer, and served the remainder of the year. W. J. Diercks served as messenger throughout the year. Information of interest to the Survey, collected by Assistant Rodgers, was promptly transmitted to the Office.

In accordance with the request of the Secretary of State, the Secretary of the Treasury and the Secretary of the Interior assigned to the Superintendent of the Coast and Geodetic Survey and the Director of the Geological Survey the duty of making a reconnaissance along the forty-ninth parallel, and especially from the Rocky Mountains to the westward. These officers received more specific instructions from the Secretary of State, and with his approval detailed officers of their bureaus to carry out the reconnaissance. The following statement deals only with the work executed by Assistant Sinclair and the party under his direction, except as stated in the paragraph referring to the opening of the vista.

During February, March, and April Assistant Sinclair made an examination of the records and other material relating to the northwest boundary of the United States, on file in the State Department and deposited in the Congressional Library. He also prepared a list of stars for latitude observations covering twenty-four hours of time, and made all necessary preparations that could be made in Washington for taking up an examination of the northwest boundary for the purpose of recovering the monuments established by the International Commission and making the desired reconnaissance. The principal work assigned Assistant Sinclair was the reoccupation of such old astronomic stations as could be found and the determination of such new stations as might be found desirable to establish.

He left Washington accompanied by Assistant H. F. Flynn, as a member of his party, on May 7, and proceeded to Seattle, Wash., where the preparations for the season's work were completed and a party was organized.

The party left Seattle on May 16 and proceeded by way of New Whatcom and Sumas to Chilliwack, British Columbia. A pack train was secured and the party started on May 22 over 12 miles of road and 20 miles of trail to the boundary observation station of 1859 on Silicia Creek, near which a number of mining claims had been located. The trail was in very bad condition from constant rains and lack of repairs and was traversed with difficulty. Several of the animals rolled down steep slopes, but fortunately without serious damage to themselves or their packs. The astronomic station was recovered and observations made which identified it beyond question. From this station the distance stated in the old field notes was measured and the adjacent mark on the boundary was recovered. Rain and clouds seriously retarded the work and satisfactory observations were not obtained before June 15. The constant rains also retarded the work of clearing the vista along the line to such an extent that comparatively little was accomplished. It was desirable to extend the vista from this boundary mark in both directions to the adjacent marks, but the summits of the mountains in the vicinity were covered with deep snow and it was impracticable to do so at this season of the year.

There were no trails open to the points east and west in June, but a party of Canadian surveyors were reported working their way along the Chilliwack River toward Chilliwack Lake.

A line was cut through the heavy timber 4 000 feet west and 6 000 feet east of the starting point by the conjoint parties, and four wrought-iron posts were placed in position to indicate the random line forming the axis of the vista opened by cutting the timber. These posts are 4 feet long and 3½ inches in diameter with a flange 10 inches wide at the bottom. Each post has a bronze cap with two lines and the figures "1901" cut in the top, and the intersection of these lines marks the random line.

An iron post suitably marked was also established near to, and due west of, the old latitude station and a witness mark was made on a large bowlder a short distance to the southeast of the station. The old wooden block is in bad condition and these marks were established to assist in recovering the station at any future time.

On June 23 the pack train with the outfit started to Chilliwack and reached there the following day. On the 26th the party left Chilliwack by steamer and proceeded via the Columbia River and the Canadian Pacific Railway to Midway, British Columbia, arriving there on the 27th. Preparations were made to extend the work to the eastward of Midway and the work was in progress on June 30.

Assistant Sinclair calls special attention to the valuable service of Assistant Flynn and mentions in detail the work executed by him and states that his previous experience in the field and office made him particularly valuable on this expedition.

HYDROGRAPHIC. CALIFORNIA. WASHINGTON. F. WESTDAHL, Commanding. Steamer *McArthur*.

B. J. CROWLEY, *First Watch Officer*. JAMES SULLIVAN, *Chief Machinist*. R. H. HAWKES, *Hospital Steward*. L. H. WESTDAHL, *Yeoman, First Class*. F. G. CRIST, *Chief Yeoman*.	July 1 to July 30.
B. J. CROWLEY, *First Watch Officer*. CHAS. LYMAN, *Second Watch Officer*. JAMES SULLIVAN, *Chief Engineer, Third Class*. R. H. HAWKES, *Assistant Surgeon*. L. H. WESTDAHL, *Deck Officer, First Class*.	Nov. 1 to Dec. 15.

SUMMARY OF RESULTS.

Washington.

2 square miles of area covered by hydrography.
163 miles of lines sounded.
1 sheet completed.

On July 1 the *McArthur*, under command of Assistant Ferdinand Westdahl, was at Sausalito, Cal., engaged in completing the resurvey of the bar off the entrance to San Francisco Bay.

On July 14 the work was suspended for the season on account of the prevailing fog and other unfavorable weather conditions. Only a portion of five days had been suitable for the work during the month. A more detailed account of this work is published in the Report for 1900.

The vessel was taken to Oakland, where the boiler was cleaned and repaired, and other necessary repairs to the ship were made. The transfer of the new crew from the Navy pay roll to a civil establishment was effected. While engaged on this work, orders were received on August 21 to proceed with the ship to Seattle, Wash.

After returning from the cruise in Alaska with the Coast Pilot party, Assistant Westdahl received instructions to take up the hydrographic survey along the water front at Seattle, Wash. Active field operations began on November 12 and were completed on December 6.

The weather was stormy, cold, and very unfavorable to rapid progress. After obtaining the results mentioned in the above summary, the work was closed because the weather conditions indicated that thick weather and fog would prevail for a long period.

The *McArthur* left Seattle on December 9 and reached San Francisco on the 15th.

Various repairs were made, and the ship was ready for work on March 15. Active field operations in making supplementary surveys to complete seven hydrographic sheets of former work, covering portions of San Francisco and San Pablo bays, began on March 22 and continued until April 12, when the work assigned to the ship was completed, and the *McArthur* returned to Oakland Harbor in order to complete the field records for transmission to the Office.

DIVISION OF ALASKA.

MAGNETIC. ALASKA. L. A. BAUER.

W. WEINRICH, Jr., *Magnetic Observer.*	Sept. 5 to Oct. 27.
S. K. PAUL, *Recorder.*	Oct. 1 to June 30.

The selection of a suitable location for a magnetic observatory to serve as a base station in the magnetic survey of Alaska was assigned to Assistant Bauer. He left Seattle, Wash., on September 12 and made a magnetic examination at Fort Wrangel, Juneau, Skagway, and Sitka. He was at Sitka from September 20 to October 4, and made a thorough examination of all available sites in this vicinity, determining the magnetic elements at four stations. The observations indicated that the distribution of the earth's magnetism was fairly uniform in the region covered by the stations, and it was decided to locate the observatory at Sitka.

On the return trip to Seattle he made magnetic observations at Dundas Bay and Killisnoo and at various stations in Gastineau Channel. He left Juneau on October 9 and reached Seattle on the 12th.

In order to make such magnetic observations as circumstances permitted during a cruise of the steamer *McArthur* in Alaska with a Coast Pilot party on board, Magnetic Observer W. Weinrich, jr., reported for this duty at Seattle, Wash., on September 5, and continued the work until the end of the cruise on November 1.

He made magnetic observations at Bartletts Bay, Battery Point, Chasina Point, Dixon Harbor, Dolomite, Juneau Isle, Carta Bay, Killisnoo, Ketchikan, McLean Arm, Port Chester, Port Snettisham, Skawl Point, Sitka, Spasskaia Island, and William Henry Bay. He also aided in the determination of the amount and direction of the unusual local disturbance of the compass existing in Peril Strait, Lynn Canal, near Battery Point, in Gastineau Channel, and at Port Snettisham. Magnetic observations were also made at Comox, British Columbia.

Daily (except Sunday) declination readings at Sitka were made by Recorder Paul from 7 a. m. to 3 p. m. October 1 to June 30.

RECONNAISSANCE. ALASKA. E. F. DICKINS, Commanding, Steamer *Gedney*.

C. W. FITZGERALD, *First Watch Officer.* Mar. 2, to Jan. 15.
W. H. BURGER, *Aid.* May 15 to June 30.
J. W. MCGRATH, *Second-Watch Officer.*
F. G. CRIST, *Deck Officer, Second Class.*
W. W. MARKOE, *Assistant Surgeon.*

The steamer *Gedney*, Assistant E. F. Dickins commanding, remained in San Francisco Bay March 10 to May 24, having repairs made and attending to routine matters. On May 25 the vessel sailed for Seattle and reached there on the 29th. Bids were obtained for a new boiler and a contract for one was completed on June 12. On June 13 the vessel proceeded to Victoria, B. C., and during the night Mr. Fitzgerald, first watch officer, was attacked by pleurisy and it was necessary to return to Port Townsend and place him in the marine hospital at that place. This was accomplished, and on June 16 the vessel sailed for Alaska.

The vessel reached Cross Sound, the working ground, on the 27th, having stopped for coal at Union Bay, B. C., and at Juneau, Alaska, for coal, water, and lumber.

The work of the season began immediately and was in progress at the close of the fiscal year.

For the purpose of locating a magnetic observatory at Sitka, Alaska, and making arrangements for the erection of the necessary buildings Aid Fleming proceeded to that place in May. He reached Sitka on June 1, and remained there until the close of the fiscal year. A final selection of the observatory site, and bids for the construction of the observatory were obtained from Seattle, Juneau, Skagway, and Sitka. Estimates of the cost of labor and material were also obtained.

The selection of the observatory site involved the examination of five proposed building sites. Special magnetic observations were made to determine the local disturbance, if any, and also to determine the effect of iron ships anchoring in the harbor or lying at the wharf.

The necessary preliminary work was completed during the month.

BASE LINE.
GRAVITY.
HYDROGRAPHIC.
MAGNETIC.
RECONNAISSANCE.
TOPOGRAPHIC.
TRIANGULATION.

ALASKA.

J. J. GILBERT, Commanding,
Steamer *Pathfinder*.

July 1 to October 14.

H. F. FLYNN, *Assistant.*
A. H. DUTTON, *First Watch Officer.*
J. T. GOLDSBOROUGH, *Chief Engineer.*
E. R. FRISBY, *Aid.*
C. W. FITZGERALD, *Second Watch Officer.*
W. M ATKINSON, *Third Watch Officer.*
C. F. DEICHMAN, *Chief Yeoman.*
J. J. MURPHY, *Hospital Steward.*
R. C. MCGREGOR, *Recorder.*
J. T. WATKINS, *Draftsman.*

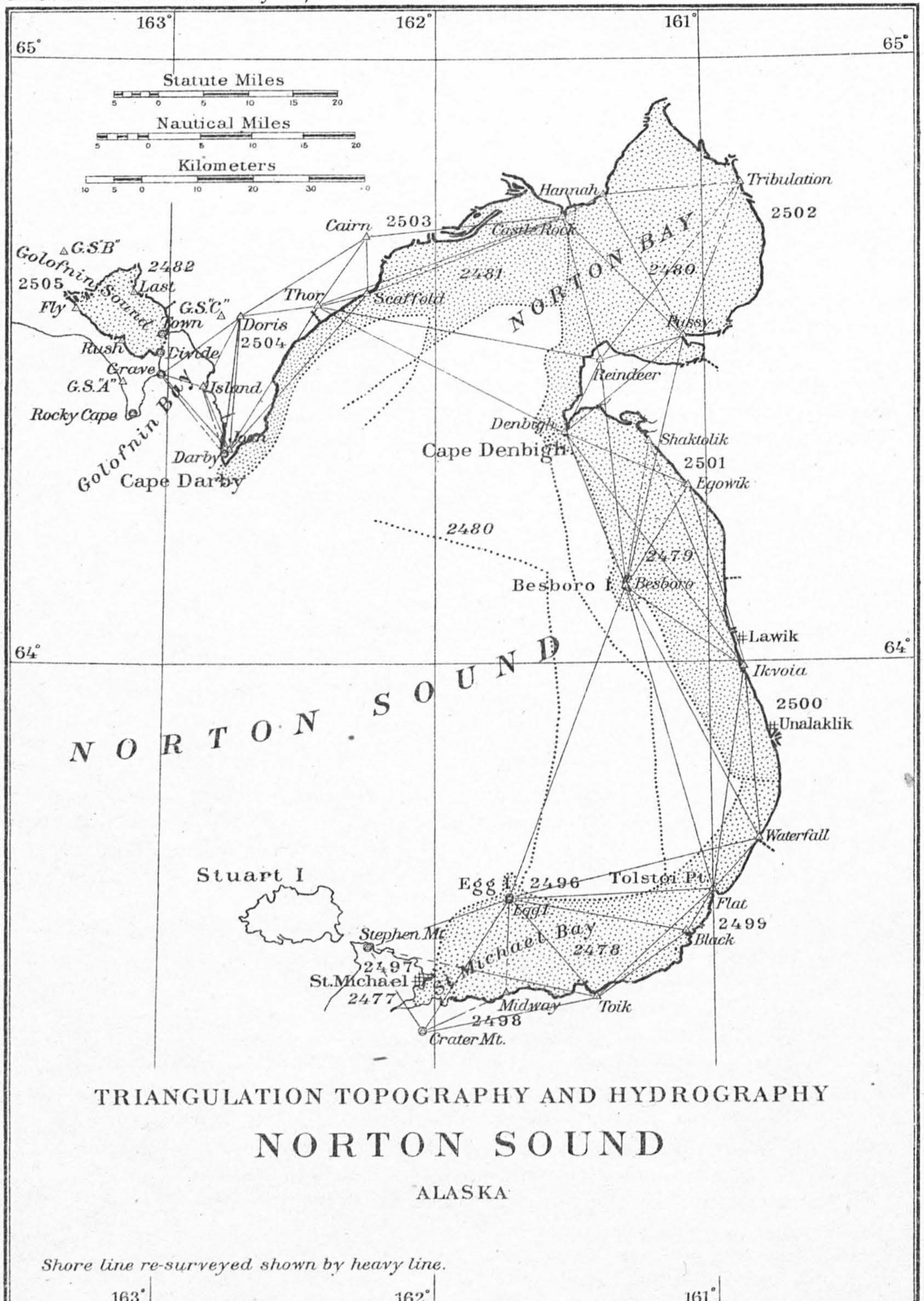
SUMMARY OF RESULTS.

Norton Sound and Bay.

24 triangulation stations occupied.
32 geographic positions determined.
2 600 square miles area covered by triangulation.
1 969 square miles of area sounded.
1 121 miles of lines sounded.
5 tide stations established.
6 hydrographic sheets completed.
144 square miles area surveyed.
440 miles of shore-line surveyed.
10 topographic sheets completed.
1 magnetic station occupied.
1 pendulum station occupied.

April 18 to June 30.

C. C. YATES, *Assistant.*
W. M. ATKINSON, *Second Watch Officer.*
L. M. FURMAN, *Third Watch Officer.*
J. T. GOLDSBOROUGH, *Chief Engineer.*
F. H. BRUNDAGE, *Aid.*
J. J. MURPHY, *Surgeon.*
CARL F. DEICHMAN, *Captain's Clerk.*
F. PFAU, *Draftsman.*
R. C. MCGREGOR, *Deck Officer, Third Class.*



TRIANGULATION TOPOGRAPHY AND HYDROGRAPHY

NORTON SOUND

ALASKA

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

SUMMARY OF RESULTS.

Fox Island Group.

25 triangulation stations established.
1 base line measured.
45 square miles area covered by triangulation.
15 triangulation stations occupied.
27 square miles area surveyed by topography.
42 miles general coast line surveyed.
979 soundings made (not plotted June 30).
4 tide stations established.

On July 1 the steamer *Pathfinder*, under command of J. J. Gilbert, Assistant, Coast and Geodetic Survey, was at St. Michael, Alaska, engaged in preparation for the season's work. The small steamer *Yukon* and two launches which had been hauled out of the water at this place in the preceding year were launched.

On the evening of July 4 a party was sent in a launch to place buoys in the approach to the Apoon entrance to the Yukon River, and on the 6th the work of constructing signals began.

Having recently arrived from Nome, against which a quarantine had been established, the vessel was required to remain at the quarantine station fourteen days or keep away from St. Michael during that period. The latter alternative was adopted, and the topographic work began near Toik station instead of in St. Michael Bay.

Signals were erected and observations began in all branches of the work, every effort being made to accomplish as much as possible during the short season available for the work.

Assistant Flynn returned on the 14th of July, after successfully placing buoys to mark the Apoon entrance to the Yukon River. His work was much delayed by the launch breaking down and the difficulty of covering the long distance traveled in safety. The *Yukon*, with the necessary complement of men, was assigned to Assistant Flynn, and he was put in charge of the triangulation work. He occupied 24 stations, most of which were difficult of access, and connected the triangulation at St. Michael with that of Golofnin Bay.

It was evident that in order to complete the survey of the shoreline between St. Michael and Golofnin Bay and of Golofnin Sound in one short season, the usual method of executing such work would have to be abandoned and a more expeditious one adopted. It was decided to proceed without waiting for geographic positions, to dispense with projections, and to run the shoreline as carefully as these conditions permitted, using sufficient expedition to accomplish the work as outlined above, and to adjust the topographic work to the triangulation when the positions became available. All the shore line was run by Assistant Gilbert and Aid Frisby, working from the ship to a point a short distance beyond Cape Denbigh, when the work proved to be too far away from the ship's anchorage and it became necessary to use a tent.

Watch Officer Fitzgerald was placed in charge of the hydrographic work.

Owing to the great distance to be covered, it was decided not to extend the hydrography beyond the 6-fathom curve, except on a few lines to verify the soundings shown on the charts beyond that depth.

At the close of the season, while waiting to haul out the *Yukon*, a more careful survey of the harbor at St. Michael was completed, and a special effort was made to locate a sunken scow, but without success.

The survey of Golofnin Sound proved that it is not more than one-third of the size shown on the published chart, in use at the time, and that more than half of it is too shallow to be used except by small craft.

After completing the work the vessel returned to St. Michael for the purpose of housing and storing all the boats and other property. Owing to unfavorable weather, this work was not completed until September 21. On the 22d the ship went to Egg Island and made a topographic survey of it on the 24th. On the 25th soundings were made between Egg Island and Cape Darby.

All the members of the U. S. Geological Survey party, who were to return on the *Pathfinder*, were on board by September 28, and the vessel started to Dutch Harbor during the night.

The vessel reached Dutch Harbor on October 2, was delayed three days coaling, sailed for San Francisco on October 5, and arrived at that place on October 14.

The *Pathfinder* remained in San Francisco Harbor until April 18, and on that day sailed for Seattle. The vessel stopped at Port Stanley and the Government property stored there was examined and disposed of, the useless articles being sold at public auction and the remaining property taken on board and carried to Seattle for storage or shipment to Washington.

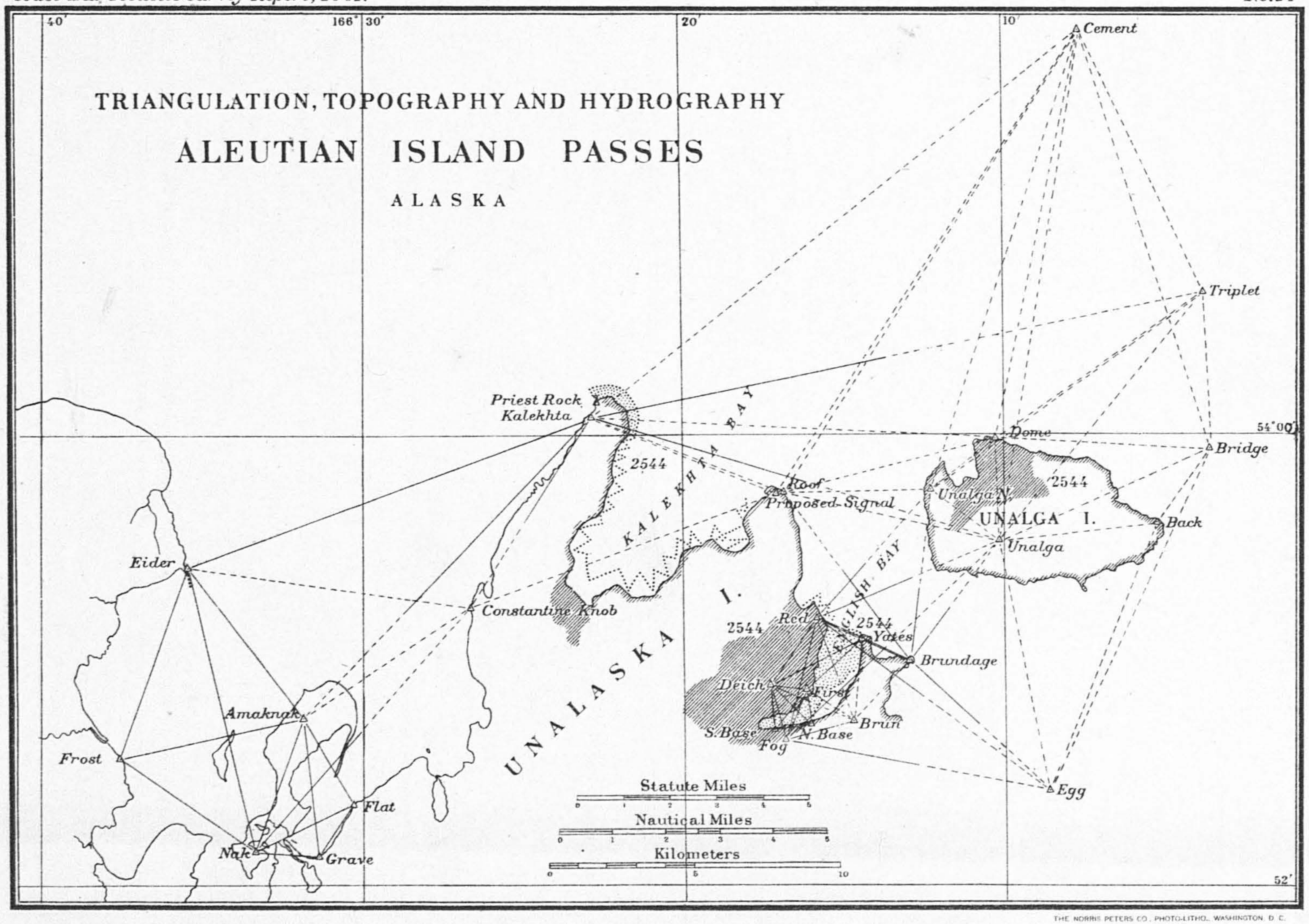
The vessel reached Seattle on the 25th and remained there until May 2, when she sailed for Alaska, stopping for coal at Comox, British Columbia, and at Victoria, British Columbia, where a "submarine sentry" was purchased. Attention was called to this useful device by Captain Welbron of the steamer *Quadra*, who referred to its value in exploring unknown waters and strongly recommended it as a safeguard in such work as the vessel would have to do during the season. Assistant Gilbert was enabled to purchase the device through the good will of the Canadian Pacific Navigation Company, the owners. The voyage north was a stormy one, but was attended by no greater disaster than the loss of one of the boat booms, which was washed away, and the vessel anchored in Dutch Harbor on May 16.

The work was at once begun by the erection of an automatic tide gauge. The great obstacle to work of any kind in this vicinity is the constant fog which covers all the hills the greater portion of the time, and never disappears entirely at this season.

The line Flat to Grove was used as a base for work in Unalaska Bay and a base line was measured in English Bay and the triangulation extended to the passes. An examination was then made as far east as Ugamuk Island, and a number of signals were built to be used in extending the triangulation through the channel between the Tagalda groups of islands and Akutan and Akur Islands. This channel was examined with the sentry and found to be free from dangers.

The observation of angles and topographic work was continued whenever the weather permitted. Tide gauges were erected around Unalaska Island and tide observations were made.

The shores of the island are extremely interesting, the many picturesque bays, the remarkable cliffs and bluffs of basalt, and the hundreds of outlying rocks, large and


TRIANGULATION, TOPOGRAPHY AND HYDROGRAPHY
ALEUTIAN ISLAND PASSES
ALASKA
40'
166° 30'
20'
10'
54°00'
52'
Cement
Triplet
Bridge
Dome
Back
Unalga
Unalga N.
UNALGA I.
2544
Priest Rock
Kalekhta
KALEKHTA BAY
Roof
Proposed Signal
ENGLISH BAY
Red
Yates
Brundage
Deich
First
Brun
S. Base
N. Base
Fog
Egg
Constantine Knob
UNALASKA I.
Eider
Amaknak
Frost
Flat
Nak
Grave
Statute Miles
Nautical Miles
Kilometers
THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

small, and of all shapes, the snow-capped mountains now and then showing through the clouds, and the continual succession of waterfalls, all contribute to impress the visitor.

The "submarine sentry" proved to be very valuable. The device is set to give warning when any required depth is reached, and when the vessel passes over a spot with that depth of water on it, the sentry bell rings and a "kite" is tripped and comes to the surface, thus giving warning in time to steer away from danger. The "sentry" is reliable for any depth up to 25 fathoms with one "kite" and 40 fathoms with the other, and it is also provided with a tube for sounding in same manner as with the Kelvin machine.

This region offers few facilities for camping along the shore on account of the difficulties of moving, as it is not possible to land except in sheltered places and most of the work was necessarily done from the vessel.

Assistant Gilbert reports that Assistant Yates, in addition to other duties, performed those of executive officer in a very satisfactory manner, and the other officers were equally attentive and efficient in their positions.

The work was in progress at the close of the fiscal year.

A new edition of the United States Coast Pilot, Pacific Coast, Alaska, having become necessary, Nautical Expert Graves was assigned to the work, and on July 1, 1900, was on board the U. S. Light-House Tender *Columbine* in Alaskan waters collecting the material needed for the revision of the former edition.

Mr. E. H. Francis, the well-known pilot for Alaskan waters, was associated with Mr. Graves in this work.

The *Columbine* left Sitka on July 6 for Unalaska on light-house inspection work and visited the Fox Island passes and Unalaska Bay. A pilot from Unalaska was on board while the vessel was cruising in the Fox Island passes. Advantage was taken of every available opportunity to acquire personal knowledge, and copious notes were made of information useful to mariners.

The *Columbine* returned to Sitka on July 24 and sailed on the 27th for buoy and inspection work in southeast Alaska. The route included all of the important channels of commerce. The weather was exceptionally good and the runs were nearly all made in daylight. The Coast Pilot information is practically complete for the principal channels where the surveys are good.

Commander W. P. Day, U. S. N., and Capt. William C. Langfitt, U. S. A., the Light-House Inspectors, and Captain Richardson and the officers of the *Columbine* kindly aided in the work to the extent permitted by their regular duties.

The *Columbine* reached Seattle on August 15, and Messrs Graves and Francis left the vessel and reported at the suboffice. They were occupied with office work in connection with their work in the field until September 2, when they reported on board the steamer *McArthur* in accordance with instructions dated August 22.

The *McArthur* sailed on the 6th for Coast Pilot duty in Alaska, being used as a transport for Messrs Graves and Francis.

On this trip the ship steamed 3 600 nautical miles and visited 87 harbors and anchorages in southeastern Alaska and British Columbia. The weather was generally good until October 6, but after that date it was quite the reverse until November 1, when the voyage ended at Seattle.

Coast Pilot notes were made on all the waters visited, and numerous photographs and sketches were made. As much information was collected as the conditions permitted without unduly delaying the voyage. Mr. Graves left the ship on November 7 and Mr. Francis on November 11.

ASTRONOMIC.
BASE LINE.
HYDROGRAPHIC.
MAGNETIC.
RECONNAISSANCE.
TIDE.
TOPOGRAPHIC.
TRIANGULATION.

ALASKA.

J. F. PRATT, Commanding,
Steamer *Patterson*.

July 1 to October 29.

R. L. FARIS, *Assistant.*
W. G. APPLETON, *First Watch Officer.*
H. S. POWELL, *Chief Engineer.*
R. B. DERICKSON, *Aid.*
H. W. RHODES, *Aid.*
W. I. EISLER, *Second Watch Officer.*
L. M. FURMAN, *Third Watch Officer.*
F. H. THOMPSON, *Surgeon.*
A. L. GIACOMINI, *Chief Yeoman.*
R. J. CHRISTMAN, *Draftsman.*
C. E. MORFORD, *Recorder.*

SUMMARY OF RESULTS.

1 azimuth station occupied.
1 latitude station occupied.
1 longitude (chronometric) determined.
1 995 square miles area covered by sounding.
2 095 miles of lines sounded.
58 current stations occupied.
10 hydrographic sheets finished.
3 magnetic stations occupied.
2 base lines measured.
6 stations for observing tides occupied.
850 square miles area covered by reconnaissance.
313 miles of general coast line surveyed.
561 square miles area surveyed.
190 miles of shore line of rivers and creeks surveyed.
2 miles of roads surveyed.
10 topographic sheets completed.
850 square miles area covered by triangulation.
56 triangulation stations occupied.
130 geographic positions determined.

May 16 to June 30.

R. B. DERICKSON, *Assistant.*
W. G. APPLETON, *First Watch Officer.*
W. I. EISLER, *Second Watch Officer.*
F. H. THOMPSON, *Surgeon.*
W. E. PARKER, *Aid.*
A. L. GIACOMINI, *Deck Officer, First Class.*
L. H. WESTDAHL, *Deck Officer, First Class.*
R. J. CHRISTMAN, *Draftsman.*

SUMMARY OF RESULTS.

Icy Strait.

590 square miles area covered by reconnaissance.
540 square miles area covered by triangulation.
13 triangulation stations occupied.
27 geographic positions determined.
2 magnetic stations occupied.
2 tide stations established.

On July 1 the steamer *Patterson*, commanded by J. F. Pratt, Assistant, Coast and Geodetic Survey, was making the voyage to Nome, Alaska, and reached that place on July 6.

Mr. E. C. Barnard, Topographer, U. S. Geological Survey, and his three assistants, had been authorized to take passage on the *Patterson*, in the wardroom, from Seattle to Nome, Alaska, and the eleven hands belonging to his party were carried in the forecastle.

A portion of the supplies and outfit for this party was landed at the United States Army post on Nome River. The party and the remainder of their outfit, and nearly all the remaining portion of their supplies, were landed at Chignick, Golofnin Bay.

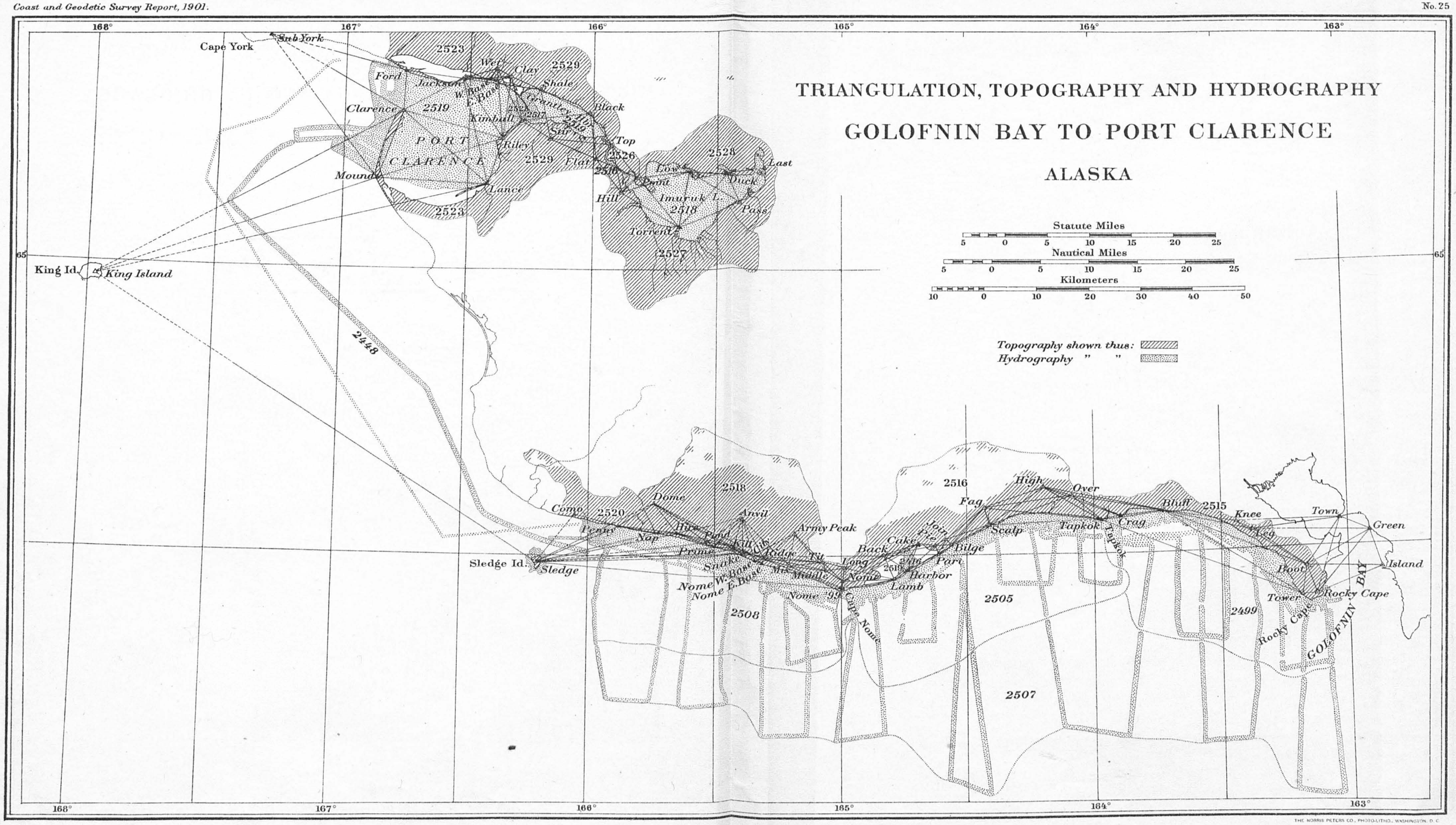
At Mr. Barnard's request a small portion of their supplies was kept on board to be delivered to the party later in the season at Port Clarence.

During the season forage for the party was taken from the army post at Nome and landed at Quartz Creek, in the vicinity of Cape Rodney. In addition to carrying out his instructions in regard to transporting this party and outfit, Assistant Pratt furnished them with a spare ship's cutter and during the season supplied them with all the information and data in his hands which they needed to facilitate the work of the survey Mr. Barnard was making.

The survey work of the season began on July 9, when the triangulation of Golofnin Bay was taken up. It was extended across the high peninsula on the west side of the bay and then westward along the coast. The hydrographic and topographic work progressed at the same time, and an effort was made to keep each branch of the work up with the others.

The season was an unusual one, and from the time the snow melted until late in August there was no rain.

The tundra became so dry that fires, starting from the camp fires kindled by the numerous prospectors in this region, spread and smoldered in all directions, and the country between Rocky Cape and Cape Nome was enveloped in smoke the greater portion of the time for a period of five weeks. This atmospheric condition greatly delayed the progress of all classes of the work, and kept the triangulation behind all the other classes.



THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

During the season the following triangulation work was done. A chain of figures beginning on the east side of Golofnin Bay was extended to the westward along the coast to Sledge Island, a distance of about 96 miles. This work is checked by a base line about 1 mile long, measured with a steel tape on the beach between Nome and Snake rivers. The observations were made under difficult and dangerous conditions, as it was necessary for the observing party to land every day through the surf on an outside unprotected coast.

Another scheme of triangulation starts from a base line, measured with a steel tape near the Teller reindeer station in the northeast corner of Port Clarence, and covers all of Port Clarence, Grantley Harbor, Imurook Passage, and Imurook Basin, forming a continuous chain 58 miles in length. The triangulation work was done by Aids Derickson and Rhodes.

The topography was taken up at the point where work was suspended at the close of the season in the previous year, just inside Rocky Cape, Golofnin Bay, and extended westward to Sledge Island, and a survey of this island was also made.

This work was also executed under extremely dangerous conditions, as it was necessary for the topographic party to land through the surf on the outside unprotected coast under many unfavorable weather conditions. A topographic survey of Port Clarence, Grantley Harbor, Imurook Passage, and Imurook Basin was made.

The topographic work was done by Assistant R. L. Faris.

The hydrographic work was extended along the coast covered by the triangulation and topography.

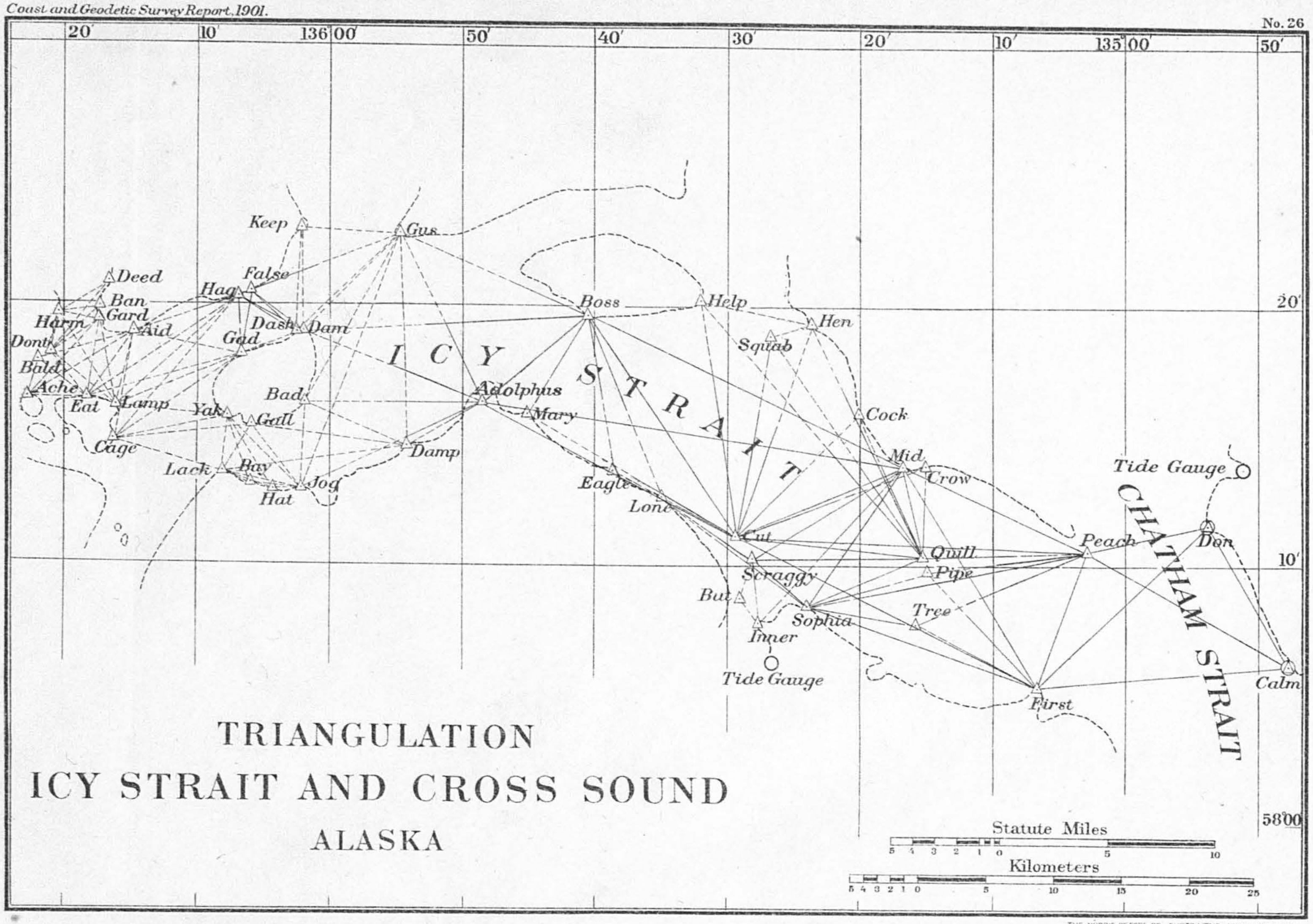
That portion between Golofnin Bay and Sledge Island is called the "Gold Coast," along which the landing of stores and provisions has been made at short intervals. A careful hydrographic survey was made of the coast between Rocky Cape and Sledge Island, from just outside the breakers out to a depth of from 5 to 7 fathoms of water, covering the ground with lines normal to the coast and about one-half mile apart. The steam launches were used on this work and lines normal to the coast were sounded by using the ship out to the limits of the hydrographic sheets at intervals of about 2½ miles. At intervals of 5 miles the lines of soundings extended to a distance of 25 to 30 miles offshore.

It was evident that a change had occurred in the entrance to Port Clarence, and consequently a careful survey was made and plotted on a large scale. Diligent search was made for the shoal reported to be about 8 miles west of Cape Nome, and 1⅔ miles offshore, but it was not discovered. All of the hydrographic work resulting from the use of the launches and boats was done by Messrs. Appleton, Eisler, Furman, and Giacomini.

A self-registering tide gauge was erected at Tapkok, behind the rocky projection at the southeast corner of the headland, at the United States Army post at Nome, at Sledge Island, and at Cape Riley, Port Clarence. The record obtained by using the gauges was supplemented by two tide staffs erected near the camps, from which all the survey work was done in Imurook Basin.

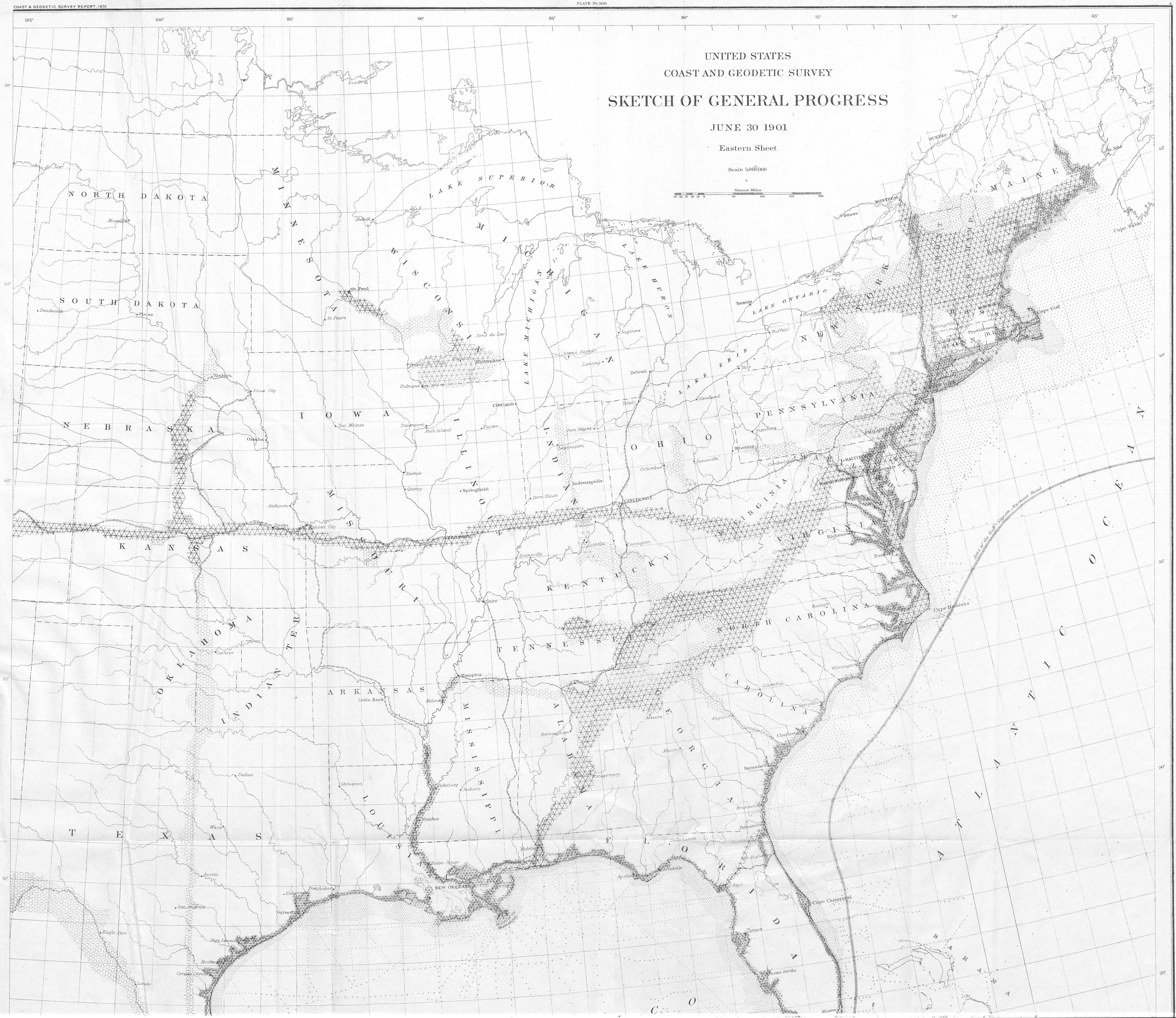
The work in Port Clarence and Grantley Harbor was done in the tempestuous weather of early winter.

Imurook Basin was about 25 miles from the nearest anchorage for the ship, too far to make the survey from the ship, and consequently rough camps were established.



TRIANGULATION
ICY STRAIT AND CROSS SOUND
ALASKA

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.


UNITED STATES
COAST AND GEODETIC SURVEY
SKETCH OF GENERAL PROGRESS
JUNE 30 1901
Eastern Sheet
Statute Miles
105°
100°
95°
90°
85°
80°
75°
70°
65°
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
INDIAN TER
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MISSISSIPPI
MICHIGAN
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
OHIO
GEORGIA
FLORIDA
PENNSYLVANIA
VIRGINIA
NORTH CAROLINA
NEW YORK
MAINE
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
ATLANTIC OCEAN
Bismarck
Pierre
Deadwood
Yankton
Sioux City
Omaha
Atchison
Topeka
Kansas City
St. Paul
Duluth
Des Moines
Davenport
Rock Island
Keokuk
Quincy
Springfield
CHICAGO
Milwaukee
Fond du Lac
Dubuque
Grand Rapids
Lansing
Saginaw
Detroit
Toledo
Fort Wayne
Logansport
Indianapolis
Terre Haute
CINCINNATI
Evansville
Lexington
Cairo
Memphis
Little Rock
Helena
Vicksburg
Jackson
Natchez
Shreveport
Baton Rouge
NEW ORLEANS
Mobile
Pensacola
Montgomery
Birmingham
Atlanta
Macon
Augusta
Columbia
Charleston
Savannah
Brunswick
Fernandina
Tallahassee
Apalachicola
Cedar Keys
Tampa
Punta Gorda
Cape Canaveral
Miami
Wilmington
Newbern
Raleigh
Cape Hatteras
Norfolk
Richmond
WASHINGTON
BALTIMORE
PHILADELPHIA
Pittsburg
Wheeling
Cumberland
Columbus
Zanesville
Cleveland
Erie
Buffalo
Rochester
Toronto
Ottawa
MONTREAL
QUEBEC
Ogdensburg
Poughkeepsie
Providence
Cape Cod
Cape Sable
St. John
Dallas
Waco
Austin
San Antonio
Houston
Galveston
Port Arthur
Eagle Pass
Port Lavaca
Rockport
Corpus Christi
Laredo
Guthrie
Axis of the Gulf Stream Warmest Band
BAHAMA

EXPLANATION OF SYMBOLS
Primary Triangulation
Secondary / Tertiary Triangulation
Reconnaissance
Surveyed Topography
do. In-shore Hydrography
do. Off-shore do.
Lines of Deep Sea Soundings
do. Geodetic Levelling
ATLANTIC OCEAN
GULF OF MEXICO
Axis of the Gulf Stream—Warmest Band
NEBRASKA
KANSAS
OKLAHOMA
INDIAN TER.
TEXAS
MEXICO
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
NORTH CAROLINA
VIRGINIA
OHIO
INDIANA
ILLINOIS
MISSOURI
CUBA
YUCATAN
BAHAMA ISLANDS
NEW ORLEANS
BALTIMORE
WASHINGTON
PHILADELPHIA
CINCINNATI
Cape Hatteras
Cape Canaveral
Cape Catoche
C. San Antonio
HAVANA
Key West
Tortugas
Miami
Tampico
Vera Cruz
Campeche
Progreso
Frontera
Belize
Monterey
Matamoras
Rio Grande
Galveston
Port Arthur
San Antonio
Austin
Waco
Dallas
Eagle Pass
Laredo
Little Rock
Memphis
Vicksburg
Jackson
Natchez
Baton Rouge
Mobile
Montgomery
Birmingham
Atlanta
Savannah
Charleston
Columbia
Wilmington
Raleigh
Richmond
Norfolk
Lexington
Louisville
Evansville
Cairo
Springfield
Indianapolis
Columbus
Wheeling
Pittsburg
Omaha
Topeka
Kansas City
Atchison
Keokuk
Quincy
Shreveport
Tallahassee
Jacksonville
Fernandina
Tampa
Punta Gorda
Nassau
Cienfuegos
Santiago de Cuba
100°
95°
90°
85°
80°
75°
40°
35°
30°
25°
20°

In referring to the officers under his command, Assistant Pratt's report contains the following:

The triangulation was executed by Messrs Derickson and Rhodes, aids, and it becomes my agreeable duty to call attention to the persistent and painstaking manner in which they did their work and the excellent manner in which they handled their boat crews.

Successful surf landing under almost all weather conditions brings to light the good judgment and capacity of the young officer to handle men, and I have the pleasure of stating that both of these young gentlemen demonstrated their possession of these qualifications far above the average.

Too much credit can not be given them for the hard and hazardous duty that they have so successfully performed.

I especially desire to call attention to the topographic work of Assistant Faris on account of its comprehensiveness and the great rapidity with which it was executed, and also to the unusual capacity he possesses for the execution of all the different classes of the field work of the Survey, and to the excellent judgment that he has displayed in handling work, officers, and crew. Assistant Faris was constituted official and responsible navigator of the ship, and performed this work with unusual promptness and precision.

It is with pleasure that I have to report that all the watch officers, chief engineer, yeoman, surgeon, and draftsman were always more than willing to take hold, irrespective of what or how disagreeable the duties might be, whenever their services could be made available.

The survey of Icy Strait and Cross Sound was assigned to Assistant J. F. Pratt, commanding the steamer *Patterson*. He completed all necessary preparations and sailed from Seattle, Wash., May 16, under instructions to proceed to southeast Alaska and take up the work.

Assistant E. F. Dickins, commanding the steamer *Gedney*, was also assigned to this work under Assistant Pratt's direction, but he was delayed in San Francisco and Seattle securing bids for a new boiler for his vessel and did not report at Bartlett Bay until June 25. The details of the work of the *Gedney* are stated elsewhere in the extract from the report of Assistant Dickins.

On May 18 coal was taken on board the *Patterson* at Union Bay, British Columbia, and the vessel then proceeded to Sitka, via Juneau, and reached that place on May 26. The steamer *Cosmos* was put in order and launched, and on May 30 the *Patterson* started to the field of work with the *Cosmos* in tow.

A hurried reconnaissance was made of Icy Strait as far west as Bartlett Bay before sending Pilot E. H. Francis back to Seattle to bring up the steamer *Gedney*. On June 1 the *Patterson* took Pilot Francis to Juneau, and returned to the field of work on June 3. Assistant Derickson was placed in command of the *Cosmos*, and made observations at triangulation points which it was impracticable to reach from the *Patterson*.

The triangulation points at the eastern entrance to Icy Strait could not be found, and the line Don to Calm, on the eastern side of Chatham Strait, was used as a base from which to extend the work. From this base the reconnaissance was carried as far west as Dundas Bay, and the triangulation was completed as far west as Glacier Bay.

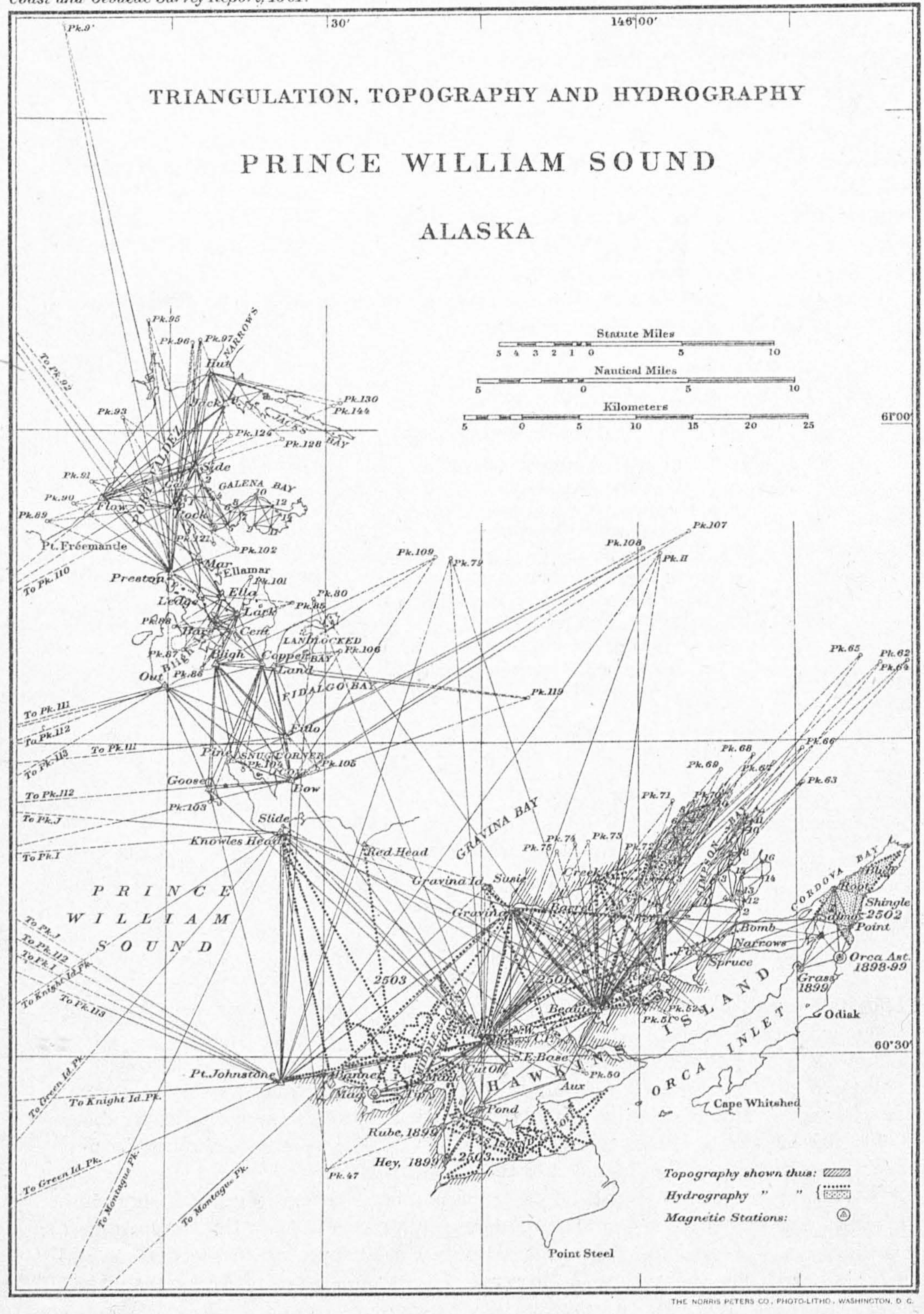
Whenever practicable, magnetic observations were made at the triangulation points with a compass declinometer.

Self-registering tide gauges were established at Funter Bay and Hooniah, for the purpose of transferring the plane of reference for soundings to Hooniah.

When the report closed only three anchorages—Swansons Harbor, Hooniah, and the head of Port Althorp—had been found free from icebergs. Three others had been utilized—Bartlett Bay, Mud Bay, and Dundas Bay—into which large icebergs floated.

The currents were very much stronger than anticipated, and in the anchorages ranged from slack water to 2½ knots. The ice varied in size from small float ice to bergs which grounded in 30 fathoms of water, and rendered the anchorages dangerous when the icebergs could approach the vessel with a 2-knot current. In Mud Bay the vessel was anchored in 9 fathoms of water, and pieces of ice grounded about one-quarter of a mile outside the vessel. The strong ebb and flood currents running 4 to 5 knots collect the ice and mass it across the passages, at times completely blocking them. The narrow passages are full of swirls and eddies, and it was dangerous to use them. In going through the passage to the north and west of Lemesurier Island one night in order to anchor in Bartlett Bay, a windrow of ice in one of these swirls was encountered, and a large piece struck the stem of the *Patterson* and carried off sideways the upper part of her cutwater.

The work was in progress at the close of the fiscal year.


TRIANGULATION, TOPOGRAPHY AND HYDROGRAPHY
PRINCE WILLIAM SOUND
ALASKA
Statute Miles
Nautical Miles
Kilometers
Topography shown thus:
Hydrography " "
Magnetic Stations:
PRINCE WILLIAM SOUND
GRAVINA BAY
FIDALGO BAY
GALENA BAY
HAWKINS ISLAND
ORCA INLET
CORDOVA BAY
Pt. Freemantle
Pt. Johnstone
Knowles Head
Red Head
Cape Whitshed
Point Steel
Odiak
Orca Ast. 1898-99
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ASTRONOMIC.
BASE LINE.
HYDROGRAPHIC.
MAGNETIC.
RECONNOISSANCE.
TOPOGRAPHIC.
TRIANGULATION.

ALASKA.

H. P. RITTER, Commanding, steamer *Taku*.

July 1 to October 25.

H. C. DENSON, *Aid.*
H. M. W. EDMONDS, *Foreman.*

SUMMARY OF RESULTS.

1 azimuth station occupied.
1 base line measured.
175 square miles area covered by soundings.
271 miles of lines sounded.
1 tide station established.
3 magnetic stations occupied.
1 500 square miles area covered by reconnaissance.
155 miles coast line surveyed.
150 square miles area covered by triangulation.
29 triangulation stations occupied.
55 geographic positions determined.

April 2 to June 30.

WILLIAM BOWIE, *Assistant.*
B. A. BAIRD, *Aid.*
CHAS. FICK, *Sailing Master.*
J. H. ROBINSON, *Engineer.*

SUMMARY OF RESULTS.

1 295 square miles area covered by triangulation.
90 triangulation stations occupied.
86 geographic positions determined.
35 elevations determined by vertical angles.
125 miles general shore line surveyed.

The survey of Prince William Sound was in active progress on July 1, with Assistant Ritter in charge of the work.

The work continued without interruption until the close of the season, October 10.

The party left Orca on the following day and reached San Francisco on October 25.

The following statement refers to the whole season, while the statistics given above cover only that part of the work completed after July 1, the statistics covering the first part of the season having been included in the Report for 1900.

The work of the season consisted of triangulation, hydrography, and shore-line topography, including the location of prominent mountain peaks and the determination of their elevation. A base line was measured with a steel tape line at the western end of Hawkins Island, for the purpose of checking the triangulation already completed and to serve as a base for the work in progress.

Astronomic observations to determine the azimuth of a line were made at Orca.

Magnetic observations to determine the declination were made at Orca and at stations 10 and 30 miles west of Orca.

Photographs for general and topographic use, and the usual tide and meteorologic observations were made. The triangulation was extended from the head of Cordova Bay to Point Johnstone, the north point of Hinchinbrook Island. It was connected with the triangulation of 1899 at Orca and at Station Pond, which is near the check base line. On a few days, when the clouds did not obscure the mountains, observations of horizontal and vertical angles were made on them. All the observations of angles were made by Aid Denson. The areas sounded during the season comprised Hawkins Island cut-off from the eastern end, where it joins the work of the previous season, to the northwestern extremity where it connects with Prince William Sound.

The so-called Middle Ground Shoal was developed. This shoal extends from Makaka Point on the east, in a westerly direction toward Point Johnstone, and in a northerly direction toward Gravina Bay. From Makaka Point sounding lines were run embracing the area to the eastward as far as the eastern end and head of Sheep Bay.

The hydrography of the upper end of Cordova Bay, joining and extending the work executed in 1897 by the U. S. Fish Commission steamer *Albatross*, was developed.

The topographic work consisted mainly in delineating, by using a plane table, the shore line, the rocks, and the adjacent topography. The localities thus mapped included the western end of Hawkins Island cut-off, the south shore of Prince William Sound from a point 5 miles west of Salmo Point to Point Johnstone, and the north shore of the sound in the vicinity of Sheep Bay.

Thirteen stations were occupied with a phototopographic camera, most of these being triangulation stations.

The survey of Prince William Sound was continued in April by Assistant Ritter and his party. He arrived at Orca on April 11, and field operations began immediately.

It was decided to extend the triangulation from the line Makaka to Point Johnstone, as a base, northward and then along the eastern shore of the sound, using stations on the main land and adjacent islands. The camp was set up at Snug Corner Cove, a sheltered harbor at the southwestern extremity of Port Fidalgo, 20 miles from Point Johnstone and 45 miles from Orca. From this camp the work was completed south to the base line and 15 miles to the northward.

On June 7 the camp was moved to the mouth of Jacks Bay, on the south shore of Valdez Arm, 18 miles from Valdez, and the triangulation was completed to Jacks Bay at the end of the fiscal year.

In selecting the stations care was exercised in placing them in such positions that future extensions of the work will be comparatively easy at the points where such extensions will be necessary.

Auxiliary positions were determined wherever they were necessary to control the shore line topography. In Galena and Jacks Bay, the angles in the subsidiary triangulation were measured by using a sextant.

The position of each prominent and characteristic mountain peak visible from two or more triangulation stations was determined and the elevation obtained by measuring vertical angles.

The work was in progress at the close of the fiscal year.

BASE LINE. COAST PILOT. RECONNAISSANCE. TRIANGULATION.	ALASKA.	F. WESTDAHL, Commanding. Steamer *McArthur*.

September 6 to November 1.

B. J. CROWLEY, *First Watch Officer.*	
CHARLES LYMAN, *Second Watch Officer.*	
JAMES SULLIVAN, *Chief Engineer, Third Class.*	
R. H. HAWKES, *Assistant Surgeon.*	Aug. 21 to Sept. 4.
W. W. MARKOE, *Assistant Surgeon.*	Sept. 4 to Nov. 12.
L. H. WESTDAHL, *Deck Officer, First Class.*	
F. G. CRIST, *Deck Officer, First Class.*	Aug. 21 to Sept. 4.

May 4 to June 30.

R. L. FARIS, *Assistant.*
B. J. CROWLEY, *First Watch Officer.*
CHARLES LYMAN, *Second Watch Officer.*
JAMES SULLIVAN, *Chief Engineer, Third Class.*
R. H. HAWKES, *Assistant Surgeon.*
O. M. LELAND, *Aid.*

SUMMARY OF RESULTS.

670 square miles area covered by reconnaissance.
19 triangulation points selected.
1 base line measured.
1 triangulation station occupied.

On August 21, Assistant Ferdinand Westdahl, commanding the steamer *McArthur*, received instruction to proceed with the vessel to Seattle, Wash., for the purpose of conveying H. C. Graves, nautical expert, and E. H. Francis, Alaska pilot, to Alaska and along the southeastern coast to enable Mr. Graves to collect the data required in a revision of the Coast Pilot covering this region.

All the necessary preparations were made and the vessel left San Francisco on August 28. The *McArthur* reached Seattle on September 1, and Messrs. Graves and Francis came on board on the following day.

Mr. William Weinrich, jr., magnetic observer, came on board on September 5. The vessel left Seattle on September 6 and went to Union Bay, near Comox, British Columbia, where a supply of coal was taken on board, and on September 8 sailed for southeastern Alaska. On this cruise the ship steamed 3,600 nautical miles and visited 87 harbors and anchorages in southeastern Alaska and British Columbia.

The weather was generally good until October 6, but after that date it was quite the reverse until the voyage ended at Seattle, Wash., on November 1.

The vessel on this cruise was used exclusively as a transport for the Coast Pilot party, and the work accomplished will be reported in detail by Mr. Graves, Nautical Expert. All possible assistance was extended to him and the ship was practically under his orders during the cruise.

Messrs Graves and Weinrich left the ship on November 7 and Mr. Francis on November 11, and the vessel afterwards proceeded to San Francisco and was engaged in supplemental survey work in the bay.

Preparations for work in Alaska were completed, and the steamer *McArthur*, F. Westdahl, Assistant, Coast and Geodetic Survey, commanding, left San Francisco on May 4 and reached Seattle on the 9th. The steamer *Patterson* was almost ready to sail for Alaska with a pilot on board and the *McArthur* waited to follow her. Both ships sailed on the 16th and reached Juneau, Alaska, on May 23, having taken on coal at Union Bay, British Columbia.

The *McArthur* filled her coal bunkers again and both ships proceeded to Funter Bay on the 25th and anchored for the night. On the following day the ships separated, and the *McArthur* passed through Icy Strait and Cross Sound to the Pacific Ocean. A good deal of floating ice was encountered and the land was covered with snow to the water's edge. The ship reached Kodiak on the 29th and replenished the supply of coal and water and engaged Paul W. Pavlof as pilot. The waters to be surveyed were not familiar to the officers of the ship and were said to contain many dangerous rocks. The ship proceeded to the working ground and reached there on June 6, after a very stormy passage, being forced to seek shelter several times and to remain in Kuprianof Harbor for two days.

Field operations began on June 7 and continued until the end of the fiscal year, but very little work was accomplished. A reconnaissance was made and nineteen triangulation stations were selected.

A base line was measured and lumber was landed through the surf for the erection of signals. Only one triangulation station was occupied. The weather continued stormy, and most of the time was spent in looking after the safety of the ship, as many of the anchorages were roadsteads without much protection.

On June 13 it was necessary to proceed to Dutch Harbor for coal. While at that port an unsuccessful effort was made to observe for a time at the astronomic station. A comparison of the ship's chronometers was made with those on the steamer *Pathfinder* and also with those on the U. S. Army transport *Warren*.

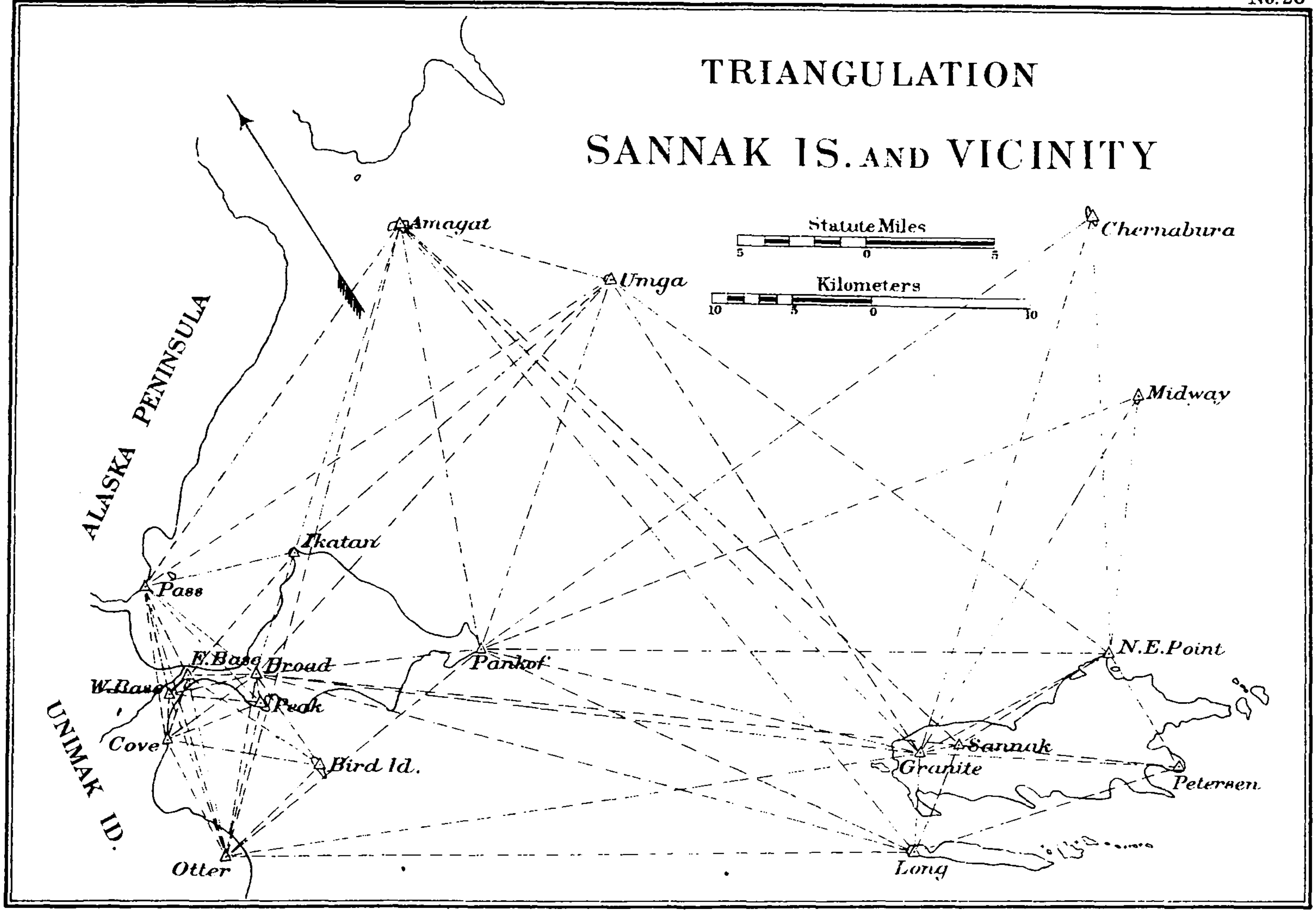
The *McArthur* left Dutch Harbor on June 19 and anchored in Acherk Harbor on the following day.

The erection of signals continued whenever the weather conditions permitted. The field of work was a difficult one with no safe harbors near, and no anchorages were available where the ship was not liable to exposure to danger at any time from a sudden change in the direction of the wind.

Safety in the open sea could not be considered on account of the dangerous rocks in the area off the coast and the prevailing thick weather. The local knowledge of the pilot was very useful, but could not be wholly relied on as to the safety of the anchorages. His presence aided materially in advancing the work.

Views of the land for the Coast Pilot were made whenever the conditions permitted and all other useful information collected as opportunity offered. The work was actively in progress at the close of the fiscal year.

Assistant Westdahl commends Watch Officer Crowley, Second Watch Officer Lyman, and Chief Engineer Sullivan for their attention to duty and interest in their work, and mentions particularly the care with which Watch Officer Crowley prepared the accounts of the ship's expenses.


TRIANGULATION
SANNAK IS. AND VICINITY
Statute Miles
5 0 5
Kilometers
10 5 0 10
ALASKA PENINSULA
UNIMAK ID.
Amagat
Umga
Chernabura
Midway
Ikatan
Pass
E. Base
Broad
W. Base
Peak
Cove
Bird Id.
Otter
Pankof
N.E. Point
Sannak
Granite
Petersen
Long

OUTLYING TERRITORY.

REGISTER OF GEOGRAPHIC NAMES.	HAWAIIAN ISLANDS.	W. D. ALEXANDER.
REGISTER OF GEOGRAPHIC POSITIONS.		
TIDE.		

On January 31, 1901, Prof. W. D. Alexander took the oath of office as Assistant in the Coast and Geodetic Survey. For many years previous to this date he held the office of surveyor-general of the Hawaiian Islands, before and after the annexation of the islands by the United States.

After his appointment in the Coast and Geodetic Survey he continued to supervise the preparation of a large scale map for the Territorial government and had directions of the tide observations made in the islands.

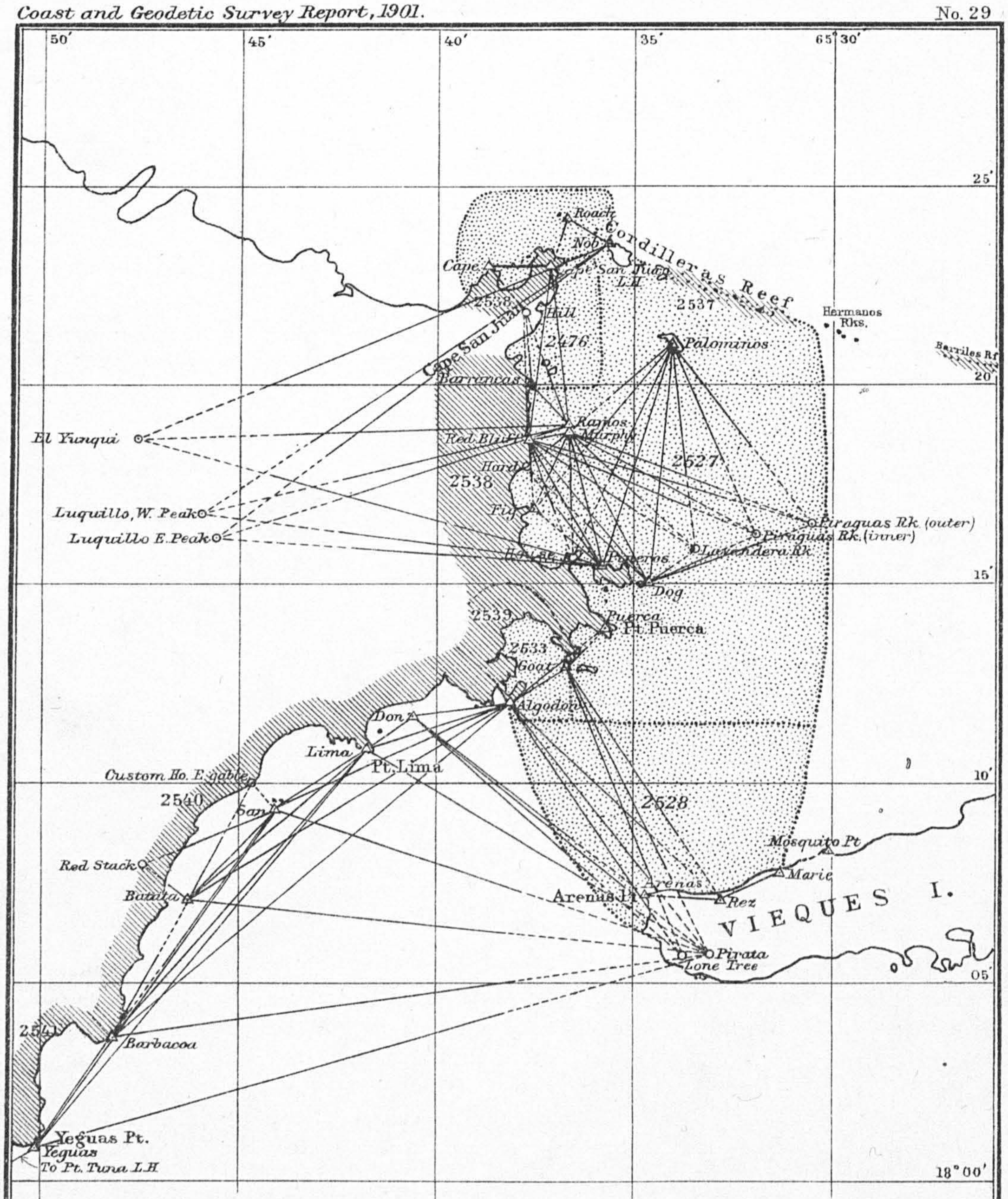
He prepared a list of the geographic positions already determined on the islands, except the islands of Kauai and Niihau, reducing the latitudes and longitudes to one uniform mean standard and converting the distance from feet to meters.

He also began the preparation of a dictionary of Hawaiian geographic names and performed various duties in connection with the transfer of records and instruments from the surveyor-general's office to the Coast and Geodetic Survey.

He was engaged in performing the above duties at the close of the fiscal year.

The selection of a location for the magnetic observatory in the Hawaiian Islands to serve as a base station in the magnetic survey was assigned to Assistant Bauer, and he left San Francisco on October 17 under instructions to make the necessary examination. He examined various sites on Oahu and Hawaii Islands and selected a point on the extensive coral plain in the southwestern part of Oahu Island, near Sisal, as the best available site. He also made magnetic observations at Kahuku, Waialua, Honouliuli Ranch (two stations), Ewa Mill, Sisal (two stations), Honolulu, Diamond Head, Puuloa Railroad Station, and Puuloa Point (Pearl Harbor) on the island of Oahu, and at Kilauea on the island of Hawaii.

He returned to San Francisco on November 29.



TRIANGULATION, TOPOGRAPHY AND HYDROGRAPHY

EAST END OF PORTO RICO

June 30, 1901

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

HYDROGRAPHIC.
RECONNAISSANCE.
TIDE.
TOPOGRAPHIC.
TRIANGULATION.

PORTO RICO.

J. B. BOUTELLE, Commanding,
Schooner *Eagre.*

V. R. LYLE, *First Watch Officer.*
F. F. WELD, *Aid.*
WM. B. PROCTOR, *Second Watch Officer.*
J. H. ULLRICH, *Assistant Surgeon.*
R. McD. MOSER, *Deck Officer, First Class.*
D. B. WAINRIGHT, *Deck Officer, First Class.*
V. SOURNIN, *Draftsman.*

SUMMARY OF RESULTS.

73 square miles area of reconnaissance.
73 square miles area of triangulation.
22 triangulation stations occupied.
26 geographic positions determined.
18 square miles area covered by topography.
87 miles general coast line surveyed.
2 miles river shore line surveyed.
22 miles roads surveyed.
5 topographic sheets completed.
55 square miles area covered by hydrography.
1 697 miles of sounding lines completed.
3 tide stations established.
3 hydrographic sheets completed.

The schooner *Eagre*, Assistant J. B. Boutelle, commanding, sailed from Baltimore on December 3 and reached San Juan, Porto Rico, on December 20. The vessel remained at San Juan until January 8, taking on coal, lumber, and stores, making repairs to the steam launch *Inspector*, and other necessary preparations for the season's work.

The vessel left San Juan on January 8 and proceeded to Fajardo, on the east coast of Porto Rico. Signals were erected along the Cordilleras Reef and southward along the coast to Ensenada Honda, and the triangulation, topography, and hydrography in this vicinity was commenced. The topography was extended from the work of the previous year to the eastern extremity of the Cordilleras Reef and southward to the vicinity of Cabras Island. The hydrographic work was extended from Cape San Juan Head to the Piraguas Rocks and about 6 miles to the eastward, off shore. On March 7 the vessel was moved to Ensenada Honda and the work was then extended from the above limits southward. The triangulation and topography were completed as far as Punta Yeguas, the southeast point of Porto Rico, and the hydrographic work to a line running a little west of south from the outer Piraguas Rock to Vieques Island, and from the west side of Punta Arenas to Punta Cascajo, at the south side of Ensenada Honda.

The weather was much more favorable than during the previous season, light southerly winds prevailing much of the time instead of the regular easterly trades; but the hydrographic work was very much delayed by frequent repairs which were necessarily made to keep the boiler of the steam launch in running order. The rainy season began in the latter part of April, and after that date rain showers were of frequent occurrence. Field work closed on May 31 and the vessel proceeded to San Juan. The vessel sailed from San Juan for Baltimore on June 11, reaching there on the 20th, and remained there until the close of the fiscal year.

HYDROGRAPHIC. PORTO RICO. GEO. L. FLOWER, Commanding,
TIDE. Schooner *Matchless*.

F. H. AINSWORTH, *First Watch Officer*.
A. F. ADAE, *Second Watch Officer*.
S. EARLE, *Deck Officer, Second Class*.
H. S. MCCRAE, *Deck Officer, Third Class*.
E. V. MILLER, *Junior Captain's Clerk*.

SUMMARY OF RESULTS.

154 square miles area covered by sounding.
1 203 miles of lines sounded.
5 tide stations established.

The *Matchless* was undergoing repairs at New York October 8 to November 26, when the repairs were completed. Preparations for survey work in Porto Rico were completed, and the vessel sailed on December 3 for Ponce, Porto Rico, under the command of George L. Flower, Assistant, Coast and Geodetic Survey. The *Matchless* reached that port on the 21st and field operations began immediately.

A tide gauge was erected at Ponce and in Guanica Harbor, and the hydrographic survey of the harbor began on December 25. The soundings were made by using a whaleboat, as no launch was available, and the party was too small to man two sounding boats.

Much time was lost while at work on the southern coast in making trips to Ponce for water and stores, as it was the only port at which they could be obtained. The work progressed as rapidly as circumstances permitted, and the boat work was completed on January 16. The vessel sailed the same day for Ponce for water and stores, and then proceeded to Guayanilla Harbor and began the survey of the harbor on January 22, and the boat work was completed on February 14. This harbor possesses a fine, deep entrance, well protected, and affords a safe refuge for vessels.

On February 16 work began at Tallaboa Bay, still using the whale boat for the sounding party. The bay is only partially protected by a few small islands, and the progress of the work was much retarded by rough water. The sounding work at this place was completed on March 5, and on the following day work with the schooner began off the southern coast.

The water was continually rough and the soundings were made without waiting for smooth water.

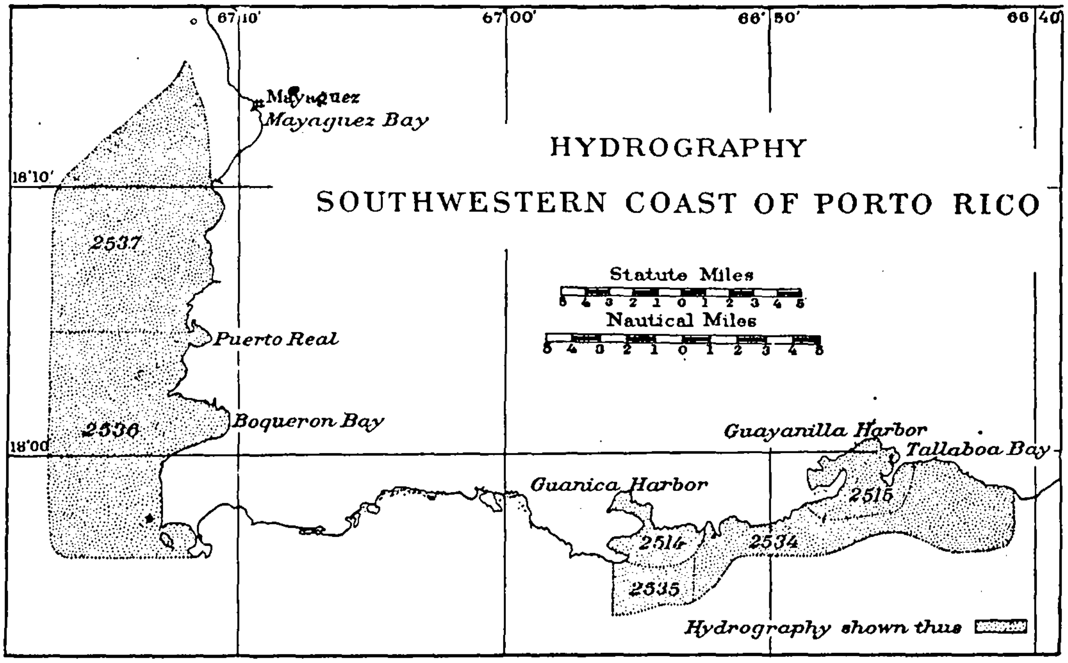
On March 26 the launch *Rudy* arrived at Ponce, and afterwards aided materially in advancing the work.

The development of the south coast from Ratones Island to Point Brea out to the 28-fathom curve was completed on April 12. On the 13th the vessel sailed for the west coast, under instructions to develop the shoals and channels between Cabo Rojo and

Mayaguez. A general reconnaissance of this portion of the coast was made, and an automatic tide gauge was established at Puerto Real, but it was impracticable to place it in charge of anyone on shore, as no one could be found with sufficient intelligence in the vicinity.

The sounding work began on April 23 and continued until June 4. During this time lines of soundings, normal to the shore line, averaging 400 meters apart, and extending to a point approximately 5 miles off shore, were run between Cabo Rojo and Mayaguez, and the shoals developed.

No. 30.



In addition to this work a survey was made of Puerto Real. The northeast winds of the northern coast meeting the southeast winds of the southern coast made the wind of the west coast so variable that it was impracticable to work with the schooner. Several attempts were made to locate the outlying shoals indicated on the chart.

Some of these were found, but the rainy season was so far advanced and the coast so much hidden by rain squalls and haze that the attempts to locate them proved unsuccessful.

Water and stores were procured at Mayaguez while working on the west coast.

On June 6 the launch was stored at Mayaguez, and on June 8 the vessel sailed for Baltimore and reached her destination on June 17.

MAGNETIC. PORTO RICO. STEHMAN FORNEY.
TOPOGRAPHIC.
TRIANGULATION.
W. C. DIBRELL, *Aid.*

SUMMARY OF RESULTS.

12 square miles area covered by triangulation.
4 triangulation stations occupied.
3 geographic positions determined.
29 stations occupied for triangulation, with plane table.
34 positions determined, with plane table.
60 square miles area covered by triangulation, with plane table.
63 square miles area surveyed.
69 miles of coast line surveyed.
12 miles of shore line of rivers surveyed.
15 miles of shore line of ponds surveyed.
59 miles of roads surveyed.
2 topographic sheets completed.
5 magnetic stations occupied.

The topographic survey of Vieques Island, Porto Rico, was assigned to Assistant Forney, and he was also directed to occupy a station in the main triangulation, located on the island.

Stores and supplies were obtained in New York and the party sailed for San Juan, Porto Rico, on January 5, and reached that port on January 10.

It was necessary to remain in San Juan until the 17th, in order to take passage on the next steamer for Vieques Island. During this period of delay, Aid Dibrell occupied one of the triangulation stations in this vicinity and made observations to determine the magnetic elements. On the 17th the party proceeded to Vieques Island and pitched camp on the ramparts of the old Spanish fort south of the town of Isabel Segunda.

A reconnaissance of the island was made and the triangulation points established and determined by Assistant Hodgkins were recovered.

Triangulation stations were occupied to complete the connection with the triangulation previously executed and to connect two light-houses, Puerto Mulos and Puerto Ferro. A plane-table triangulation was then executed, based upon the points already determined, for the purpose of determining the additional positions necessary for the topographic work.

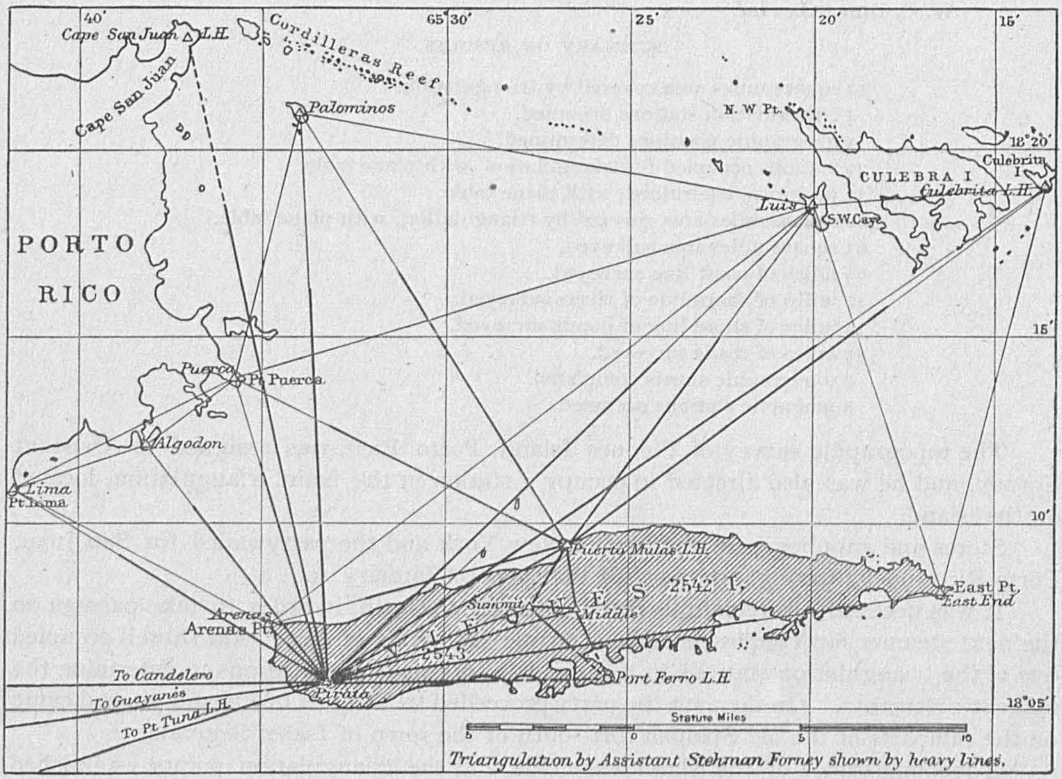
On the topographic sheets the heights were expressed in meters and refer to mean high water. The contour interval was fixed at 10 meters. The interior ridges and valleys were shown by form contours depending upon a topographic reconnaissance with the plane table. The Spanish names used on the plane-table sheet were obtained from Clandomino Flores, a native of Vieques Island, who acted as pilot for Admiral Sampson, U. S. N., while he was cruising in these waters during the war with Spain.

Some confusion of names exists in this region and the island is called "Crab Island" on many published charts, while the inhabitants and the old inhabitants of the island of Porto Rico use the name "Isla de Vieques."

Large numbers of land crabs are found on the island and the name Crab Island probably originated from this condition. Tide observations extending over a lunar month were made at Puerto Ferro on the south coast.

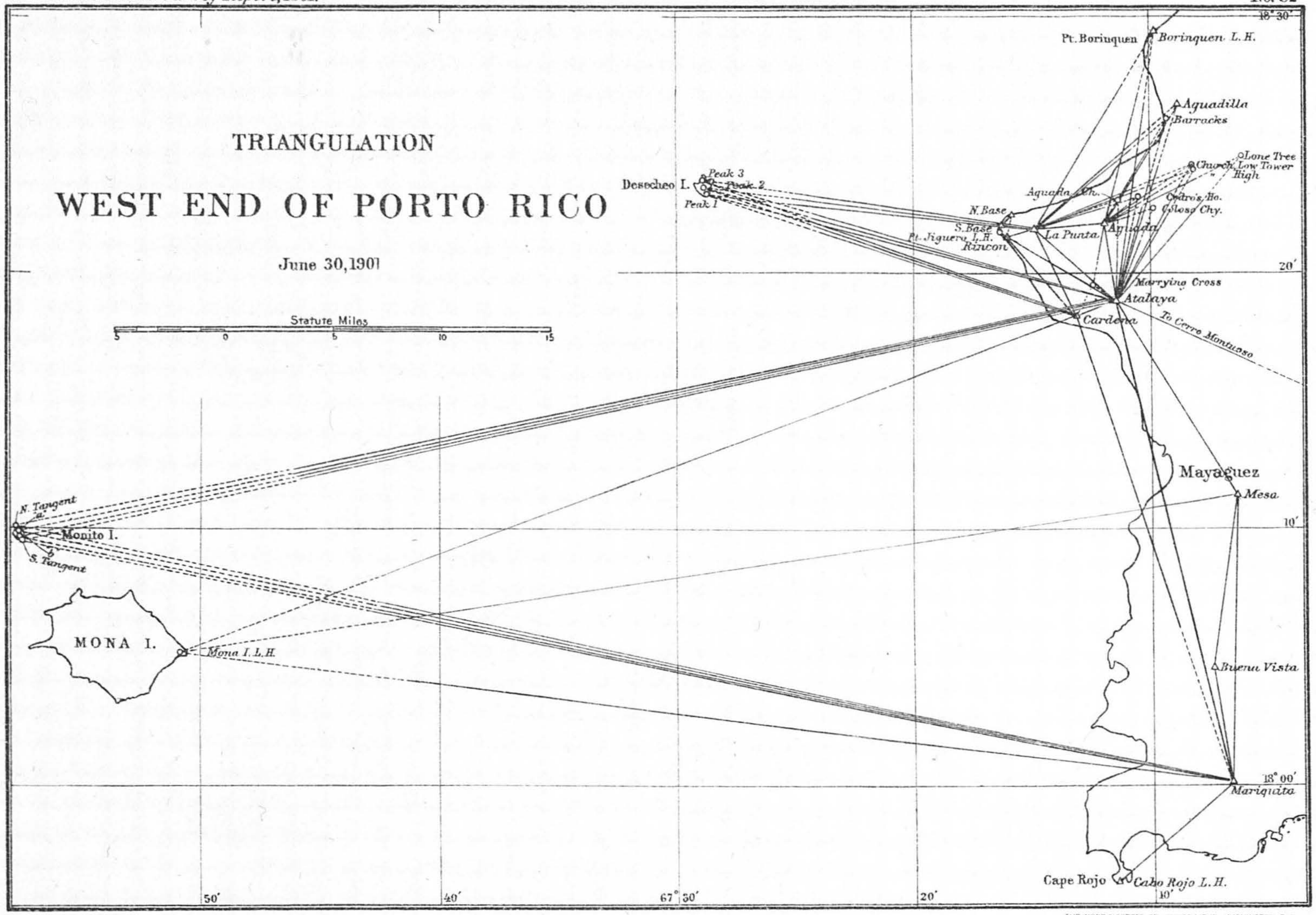
Magnetic observations were made at a station near Isabel Segunda, at Great Harbor, Culebra Island, at Ponce, and at Aibonita.

No. 31.



Assistant Forney expresses his appreciation of the service rendered during the season by Aid Dibrell, who joined the party well informed on the theory of the plane table and soon became proficient in its use in the field. Most of the topographic work on the island was executed by him.

The work for the season closed on June 13. The camp outfit was packed, transported to San Juan, and shipped by steamer to Washington. The party started to Washington and reached New York on June 30.



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BASE LINE.
MAGNETIC.
RECONNAISSANCE.
TRIANGULATION.

PORTO RICO.

JOHN E. MCGRATH.

THOMAS NELSON PAGE, Jr., *Acting Aid.*

SUMMARY OF RESULTS.

997 square miles area covered by reconnaissance.
31 triangulation stations selected.
997 square miles area covered by triangulation.
20 triangulation stations occupied.
45 geographic positions determined.
1 base line measured.

The determination of the geographic position of Mona Light-House, Monita Island, and Desecheo Island, and the extension of the west coast triangulation to Point Borinquen and the connection of the triangulation east of Ponce along the south coast with the work which had been extended south and west from St. Thomas and Culebra islands to Point Lima, Porto Rico, and Mount Pirata, Vieques Island, were assigned to Assistant McGrath.

He spent two days in New York completing his outfit, then sailed for Porto Rico on January 5 and reached San Juan on January 10. Three days were spent in San Juan, and during this time arrangements were made to obtain supplies from the Quartermaster and Commissary Departments of the Army, and information was obtained from the Light-House Department.

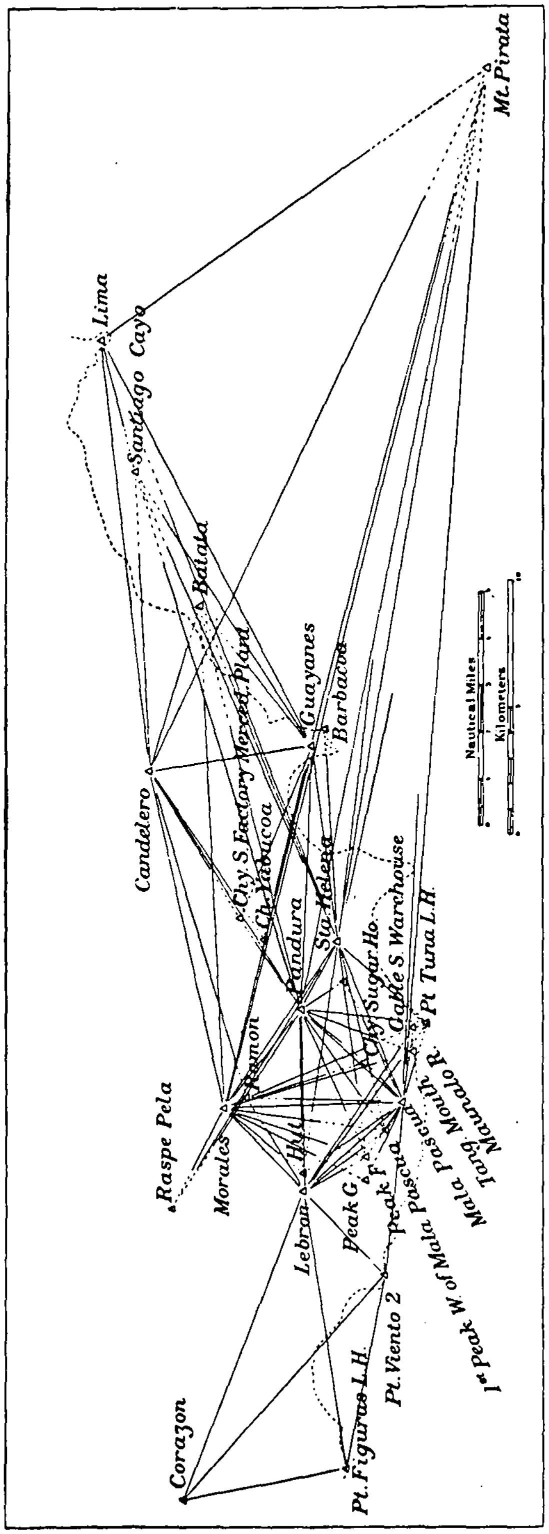
Assistant McGrath makes special report of his cordial reception by Col. John L. Clem, chief quartermaster, U. S. A., at San Juan, and states that the Survey is greatly indebted to him for the liberal arrangements made by him which greatly facilitated the work. The Light-House Engineer and the Inspector were both absent on duty, but the request for information was honored as fully as possible at their office. The party reached Mayaguez on January 14, and the deputy collector of customs in charge of the port, Mr. F. Cuebas, kindly passed the outfit through the custom-house without delay.

Active field operations began at once and the position of Mona Light-House and the offshore islands was determined by occupying the triangulation points at Mariquita, Mesa, and Atalaya, which positions had been determined during the previous year.

The observations at the stations named above were completed on February 3, after many delays and considerable hardship from lack of proper accommodations.

In connection with the determination of the offshore islands, several mountain peaks were located and tangents were observed to coast lines of Mona, Monita, and Desecheo islands. An effort was made to occupy Desecheo Island, and with this in view a fisherman at Aguadilla who had more experience and local knowledge of the

No. 33.



Southeast coast of Porto Rico.

island than anyone else on the coast was engaged to transport the party to the island whenever the proper weather conditions prevailed to make a landing possible. The triangulation was then extended from the point reached during the previous year to Point Borinquen, and all notable points between Point Rincon and Point Borinquen that were visible from the triangulation stations and which seemed to be of importance for geographic or topographic purposes were located. Observations for magnetic declination were made with a declinometer at three of the triangulation stations.

While the work was in progress Assistant McGrath was ready at all times to respond to a summons from the fisherman at Aguadilla when the conditions for visiting Desecheo Island were favorable, and did respond to one call, but found upon arrival that an interval of two hours had so changed the conditions as to make the trip hopeless. After completing the triangulation to Point Borinquen, and having no immediate prospect of securing the proper weather conditions, the plan of occupying Desecheo Island was abandoned. Several of the signals at triangulation points on the west coast were found undisturbed. The respect with which the signals and station marks on this coast are treated by the native population is very satisfactory, and is in keeping with the consideration and courtesy shown the party in all their relations with these people.

When the work on the west coast was completed the party proceeded to Guayamas, and reached there on March 8.

A reconnaissance of the coast was made, and the line Corazon to Point Figuras Light-House was selected as the base from which to extend the work. The necessary observations to extend the triangulation to Point Lima and complete the work assigned to the party were finished on May 3.

It was not necessary to use lamps as signals except at stations Guayanes, Candelero, and Lima, where they were necessary in observing from Mount Pirata, which station was occupied by Assistant Forney in connection with his topographic survey of Vieques Island.

The work was delayed by the lack of accommodation, the very inferior facilities for transportation, the poor roads, and the necessity of using trails where there were no roads.

Assistant McGrath makes special mention of his aid, Thomas Nelson Page, jr., who proved to be a faithful, earnest, diligent, and ambitious worker, and showed a most gratifying interest in his duties. After completing the work the party proceeded to San Juan, and sailed for New York on May 14.

Assistant McGrath reached Washington on May 22 and reported in person at the Office.

MAGNETIC.
RECONNAISSANCE.
TOPOGRAPHIC.
TRIANGULATION.

PORTO RICO.

JOHN NELSON.

O. W. FERGUSON, *Assistant.*
B. E. TILTON, *Aid.*

SUMMARY OF RESULTS.

450 square miles area covered by reconnaissance.
43 triangulation points selected.
300 square miles area covered by triangulation.
43 triangulation stations occupied.
77 geographic positions determined.
55 square miles area surveyed.
101 miles of coast line surveyed.
68 miles of shore line of rivers, creeks, and ponds surveyed.
73 miles of roads surveyed.
7 topographic sheets completed.
5 magnetic stations occupied.

The triangulation, topographic, and magnetic work on the northwest coast of Porto Rico was assigned to Assistant Nelson. He spent three days in New York purchasing supplies and outfit and then proceeded, on January 5, to San Juan, P. R., and reached that port on January 10.

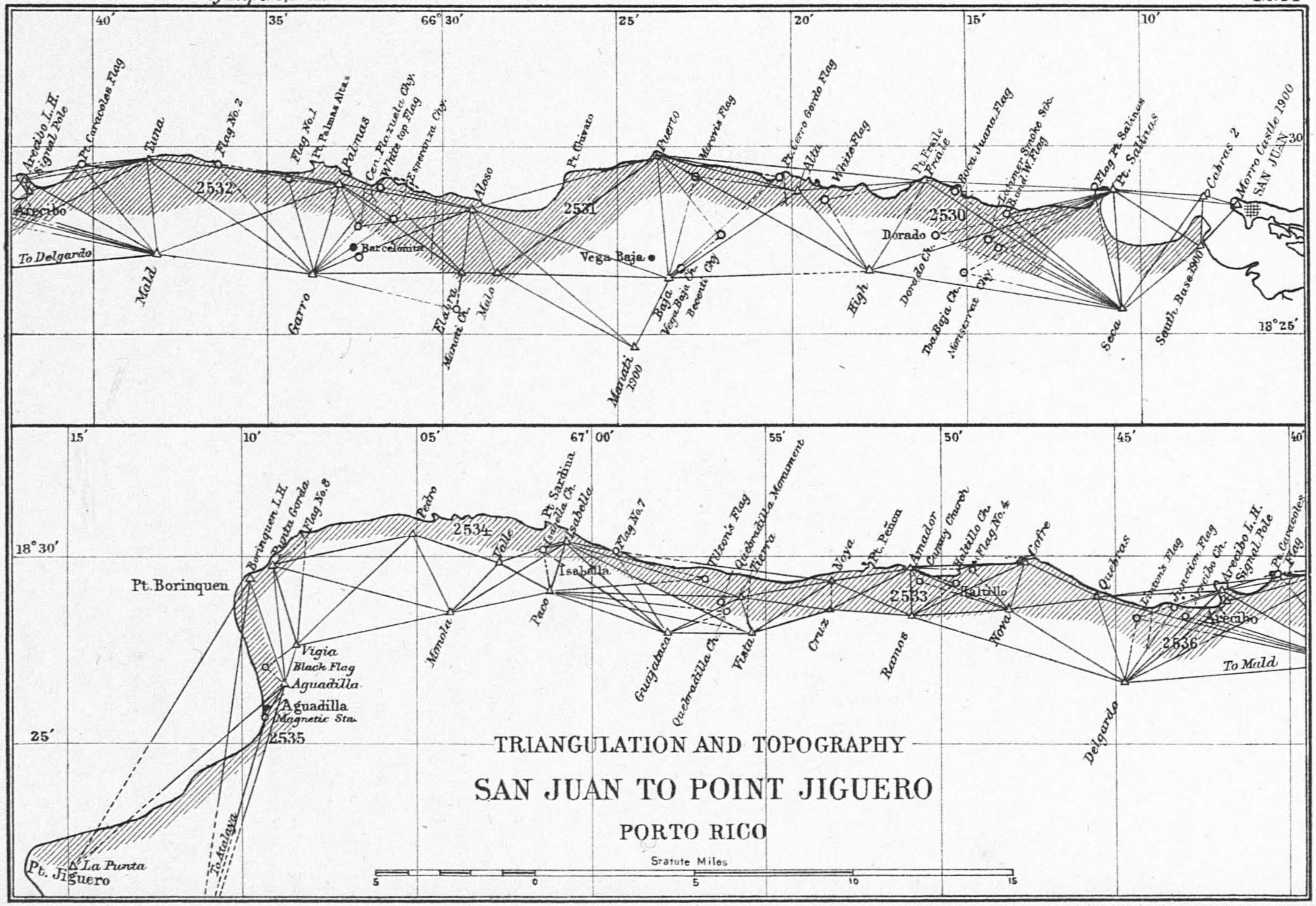
A party was immediately organized and field work began without delay.

The triangulation points from which it was necessary to extend the work to the westward were not conveniently located, and much time was spent in making a reconnaissance and clearing the lines.

Observations in all three branches of the work began on January 22, and steady progress was made until the close of the season. The party moved from San Juan to Toa Baja, about 20 miles to the westward, on January 28. The lack of roads and bridges and the primitive methods of transportation greatly retarded the work throughout the season. Fortunately the railroad extends from San Juan 60 miles along the coast to the westward, and this made it possible to complete the work to a junction with that of the previous season, at Point Jiguero.

The roads are simply bull-cart tracks and trails all the way from San Juan to Aguadilla and even to Anasco.

A few pieces of road were begun between Arecibo and Utuada and between Manati and Ciales, but never completed, and landslides have since occurred which have rendered these roads practically useless. The party moved to Vega Baja on February 28, to the Manati River on March 14, to Arecibo light-house on April 4, and to Amador plantation, near Camuy, on April 27. The railroad ends at Camuy, and the road to the westward hardly deserves the name at any time, and becomes almost impassable in the rainy season. It was over this road that the last move was made to Aguadilla, a distance of 26 miles, when, with the assistance of ten bull carts and a relay of bulls and drivers at the Fortuna plantation, about the middle point, the trip was made in twenty-six hours.



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The reconnaissance and triangulation preceded the topography, and numerous obstacles had to be overcome, and at all interior points it was necessary to cut lines in all directions.

The difficulties in the way of triangulation increased as the work progressed to the west, and Borinquen Light-House and Aguadilla were so unfavorably located that it was almost impossible to make a connection with them from the east.

The plane-table work began near the eastern entrance to San Juan Harbor, and was extended to Point Jiguero, on the west coast, where it joined the work executed during the previous season. This was accomplished with comparative ease, as the coast line consists largely of sand beach, with intervening cliffs and bluffs of soft limestone not over 50 or 60 feet high. There are numerous outlying rocks of small size in places, and along the beach sand dunes ranging from 10 to 30 feet in height were found, which were difficult to represent on the topographic sheet. Aguadilla Bay is an open arm of the sea, and vessels can approach to about one-quarter of a mile of shore.

The Arecibo anchorage is only suitable for small craft. The swell and surf are heavy at all seasons of the year. In fact, the surf is so strong on the entire northern coast that it is dangerous for small boats to land except behind Point Salinas and at one other point near Camuy. The bar across the mouth of the Rio Grande de Arecibo prevents anything but lighters and rowboats from going in or out.

The Rio Plata is the first river west of San Juan, and is the largest and longest on the island. It is very turbulent and treacherous during the rainy season. There are two small towns, Toa Baja and Dorado, near its mouth. There are no bridges over this river except the railroad bridge, and it is not possible to cross over this with animals. The Manati is the next river of importance, and is considered the most dangerous on the island. The partially completed railroad bridge was the only one over the river, and it was necessary to use the ferry in crossing.

While in camp near this river in March, a hurricane visited this portion of the island and lasted about ten hours. The camp was in danger of being washed away, as the water rose 15 feet in six hours, but fortunately only one tent was lost, though the party was cut off from field work for two days.

The mouth of the Rio Grande at Arecibo is about half a mile wide at high water, but at low water is bare except the channel, which changes with every rain as the water pours down out of the mountain gorges.

Sugar plantations extend along the valleys of all these rivers, and also for some distance along the coast, at intervals, from Bayamon to Camuy River. The country from Camuy west consists of irregular ridges heavily covered with brush, and in many places with cocoanut trees, royal palms, mangoes, coffee, and banana trees.

Magnetic observations were made at the following places: Fraile, Baja, Amador, Point Caracoles, and Aguadilla.

Assistant Nelson makes special mention of the kindness and aid extended to him by Col. John L. Clem, chief quartermaster, U. S. A., at San Juan, in furnishing forage and transportation and in facilitating the work to the extent of his ability.

The rainy season began about April 15, and after that date there was rain every afternoon. In spite of every obstacle, such as those mentioned above and others equally as troublesome and difficult to overcome, the work was pushed steadily forward to completion and a junction was effected in June.

On June 19 Assistant Nelson sailed with the officers of his party from San Juan for New York, and reported in person on the 25th at the Office in Washington.

COLLECTING INFORMATION RELATING TO SURVEYS.	PHILIPPINE ISLANDS.	FRANK WALLEY PERKINS.

As stated in the Report for 1900, Assistant Perkins was at Manila, P. I., on July 1, engaged in the investigation of the existing conditions relating to surveys and in collecting information as to the future needs of the Philippine Islands.

Several interesting communications were submitted by him containing important information upon which to base the plans for the future survey of the islands, as demanded by the necessities of the situation.

An abstract from his reports is given in the Report for 1900, under the heading "Special duty."

On July 15 he sailed for the United States on the U. S. transport *Sherman*, via Nagasaki, Japan, and arrived in San Francisco, Cal., on August 6. He was detained on duty in San Francisco until August 16, when he started to Washington and reported for duty at the Office on August 28.

BASE LINE.
HYDROGRAPHIC.
MAGNETIC.
TOPOGRAPHIC.
TRIANGULATION.

F. W. EDMONDS, *Assistant.*
H. C. DENSON, *Assistant.*
H. W. RHODES, *Aid.*
H. C. MITCHELL, *Aid.*
C. E. MORFORD, *Recorder.*
J. S. HILL, *Recorder.*
H. O. PIXLEY, *Recorder.*
ALEXANDER COLT, *Recorder.*
HENRY BERNHARDT, *Recorder.*
H. S. HODGSON, *Recorder.*
WILLIAMS WELCH, *Chief Draftsman.*
POTENCIANA ALONZO, *Draftsman.*
JOSE ASUNCION, *Draftsman.*
JOSE SALANGA, *Copyist.*
ETHAN E. ALLEN, *Acting Chief Engineer.*
PABLO CARPIO, *Messenger.*

SUMMARY OF RESULTS.

Astronomic work.

13 longitudes determined (by telegraph).
1 longitude determined (by chronometer).
15 latitudes determined.
14 azimuths measured.
14 meridian lines established.

Base lines.

2 measured.

Hydrographic work.

253 miles sounding lines.
7 sheets completed

Magnetic work.

13 stations occupied with compass declinometer.

Topographic work.

76 square miles area covered.
119 miles general coast line surveyed.
35 miles roads surveyed.
8 sheets completed.

Triangulation.

78 stations occupied.
123 geographic positions determined.

The inauguration of the survey of the Philippine Islands and the establishment of a suboffice in Manila, P. I., was assigned to Assistant Putnam.

After making all necessary preparations in Washington and San Francisco, he sailed from San Francisco for Manila, P. I., on November 16, and reached his destination on December 15. Two assistants, Edmonds and Denson, one aid, Rhodes, and five recorders, Morford, Hill, Pixley, Colt, and Bernhardt, accompanied him as members of his party. H. C. Mitchell, aid, and Williams Welch, draftsman, sailed at a later date and reached Manila on December 31.

The additional members of the party mentioned above were employed at various dates between January 14 and March 22, as their services became necessary and suitable men could be found. General instructions were given Assistant Putnam to make all necessary arrangements for the inauguration of a survey of the coasts of the Philippine Islands. A suboffice was established at Manila as headquarters from which the work of surveying the coast could be managed and a place where all data could be collated for the preparation and publication of preliminary results, when such publication would be of immediate benefit to commerce and navigation.

Assistant Putnam presented his credentials promptly to the Commanding General and as soon as practicable called on the President and members of the Philippine Commission, on the Admiral of the Fleet, and on the officers of the Military Government. The requests that it was necessary to make were granted, receiving such consideration as could be expected in view of the disturbed condition of the country.

The Survey is especially indebted for assistance in its work to the United States Philippine Commission, the Adjutant-General, Chief Quartermaster, Chief Signal Officer, Chief Engineer Officer, Chief Commissary, Depot Quartermaster, Captain of the Port, and other officers of the Division of the Philippines, as well as to the officers of the Eastern Extension Australasia and China Telegraph Company and to the managing director of the Campañia Maritima.

Messrs. Edmonds, Denson, Rhodes, Mitchell, Morford, and Hill were assigned to the charge of parties in the field away from Manila during the year by Assistant Putnam, and he remained at Manila in charge of the suboffice and executed such field work in the vicinity as was found to be desirable and practicable. The field work was considerably retarded by lack of transportation facilities about the islands, by the condition of the telegraph lines, by the lack of suitable boats for hydrographic work, and, toward the close of the year, by unfavorable weather. No difficulty was experienced on account of the insurgents, though Batangas was fired upon while a party was at work in the town. At two places a party lived in towns not garrisoned. The work was delayed only to a slight extent by sickness, as the general health of the party was good. The plan of work followed comprised the determination of geographic positions and the making of detached harbor surveys. This plan was demanded by the existing conditions and the small force and the limited equipment available for the work.

Great difficulty was experienced in obtaining suitable boats for hydrographic work and at one important place no boat could be obtained for this work. The native boats are long and slender, with wide bamboo outriggers, and can not be used for hydrographic work.

All the field parties received great assistance from the commanding officers of military posts and other military and civil officers.

The following is a condensed statement of the work accomplished by the various parties before the end of the fiscal year.

The statement of the work executed is presented in this form as a matter of convenience.

The officers on duty under Assistant Putnam's direction were placed in charge of parties by him and were entirely dependent on their own ability and resources in carrying out the instructions for the work assigned to them as chiefs of parties.

LONGITUDES DETERMINED.

By telegraphic method.

Place.	Island.	In field.	At Manila.
Sual	Luzon	Edmonds	Putnam.
Vigan	do	Rhodes	Do.
Subig	do	do	Do.
Iba	do	do	Pixley.
Santa Cruz	do	do	Do.
Batangas	do	do	Do.
Balayan	do	do	Do.
Iloilo	Panay	do	Putnam.
Carrimao	Luzon	Mitchell	Do.
San Fernando	do	do	Pixley.
Candon	do	do	Do.
Cape Bojeador	do	do	Do.
Cebu (not completed)	Cebu	Hill	Putnam.

By chronometric method.

Aparri (approximate determination). Mitchell.

LATITUDES BY ZENITH TELESCOPE OBSERVATIONS.

Observations for latitude were made at all longitude stations except Cebu by the observers in the field and at Manila (Putnam, observer), making fifteen stations in all.

AZIMUTH OBSERVATIONS.

Azimuths were derived from the time observations at all the longitude stations except Cape Bojeador, and meridian lines were permanently marked on the ground except in a few cases where this was impracticable, and in such cases the azimuth of some other marked line was derived as above stated. To control local triangulation, azimuths were determined by theodolite observations on Polaris at Manila (Putnam) and at Bolinao (Denson), and by theodolite observations on the sun at Santo Tomas (Denson) and at Darigayos (Denson).

MAGNETIC OBSERVATIONS.

Observations with a compass declinometer were made at all the longitude stations except Cape Bojeador.

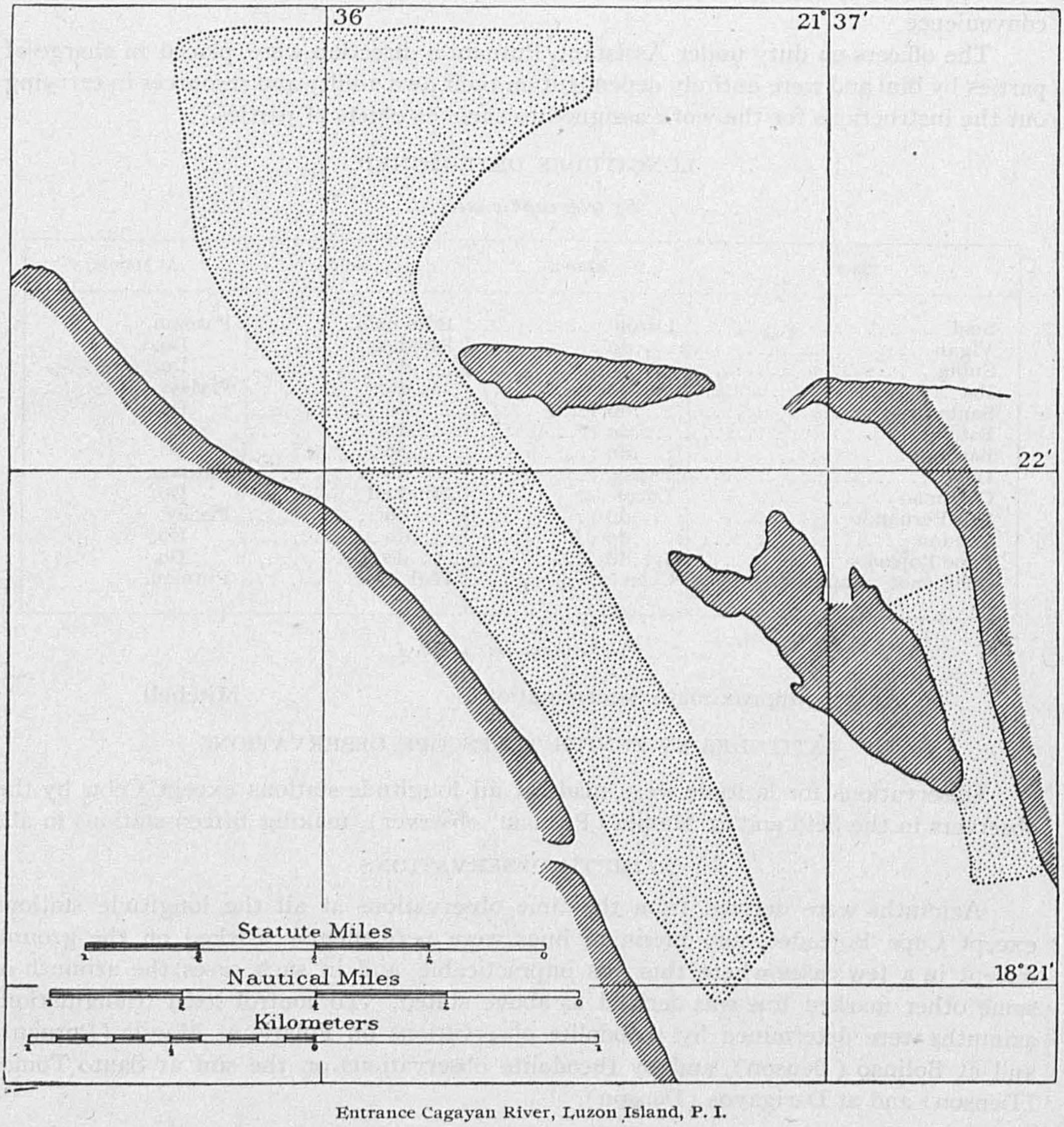
HARBOR SURVEYS.

Local harbor surveys, or reconnaissances, were made as follows (name of officer in charge in parentheses):

Port Sual, Luzon (Denson).

Triangulation, hydrography and topography. (Hydrography of approaches not completed.)

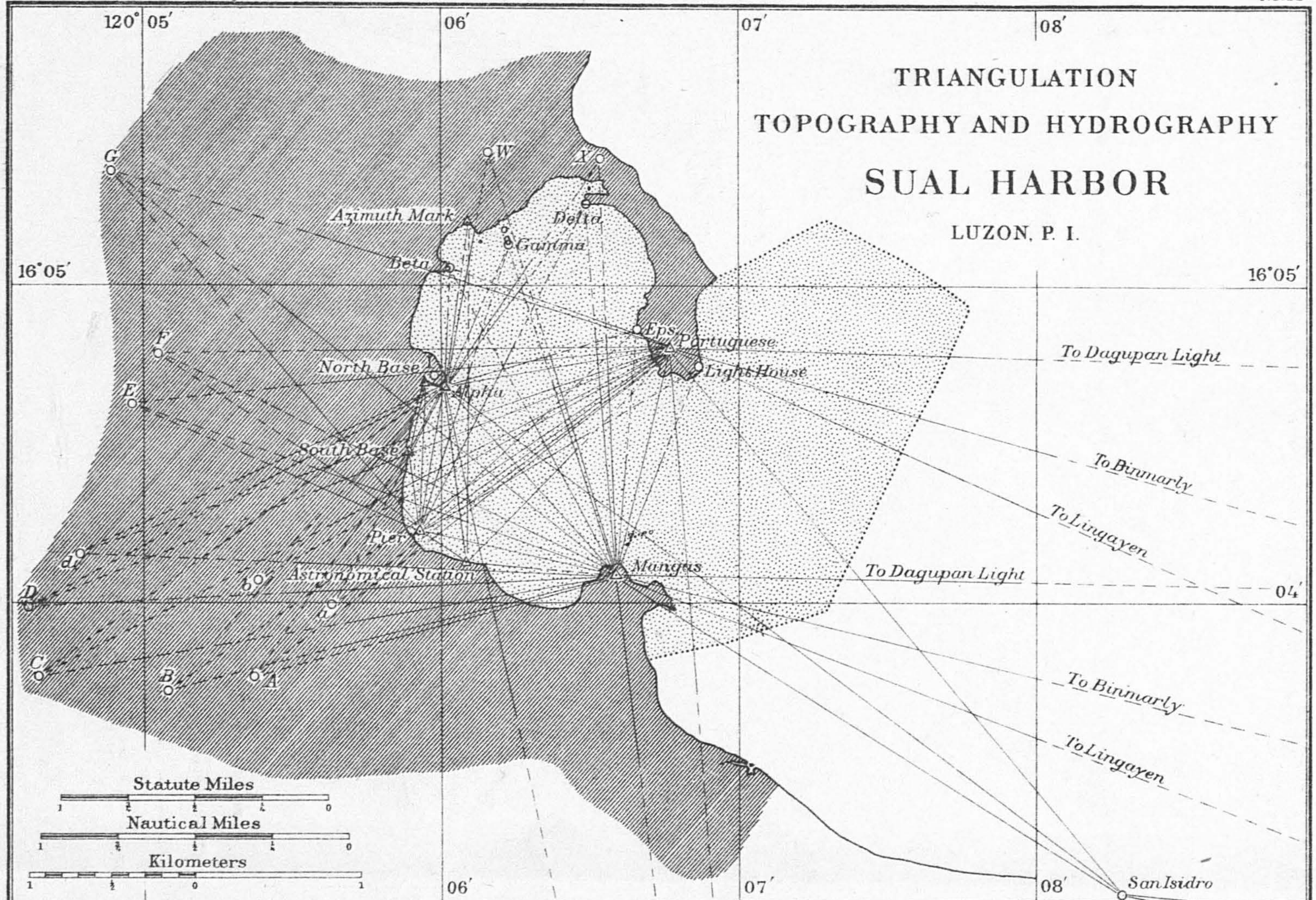
No. 36.



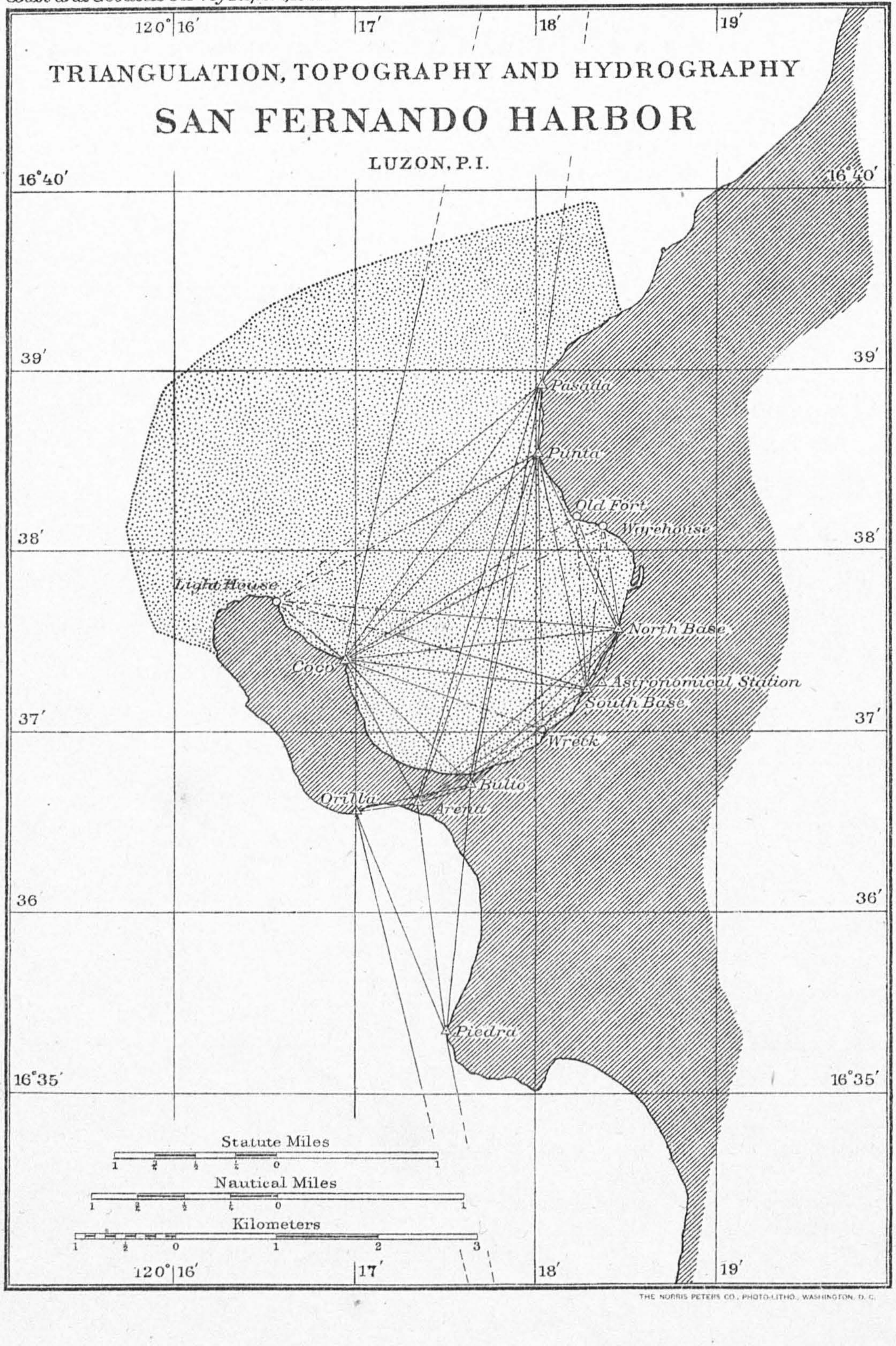
Entrance Cagayan River, Luzon Island, P. I.

Cagayan River Entrance, Aparri, Luzon (Rhodes).

Reconnaissance, topography and hydrography.



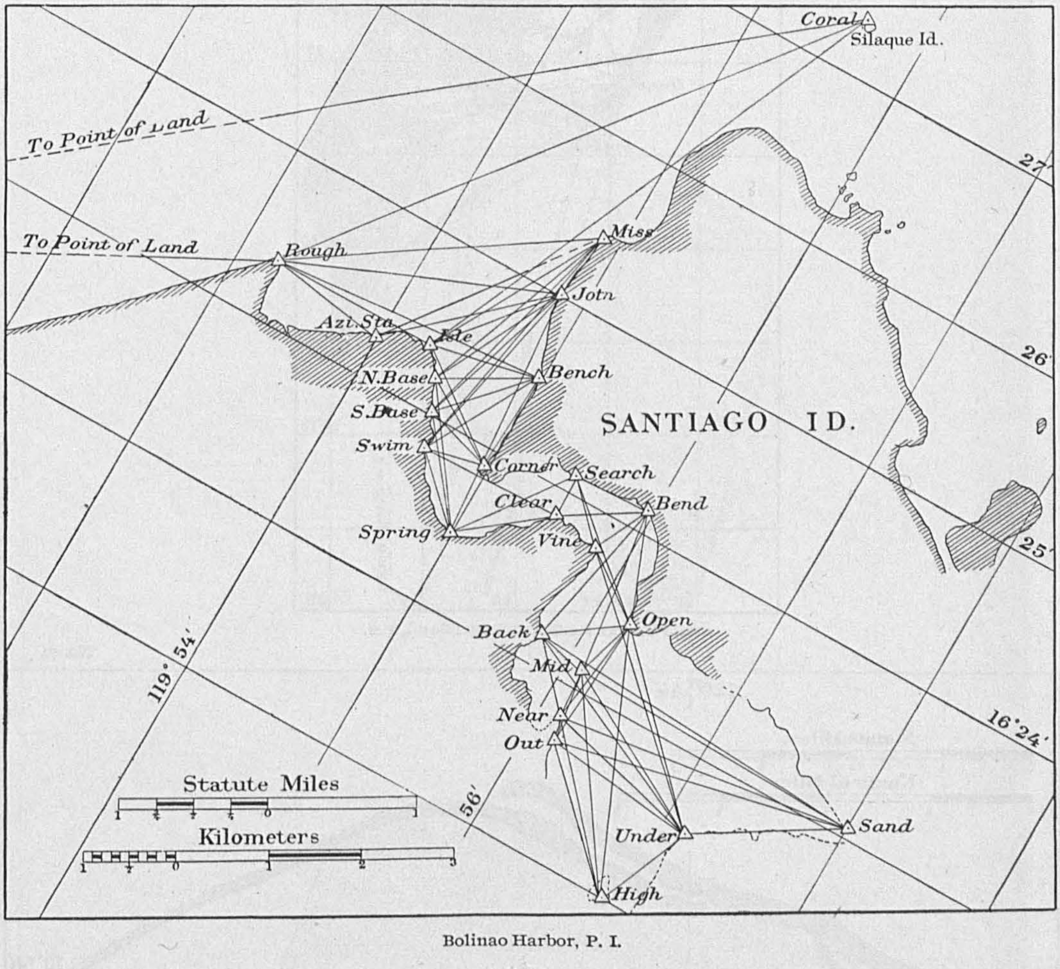
THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.



THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

Bolinao Harbor, Luzon (Denson).
Triangulation and topography.
San Fernando Harbor, Luzon (Denson).
Triangulation, topography and hydrography (north harbor).
Santo Tomas Harbor, Luzon (Denson).
Triangulation, topography and hydrography.

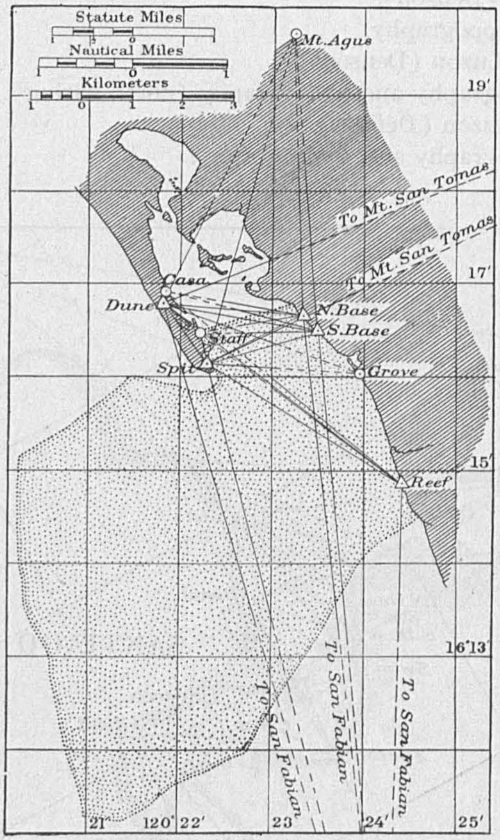
No. 37.



Bolinao Harbor, P. I.

Balayan Anchorage, Luzon (Rhodes).
Reconnaissance, topography and hydrography.
Darigayos Inlet, Luzon (Denson).
Topography and hydrography.
Tacloban Harbor, Leyte (Morford).
Triangulation, topography and hydrography. (Survey in progress June 30.)

No. 39.



Santo Tomas Harbor, Luzon Island, P. I.

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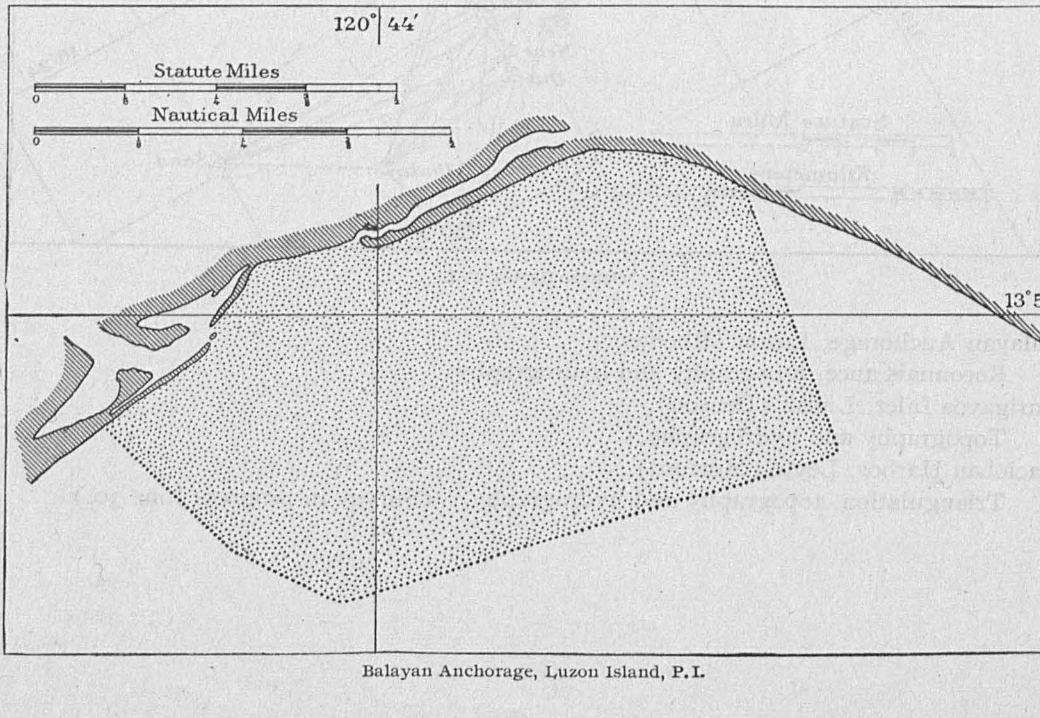

Balayan Anchorage, Luzon Island, P. I.

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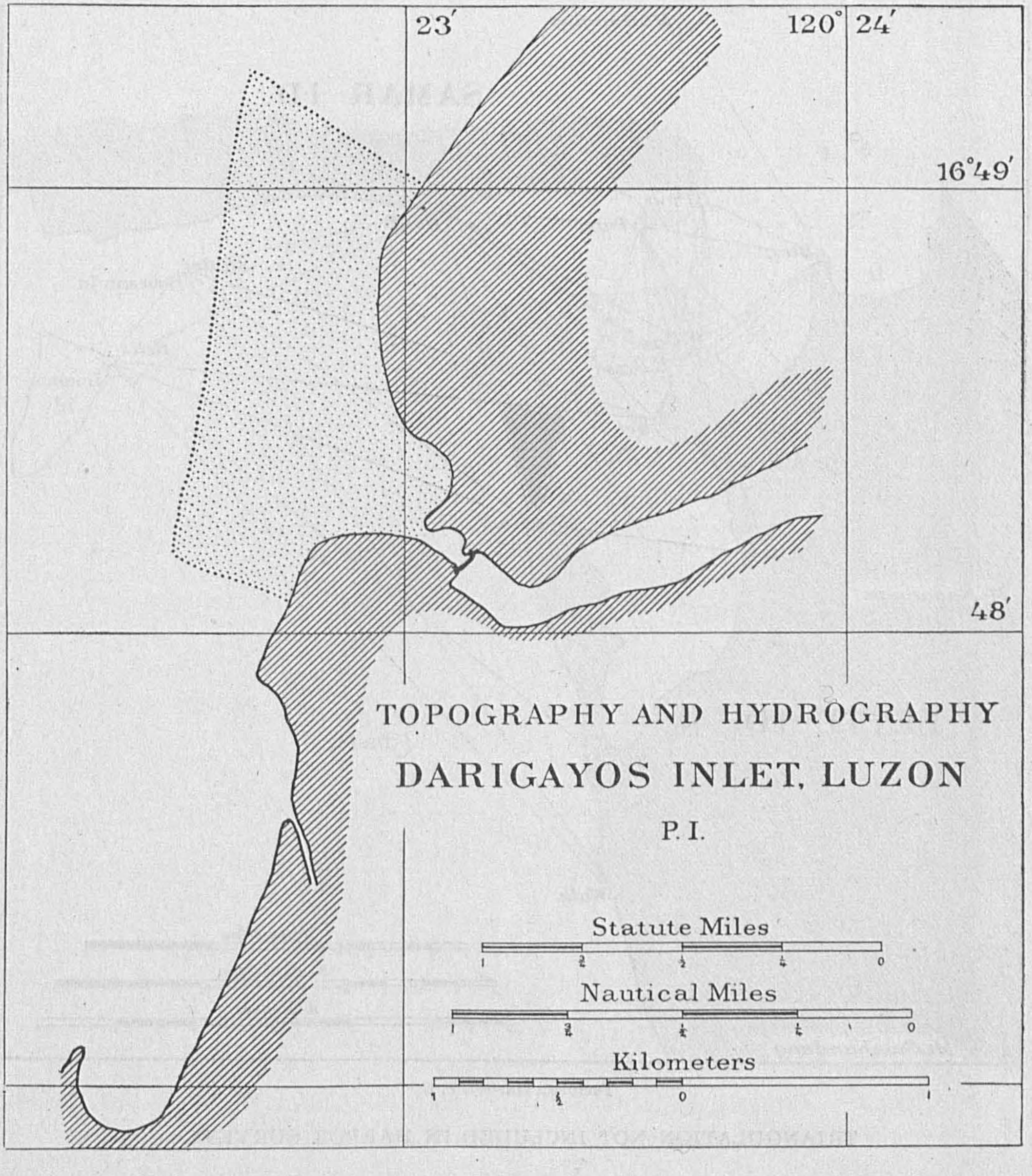
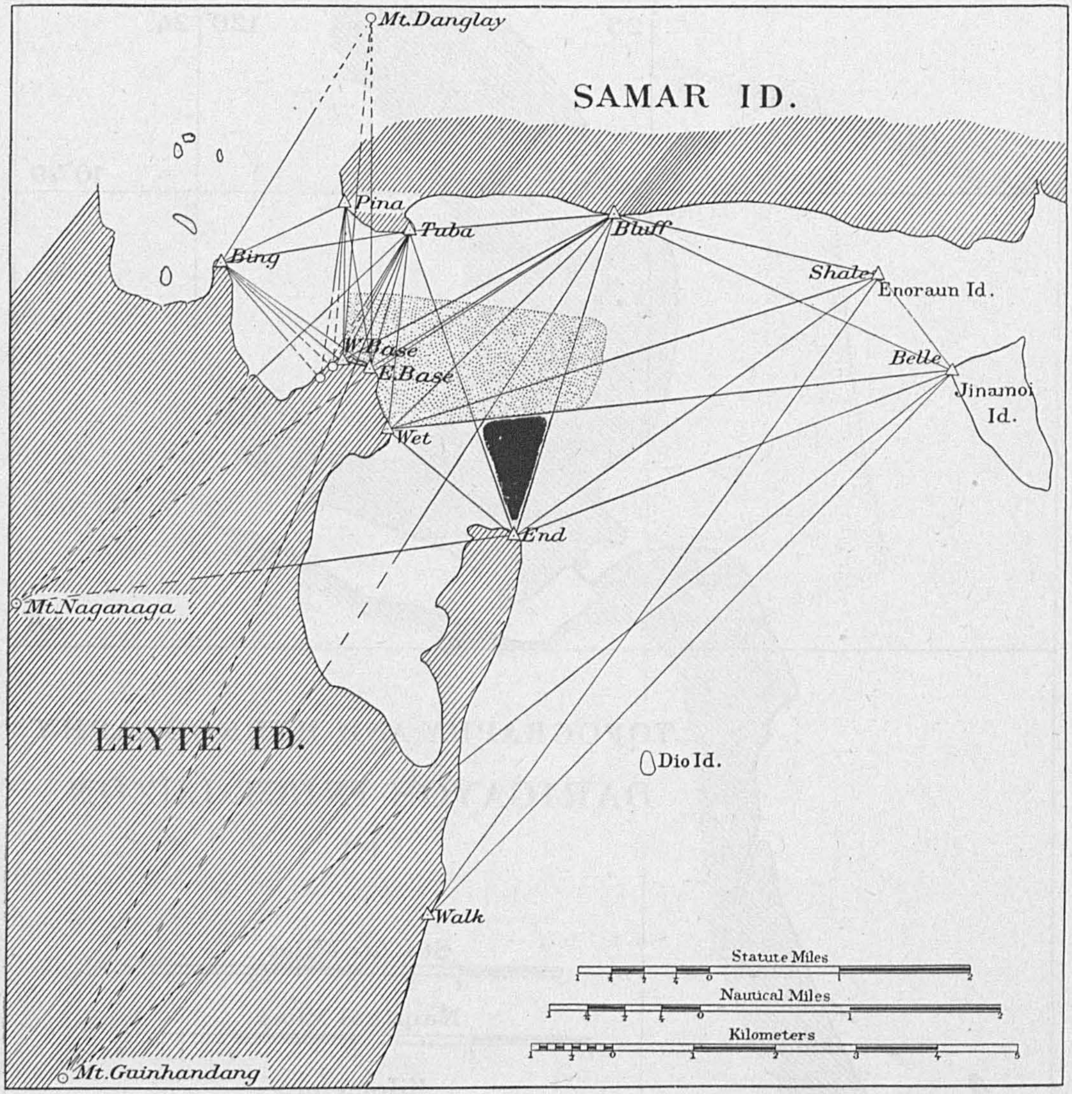

23′
120° 24′
16°49′
48′
TOPOGRAPHY AND HYDROGRAPHY
DARIGAYOS INLET, LUZON
P. I.
Statute Miles
Nautical Miles
Kilometers

No. 42.



Tacloban Harbor. P. I.

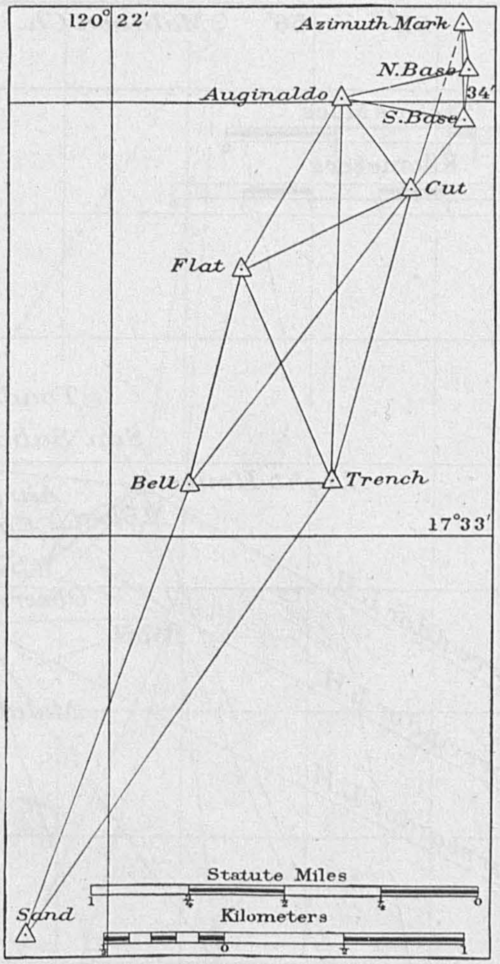
TRIANGULATION NOT INCLUDED IN HARBOR SURVEYS.

Vigan, Luzon (Rhodes).
Longitude station to the coast.

Candon, Luzon (Mitchell).
Longitude station to the coast.

Manila, Luzon (Putnam).
Connection of important points along the coast between Manila, Cavite, and Malabon and Corregidor Light-House.

No. 43.



Vigan, Luzon Island, P. I.

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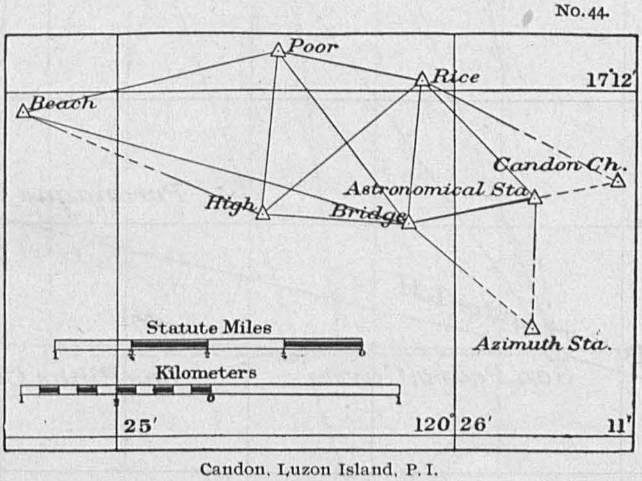

Candon, Luzon Island, P. I.

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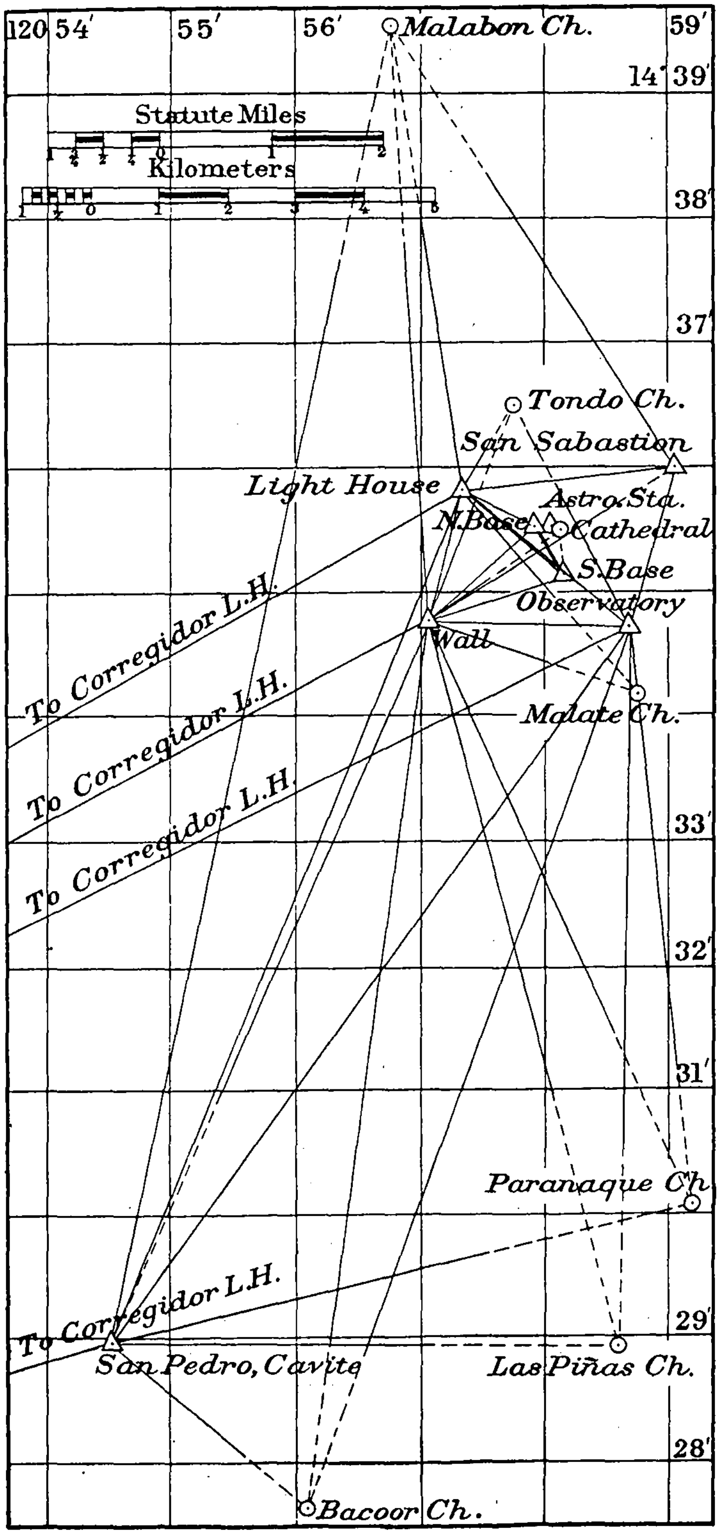


Vicinity of Manila, P. I.

TIDE OBSERVATIONS.

Observations were made as follows:

Manila, Luzon, February 11 to June 30.
Sual, Luzon, January 30 to March 6.
San Fernando, Luzon, January 26 to March 14.
Santo Tomas, Luzon, May 6 to May 23.
Darigayos, Luzon, June 17 to June 20.
Aparri, Luzon, January 3 to April 10.
Balayan, Luzon, May 14 to May 16.
Tacloban, Leyte (dates not given).

Reports were made by each chief of party, in which the details of the work executed were stated. Office work was undertaken as soon as necessary quarters and furniture could be obtained. The supply of many necessities for sale is very limited, and no desks could be obtained for more than a month after the party reached Manila. The demands upon Assistant Putnam were very exacting and his time was fully occupied with the numerous details involved in directing the surveys in the field, in addition to the routine work necessary in conducting the office, involving correspondence, computation, furnishing information on request, preparing results for publication, disbursement of funds, and many other details too numerous to mention.

Draftsman Welch was placed in charge of the Drawing Division and two Filipino draftsmen were employed to assist him.

Five charts were drawn and traced with lithographic ink, as follows:

	Scale.
Port Sual	1:10 000
Cagayan River entrance	1:10 000
Murcielagos Bay	1:30 000
Port Carrimao	1: 5 000
Manila and Cavite Anchorage	1:30 000

Four charts were completed ready for tracing with lithographic ink, as follows:

	Scale.
Balayan Anchorage	1: 5 000
San Fernando Harbor	1:15 000
Port Santo Tomas	1:20 000
Darigayos Inlet	1: 5 000

Five tracings were prepared for the Captain of the Port, one for the Captain of the transport *Sheridan*, and one for the Collector of Customs at San Fernando.

Considerable work in plotting and verifying hydrographic sheets and some inking of original sheets was done. When the tracing of a chart with lithographic ink on lithographic paper was completed, the tracing was placed face down on a clean lithographic stone, which was run through the press several times. This transferred the ink to the stone and the paper can then be washed away without removing any of the ink. The characters for sand, trees, swamp, hachures, lettering (in part), and the projection were drawn directly on the stone. About 100 blue prints of various sketches were made and distributed on request of the Captain of the Port and other officials. After overcoming many obstacles, three charts were published by lithography, and publication was then suspended until suitable paper could be obtained, as there was none for sale in Manila or Hongkong.

Six additional charts, four from Coast and Geodetic Survey work and two from Spanish charts needing publication with additions, were prepared for publication.

About 200 copies of the advance prints of the three charts mentioned above were distributed. Three numbers of a Notice to Mariners, dated March 1, April 1, and July 1, were prepared and published in an edition of 500 copies, and most of these were distributed to the various officials, including the collector of customs at every port. The Spanish board of trade republished these notices in Spanish and they were received with favor by others.

In response to a request addressed to the President of the United States Philippine Commission, under date of December 24, 1901, the Commission, on March 8, 1901, made an appropriation to purchase a small steamer for the use of the Coast and Geodetic Survey, and subsequently appropriated money for repairing and refitting the steamer and also an amount to purchase coal for the use of the steamer. The steamer *Research* was purchased and at the close of the fiscal year was still undergoing alterations, as it was found impossible to avoid long delays from lack of facilities and other causes.

The different classes of work were actively in progress at the close of the fiscal year.

PROCESSES USED IN THE PRODUCTION OF CHARTS IN ENGLAND AND FRANCE.	ENGLAND. FRANCE.	E. H. FOWLER.

Advantage was taken of the presence of the chief draftsman, Mr. Edwin H. Fowler, in London and Paris, during his vacation, to instruct him to make an examination of the methods of photo-engraving and the reproduction of topographic charts and drawings and other processes used in the production of charts, with the view of collecting information which would result in the improvement of the methods used by this Survey.

He began the work on August 1 and continued it during the remainder of his stay in Paris and London, and reported at the Office on September 8 to resume his regular duties in the Drawing and Engraving Division.

In Paris he secured an introduction to M. Emile Levasseur, member of the Institute of France, and professor in the College of France, through the courtesy of the United States Ambassador, Gen. Horace Porter. M. Levasseur gave him letters of introduction which secured the authority and facilities he desired in the prosecution of his work. He visited the office of the "Service Géographique de l'Armée," the office of the "Service Hydrographique," and the office of the "Directeur de la Carte de France et du Statistique Graphique," where every courtesy was shown him as the result of presenting the letters given him by M. Levasseur.

While in London Mr. Fowler visited the Admiralty Office and several of the large publishing houses. Information was obtained bearing upon the subject under investigation and the details reported by Mr. Fowler after his return to the Office.

The resurvey of Mason and Dixon's line, the boundary line between the States of Pennsylvania and Maryland, having become desirable, a commission was authorized by the legislature of the respective States to undertake the work.

This commission is composed of three members, the Superintendent of the United States Coast and Geodetic Survey, the Secretary of Internal Affairs of Pennsylvania, and the State Geologist of Maryland. Assistant W. C. Hodgkins was selected to execute the necessary work in the field, and he was detached from duty at the Office for that purpose.

He left Washington on October 21 and proceeded to Cumberland, Md., and on the following day began a reconnaissance of the region adjacent to the boundary.

As a result of this work he decided to begin operations at the northwest corner of Maryland, and the actual running of the trial line began on November 5. Unfortunately, winter weather was experienced at an unusually early date, and progress was delayed by frost and snow. The work proceeded until December 20, when the party was disbanded and operations were suspended to wait for more favorable conditions.

Assistant Hodgkins proceeded to Washington and was engaged on other work until April 8, when he resumed the survey of the boundary to the eastward of the Susquehanna River. This portion of the line between Cecil County, Md., and Chester and Lancaster Counties, Pa., was originally marked by monuments of cut stone, approximately 1 mile apart. Most of these monuments were found in place, but nearly all of them had been disturbed, and many of them were in a mutilated condition. When any monument, or portion of a monument, was found in its original position, this was assumed to be the boundary line, and the position was marked in a much more permanent manner than that originally adopted.

Notes were made along the line in order to prepare a topographic sketch in its vicinity. The progress of the work was seriously retarded by long-continued and heavy rains, and to some extent by extremely hot weather in June.

On June 30 this work was still in progress, and a section 23 miles long had been covered.

While engaged in this work Assistant Hodgkins was named as a member of the commission appointed by the United States Supreme Court to re-mark the boundary line between Virginia and Tennessee, and was absent on that duty May 17 to 22 and June 10 to 26. During his absence the party continued at work under his assistant, Robert H. Blain. The incidental expense of this work was paid by the States interested.

MARKING THE VIRGINIA AND TENNESSEE BOUNDARY.	VIRGINIA. TENNESSEE.	W. C. HODGKINS. J. B. BAYLOR.

On April 30, 1900, a decree was announced for the United States Supreme Court by Mr. Chief Justice Fuller which ordered the re-marking of the boundary line between the States of Virginia and Tennessee, established in 1801–1803 by the joint action of these States, commonly known as the "diamond line," as the "real, certain, and true boundary between the said States." In this decree William C. Hodgkins, of Massachusetts, James B. Baylor, of Virginia, and Andrew H. Buchanan, of Tennessee, were appointed a Commission "to ascertain, retrace, re-mark and reestablish said boundary line, but without authority to run or establish any other or new line."

W. C. Hodgkins and James B. Baylor are Assistants in the United States Coast and Geodetic Survey, and they were detailed to perform the duties imposed by this decree whenever the necessary conditions permitted.

On May 17, 1901, funds for field expenses provided by the States interested having become available, the Commission met at Coast and Geodetic Survey Office in Washington and organized by electing Assistant Hodgkins, chairman; Assistant Baylor, secretary, and Professor Buchanan, treasurer.

A considerable amount of preparatory work had already been accomplished by the Commissioners through correspondence. The necessary instruments and outfit were furnished by the United States Coast and Geodetic Survey to the extent permitted by the available supply.

On May 20 Assistant Baylor and Professor Buchanan proceeded to Bristol, Tenn., to begin active field operations, and Assistant Hodgkins returned to his work on the Pennsylvania and Maryland boundary. Assistant Baylor continued on the work during the remainder of the fiscal year, and the work was still in progress on June 30. Assistant Hodgkins was engaged on this work in the field from June 10 to 25.

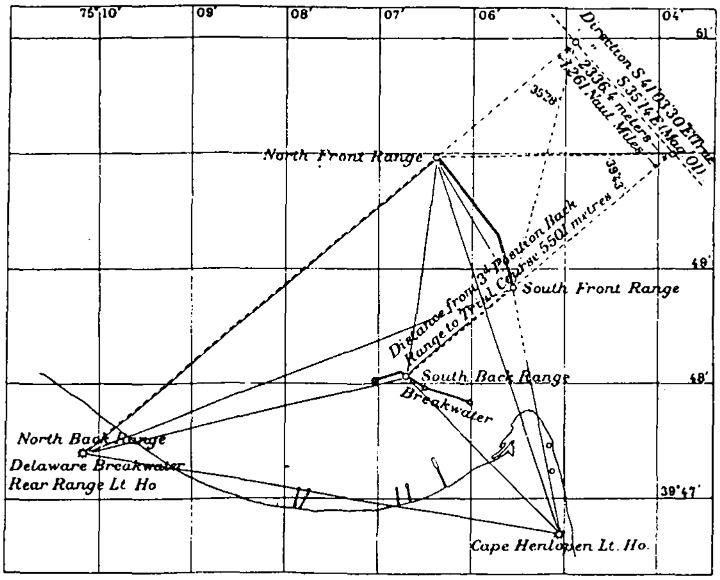
MARKING PROPOSED AVENUE ACROSS THE MALL. | DISTRICT OF COLUMBIA. | JOHN E. MCGRATH.

In the latter part of May a request was made by the Senate Committee on the District of Columbia, through its clerk, that an officer be detailed to mark by flags the lines of a proposed avenue across the Mall, between the Capitol and the Washington Monument, in the City of Washington. This work was executed for the information of a Commission for the Improvement of the Parks of the District of Columbia recently created by Congress. Assistant McGrath was assigned to this work and completed it on June 1 and 3, to the satisfaction of the Commission.

ESTABLISHING SPEED TRIAL COURSE IN DELAWARE BAY.

On May 8 Assistant Marindin left Washington under instructions to cooperate with Commander C. E. Vreeland, U. S. N., representing the Board of Inspection and Survey of the Navy Department in laying out, at the expense of the Messrs Cramp & Sons, of

No. 46.



Speed Trial Course, Delaware Breakwater.

Philadelphia, a mile course in the Delaware for use in connection with the trial of vessels built for the Navy. This work was successfully accomplished at the Delaware Breakwater during the month, and a special report was submitted covering the necessary operations.

MEMBER OF MISSISSIPPI RIVER COMMISSION. HENRY L. MARINDIN.

Assistant Marindin has continued to serve as a member of the Mississippi River Commission under the appointment of the President.

The month of July was spent in attending to his duties as a member of the Commission. On November 7 he went to St. Louis and attended a meeting of the Commission on the 9th, and accompanied the Commission on a low-water inspection trip to New Orleans. He was selected to prepare the annual report of the Commission, and did so after his return to Washington. The Commission disbanded, and Assistant Marindin returned to Washington, reporting at the Office on the 21st. He was engaged upon routine matters connected with the Commission and other temporary duties until April, when he again went down the river on an inspection trip which lasted from the 8th to the 20th.

From June 2 to 24 he was again attending to his duties as a member of the Commission, during which time he completed the annual report, and submitted it to the Commission at a meeting held in St. Louis.

GRAVITY MEASURES. | LONDON, ENGLAND. POTSDAM, GERMANY. PARIS, FRANCE. | G. R. PUTNAM.

In continuation of the work of connecting the base station for gravity determinations in the United States with the base stations for such work in Europe, Assistant Putnam made observations at the above stations in July and August.

The Survey was requested to undertake this work, by the International Geodetic Association, and all the incidental party expenses were paid out of funds furnished by the association.

The work in Europe was completed, and Assistant Putnam returned to Washington, reporting for duty at the Office on September 21.

He was directed to prepare the results for transmission to the association and to complete the connection by making the final set of observations in Washington. These observations were made early in October, and on October 12 a report on the work was submitted.

LATITUDE OBSERVATIONS FOR INTERNATIONAL GEODETIC ASSOCIATION. EDWIN SMITH.

The charge of the International Geodetic Association latitude station at Gaithersburg, Md., was assigned to Assistant Smith from July 1 to January 4.

This special duty was assigned to him under the authority of the honorable Secretary of the Treasury on July 1, 1899. As stated in the Report for 1900, the latitude stations at Gaithersburg, Md., and at Ukiah, Cal., are under the direction of the Superintendent of the Coast and Geodetic Survey, who undertook this supervision in compliance with a request from the association.

The party expenses at the Gaithersburg station were paid out of funds furnished by the association for this purpose.

The records and reports were forwarded to the Central Bureau of the association for discussion and publication.

On January 5 Dr. Herman S. Davis relieved Assistant Smith and assumed charge of the station.

MARKING PROVISIONAL BOUNDARY BETWEEN ALASKA AND BRITISH COLUMBIA. O. H. TITTMANN.

The work of marking the provisional boundary between Alaska and British Columbia as defined in the modus vivendi agreed to by the United States and Great Britain under date of October 20, 1899, was continued under the direction of Mr. O. H. Tittmann, assistant superintendent, United States Coast and Geodetic Survey, commissioner of the United States, and Mr. W. F. King, British commissioner, after July 1 until the end of the month, when the demarcation of the temporary boundary was completed.

Assistant O. B. French continued under Mr. Tittmann's direction as United States engineer and executed the necessary field work on the part of the United States.

Mr. Tittmann returned to Washington and reported at the office on August 20.

ESTABLISHING TIDE GAUGES IN THE DELAWARE RIVER. D. B. WAINWRIGHT.

In order to comply with a request from the Philadelphia Maritime Exchange for the establishment of tide staffs in the Delaware River for the use of shipping Assistant Wainwright was instructed to make the necessary arrangement and execute the work. He left Washington on April 10 and erected large tide staffs, or gauges, on the principal wharf at Chester, Pa., on the wharf of the United States Oil Company, near Marcus Hook, and on the naval magazine wharf, near Fort Mifflin.

Each gauge was an inch board 9 inches wide and 13 inches long, firmly attached to the outer face of the wharf. The face of the gauge was painted in square blocks 1 foot high, alternately black and white, with large figures on the squares of the opposite color. Provision was made for the removal of the gauges when necessary to repaint them and for replacing them in the same position.

The work was successfully completed on April 19, and Assistant Wainwright returned to Washington. A steam tug was furnished by the maritime exchange and was used as the means of transportation.

On December 27 Assistant Wainwright was instructed to resume charge of matters relating to the preparation of the exhibit intended for the Pan-American Exposition at Buffalo, N. Y. He had already devoted such time as was necessary to this work when permitted to do so by other duties assigned to him. He continued the work under the conditions stated above until April 23, when he left Washington for Buffalo to instal the exhibit. After this was completed he remained at Buffalo in charge of the exhibit until the close of the fiscal year.

DELEGATE TO THE INTERNATIONAL GEODETIC ASSOCIATION. EUROPE. ISAAC WINSTON.

EXAMINATION OF INSTRUMENTS OF PRECISION AT THE PARIS EXPOSITION.

The duty of representing the United States as delegate to the meeting of the International Geodetic Association at Paris, France, was assigned to Assistant Winston, and he was directed to make the necessary preparations to attend the thirteenth General Conference of the Association, which was to assemble at Paris on September 25.

While in Paris he was directed to avail himself of the opportunity presented by the exhibit at the Paris Exposition and to examine and report upon the instruments of precision which might be used in the various operations of this service.

He left the Office on August 17 and sailed the following day from New York for Paris, where he arrived on September 13, having spent some time in England en route.

The examination of the instruments exhibited at the Exposition began on the 14th, and this work continued until the 23d.

On the 24th preparations to attend the sessions of the International Geodetic Association were made and on the 25th the opening session was held. Assistant Winston attended all the sessions of the conference until it adjourned on the 6th of October. He then continued the examination of instruments and completed this work on October 14.

After spending some time in Europe, on leave of absence, Assistant Winston returned to Washington and reported for duty at the Office on December 6.

He submitted a report upon the instruments examined and also a report giving a résumé of the work of the International Geodetic Association.

The association publishes the proceedings of each conference in detail and consequently no extracts from this résumé are stated in this place.

He makes special acknowledgment of the many courtesies extended to him as delegate of the United States by the officials of the French Republic and by the French Geodetic Association.

EXAMINATION OF HYDROGRAPHIC METHODS IN USE IN EUROPE. C. C. YATES.

Advantage was taken of the presence abroad of Assistant Yates, and he was instructed to make an examination which would enable him to submit a report upon the hydrographic surveys of England, France, and Germany, and upon the heliographic methods of making copper plates for printing maps in use by the Military Geographic Institute at Vienna, Austria.

He was also instructed to investigate the desirability of establishing foreign agencies for the sale of Coast and Geodetic Survey Charts.

A reference was made to this work in the previous Annual Report.

As a result of presenting his credentials, Assistant Yates was granted unusual authority to pursue the investigations under his charge and many courtesies were extended to him by the representatives of the United States abroad and the officials of the Government in the countries visited.

Many delays occurred and the investigation extended far beyond the date anticipated in the beginning.

Various offices and institutions were visited and time was spent on board the survey vessels of England and France, by special permission, watching the methods in actual use in the field. Assistant Yates visited Berlin and Vienna, and, having completed the duty assigned to him, returned to the United States and reported at the Office on August 20.

He expresses his great appreciation of the courtesy and kind attention shown him and reports a long list of officials and others to whom the thanks of the Survey are due for the aid extended to him in the prosecution of his work.

APPENDIX No. 2.

REPORT 1901.

DETAILS OF OFFICE OPERATIONS.

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CONTENTS.

APPENDIX No. 2.

DETAILS OF OFFICE OPERATIONS.

OFFICE OF THE ASSISTANT IN CHARGE.

ANDREW BRAID, *Assistant in Charge.*

The Assistant in Charge of the Office has direct supervision of the routine work of the different divisions of the Office.

The following persons were employed under his immediate direction:

Name.	Occupation.
George A. Fairfield,	Clerk.
A. B. Simons,	Do.
E. B. Wills,	Clerk (January 6 to June 30).
Miss Kate Lawn,	Writer.
TEMPORARY FORCE.	
Miss E. M. French,	Writer.
Miss L. Helen,	Do.
Miss E. L. Mewshaw,	Do.

An extract from the report of the Assistant in Charge is given below:

The Annual Report of the Office for the fiscal year ending June 30, 1901, is accompanied by the Annual Reports of the various divisions thereof, namely: Computing Division, Division of Terrestrial Magnetism, Tidal Division, Drawing and Engraving Division, Chart Division, Instrument Division, Library and Archives Division, Miscellaneous Division, and Special Duty.

The Computing Division continued under the direction of Assistant J. F. Hayford, whose report shows a creditable amount of work accomplished, especially considering the limited force at his disposal. The Division has, as heretofore, been reinforced from time to time by the temporary detail of Assistants and Aids when not actively engaged on field duty. The regular employees of the Division and the field officers temporarily detailed for office duty are given in Mr. Hayford's report and need not be enumerated here, and the usual statistical information concerning the correspondence and routine work are also furnished. Among the most important items of work accomplished may be mentioned the following.

The work of reducing the geographic positions in southeast Alaska to a uniform standard was almost completed.

The computation of more than 1,000 miles of precise leveling was made.

A United States Datum, to which all connected geographic positions are to be reduced, was adopted, and the positions of the primary points along the thirty-ninth parallel triangulation, along the eastern oblique arc, and along the western oblique arc were reduced to this datum before the close of the fiscal year.

The Division of Terrestrial Magnetism continued under the charge of Assistant L. A. Bauer. His report contains the usual detailed account of the correspondence, routine work, and distribution of magnetic information. During his absences on field inspection the office work of the Division was attended to by Mr. D. L. Hazard. Bulletin No. 41, "Magnetic Survey of North Carolina," was prepared for publication; various magnetic instruments were carefully examined and their constants determined; plans were prepared for magnetic observatories at Sitka, Alaska, and Honolulu, Hawaiian Islands; the preparation of a new edition of the Magnetic Declination Tables was begun, and a revision of all field magnetic observations to date was undertaken and good progress made. Mention may also be made of the wide distribution of a circular to surveyors, professors of engineering, etc., requesting information relative to magnetic declination, secular change allowed for in relocating old boundary lines, etc. The large correspondence resulting from this circular has been critically examined and the information derived therefrom has been tabulated for publication.

The Tidal Division, as heretofore, remained under the charge of Mr. L. P. Shidy, and his report gives full details as to work accomplished during the year. The annual volume of Tide Tables (for 1902) was prepared, verified, and published, and the usual reprints for the Atlantic and Pacific coasts were issued; the usual reductions and discussions of tides were attended to and information furnished for tide notes of charts; tidal information has been furnished in response to numerous inquiries, etc. Dr. R. A. Harris prepared for publication, as an Appendix to the Annual Report for 1900, a paper entitled, "Outlines of Tidal Theory," and also a leaflet on tides and tidal currents for distribution at the Buffalo Pan-American Exposition. Mr. Shidy also revised and extended the portion of "General instructions for Hydrographic Parties" relating to tides and currents. In the Tide Tables for 1902 several new features were introduced, among which two current diagrams for New York harbor and tables for finding the height of the sea at any time between high and low water are worthy of special mention.

The Drawing and Engraving Division continued under the charge of Assistant W. W. Duffield, and his report shows in detail the work accomplished by each of the five sections of the Division, and gives the usual statistical information as to information furnished, etc. In the Engraving Section the work of chart production has been facilitated and expedited by the introduction of the new engraving machines. The one for engraving soundings especially has proved a great labor-saving device and shortens very materially the time required for putting hydrography on copper. In the Drawing Section, under the immediate supervision of Chief Draftsman E. H. Fowler, the principle of transfer from negatives or copper plates has been successfully applied in the matter of making titles to original sheets and in adding sanding, etc., to drawings for photolithographic reproduction. This has resulted in a considerable saving of draftsmen's time and has enabled the section better to keep up with the increasing demands upon it. In addition to the regular work of the section, a map of the world, 8 feet by 20 feet, on which the Colonial possessions of all the great nations are shown in appropriate colors, was prepared for the use of the President. In the Printing Section, under the immediate direction of Foreman D. N. Hoover, the regular work has been kept up as usual and some progress made in printing bond copies for the files of the old plates in the archives with a view of properly cataloguing the same and eliminating useless plates. The facilities of the Photographing Section have been increased by the purchase of necessary new outfit and by the removal to the more commodious quarters in the attic of the main building. The increase of facilities, the new equipment and the improvement of processes have resulted in a gratifying increase of the output and improvement in quality of work of this section. The usual amount of work has been accomplished in the Electrotyping Section.

The Chart Division, consisting of the Chart Section and the Hydrographic Section, has remained under the charge of Assistant Gershom Bradford, the Inspector of Charts. In the Chart Section the voluminous correspondence relating to charts, the keeping of the accounts with sales agents, the general issue of charts, coast pilots, and tide tables to Departments of the Government and to the outside public, the hand corrections of charts from recent information, and the coloring by hand of lights and buoys, have received careful and prompt attention. The usual statistical information concerning the work of the section and the distribution of charts, etc., is given in Mr. Bradford's report.

In the Hydrographic Section the usual monthly Notices to Mariners have been prepared for publication, the aids to navigation were kept up to latest information on our various charts, numerous hydrographic sheets of field parties were plotted or verified, and much miscellaneous work was done. The Hydrographic Section was aided to some extent by occasional details for short periods of field draftsmen, who, however, were usually confined to the work of the party from which they were detailed.

In the Instrument Division, under the charge of Chief Mechanician E. G. Fischer, the usual amount of work has been accomplished. This consisted of repairs to instruments, the construction of such new instruments as are not obtainable in the open market, the issue of instruments, camp outfit, and general property of the Survey, including the checking of the annual inventories. Minor repairs to buildings, repairs of office furniture, construction of cases for library, etc., and the care of office bells, pneumatic clocks, etc., also received due attention. The complete work of the Division during the year is given in detail in Mr. Fischer's report in statistical form. Mr. Fischer also modified and improved an electrical tide indicator and attended to its installation at the rooms of the Philadelphia Maritime Exchange, supervised the construction of a 5-meter iced bar and base tape apparatus for the Japanese Government, and subsequently aided in the standardization of the same. He also performed like functions in connection with the construction and standardization of a 100-meter base tape apparatus for the Trigonometrical Survey of the Straits Settlements. Much of the work of preparation of the Coast and Geodetic Survey exhibit for the Pan-American Exposition also devolved on this Division.

The Library and Archives Division has continued under the charge of Mr. E. L. Burchard and his report gives full statistical information in regard to the books, pamphlets, serials, maps, and charts purchased, donated, or received in exchange, and the original sheets and records received from field parties. Good progress has been made in the indexing of the archives.

The Miscellaneous Division has as heretofore attended to the purchase and distribution of supplies required for the Office and making requisitions for printing and binding, the issue of stationery to field parties and Office Divisions, the custody of the publications of the Survey, and the keeping of the records relative to their distribution. The report is submitted in the usual statistical form.

The special assignment of Assistant C. A. Schott was continued, but, owing to his illness in the latter part of the fiscal year, the report of the work accomplished was submitted for him by Miss Lilian Pike. The computation and discussion of the Eastern Oblique Arc from Maine to Louisiana occupied the greater part of the year, and was finally completed and the report submitted for publication. The computation of geographic positions in the New England States was also completed and the Tennessee triangulation adjusted. The proof reading of Special Publication No. 4, the Transcontinental Arc, was also completed and work resumed on the reduction of the California arc.

In the immediate Office of the Assistant in Charge Mr. George A. Fairfield has assisted in the correspondence and attended generally to routine business; Mr. A. B. Simons, in addition to his clerical duties and the keeping of the accounts of moneys received from sale of publications, sale of old condemned property, and for work done for outside parties, has had general charge of the watchmen, the messengers, and labor force, and the keeping in order of the Survey buildings. Mr. E. B. Wills has kept the time records of the Office and Field employees, the express and freight matters, and the registered mail records. Miss Kate Lawn has in general attended to the typewriting and copying for the Office and miscellaneous clerical duty. She has also attended to the distribution of Notice to Mariners and largely to the distribution of other publications of the Survey. She has been assisted in this work by temporary appointees—Miss E. M. French, Miss L. Helen, and Miss E. L. Mewshaw—their terms of service aggregating sixty-six days.

In conclusion I take pleasure in reporting that the condition of the Office is in general very satisfactory and the reports of the various Divisions show an unusually large amount of work accomplished during the year. This is in part due to the introduction of new facilities, the improvement of the methods, and the adopting of labor-saving devices, but due credit must also be given to the hearty and efficient cooperation of all the chiefs of Divisions. Strenuous efforts have been made to expedite the work of the Survey, particularly in the matter of preparation of charts for publication, and also to so systematize the work as to eliminate as far as possible sources of error.

The following extracts from the reports of the chiefs of Divisions contain additional details:

COMPUTING DIVISION.

Personnel.

Name.	Occupation.
J. F. Hayford	Chief of Division.
E. H. Courtenay	Computer.
M. H. Doolittle	Do.
A. L. Baldwin	Do.
W. H. Dennis	Do.
J. H. Millsaps	Writer.
TEMPORARY FORCE.	
A. T. Mosman	Assistant.
Wm. Eimbeck	Do.
C. H. Sinclair	Do.
F. D. Granger	Do.
Isaac Winston	Do.
S. Forney	Do.
E. Smith	Do.
J. E. McGrath	Do.
R. L. Faris	Do.
O. B. French	Do.
E. B. Latham	Do.
F. M. Little	Do.
H. F. Flynn	Do.
W. Bowie	Do.
H. S. Davis	Do.
E. R. Frisby	Aid.
W. H. Burger	Do.
O. M. Leland	Do.
F. H. Brundage	Do.
W. E. Parker	Do.
O. E. Carr	Do.
G. E. Selby	Do
J. K. Mills	Do.

The work of this Division may be divided into four classes:

(1) Supplying information of various kinds to the field parties and to persons outside the Survey.

(2) Final computations or revisions of computations in connection with recent field operations:

(3) Computations which are necessary to reduce older field work to a standard datum.

(4) The preparation of results for publication.

The detail of the temporary force was made for short periods from time to time as the necessities of the field operations permitted, and many of this temporary force were engaged in completing their records of field work while attached to the Computing Division. Consequently these temporary details only brought the average effective force of the Division up to 8 men besides the chief.

The average effective force for the different months varied from 3 in August to 15 in March. From December 5 to 22, Assistant William Eimbeck acted as chief of

Division, and from May 31 to June 30 Mr. A. L. Baldwin, computer, occupied this position. During the first period Assistant Hayford was absent on field duty and during the second period he was on leave of absence. Within the limits of this report it is possible to state only a few of the more important results reached in the work of the Division during the year.

The routine work of answering correspondents and furnishing information to field parties has always been heavy and is steadily increasing. For considerable periods it has absorbed nearly all the energy of the Division. Some idea of the volume of the correspondence may be obtained from the statement that during the year 2 319 geographic positions and 1 185 descriptions of stations were furnished to various parties. In judging of the work involved in these descriptions and positions, it should be borne in mind that the data required must be collected from numerous volumes covering the operations of the Survey in past years, that nearly all the descriptions of stations require accompanying sketches, and that many letters require special computations to be made before an answer can be prepared.

Aside from this routine work and other routine computations necessary to make the results of recent field work available, notable progress was made in the following work:

The work of reducing the positions in southeast Alaska to a uniform standard was almost completed, and about 1 300 of the geographic positions were entered in the register.

During the year more than 1 000 miles of precise leveling lines were completed, and the Office computations made.

On March 13, 1901, a United States Standard Datum, to which all connected geographic positions are to be reduced, was adopted. This datum is the one already used by the Coast and Geodetic Survey in publishing the geographic positions of several of the Eastern States. The positions of the primary points along the 39th parallel triangulation, along the eastern oblique arc to Mobile, and along the western oblique arc, were reduced to this datum before the close of the fiscal year.

The tables for the computation of geodetic positions published in Coast and Geodetic Survey Report for 1894, Appendix No. 9, extend from 18° to 72° of latitude. The computation necessary to extend these tables from 18° to the equator was made, and the result is published in Appendix No. 4 to this Report. This extension makes the table available for all latitudes from 72° north to 72° south.

Assistant Hayford mentions the individuals of the regular force of the Division by name, and highly commends the value of their service, and the ability and efficiency with which they have executed the duties assigned to them.

DIVISION OF TERRESTRIAL MAGNETISM.

Personnel.

Name.	Occupation.
L. A. Bauer	Chief of Division.
D. L. Hazard	Computer.
W. H. Davis	Clerk (July 1 to Aug. 1).
Miss L. L. Jones	Clerk (Jan. 30 to Feb. 24).
A. S. Barnes	Clerk (Mar. 1 to May 31).
Miss J. E. Haslup	Clerk (June 21 to June 30).
TEMPORARY DUTY.	
J. B. Baylor	Assistant.
J. A. Fleming	Aid.
W. C. Dibell	Aid.
R. W. Walker	Temporary aid.
G. H. Draper	Clerk.

The work of this Division was continued on the same lines as during the previous fiscal year. It was largely routine work and included furnishing a large number of compass directions for the charts issued by the Survey, supplying declinations for the Coast Pilots, and correcting the position of the isogonic lines on charts of Alaska for secular change.

Numerous calls for information relating to magnetic declination and its secular change were received and answered. The demand for information of this character is steadily increasing.

A circular requesting information relating to magnetic declination and the amount of secular change allowed in relocating old boundary lines was widely distributed over the United States by being sent to surveyors and professors of engineering and mechanics and the information received in reply was critically examined and tabulated for publication.

Bulletin No. 41, "Magnetic Survey of North Carolina," was prepared for publication, and the proof of Appendixes Nos. 9 and 10, Report 1899, was read. The preparation of a new edition of the Magnetic Declination Tables was begun, and the revision of the computation of all magnetic observations previously made by the Survey was undertaken, and nearly all the declinations were completed. Progress was made in the preparation of the isogonic chart of the United States for 1902.

Various magnetic instruments were compared and their constants were determined.

Plans were prepared for magnetic observatories at Sitka, Alaska, and at Honolulu, Hawaiian Islands.

Mr. D. L. Hazard acted as Chief of Division from September 5 to December 10, and also at other times when Assistant Bauer was absent on short trips of inspection.

About one-half of Assistant Bauer's time was devoted to duties relating to the direction and inspection of field work which devolved upon him as Inspector of Magnetic Work. Assistant Bauer commends the able manner in which Mr. Hazard performed the various duties assigned to him.

TIDAL DIVISION.

Personnel.

Name.	Occupation.
L. P. Shidy	Chief of Division.
R. A. Harris	Computer.
J. C. Hoyt	Do.
Artemas Martin	Do.
D. S. Bliss	Do.
Alice G. Reville	Clerk.
Virginia E. Campbell	Writer.
Mary A. Grant	Writer (July 1 to June 6).
Fred A. Kummell	Tide observer.

The annual volume of Tide Tables for the year 1902 was prepared and published. The separates for the Atlantic coast and for the Pacific coast were also published. The volume has several new features, among which may be mentioned two current diagrams for New York Harbor and some tables for finding the height of the sea at any intermediate time between high and low water.

Sixty-one volumes of tidal records were prepared for binding. Nonharmonic reductions were made for 64 stations with about one month's observations at a station. Harmonic analyses were completed for a year of hourly ordinates at each of three stations and also for several short series, which, together with the work in progress at the close of the last fiscal year, brings the total to an equivalent of the complete analysis of five years' continuous record. The plane of reference was determined for 54 stations. About twelve years of automatic tide-gauge record was tabulated as high and low waters and also as hourly heights of the sea.

Tide notes were prepared for a large number of stations upon charts and hydrographic sheets. Tidal information was prepared in response to requests from numerous field parties and persons not connected with the Survey. This involved the preparation of tidal data for 566 stations and descriptions of 264 bench marks.

The following records were received during the fiscal year:

One year's record from the automatic gauges at Fort Hamilton, N. Y., Philadelphia, Pa., Reedy Island, Del., Washington, D. C., Fernandina, Fla., Presidio, San Francisco Bay, California, and Seattle, Wash. One year's record at Providence, R. I., from the city engineer. One year's record from 3 stations at Habana Harbor, Cuba, from the Corps Engineers, United States Army. Records covering shorter periods from automatic gauges and staff and box gauges were received from 37 stations in the Eastern Division, 16 stations in the Western Division, 14 stations in Alaska, 16 stations in Porto Rico, and 4 stations in the Philippine Islands.

An aggregate of thirty-five years of record from automatic tide gauges was received, examined, and registered. In addition to the above, an aggregate of two years' record from staff and box gauges at 77 stations was received.

A tracing of the original tide record at Wellington, New Zealand, for one year, and a table of high and low water times and heights for three additional years were received from an official of the Government. The above observations cover an aggregate of thirty-seven years' tide observations, all of which were examined and registered.

A leaflet on Tides and Tidal Currents was prepared for distribution at the Pan-American Exposition and the portion of the General Instructions for Hydrographic Parties, relating to tides and currents, was revised and extended.

DRAWING AND ENGRAVING DIVISION.

Personnel.

Name.	Occupation.
W. W. Duffield	Chief of Division.
James M. Griffin	Clerk.
E. Meads	Writer.
Edwin H. Fowler	Chief draftsman.
Harlow Bacon	Draftsman.
J. N. Baker	Draftsman (Jan. 16 to June 30).
P. B. Castles	Draftsman (Aug. 16 to Dec. 1).
Chas. H. Deetz	Draftsman.
D. Derickson	Draftsman (July 11 to Sept. 10).
F. C. Donn	Draftsman.
E. P. Ellis	Do.
P. Von Erichson	Do.
C. M. Hahn	Draftsman (Jan. 2 to June 30).
D. M. Hildreth	Draftsman.
Jas. P. Keleher	Do.
A. Lindenkohl	Do.
H. Lindenkohl	Do
J. W. McGuire	Draftsman (Jan. 28 to June 30).
Chas. Mahon	Draftsman.
S. B. Maize	Do.
J. F. Pfau	Draftsman (Sept. 25 to Apr. 6).
E. J. Sommer	Draftsman.
V. Sournin	Draftsman (July 1 to Oct. 10).
R. W. Walker	Draftsman (Nov. 26 to Mar. 25).
J. T. Watkins	Draftsman (absent from Oct. 2 to Nov. 26).
Williams Welch	Draftsman (July 1 to Nov. 21).
W. H. Davis	Engraver.
H. E. Franke	Do.
R. H. Ford	Do.
P. H. Geddes	Do.
F. Geoghegan	Do.
Geo. Hergesheimer	Do.
W. H. Holmes	Do.
H. M. Knight	Do.
Wm. Mackenzie	Do.
W. F. Peabody	Do.
A. H. Sefton	Do.
E. H. Sipe	Do.
H. L. Thompson	Do.
W. A. Thompson	Do.
W. A. Van Doren	Do.
Theo. Wasserbach	Do.
F. G. Wurdemann	Do.
D. N. Hoover	Foreman of printing.
E. F. Campbell	Plate printer.
W. M. Conn	Do.
R. J. Fondren	Do.
Eberhard Fordan	Do.
C. J. Harlow	Do.
C. J. Locraft	Do.
C. W. Buckingham	Printers' helper.
E. M. Kline	Printers' helper (Aug. 23 to June 30).
R. F. Le Mat	Printers' helper (July 1 to Aug. 30).
W. B. Mehler	Printers' helper (July 1 to July 18).

DRAWING AND ENGRAVING DIVISION—Continued.

Personnel—Continued.

Name.	Occupation.
C. F. Blacklidge	Photographer and electrotyper (July 18 to June 30).
L. P. Keyser	Assistant photographer.
Roy Thomas	Assistant electrotyper.
George Newman	Messenger.
W. J. Bickford	Laborer.
Hans Bowdwin	Do.
H. Murray	Do.
Frank Thomas	Do.
A. A. Meredith	Extra laborer (Mar. 29 to June 30).
R. J. Trostler	Extra laborer (July 1 to Dec. 10).
W. Waple	Extra laborer (Jan. 3 to Mar. 28).
TEMPORARY FORCE.	
J. A. French	Aid (Jan. 14 to Feb. 15).
W. Sanger	Captain's clerk (Sept. 24 to Nov. 26).

This Division is divided into five sections—the Drawing, the Engraving, the Printing, the Photographing, and the Electrotyping sections. Each section executed the work indicated by its title and the combined result is shown in the charts published by the Survey.

DRAWING SECTION.

The following statements and tables show in detail the work accomplished in this section, which was continued under the personal direction of Mr. E. H. Fowler, chief draftsman. Several changes in the method of work were introduced to increase the output without lowering the high standard of excellence in execution heretofore maintained. The process of transferring to original sheets the notes, titles, and general lettering which are common to all has been perfected so that the work of preparing these sheets for approval and registration is reduced to a minimum and results in saving much labor and expense.

A new sheet of standard letters (Roman capitals), accompanied by a self-spacing device, was completed and the resulting method of building up titles will eventually insure uniformity in the titles of all the field sheets and all the charts published by photolithography and also result in saving much time in their preparation, thus reducing the cost of publication.

A large map of the world, 8 feet by 20 feet, was prepared for the use of the President, on which the colonial possessions of the great powers are shown by appropriate colors.

The work of the Division, as a whole, is commended by its Chief, and Messrs Fowler and H. Lindenkohl are specially mentioned for the energy and ability displayed by them.

During the year the following drawings were completed for photolithographing or engraving:

Chart No.	Title.	Scale.
79	Chesapeake Bay	1-200 000
293	New London Harbor and Naval Station	1-10 000
517	Sabine Pass and Lake	1-40 000
577	Fernandina to Jacksonville	1-40 000
908	San Juan Harbor, Porto Rico	1-10 000
911	Ponce Harbor, Porto Rico	1-20 000
913	Great Harbor, Culebra Island, West Indies	1-6 500
919	Fajardo Harbor, Porto Rico	1-10 000
1007	Gulf of Mexico	Mercator.
4104	Maalaea Bay, Maui Island, Hawaiian Islands	1-10 000
4105	Kahului Harbor and approaches, Hawaiian Islands	1-10 000
4106	Kaunakakai Harbor, Hawaiian Islands	1-10 000
4231	Port of Manila, Philippine Islands	1-10 000
5984	Coos Bay, Oregon	1-20 000
6195	Grays Harbor, Washington	1-40 000
8244	Sitka Harbor, Alaska	1-10 000
9007	Unalaska Bay, Alaska	1-40 000
9370	Cape Romanzof to St. Michael	1-300 000
9372	Yukon River, Apoon Mouth to Head of Passes	1-80 000
9373	Yukon River, Kwiklowak Mouth	1-80 000
9375	St. Michael Bay, Alaska	1-20 000
9380	Norton Sound, Alaska	1-400 000

The following drawings are in progress:

Chart No.	Title.	Scale.
109	Boston Bay and approaches	1-80 000
281	Hudson River—New York to Haverstraw	1-40 000
920	Porto Rico	Mercator.
5532	Entrance to San Francisco Bay	1-40 000
6381	Roche Harbor, Washington	1-10 000
6445	Seattle Harbor, Washington	1-20 000
7002	Cape Flattery to Dixon Entrance	Mercator.
8002	Dixon Entrance to Cape St. Elias	Mercator.
8502	Cape St. Elias to Shumagin Islands	Mercator.

Number of drawings finished for new charts	13
Number of drawings finished for new editions	9
Number of drawings corrected for new prints	5
Number of drawings unfinished for new charts	8
Number of drawings unfinished for new editions	1

Four hundred and thirty-three charts were revised, corrected, and verified for new editions or reprints from copper plates. Thirty-six topographic and 44 hydrographic projections were constructed for the use of the Office and the field parties and 12 projections were made on copper plates. Nearly 400 illustrations were made for the Annual Report and the Special Publications (including the Coast Pilot).

ENGRAVING SECTION.

The work in this Section continued under the personal direction of the Chief of Division. During the year three engraving machines were installed and put into use. The machine for engraving soundings works well, and makes it possible to engrave the hydrography of a chart in a short time (one to three days). A large border cutting and tinting machine and a new and improved compass cutting machine have added to the efficiency of the Division by increasing the output of charts.

Several charts were published by transfer from copper plates cut by machine work, except the sanding, fathom curves, and bottom characteristics engraved by hand, and the topography, notes, title, etc., which were added by photolithography from drawings made to fit the engraved plates.

This process proved very successful and is very useful in the publication of preliminary editions. The following tables show the work of the section in detail.

The following original plates were completed:

Chart No.	Title.	Scale.
244	Salem Harbor and Approaches	1-20 000
246	Boston Harbor	1-20 000
255	Higganum to Rocky Hill	1-20 000
256	Rocky Hill to Hartford	1-20 000
571	Port Royal Sound	1-40 000
909	Jobos Harbor, Porto Rico	1-20 000
3 089	Olympia, Wash., to Mount St. Elias	1-3 600 000
	Catalogue plate	
	Field sheet notes, transfer plate	
	Buffalo Exposition plate	
	Curves of equal depth	
	Reducing lines, four sizes	
	Hydrographic symbols	
	Topographic symbols	
	Diagram for measuring mercator projection	
	Transfer letter plate	
	Width and spacing of Roman capital letters	
	Standard note plate	
	Superintendent's letter transmitting Publication No. 4	

The following plates for new editions of charts were completed:

Chart No.	Title.	Scale.
T	General chart of Alaska	1-3 600 000
14	Cape Canaveral to Fowey Rocks	1-400 000
113	Cuttyhunk to Block Island	1-80 000
114	Newport to Plum Island	1-80 000
146	Ocracoke Inlet to Beaufort	1-80 000
154	Isle of Palms to Hunting Island	1-80 000
157	Sapelo Island to Amelia Island	1-80 000
157	.....do	1-80 000
158	St. Mary's Entrance to latitude 30° north	1-80 000
169	Newfound Harbor Key to Boca Grande Key	1-80 000
169	.....do	1-80 000
170	Key West to Rebecca Shoals	1-80 000
171	Rebecca Shoals to Dry Tortugas	1-80 000
177	Tampa Bay	1-80 000
203	Sabine Pass to High Island	1-80 000
203	.....do	1-80 000
204	Galveston Bay	1-80 000
204	.....do	1-80 000
205	Galveston Bay to Oyster Bay	1-80 000
205	.....do	1-80 000
210	Aransas Pass and Corpus Christi Bay	1-80 000
246	Boston Harbor	1-20 000

Chart No.	Title.	Scale.
246	Boston Harbor	1-20 000
255	Higganum to Rocky Hill	1-20 000
256	Rocky Hill to Hartford	1-20 000
337	Boston Harbor	1-40 000
348	Woods Hole, Mass	1-10 000
352	Port of Providence	1-10 000
353	Narragansett Bay	1-40 000
359	New London Harbor and Approaches	1-20 000
380	Philadelphia water front, Delaware River	1-9 600
381	Philadelphia water front, Schuylkill River	1-9 600
424	Cape Fear River, entrance to Reeves Point	1-40 000
431	Charleston Harbor, South Carolina	1-30 000
431	....do	1-30 000
445	Charleston and Vicinity	1-20 000
455*c*	St. Johns River, Hibernia to Racys Point	1-40 000
455*d*	St. Johns River, Tocoi to San Mateo	1-40 000
469	Key West Harbor	1-50 000
469	....do	1-50 000
520	Galveston Entrance	1-40 000
571	Port Royal Sound	1-40 000
909	Jobos Harbor, Porto Rico	1-20 000
5 002	San Diego to Point St. George	Mercator.
5 052	San Francisco to Cape Flattery	Mercator.
5 106	San Diego Bay	1-40 000
6 100	Cape Lookout to Grays Harbor	1-200 000
6 140	Columbia River, entrance to Upper Astoria	1-40 000
6 145	Columbia River, Fales Landing to Portland	1-40 000
6 400	Seacoast and interior waters of Washington	1-300 000
8 800	Alaska Peninsula	1-1 200 000

Number of plates for new charts completed	7
Number of plates for new editions of charts completed	51
Number of new miscellaneous plates completed	12
Number of plates for new charts commenced	9
Number of plates for new editions of charts commenced	41
Number of new miscellaneous plates commenced	12
Number of plates corrected for printing	992
Number of unfinished plates for new charts	14
Number of unfinished plates for new editions	23

PRINTING SECTION.

In addition to the regular work of this Section, file copies on bond paper from 1 395 old plates and similar copies from all plates for new charts and new editions of charts were made, which accounts for the large number of bond proofs in the tabular list. A file of five copies of each plate is maintained.

Number of impressions made for distribution	*59 287
proofs	7 950
standards	65
transfers, including those used in Drawing Section	517
on bond paper	7 511
Total number of impressions	75 330

*This number includes 561 copies of the Pan-American Exposition plate and 52 copies of the base map of the United States. Thirteen hundred and thirty-six copies required two impressions and 1 405 copies four impressions.

In addition to the number of charts printed from copper plates, the following charts were published by contract with photo-lithographers:

NEW CHARTS.

Chart No.	Title.	Scale.
293	New London Harbor and Approaches	1-10 000
517	Sabine Lake and Pass	1-40 000
577	Fernandina to Jacksonville	1-40 000
913	Great Harbor, Culebra Island, West Indies	1-6 500
919	Fajardo Harbor, Porto Rico	1-10 000
1 002	Straits of Florida and Approaches	Mercator.
1 007	Gulf of Mexico	Mercator.
4 103	Hilo Bay, Hawaiian Islands	1-10 000
4 104	Maalaea Bay, Hawaiian Islands	1-10 000
4 105	Kahului Harbor and Approaches, Hawaiian Islands	1-10 000
4 106	Kaunakakai Harbor, Hawaiian Islands	1-10 000
4 231	Port of Manila, Philippine Islands	1-10 000
4 241	Port Sual, Luzon Island, Philippine Islands	1-10 000
8 455	Yakutat Bay, Alaska	1-80 000
9 302	Bering Sea, eastern part	Mercator.
	Three Maps of Provisional Boundary Line, Alaska, vicinity of Dalton Trail, White and Chilkoot Passes.	

NEW EDITIONS.

Chart No.	Title.	Scale.
244	Salem Harbor and Approaches	1-20 000
268	Sheffield Island to Westcott Cove	1-10 000
269	Stamford Harbor to Little Captain Island	1-10 000
468	Palatka to Lake Monroe	1-80 000
517	Sabine Pass and Lake	1-40 000
549	Approaches to Baltimore Harbor	1-40 000
571	Port Royal Sound	1-40 000
908	San Juan Harbor, Porto Rico	1-10 000
911	Ponce Harbor, Porto Rico	1-20 000
1 001	Chesapeake Bay to Jupiter Inlet	Mercator.
3 089	Olympia. Wash., to Mount St. Elias	1-1 200 000
4 100	Hawaiian Islands	1-600 000
4 202	Guam Island	1-80 000
5 002	San Diego to Point St. George	Mercator.
5 052	San Francisco to Cape Flattery	Mercator.
5 832	Humboldt Bay, California	1-30 000
6 195	Grays Harbor, Washington	1-40 000
6 400	Seacoast and Interior Waters of Washington	1-300 000
7 000	Cape Flattery to Dixon Entrance	1-1 200 000
8 050	Dixon Entrance to Head of Lynn Canal	1-600 000
8 179	Port McArthur, Washington	1-10 000
9 007	Unalaska Bay, Alaska	1-40 000
9 302	Bering Sea, eastern part	Mercator.
9 372	Yukon River, Apoon Mouth	1-80 000
9 373	Yukon River, Kwiklowak Mouth	1-80 000
9 375	St. Michael Bay, Alaska	1-20 000
9 380	Norton Sound, Alaska	1-400 000

NEW PRINTS.

Chart No.	Title.	Scale.
549	Baltimore Harbor	1-200 000
1 000	Cape Sable to Cape Hatteras	Mercator.
1 007	Gulf of Mexico	Mercator.
5 052	San Francisco to Cape Flattery	Mercator.
8 000	Dixon Entrance to Cape St. Elias	1-1 200 000

PHOTOGRAPHING SECTION.

The facilities of this Section were increased by moving it into larger and more convenient quarters. Numerous negatives were made as required in the various operations of the Office and more than 1 000 prints were mounted. The work in this Section greatly facilitates the work in the other Sections of the Division.

ELECTROTYPING SECTION.

Work in this Section was in constant demand and much depends upon the prompt execution of all demands upon it.

Number of pounds of copper deposited	2 074
Number of alto plates made	59
Number of basso plates made	36

CHART DIVISION.

Personnel.

Name.	Occupation.
Gershom Bradford	Inspector of Charts and Chief of Division.
Miss L. A. Mapes	Chief of Chart Section.
W. C. Willenbucher	Draftsman.
E. H. Wyvill	Chart Corrector.
H. R. Garland	Chart Corrector.
J. B. Quinlan	Clerk.
Neil Bryant	Clerk (July 1 to Dec. 25).
Miss M. L. Handlan	Buoy Colorist.
A. B. Simons, jr	Buoy Colorist.
R. F. Le Mat	Buoy Colorist (Sept. 1 to Jan. 30).
Wm. A. Naghten	Buoy Colorist (Feb. 4 to June 30).
M. W. Long	Buoy Colorist (May 9 to June 7).
Archie Upperman	Map Mounter.
S. B. Wallace	Messenger.
TEMPORARY FORCE.	
V. Sournin	Draftsman (Oct. 16 to Nov. 27).
Wm. Bauman, jr	Draftsman (Dec. 15 to Mar. 23).
P. B. Castles	Draftsman (June 29 to June 30).

The Chief of this Division gave personal attention to the final inspection of new charts and new editions in their various stages of progress. The work of the Division was divided into two sections, the Chart Section and the Hydrographic Section.

1. THE CHART SECTION.

In this Section all correspondence relating to charts was carried on, and the accounts with sales agents were kept. Corrections to printed charts were made before they were issued to the persons requiring them. The work of coloring buoys on the charts, of mounting maps and charts, and other routine work was done in this Section. A new edition of the Chart Catalogue for 1900 was prepared and published. Copies of 15 new charts, printed by photolithography, were received for distribution. Forty-six new copperplate editions, and 22 new lithographic editions, 71 in all, were received for issue.

Sale agencies.

Agencies established	5
Agencies discontinued	1
Agencies now existing	175

Publications sent to sale agencies.

	Volumes.
United States Coast Pilot, Atlantic coast	1 193
Pacific Coast Pilot, California, Oregon, and Washington	46
Total issue	1 239
Tide Tables, United States and foreign ports	592
Tide Tables, Atlantic coast	611
Tide Tables, Pacific coast	5 050
Total issue	6 253

These figures represent only the volumes issued for sale. Omitting the issues for 1898 and 1899, when the issue of charts was abnormal on account of the war with Spain, the total issue for the fiscal year ending June 30, 1901, was 14 per cent larger than the average issue (1889 to 1901). The net sales were 16 per cent larger and the net value 20 per cent larger for the same period.

Charts were received as follows:

From Drawing and Engraving Division	53 125
From lithographers	15 009
	68 134

Charts were issued as follows:

	No. of charts.
Sales agents	34 795
Sales at the Office	1 018
Congressional account	2 712
Hydrographic Office, United States Navy	11 991
Light House Board	2 321
Coast and Geodetic Survey Office	6 049
Coast and Geodetic Survey Sub-Office at Manila	108
Executive Departments	4 042
Foreign governments	420
Libraries	104
Miscellaneous	936
Total	64 496

HYDROGRAPHIC SECTION.

The work in this Section is shown in the following tabular statement. Messrs. Willenbucher and Wyvill executed the work with the aid of the temporary force assigned to the Division from time to time for short periods.

A notice to mariners was prepared and issued each month. The hydrographic sheets received from the field parties were examined and verified and the work necessary to complete them was done. This involved a large amount of plotting, as shown in the tabular statement:

Charts corrected	2 034
Volumes of field records examined	214
Angles plotted or examined	54 279
Soundings plotted	179 092
Miles of sounding lines plotted	6 276
Original sheets prepared	14
Sheets verified	21
Sheets protracted	2
Miscellaneous drawings and tracings made	48
Reductions of hydrography verified	48
Proofs overhauled	37

INSTRUMENT DIVISION.

Personnel.

Name.	Occupation.
E. G. Fischer	Chief of Division.
W. C. Maupin	Clerk.
C. Jacomini	Instrument maker.
W. R. Whitman	Do.
M. Lauxmann	Do.
J. A. Clark	Do.
O. St. Marie	Instrument maker (June 18 to June 30).
H. O. French	Carpenter.
G. W. Clarvoe	Do.
C. N. Darnall	Do.
J. W. Hunter	Messenger (July 1 to Dec. 24).
Jere Hawkins	Messenger (Dec. 25 to June 30).

The accounting for the instruments and general property of the Survey was done in this Division. This involved the checking of the inventories submitted annually by all parties having charge of Government property in use by the Survey and the entry on the books of the Office of all property purchased by those employed in the Survey in executing the work assigned to them.

All instruments received from the field were examined and the necessary repairs made before sending them out for use in the field. During the year more than 1 600 instruments of various kinds were cleaned, adjusted, and sent to the field. Minor repairs to the Office buildings and to the office furniture were made.

The construction of twelve new plane table Alidades was undertaken and considerable progress made.

Two meridian telescopes (Nos. 2 and 16) were remodeled and repolished, and several changes were made to improve the instruments. Considerable time was spent in preparing the instruments loaned to the Baldwin-Zeigler Polar Expedition and in instructing the observer in their use.

An electric apparatus for indicating changes in water level at any distance from the point of observation was purchased for use in the Office of the Philadelphia Maritime Exchange, and the changes and improvements necessary to adapt it for use as a tide indicator were completed.

The Japanese Government having requested the Survey to supervise the construction of a 5-meter iced bar and base tape apparatus by a private firm, the Chief of this Division was assigned to that duty, and it was successfully performed. He also took part in the comparisons necessary to standardize this apparatus. He performed similar duty in connection with the construction of a 100-meter base tape apparatus for the Trigonometical Survey of the Straits Settlement.

The exhibit of the Coast and Geodetic Survey at the Pan-American Exposition was prepared and packed for shipment.

LIBRARY AND ARCHIVES.

Personnel.

Name.	Occupation.
Edw. L. Burchard	Chief of Division.
J. H. Smoot	Clerk.
A. F. Zust	Writer.
E. K. Foltz	Writer.
Mrs. M. A. Grant	Writer (June 7 to June 30).
W. H. Butler	Messenger.

The library is essentially for the purpose of reference, and this use of it involved much labor on the part of the personnel.

The daily calls upon the archives for original records also requires much time in charging the records issued to individuals using them and in crediting them when returned. The system used enables the librarian to quickly locate the records in use when they are not found on the shelves.

The indexing of the archives made steady progress, and during the year all of the astronomic records and half of the geodetic records and computations were examined and indexed. The principal growth of the library during the year was from exchanges with various foreign institutions, as shown in the following table:

Items.	Purchased.	Donated.	Exchanged.	Total.
Books	208	41	99	348
Pamphlets	29	311	333	673
Serials	69	303	710	1 082
Maps and charts	57	396	1 267	1 720
Total	363	1 051	2 409	3 823

The issues from the library and archives were as follows:

Books and pamphlets	1 745
Serials	458
Records	2 371
Original sheets	2 793
Maps and charts	1 221
Total	8 588

The following list shows the original records received:

	Volumes.	Cahiers.	Sheets.
Astronomy	9		16
Goedesy	137		
Gravity	4		
Hypsometry	132		
Magnetics		428	
Hydrography	230		57
Tides	100		100
Topography		134	48
Miscellaneous	115		
Total	727	562	221

Three hundred and fifty-nine books (including records) were sent to the bindery to be bound.

MISCELLANEOUS DIVISION.

Personnel.

Name.	Occupation.
H. C. Allen	Clerk.
E. B. Willis	Clerk (July 1 to Jan. 5).
C. W. Jones	Writer (Jan. 9 to June 30).
Thomas McGoines	Messenger.

By direction of the Superintendent, Mr. Scott Nesbit, Disbursing Agent, performed the duties of Chief of this Division during the year.

The Division was charged with the purchase and distribution of the supplies required for use in the Office and of such supplies as are furnished to the field parties on requisition; also with the making of requisitions for printing and binding, and the custody of blank forms, stationery, etc., these duties having formed the greater part of the occupation of the clerical force of the Division.

In addition to the above, the Division was charged with the distribution of the Reports of the Superintendent, and of all other publications of the Coast and Geodetic Survey, with the exception of charts.

The following is a statement of the publications received and issued during the year:

The following publications were received from the Public Printer:

Report of the Superintendent of the Coast and Geodetic Survey showing the progress of the work from July 1, 1898, to June 30, 1899	1 940

Geodesy. The International Geodetic Association for the Measurement of the Earth, by Erasmus D. Preston, Appendix No. 3, Report for 1898–99	400
Geodesy. Determination of Gravity at Worcester, Mass., and New York City, by Edwin Smith, Assistant, Appendix No. 4, Report for 1898–99	150
Hypsometry. Resulting Elevations from Spirit Leveling between Denver, Colo., and Rock Creek, Wyo., from Observations by Isaac Winston, Assistant, between May and October, 1899, by Isaac Winston, Assistant, Appendix No. 5, Report for 1898–99	150
Hypsometry. Resulting Elevations from Spirit Leveling between Abilene, Kans., and Norfolk, Nebr., from Observations by A. L. Baldwin, Assistant, and B. E. Tilton, Aid, between May 8 and October 17, 1899, by B. E. Tilton, Aid, Appendix No. 6, Report for 1898–99	150
Hypsometry. Resulting Elevations from Spirit Leveling between Gibraltar, Mich., and Cincinnati, Ohio, from Observations by O. W. Ferguson, Assistant, between June 3 and November 28, 1899, by O. W. Ferguson, Assistant, Appendix No. 7, Report for 1898–99	150
Hypsometry. Precise Leveling in the United States, by John F. Hayford, Assistant, Inspector of Geodetic Work, and Chief of Computing Division, Appendix No. 8, Report for 1898–99	2 000
Terrestrial Magnetism. General Report on the Magnetic Survey of North Carolina, by James B. Baylor and Daniel L. Hazard, under the direction of L. A. Bauer, Assistant, Inspector of Magnetic Work, and Chief of Division of Terrestrial Magnetism, Appendix No. 9, Report for 1898–99	1 000
Terrestrial Magnetism. The Magnetic Work of the United States Coast and Geodetic Survey, by L. A. Bauer, Assistant, Inspector of Magnetic Work, and Chief of Division of Terrestrial Magnetism, Appendix No. 10, Report for 1898–99	1 000
Tide Tables for the Pacific Coast of the United States, including British Columbia and Alaska, reprinted from Tide Tables for 1901	7 065
Tide Tables for the Atlantic Coast of the United States, including Canada and the West Indies, reprinted from Tide Tables for 1901	3 120
Tide Tables for the year 1901	2 025
Tide Tables for the Pacific Coast of the United States, together with a number of foreign ports in the Pacific Ocean, reprinted from Tide Tables for 1902	7 080
Tide Tables for the Atlantic Coast of the United States, including Canada and the West Indies, reprinted from Tide Tables for 1902	3 000
Tide Tables for the year 1902	2 025
Special Publication No. 3, Atlas of the Philippine Islands	1 500
The Transcontinental Triangulation and the American Arc of the Parallel, by Chas. A. Schott, Chief of the Computing Division, Special Publication No. 4	3 015
Special Publication No. 6, Notes relative to the use of charts	7 005
Bulletin No. 40, Third Edition; with additions and changes. Alaska. Coast Pilot Notes on the Fox Islands Passes, Unalaska Bay, Bering Sea and Arctic Ocean, as far as Point Barrow	1 500
Bulletin No. 41. Magnetic Survey of North Carolina. Values of the magnetic declination at the county seats from 1750 to 1910. Prepared by D. L. Hazard, Computer, Division of Terrestrial Magnetism	1 000
Catalogue of Charts, Coast Pilots, and Tide Tables, 1900	2 500
Supplement to the reprint of Second Edition United States Coast Pilot, Atlantic Coast, Part V, from New York to Chesapeake Bay Entrance, December 19, 1900	600
United States Coast Pilot, Atlantic Coast, Part VII, from Chesapeake Bay Entrance to Key West	1 400
United States Coast Pilot, Atlantic Coast, Part V, from New York to Chesapeake Bay Entrance, Second Edition, reprint, with supplement	612
United States Coast Pilot, Atlantic Coast, Part VIII, Second Edition, Gulf of Mexico, from Key West to the Rio Grande	1 500

The publications issued were as follows:

Annual Reports (covering the years 1851 to 1899)	2 864
Appendices to Annual Reports	2 473
Bulletins	2 172
Tide Tables, General, 1898	2
Tide Tables, General, 1899	2
Tide Tables, General, 1900	67
Tide Tables, General, 1901	1 250
Tide Tables, General, 1902	52
Tide Tables, Atlantic Coast, 1893	2
Tide Tables, Atlantic Coast, 1894	2
Tide Tables, Atlantic Coast, 1895	2
Tide Tables, Atlantic Coast, 1900	4
Tide Tables, Atlantic Coast, 1901	839
Tide Tables, Atlantic Coast, 1902	4
Tide Tables, Pacific Coast, 1896	2
Tide Tables, Pacific Coast, 1900	307
Tide Tables, Pacific Coast, 1901	5 368
United States Coast Pilot, Atlantic Coast, Parts I-II	214
United States Coast Pilot, Atlantic Coast, Part III	241
United States Coast Pilot, Atlantic Coast, Part IV	480
United States Coast Pilot, Atlantic Coast, Part V	189
United States Coast Pilot, Atlantic Coast, Part VI	104
United States Coast Pilot, Atlantic Coast, Part VII	299
United States Coast Pilot, Atlantic Coast, Part VIII	30
Pacific Coast Pilot, California, Oregon, and Washington	31
Pacific Coast Pilot, Alaska	5
Catalogue of Charts, Coast Pilots and Tide Tables	1 114
Supplement to Coast Pilot Rules of the Road at Sea	1
Notice to Mariners, Nos. 259 to 272	59 412
Special Publication No. 1	18
Special Publication No. 2	120
Special Publication No. 3	1 443
Special Publication No. 4	1 719
Special Publication No. 5	72
Special Publication No. 6	5 140
Rules Governing Routine and Discipline aboard Ship	11
The Star Factors, A B C for Reducing Transit Observation	3
Laws and Regulations relating to the Coast and Geodetic Survey of the United States	16
Laws of General Application	3
Treatise on Projections, Craig	18
Deep-Sea Soundings and Dredgings, Sigsbee	5
Pillsbury's Gulf Stream	12
General Instructions for Hydrographic Parties	37
General Instructions for Hydrographic Work	1
Tables for Converting Customary and Metric Weights and Measures	232

SPECIAL DUTY.

Personnel.

Name.	Occupation.
C. A. Schott..	In charge of computation of arc measures.
Miss L. Pike..	Computer.
C. R. Duvall..	Do.

Assistant Schott continued in charge of the discussion of arc measures in the United States and the preparation of the results for publication.

The completion for publication of the computation and discussion of the eastern oblique arc of the United States required almost the entire time of the personnel until the MS. was submitted for publication on March 1, 1901. This arc extends from Maine to Louisiana along the eastern coast of the United States, and the discussion is based upon observations made from time to time as the necessity of extending the survey of the coast became urgent, covering nearly the whole period of the existence of the survey.

In consequence, the examination of records and reduction of results were exceptionally laborious.

The final proof of Special Publication No. 4, "The Transcontinental Triangulation," was read and the publication was issued in October, 1900. After March 1 the reduction of the arc along the western coast of the United States was taken up and the adjustment of the triangulation between the transcontinental triangulation and the Los Angeles base net, involving the solution of fifty-six normal equations, was completed.

The computation of latitude observations at three stations, not previously reduced, was completed, and the computation at four other stations nearly completed. The revision of former computations at other stations was in progress. On March 21 Assistant Schott was compelled to give up work on account of ill health and was not on duty at the Office after that date, though he continued to direct the work during the remainder of the fiscal year.

Miss Lilian Pike, computer, was in immediate charge of the work during this period, and executed Assistant Schott's directions.

APPENDIX No. 3.

REPORT 1901.

ON THE MEASUREMENT OF NINE BASE LINES ALONG THE NINETY-EIGHTH MERIDIAN.

BY

A. L. BALDWIN, Computer and Chief of Party.

WITH PREFACE BY

JOHN F. HAYFORD, Inspector of Geodetic Work.

CONTENTS.

ILLUSTRATIONS.

PREFACE.

Early in 1899 the writer was requested by Dr. H. S. Pritchett, then Superintendent, to consider the general questions involved in deciding upon the location and number of the bases which should control the length of the triangle sides in the ninety-eighth meridian triangulation, and to prepare instructions for the measurement of these bases. Among the suggestions made by Dr. Pritchett at this time, three were especially emphasized, namely: That it would be better to measure many bases at comparatively short intervals along the triangulation with a moderate degree of accuracy than to measure few at longer intervals with a very high degree of accuracy; that the bases could be measured at a much smaller cost if one party measured as many as possible in a single season in advance of the triangulation than if the customary plan were followed of measuring one base at a time as the connections with the triangulation were completed, and that the degree of accuracy in the base measures which it is necessary or desirable to attain should be ascertained, and the plans for the measurement made with reference to securing this accuracy as quickly and economically as possible. These suggestions have been followed faithfully.

Looking upon the methods of fixing the lengths in triangulation in the broad-minded manner forced upon one by these suggestions, one important point in regard to the selection of base sites appeared to call for an immediate decision and action.

An examination of the manner in which errors of length in a triangulation accumulate in passing from a base to a remote triangle side shows clearly that the most accurate part of the operation is the base measurement; that the accumulation of error is most rapid in passing from the base to the border lines of the base net, since poor geometrical conditions are necessarily encountered in the expansion from the base, and that the errors of length accumulate much more slowly in the chain of triangles between base nets than in the base nets, but that even here the errors are large in comparison with those involved in the base measures. If, then, in making a reconnaissance for a base it is found that two sites are available, on one of which the grades are small and uniform and the connection with the main chain of triangulation is difficult, and on the other heavy and rapidly changing grades are encountered but the geometrical conditions in the base figure are relatively good, it is evident that to select the second site is to weaken the base measures, which are the most accurate portion of the operation of fixing the lengths in the triangulation, and at the same time to strengthen the triangulation in the base net, which is the least accurate operation. Rough bases and good base nets are much to be preferred to smooth bases and poor base nets. Accordingly the reconnaissance party, which was about to select the sites for the bases from Kansas to southern Texas, was instructed to pay especial attention to securing good geometrical conditions in the base nets, even at a sacrifice of accuracy in the bases, and was informed that the accuracy of the base measures could be kept up to the required standard on any grade not exceeding 5 per cent, and that narrow, deep ravines or valleys should not be considered as obstructions to the base measures. These instructions had a decided effect in fixing the location of bases, and account for the relatively rough ground over which many of the bases were measured. The Lampasas Base * is a good example of a rough base in a good base net.

What degree of accuracy is it desirable to strive for in the measurement of base lines of which the sole function is to control the lengths in a triangulation? In the transcontinental triangulation the computed probable errors for the ten bases vary from 1 part in 128 000 (Kent Island Base) to 1 part in 1 600 000 (Salt Lake Base) and for only one base beside the Kent Island Base is the probable error greater than 1 part in 500 000, namely, the American Bottom Base, of which the probable error is 1 part in 353 000. The probable errors of the border lines of the base nets in the transcontinental triangulation vary from 1 part in 78 000 in the American Bottom base net to 1 part in 365 000 in the Yolo base net. After omitting the Kent Island base net because its base was measured with a very low degree of accuracy, in each of the remaining nine base nets the accumulation of error was so rapid that the probable errors of the border lines of the net, expressed as proportional parts, were from two to five times as great as the probable error of the base itself expressed in the same manner. The probable error of the lines in the triangulation most remote from the base varies from 1 part in 45 000 (Cape May to Cape Henlopen) to 1 part in 220 000 (Toiyabe Dome to Lone Mountain, between the Salt Lake and Yolo bases). From these figures, † and from similar indications from other triangulations in the United States and in foreign countries, it was evident that very little increase in the average accuracy of the lengths of the triangle sides of the ninety-eighth meridian triangulation would result from increasing the accuracy of the base measurement beyond that represented by a probable error of 1 part in 500 000. It was therefore decided to use this standard of accuracy in writing the instructions for the base measures.

A constant endeavor was made in planning for and making the base measures to keep the accuracy up to the standard by strengthening the methods of the past at their weakest points, while, at the same time, increasing the rapidity of the operation by such omissions of refinements and of additional measures as would have simply the effect of reducing the strength of the past methods at their strongest points.

A careful study of the past base measures, in which the writer was ably assisted by Mr. A. L. Baldwin, indicated clearly that although such measures are ordinarily of more than sufficient accuracy in so far as accidental errors are concerned, they have two weak points with reference to constant errors. Each base has usually been measured with but one set of base apparatus, or, at least, with but one type of apparatus. The apparatus is usually standardized under one set of conditions at headquarters, and used under another set of conditions in the field.

In so far as the writer is aware, there has been no exception to the rule that, whenever a base or part of a base has been measured with two different types of base-measuring apparatus, discrepancies between the measures have developed which were larger than could be accounted for by the accidental errors and too large to be consistent with the degree of accuracy which was supposed to be attainable with the apparatus. All of the

* See page — and the illustration opposite page —.

† See the "Transcontinental Triangulation," pages 247, 350–351, 368, 395, 417, 434, 451, 480, 514, 551, 567, 592, and 611.

evidence available indicates strongly that each type of base apparatus, and possibly each particular apparatus even of one type, should be suspected of being subject to an error peculiar to itself. In the base measures of 1900 it was determined to reduce such errors to smaller proportions by making the length of each base depend on several sets of apparatus of two different types.

A study in detail of the primary base measures made by the Coast and Geodetic Survey during the last ten years, namely, of the Holton, St. Albans, Salina, Salt Lake, and Versailles bases, and of the manner in which the apparatus was standardized in each case, left little room for doubt that there is an intimate relation between the conditions under which the apparatus is used or standardized and the systematic or constant errors in the results obtained. The evidence is very strong that the more serious errors are those due to erroneous determinations of the temperature of the measuring bar or tape. In general it seems to be true that the bar thermometer and the bar do not have the same temperature, and similarly mercurial thermometers seldom give the temperature of a tape accurately. It is not certain that, even with the duplex bar apparatus used independently of the thermometers, the temperature deduced from the relative expansion of the two bars was accurate. The evidence indicated strongly that the errors in temperature to be feared were dependent upon whether the apparatus was in sunlight, shade, or darkness; in rapidly rising, stationary, or falling temperatures, or inside a building, shed, or yard, or in the open fields. It was apparent that it was unsafe to assume that the length of either a bar or a tape as determined at the Office under a selected set of conditions supposed to be favorable to great accuracy, as, for example, at night undei a shed and with nearly constant temperatures, is applicable to that same apparatus under the widely different conditions encountered in the field. It seemed obvious that the proper procedure is to standardize the apparatus in the field under conditions as nearly as possible corresponding to those encountered in the base measures.

The Woodward iced bar is the only apparatus in the possession of the Coast and Geodetic Survey to which the above statements do not apply.

In the instructions for the base measurement quoted at the beginning of the following report there are four points on which especial stress is laid and of the importance of which the preceding paragraph should be sufficient explanation: First, the time and money to be used in both the standardization and the base measurement are limited strictly to the amounts necessary to keep the accidental errors down to the limit indicated by a probable error of 1 part in 500 000; second, five sets of apparatus of two different types are to be used on each base; third, the five sets of apparatus are each standardized at the beginning and end of the season and intercompared on each base on the so-called test kilometer, and therefore these measures afford unusual opportunities to determine the actual accuracy attained; fourth, the standardizing in the field is done under conditions which are as nearly as possible identical with those encountered in the base measures.

It was confidently expected that the unusual skill which would be acquired by a party making measurements of several bases in quick succession would help greatly in making the required measures rapidly and at a small cost. It may be noted also that the instructions or orders as written and enforced prohibited experimenting and striving for unnecessary accuracy, and encouraged the neglect of unessential precautions.

The writer feels that he can fearlessly invite a critical examination of the facts set forth fully and fairly in the following report. He believes that under such a critical examination these base measures will be found to have been made with a rapidity and economy that is unexcelled; that in so far as accidental errors are concerned they are more accurate than is necessary, the excess of accuracy having been attained, however, by the use of judgment and skill rather than time and money; and that in so far as systematic or constant errors are concerned, they bear within themselves positive evidence of their degree of reliability, and that this degree of reliability is certainly not less than in any of the base measurements of the past.

The writer desires to acknowledge here his full appreciation of the fact that the success of the base measurements of 1900 is due to the zeal, ability, and faithfulness with which the field operations were carried on by Mr. A. L. Baldwin and his party.

THE MASSACHUSETTS INSTITUTE TAPE APPARATUS.

It being known to the Superintendent that there had been developed at the Massachusetts Institute of Technology a new form of tape apparatus of great promise, the writer was authorized to use the opportunity afforded by a visit of inspection to the base party at Alice, Tex., in December, 1900, to make a test of this apparatus to determine its adaptability to the measurement of primary bases. The President of the Massachusetts Institute kindly loaned the apparatus to the Coast and Geodetic Survey for that purpose. Certain tests were made at Washington in November, 1900. In December the writer and Prof. A. E. Burton, of the Massachusetts Institute, aided by the base party, made other tests of the apparatus on the Alice base. As these tests are closely associated with the base measures here reported, it seems appropriate that the conclusions derived from them should be stated here.

Little has yet been published in regard to this apparatus.* It has been developed gradually during the last fourteen years by students of the Massachusetts Institute of Technology, acting under the direction of Prof. A. E. Burton, several theses having been written on different phases of this subject.

The important feature of this form of tape apparatus is the device for obtaining the temperature of the tape. The whole length of the 100-meter tape and an approximately equal length of German-silver wire form two of the arms of a Wheatstone bridge. The two variable arms of the bridge, together with the telephone which is substituted in the place usually occupied by a galvanometer, and the necessary interrupter, batteries, and connections form the thermophone proper. The thermophone has been patented by Messrs. Henry E. Warren and George C. Whipple, and is manufactured by E. S. Ritchie & Sons. It has been used for determinations of temperatures in various ways, and the work of the students at the Massachusetts Institute now under consideration is mainly that of developing this apparatus to use with long measuring tapes.

The electrical resistance of the steel tape varies more rapidly with a change of temperature than does that of the German silver. The ratio of the resistance of the tape

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*For a short account of the apparatus, together with a statement of the 1900 tests, see Technology Quarterly, June, 1901, p. 82.

to that of the German silver is therefore a measure of their temperatures. Or, with sufficient accuracy, it is a measure of the temperature of the tape, provided the German silver is similarly exposed, so as to have approximately the same temperature as the tape. This ratio is the quantity really measured by the thermophone. The thermophone dial, over which moves a pointer which indicates the position of the contact point regulating the two variable arms of the bridge, is graduated so as to indicate the temperature of the tape in Fahrenheit degrees.

In regard to the Massachusetts Institute tape apparatus as a whole, the writer is convinced:

1. That with the themophone apparatus in its present form, and using all refinements, measures can be made even in daylight, and when the temperatures are varying rapidly, with a much higher degree of accuracy than is possible with tapes and mercurial thermometers even under good conditions at night.

2. That after the apparatus has been modified and strengthened at certain points with reference to making it proof against comparatively rough usage and capable of quicker manipulation, certain refinements being omitted, much more rapid measures can be made with it than with any form of bars, and probably more rapid than with the present form of tape apparatus if the tripod method rather than the stake method is used.

3. That it can be used efficiently with no more previous preparation of the ground than is necessary for bar measurement by substituting tripods for the marking stakes at the tape ends and for the intermediate supports.

A few remarks may be necessary to explain the reference above to a possible tripod method of measurement with tapes. Base measurements with bars have ordinarily been made with the bars supported upon portable tripods. It has not been feasible to measure primary bases with tapes similarly supported upon tripods, since it was absolutely necessary to make the measures at night to secure the necessary degree of accuracy with the means heretofore available for determining the temperature. The thermophone apparatus determines the temperature with all necessary accuracy in daylight. Hence, it is now possible to substitute tripods or other portable supports, which may be placed in position as the measurement progresses, for the fixed stakes which have heretofore been used. With a well-organized base party, familiar with the work, the setting of the stakes requires considerably more time than the subsequent double-tape measure of the base.

JOHN F. HAYFORD,
Inspector of Geodetic Work.

101°
95°
41°
39°
37°
35°
33°
31°
29°
NEBRASKA
IOWA
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
INDIAN TERRITORY
LOUISIANA
TEXAS
O'Neill
Page Base
Plainview
Norfolk
Columbus
Omaha
Shelton Base
Kansas City
Paola
Garnett
Wichita
Fredonia
Anthony Base
Anthony
Medford
El Reno
El Reno Base
Bellevue
Bowie Base
Bowie
Ft. Worth
Stephenville
Stephenville Base
Brownwood
Lampasas
Lampasas Base
Cameron
Seguin Base
San Antonio
Seguin
Flatonia
Houston
Kenedy
Alice
Alice Base
LOCATION OF BASE LINES

ON THE MEASUREMENT OF NINE BASES ALONG THE NINETY-EIGHTH MERIDIAN.

By A. L. BALDWIN, *Computer and Chief of Party.*

GENERAL STATEMENT.

The general plan for the measurement of nine bases along the ninety-eighth meridian was presented to the writer in the form of instructions from Dr. Henry S. Pritchett, at that time Superintendent of the Coast and Geodetic Survey. A thorough understanding of the campaign will be hastened by printing an extract from these instructions, dated in May and July, 1900:

You will be detailed to take charge of a field party which is to measure nine bases along the ninety-eighth meridian, of which Page Base at the north, and Alice Base at the south end, are the extremes.

Four steel tapes, two 100 meters in length, and two 50-meter tapes, and the duplex base bars, are to be used in the measurement of the bases. A portion of each base, about 1 kilometer in length, is to be measured with all five sets of apparatus, and of the remainder of the base a portion is to be measured with the tapes and a portion with the bars.

Very little increase in the average accuracy of the lengths of the triangle sides of the ninety-eighth meridian triangulation will result from increasing the accuracy of the base measurement beyond that represented by a probable error of 1 part in 500 000. The following limits of accuracy on each operation are selected with a view to attaining a probable error but little if any greater than 1 part in 500 000 on each base. You will strive to keep as far within these limits as is possible by the use of good judgment and skill, but you will restrict the time and money expended upon each operation substantially to that required to keep barely within these limits.

You will standardize each tape and the duplex bars at the beginning of the field season upon a 100-meter comparator, which you will establish near Shelton Base for that purpose, by measuring the length of the comparator at least four times with each base apparatus. The measurements by each apparatus must not all be made on a single day or night. If four measures do not suffice to reduce the probable error of the mean for any apparatus below 1 part in 300 000, additional measures will be made until the probable error is reduced below that limit. The length of the comparator is to be determined by measuring it with the iced bar at such times that the longest interval between any such measurement and any measure with a piece of base apparatus for the purpose of standardization shall not exceed thirty-six hours. In computing the length of the bars and tapes, the length of the comparator shall not be assumed constant, but instead will at the time of each duplex or tape measurement be assumed to be that given by the nearest measurement with the iced bar, or by the mean of the last preceding and first following measurements. The bars and tapes are to be re-standardized in the same manner at or near the end of the field season. The conditions under which each form of apparatus is standardized should approximate as near as is feasible to those under which it is used in the actual measures of the base.

One kilometer of each base, to be known as the test kilometer, is to be measured with the duplex bars and once with each of the tapes. If any one of these five measures shows a residual from the mean of more than 17 milimeters, an additional measure of the test kilometer shall be made with that apparatus. Residuals of more than 17 milimeters on the test kilometer, which persist even after a remeasurement, shall be considered to indicate the desirability of re-standardization, but in no case shall the apparatus be standardized without special authorization, except at the beginning and ending of the season as indicated above.

Of the remainder of each base not less than one-tenth nor more than one-third is to be measured twice with the duplex bars; not less than one-fifth nor more than two-thirds is to be measured once with each 50-meter tape; and not less than one-fifth nor more than two-thirds is to be measured once with each 100-meter tape. Additional measures shall be made if the discrepancy between the two measures on any section exceeds $20^{mm} K$ (in which K is length of the section in kilometers) until two measures are obtained which agree within that limit. About one-fifth of the total length of all the bases after the test kilometers are deducted should be measured with the duplex bars, and about two-fifths each with the 50-meter tapes and the 100-meter tapes.

Such precaution should be taken to secure accurate horizontal and vertical alignment of the tapes and of the bars as is necessary to insure that the errors arising from this source on any section of the base shall be less than 1 part in 1 000 000. It is not desirable, however, to use any more time on this part of the operation than that necessary to keep well within the limit stated. This principle should also be applied to the determination of the tension on the tape while in use.

PARTY ORGANIZATION.

An effort was made to so arrange the party that the illness or disability of one man should not stop the work. A working force of ten persons was decided on and this number was varied only at the first base, where Mr. L. A. Fischer, Adjuster, of the Office of Standard Weights and Measures, had immediate charge of the preparations for and measures with the iced-bar apparatus, and when the employment of occasional day labor would increase the party's efficiency. The personnel of the party included the following:

A. L. Baldwin, Computer and Chief of Party, made all the contacts between the duplex components and forward contacts on all tape measures.

William Bowie, Assistant, aligned the bars for the duplex measures, made rear contact on tape measures, and had immediate charge of the setting of the tape supports.

Frank H. Brundage, Aid, spaced the trestles for the bar measures, ranged out the bases, aligned the tape supports in the vertical, and recorded for the tape measures.

Ora M. Leland, Aid, kept the record of the duplex bar measures and leveled the bases for tape grades and profile.

Prof. L. S. Smith, succeeded by R. S. Ferguson, Recorder, read the bar inclinations, thermometers, and assisted in the leveling operations.

Five laborers completed the party.

TIME TABLE.

The base map shows at once the general location of the nine bases, and the railroad lines there shown indicate the route followed by the party. July 16, 1900, was the date of the arrival and organization of the party at Shelton, Nebr., and after this date twenty-six days must be charged for each member of the party to the delays incident to the transportation from each base site to the one next in order of measurement. The movements of the party may be conveniently shown in tabular form.

Name of base.	Date of arrival.	Interval in days.	Remarks.
Shelton	July 16	31	Includes all comparator preparations and standardizations.
Page	Aug. 16	25	
Anthony	Sept. 10	17	
El Reno	Sept. 27	25	
Bowie	Oct. 22	16	
Stephenville	Nov. 7	13	
Lampasas	Nov. 20	17	
Alice	Dec. 7	14	
Seguin	Dec. 21	18	Includes all comparator preparations and standardizations.

The departure from the Seguin base began on January 18, 1901, so that, excluding the time spent in traveling, the average time spent at each base, not excluding Sundays and holidays, was 15.6 days.

UNIT OF LENGTH.

The 5-meter steel bar No. 17, designated as B_{17}, when immersed in melting ice, was the unit to which all determinations of length were directly referred. This bar No. 17 has been compared directly with Prototype Meter No. 21, designated as M_{21}, and known in terms of the International Meter. This makes, then, but two intermediate standards between the bars and tapes actually used on the base, and the international standard of length, the International Meter. Appendix No. 8, Report for 1892, pages 351–393, contains the complete description of the various determinations of its length in terms of the Prototype Meter No. 21, which were made previous to 1900. The length of the bar at the temperature of melting ice was there found to be 5 meters -16.2μ*. The probable error when referred to the Prototype Meter No. 21 is $\pm 0.4\mu$, but when referred to the International Meter, including the uncertainties of M_{21}, is $\pm 1.1\mu$, or one part in 4 500 000.

While this result was entirely satisfactory, the standardization of a similar bar for the Government of Japan, by the Office of Standard Weights and Measures, made the opportunity for a very desirable check on the constancy of B_{17}. These comparisons were made in July, 1900, by Mr. L. A. Fischer, of the Office of Standard Weights and Measures.

The Japanese 5-meter steel bar is identical in form and material with B_{17}, but has not the defect of having defining lines of unequal width,† these being, on the contrary, of uniform and equal width on the Japanese bar. A determination of the length of this bar, designated as J, was made to depend, first, upon comparisons with B_{17}, and second, upon comparisons with Prototype Meter No. 21.

Nine comparisons with B_{17}, five with B_{17} direct, and four with it reversed (turned end for end), gave the value of J in terms of M_{21},

$$J = 5M_{21} - 22\mu \pm 0.5\mu.$$

*The separate values for B_{17} in the sense A-end right or A-end left were neglected for this work as too small and uncertain to be taken into account and no attention was paid to reversing the bar.

† As described on page 340, Appendix No. 8, Report for 1892.

Eight direct comparisons with M_{21} in the manner fully described in sections 13 and 14 of Appendix No. 8, Report for 1892, were made with the resulting value of J in terms of M_{21},

$$J = 5M_{21} - 24.5\mu \pm 1.04\mu.$$

This result would indicate that the old value for B_{17} is too large by 2.5μ, or one part in 2 000 000, but when judged in the light of the probable errors no such conclusion can be reached. Viewed as a check this result is eminently satisfactory, and if weighted according to its probable error it would have little effect on the adopted length.

THE SHELTON 100-METER COMPARATOR.

This comparator was a line 100 meters long, prepared for measurement with the iced-bar apparatus. Nineteen well-seasoned pine posts, $1^{m}.8$ long and 15^{cm} by 15^{cm} in cross section, to hold the intermediate microscopes, were set firmly in the ground with $0^{m}.9$ projecting. The posts were accurately aligned and spaced with their centers 5^{m} apart, and the tops were sawed to the same horizontal plane. The ends of the line were marked by spherical-headed brass bolts cemented into the top of limestone blocks of peculiar shape designed to give them great stability in the direction of the line. These end monuments were 76^{cm} deep with a base 76^{cm} by 20^{cm} and top 20^{cm} by 20^{cm} (see illustration No. 2). They were set on a thin layer of gravel and rammed into position with the long side parallel to the line of the comparator. The end microscopes were mounted on heavy plates bolted to wooden piers constructed from four posts like the intermediate posts, well framed together (see illustration No. 3).

Alongside of the posts three sections of portable track were moved along the line with the progress of the measurement and supported on posts set midway between the microscope posts.

The site was chosen for the comparator by the writer in the level pasture of Mr. Joseph Owens, nearly a mile west of the town of Shelton, Nebr., and near Shelton East Base. It is parallel to the baseline and distant only about 30 meters from it.

The stability of these posts, piers, and stones may be inferred from the measures of the comparator interval which follow.

RESULTS OF MEASURES OF THE SHELTON COMPARATOR INTERVAL.

A detailed description of the iced-bar base apparatus, with instructions for its use and specimens of record and computation, may be found in Coast and Geodetic Survey Report for 1892, pages 338 to 350. Illustration No. 4 shows the apparatus in use on the Shelton comparator, and illustration No. 5 shows the method of aligning the bar in its trough horizontally, using a striding level resting on plugs about a meter apart. The speed of measurement varied only slightly from 100^{m} per hour, although single measures of the comparator interval were recorded in 50 minutes. The alignment of the bars in the vertical was accomplished by mounting a theodolite in the line of the end microscopes and bringing the intermediate microscopes into position as each was adjusted. Cut-off cylinder No. 1 was used at both ends of the line and its length was $1^{m}.01$, and the value of the level $2''.43$.

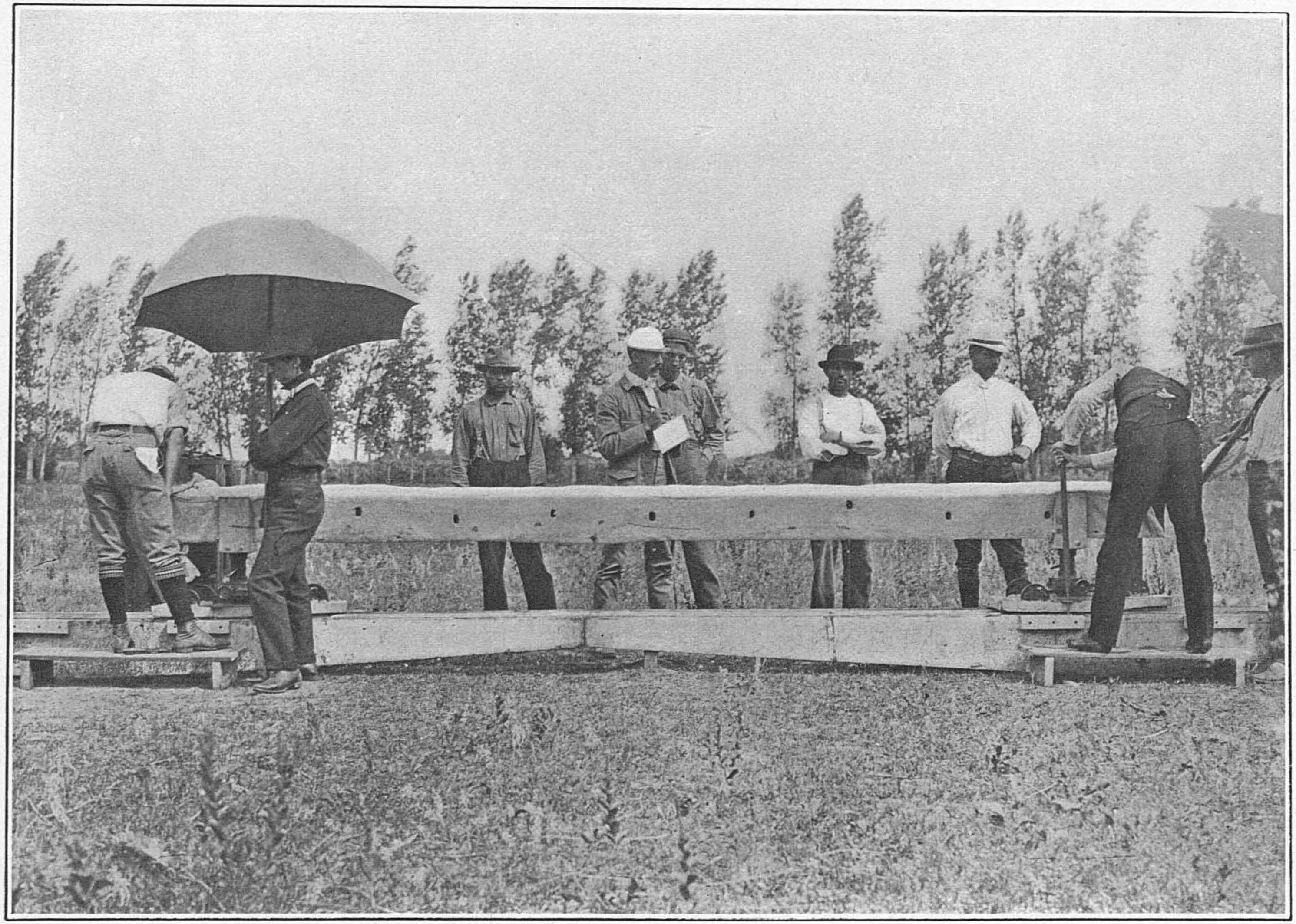
The end microscopes A and B, now called Nos. 1 and 2, have a value of one turn equivalent to 72.06μ and 71.2μ, respectively. The intermediate microscopes now numbered 3, 4, 5, and 6 have a value of one division equal to $1\ \mu$.

NO. 2.

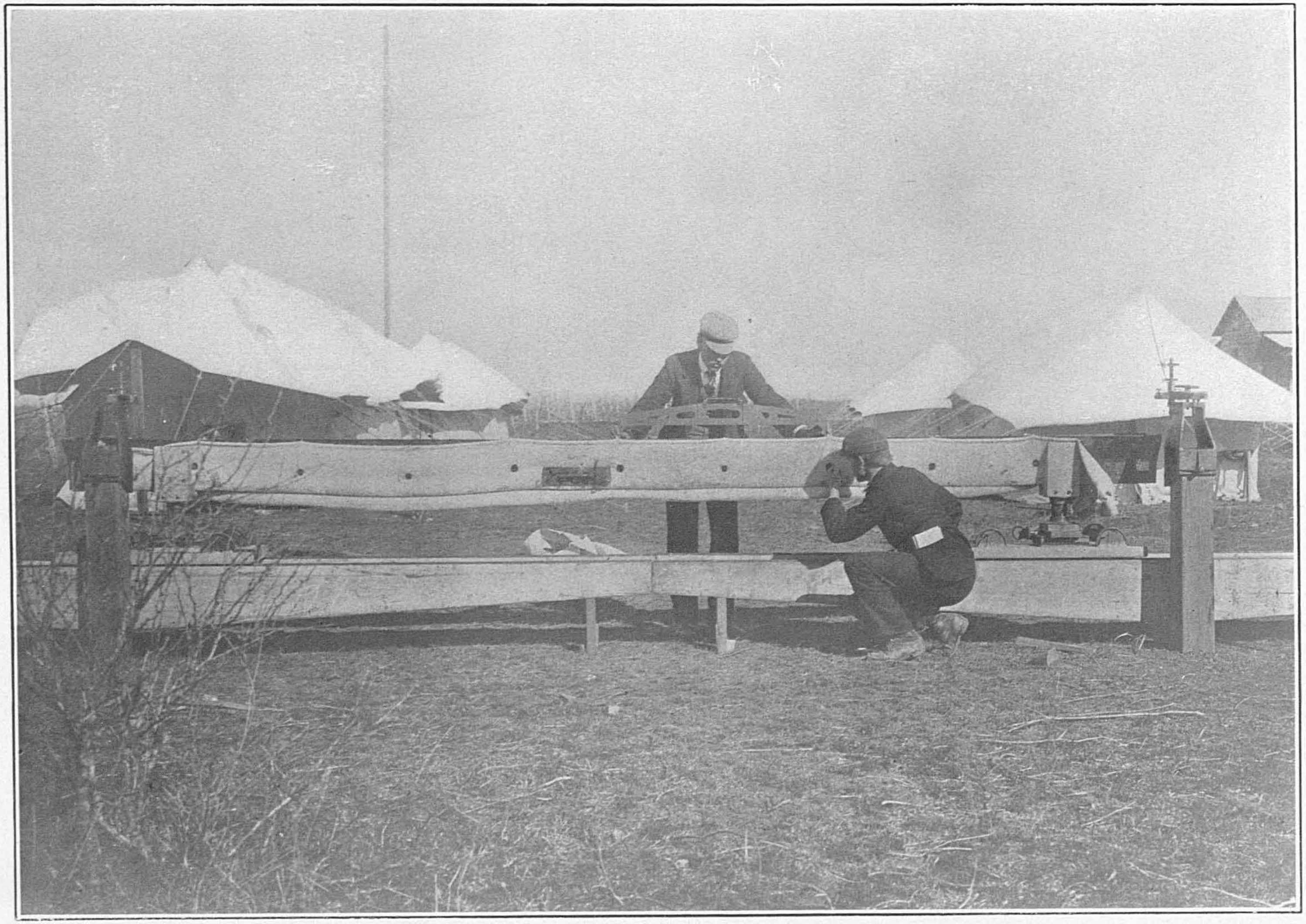
STONE FOR MARKING END OF COMPARATOR.

SUPPORT OF MICROSCOPE AT END OF COMPARATOR.

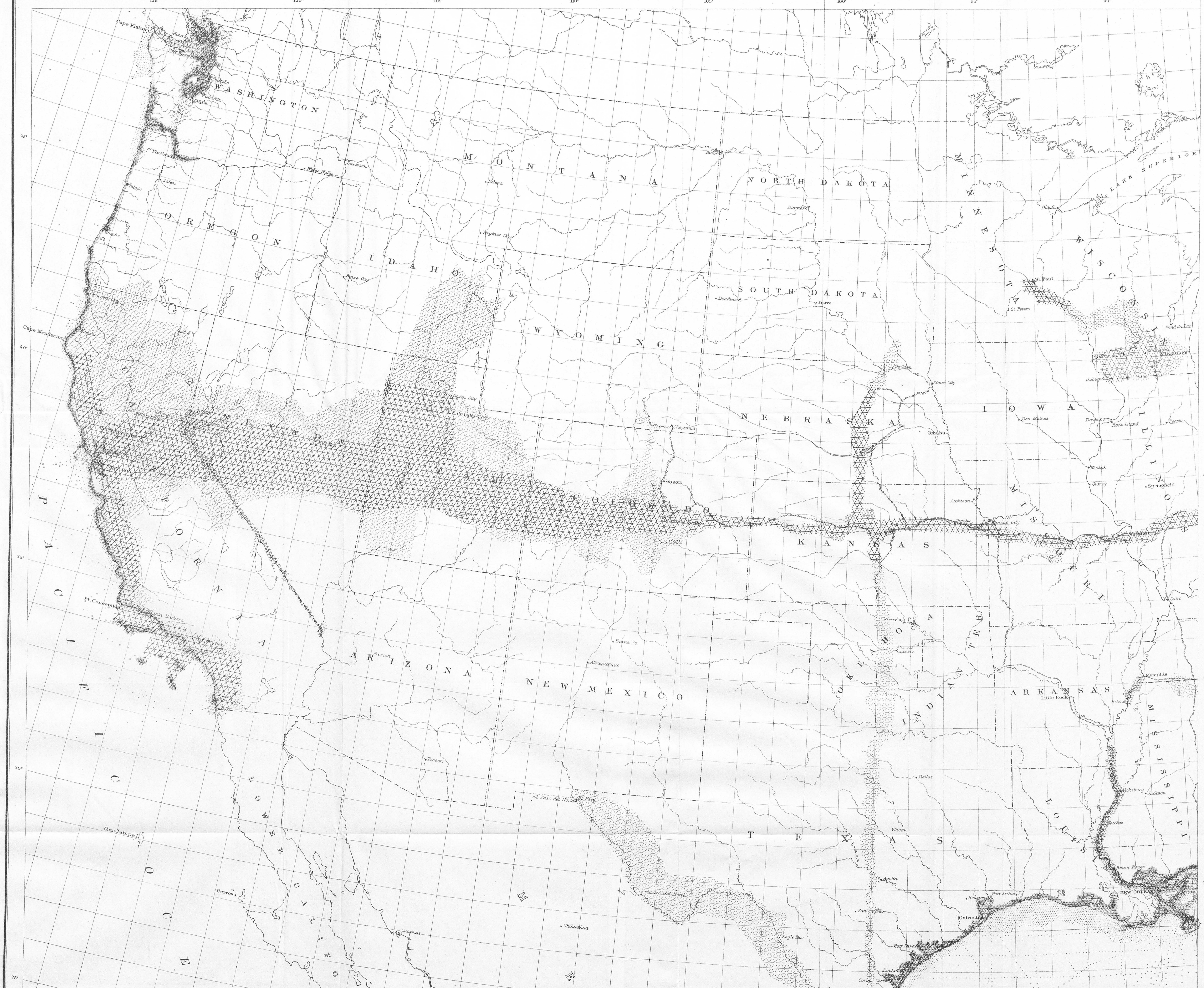
NO. 4.



ICED BAR IN USE.



ALIGNING ICED BAR WITH STRIDING LEVEL.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MISSOURI
KANSAS
COLORADO
NEVADA
UTAH
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
INDIAN TER.
TEXAS
ARKANSAS
LOUISIANA
MISSISSIPPI
LOWER CALIFOR
ME
PACIFIC OCE
LAKE SUPERIOR
Cape Flattery
Seattle
Olympia
Portland
Toledo
Salem
Empire
Walla Walla
Lewiston
Helena
Virginia City
Boise City
Cape Mendocino
Pt. Conception
Santa Barbara
Guadalupe I.
Cerros I.
Ogden City
Salt Lake City
Cheyenne
Denver
Pueblo
Santa Fe
Prescott
Albuquerque
Tucson
El Paso del Norte
Chihuahua
Guaymas
Eagle Pass
Laredo
Dallas
Waco
Austin
San Antonio
Houston
Galveston
Port Arthur
Port Lavaca
Corpus Christi
Bismarck
Deadwood
Pierre
Buford
Yankton
Sioux City
Omaha
Des Moines
Davenport
Rock Island
Peoria
Keokuk
Quincy
Springfield
Atchison
Topeka
Kansas City
Cairo
Guthrie
Little Rock
Memphis
Helena
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Jackson
Natchez
Baton Rouge
New Orleans
St. Paul
St. Peters
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Dubuque
Milwaukee
Fond du Lac
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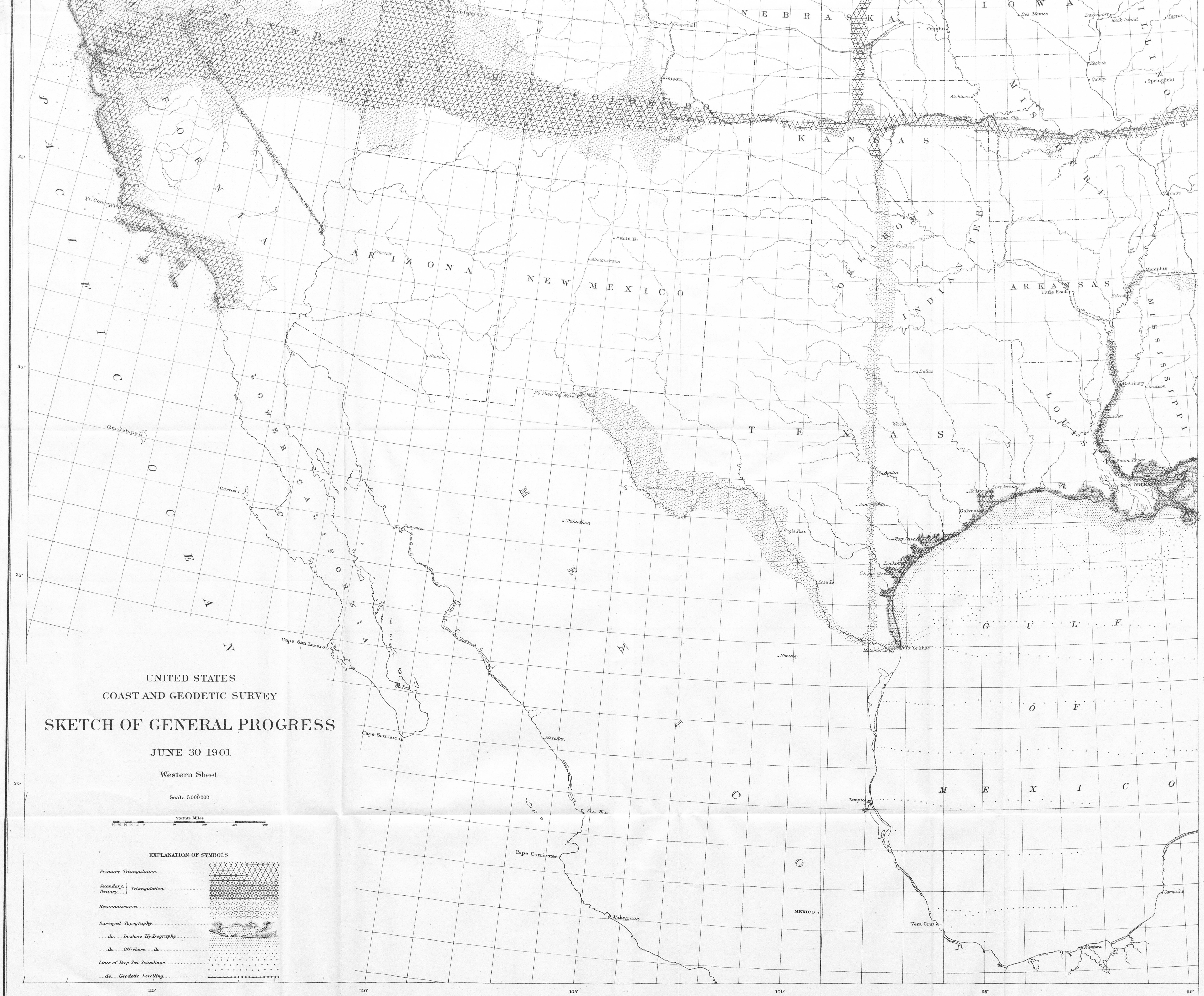


UNITED STATES
COAST AND GEODETIC SURVEY
SKETCH OF GENERAL PROGRESS
JUNE 30 1901
Western Sheet
Scale 5,000,000
Statute Miles
EXPLANATION OF SYMBOLS
Primary Triangulation
Secondary
Tertiary
Triangulation
Reconnaissance
Surveyed Topography
do. In-shore Hydrography
do. Off-shore do.
Lines of Deep Sea Soundings
do. Geodetic Levelling
PACIFIC OCEAN
GULF OF MEXICO
MEXICO
LOWER CALIFORNIA
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
INDIAN TER.
KANSAS
NEBRASKA
IOWA
ILLINOIS
MISSOURI
ARKANSAS
LOUISIANA
MISSISSIPPI
COLORADO
UTAH
NEVADA
CALIFORNIA
Salt Lake City
Cheyenne
Denver
Omaha
Des Moines
Davenport
Rock Island
Keokuk
Quincy
Springfield
Atchison
Topeka
Kansas City
Cairo
Memphis
Helena
Little Rock
Vicksburg
Jackson
Natchez
Baton Rouge
New Orleans
Port Arthur
Galveston
Houston
Austin
San Antonio
Waco
Dallas
Guthrie
Santa Fe
Albuquerque
Prescott
Tucson
El Paso del Norte
Presidio del Norte
Eagle Pass
Laredo
Corpus Christi
Rockport
Port Lavaca
Matamoras
Rio Grande
Monterey
Chihuahua
Guaymas
La Paz
Cape San Lucas
Cape San Lazaro
Cerros I.
Guadalupe I.
Pt. Conception
Santa Barbara
Mazatlan
San Blas
Cape Corrientes
Manzanilla
Mexico
Tampico
Vera Cruz
Frontera
Campeche
115°
110°
105°
100°
95°
90°
35°
30°
25°
20°
THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

The distance between the terminal spheres of the Shelton comparator was measured 10 times with B_{17} in melting ice, between July 26 and August 10. A measure as here designated means a determination of the comparator interval with readings both before and after the interchange of observers in reading on the ends of the bar. This interchange was made in all cases whether the observers were Fischer and Baldwin, as on the first two days, or Fischer and Bowie, as on the last three days.

Table No. 1 gives all the data for the length of the comparator. The first and second columns give the date and time of day of observations. The third column gives the direction in which the measure proceeded. The fourth column gives the results for the length from the single measures after the correction for the length of B_{17} has been applied, (20) ($-16.2\,\mu$), and the fifth column gives the mean result for the day.

TABLE NO. 1.—*Results for length of Shelton 100-meter comparator.*

Date.	Time of day.	Direction of measure.	Results for length of comparator.	Mean result for the day.
1900.	h.		mm.	m. mm.
July 26	9.1 a.m.	E. to W.	100 meters +22.39	
26	10.9 a.m.	W. to E.	+22.27	100+22.33
27	9.1 a.m.	E. to W.	+22.39	
27	10.5 a.m.	W. to E.	+22.26	+22.32
30	9.4 a.m.	E. to W.	+22.35	
30	10.7 a.m.	W. to E.	+22.08	+22.22
Aug. 2	4.8 p.m.	E. to W.	+22.08	
2	5.9 p.m.	W. to E.	+22.49	+22.28
10	4.7 p.m.	E. to W.	+22.13	
10	5.8 p.m.	W. to E.	+22.60	+22.36
			Mean =	100+22.30

DISCUSSION OF RESULTS OF THE SHELTON COMPARATOR MEASURES.

An inspection of these results shows no movement of the terminal spheres during the entire period and therefore a constant length for the comparator. The inspection also shows a decided tendency toward a large result when measuring away from the sun.

In considering this peculiarity it must be remembered that the practice followed throughout these measures was to shade the microscopes and iron caps which supported them while they were holding the measure. As soon as the microscope is shaded the side of the iron cap toward the sun begins to cool rapidly and the microscope begins to move toward the sun. The effect of this will be that, when the measurement proceeds toward the sun, too short a length for the comparator interval will be obtained, and vice versa. As there is no exception on the five days to this tendency, and as the observations made when the sun was farthest from the meridian show it most decidedly, it is apparent that a measure in each direction with the sun in the same position is necessary for a correct determination of the comparator interval.

The probable error of a single measure of 100 meters with this apparatus, when the entire comparator was protected from the sun, has been with various observers as follows:

	mm.
At Holton (see Report for 1892, Part II, p. 399)	±0.061
At Washington (see "Transcontinental Triangulation," p. 193)	±0.030
At Washington (see "Transcontinental Triangulation," p. 194)	±0.038

The residual from the mean, in the case of the tenth determination, exceeds five times the mean of these probable errors and would become a subject for rejection if the evidence of the sun's effect should be neglected. Moreover, the result for the length of the comparator interval will be 100 meters $+22^{mm}.30$ whether the mean be taken by days or individually.

The evidence is sufficient to show that each value in column 5 of Table No. 1 must be accepted as a single observation for the reason that it is necessary to take the mean of two consecutive measures in opposite directions to eliminate the effect of movement of microscopes. From the residuals from column 5 of Table No. 1 the probable error of the mean was deduced, $\pm 0^{mm}.02$, and the probable error of each value, $\pm 0^{mm}.04$.

THE SEGUIN 100-METER COMPARATOR.

This comparator was a line 100 meters long prepared for measurement with the iced-bar apparatus in exactly the manner previously described for the Shelton 100-meter comparator. The site of the comparator was chosen by the writer in the pasture of Mr. Henry Soefje, 8 miles north of the town of Seguin, Tex. The line of the comparator is nearly parallel to the Seguin Base Line, about 100 meters south of it and 1 kilometer from East Base. The terminal monuments were similar to those already described for the Shelton comparator except that they were of granite.

RESULTS OF MEASURES OF THE SEGUIN COMPARATOR INTERVAL.

The distance between the terminal spheres of the Seguin comparator was measured five times with B_{17} in melting ice between January 14 and 16. The new cut-off cylinder No. 2 was used here for the first time. It was used at the east end of the line with a length of $1^{m}.04$, while No. 1 was used at the west end with a length of $1^{m}.07$. No. 2 carries a level with one division equivalent to $2''.33$, and is similar to No. 1 except that its millimeter scale is extended to permit a reading of 12^{cm}. The three measures on January 14 and 15 were made with Baldwin and Bowie observers, interchanging between the first and second readings on the ends of the bar in each position. In the measures of January 16 observers Baldwin and Leland exchanged in the same manner. Table No. 2 gives the data for the length of the comparator. The results for the length of the comparator in the fourth and fifth columns is given after the application of the correction for the length of twenty bars of B_{17} $(-324\ \mu)$.

TABLE NO. 2.—*Results for length of Seguin 100-meter comparator.*

Date.	Time of day.	Direction of measure.	Results for length of comparator.	Mean result for the day.
1901.	h.		mm.	mm.
Jan. 14	11.6 a. m.	E. to W.	100 meters+1.54	100 meters+1.54
15	1.8 p. m.	W. to E.	+1.41	
15	3.0 p. m.	E. to W.	+1.55	+1.48
16	2.7 p. m.	W. to E.	+1.69	
16	4.1 p. m.	E. to W.	+1.72	+1.70
			Mean=100^{m}+1.58	

DISCUSSION OF RESULTS OF THE SEGUIN COMPARATOR MEASURES.

The agreement of the two measures in opposite directions on the 15th, and again on the 16th, is so close as to show that there was very little, if any, systematic movement of the microscopes tending to make the measurements too short when proceeding toward the sun, as noted in connection with the Shelton comparator. If the small discrepancies between the two results in each pair is attributed to such a movement of the microscopes, the movement is in the reverse direction. The explanation of the different action of the microscopes at Seguin from that at Shelton is simple when it is known that to obtain proper illumination for the microscope pointings the shade was not used during the measures of January 15, while on the 16th the day was overcast. To satisfy the instructions not to assume the comparator length a constant, the length of the comparator interval was assumed to have changed, and $100^{m}+1^{mm}.54$ was used as its length for any comparisons before the 14th, $100^{m}+1^{mm}.51$ between the 14th and 15th, and $100^{m}+1^{mm}.59$ between the 15th and 16th.

The probable error of the direct mean $\pm 0^{mm}.04$, being the most unfavorable to the accuracy, is adopted as the probable error of the length of the comparator used in standardizing the apparatus.

The probable error of the Shelton comparator being $\pm 0^{mm}.02$, and of the Seguin comparator $\pm 0^{mm}.04$, the probable error therefore of the mean length is not greater than $\pm 0^{mm}.03$. As the length of each apparatus depends on the mean of the two comparators the probable error of each hundred meters measured, in so far as the determination of the lengths of the comparators is concerned, is $\sqrt{(.03)^2+(.022)^2}=\pm 0^{mm}.037$, or one part in 2 700 000. The probable error $\pm 0^{mm}.022$ is the probable error of B_{17} $\pm 1.1\mu$, multiplied by 20, the number of bar lengths in 100 meters.

THE DUPLEX BARS.

The combined length of the duplex bars Nos. 15 and 16, with their coefficients, has been determined twice since their construction. The reader is referred to United States Coast and Geodetic Survey Special Publication No. 4, "The Transcontinental Triangulation," pages 191–197, for the results of these comparisons. The determinations of September, 1896, made on the 50-meter office test line after the return of the apparatus from the Salt Lake Base, might be expected to give a working length for the apparatus. No use had been made of the apparatus during the interval between that date and the Shelton determinations. However, it must be noted that the duplex contact slide apparatus was used during this comparison for the first time without protection from the direct rays of the sun. A complete description of the apparatus, by Assistant William Eimbeck, the designer, is given in Appendix No. 11, Coast and Geodetic Survey Report for 1897, pages 737–752. The directions for its use in the field as there stated were slightly modified as shown in the description of the field procedure given on page 252.

The results from the measurement of the Salt Lake Base* showed that the lengths resulting from the use of thermometers were more accordant than those from the use of the duplex method depending entirely on the difference of expansion of the steel and brass bars. They also showed that the three partially independent results were desir-

*See Appendix No. 12, Report for 1897, and "Transcontinental Triangulation," pp. 198–200.

able especially as they furnish information as to the thermic behavior of the apparatus. The thermometers were therefore used throughout this work.

THERMOMETER CORRECTIONS.

The thermometers used in the determinations of tape lengths, and lengths of the duplex bars Nos. 15 and 16, are the same as those used in the field measures. They are centigrade thermometers, graduated to half degrees and were read by estimation to 0°.05.

The following table gives the corrections necessary to reduce the observed readings of these thermometers to the hydrogen scale as determined by the Office of Standard Weights and Measures, July 27 and October 31, 1900, and February 8, 1901.

	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°
Corr. to 7231, July.	+.02	−.02	−.06	−.05	−.07	−.04	−.01	−.04	−.06	−.11
" " 7231, Feb.	.00	.00	−.04	.00	.00	−.04	−.05	−.02	−.07	−.05
" " 7232, June.	.00	.00	−.05	−.07	−.09	−.05	−.01	−.05	−.10	−.17
" " 7233, June.	.00	−.05	−.04	+.01	−.01	+.02	−.01	−.05	−.13	−.20
" " 7234, June.	.00	−.03	−.04	−.02	−.03	−.04	−.05	−.04	−.09	−.13
" " 7235, June.	+.01	−.01	−.02	−.03	−.07	−.07	−.05	−.04	−.09	−.09
" " 7236, June.	+.01	+.05	−.02	−.01	−.04	−.05	−.04	−.06	−.10	−.12
" " 7237, June.	.00	.00	−.03	−.02	−.04	−.05	−.07	−.05	−.09	−.07
" " 7237, Feb.	.00	+.01	−.05	.00	.00	−.04	−.03	−.07	−.10	−.08
" " 7238, June.	.00	−.02	−.06	−.01	−.04	−.04	−.06	−.07	−.09	−.10
" " 7239, June.	+.02	.00	−.03	−.06	−.09	−.07	−.07	−.11	−.15	−.16
" " 7241, June.	.00	−.03	−.03	−.08	−.09	−.10	−.09	−.09	−.14	−.08
" " 7241, Feb.	+.18	+.11	+.03	+.07	+.05	+.06	.00	+.05	+.05	+.05
" " 7843, Oct.	.00	−.06	−.04	−.06	−.09	−.08	−.07	−.05	−.12	−.10
" " 7843, Feb.	.00	−.01	−.03	.00	−.08	−.04	.00	−.05	−.10	−.08
" " 7851, Oct.	.00	−.08	−.07	−.04	−.04	−.06	−.05	−.06	−.08	−.12
" " 7851, Feb.	.00	−.01	−.07	.00	.00	−.04	−.06	−.07	−.06	−.13
" " 7852, Oct.	.00	−.04	−.10	−.02	−.02	−.06	−.07	−.06	−.11	−.14
" " 7852, Feb.	.00	−.01	−.07	.00	.00	−.04	−.07	−.09	−.11	−.17

On August 11 and August 30, and again on January 15, the readings of these thermometers when packed in melting ice were determined. The only appreciable change was noted in No. 7241, which changed from 0°.00 on August 30 to −0°.15 on January 15, and on examining the record it was found that on November 2 this thermometer was heated to unite a parted column, and observations after that date in comparison with others indicate such a change.

In the application of the thermometer corrections the mean of the determinations by the Office of Standard Weights and Measures was accepted, except as noted for No. 7241. Thermometers for which only one set of corrections is shown were broken during the field season.

FIELD TRESTLES IN USE WITH THE DUPLEX APPARATUS.

The trestles which were used on the Holton, Salina, and Versailles Bases, belonging to the secondary monometallic bars Nos. 13 and 14, were again used. The cradle arms, namely, the fixed portion of the trestle above the tripod head, were found to be too weak and flexible for the double-contact pressure of the duplex bars when used with that apparatus at the Salt Lake Base.*

* See p. 759, App. No. 12, Report for 1897, on the Measurement of the Salt Lake Base.

Before the apparatus left the Office for the work under discussion, new cradle arms with double the cross section of the old were substituted for them. A single trial of their relative flexibility was made by applying a horizontal pull at the top. This comparison showed a reduction of at least one-half in the horizontal flexure. In all other respects the trestles retained their original form. The comparisons on the 100-meter comparators were made with the bars supported on these field trestles, without foot-plates, exactly as they were used in the measurement of the base lines.

SHELTON DETERMINATION OF THE LENGTH OF THE DUPLEX BARS.

Five measures of the comparator interval were made with the duplex bars, on four different days, and at temperatures ranging from 22° to 33° C. The atmospheric conditions were as varied as it was possible to secure without delaying the work. The relative readings of the middle and end thermometers show that on the first measure the middle thermometer indicated a temperature about 1°.5 higher than the end thermometers, while on the second, third, and fifth measures they were close together. The contacts between the components were all made by the writer and in the same manner as in all previous measures with this apparatus.

The vertical alignment of the bars was controlled by pointing the adjusted aligning telescopes on the barrels of the end microscope as each bar was placed in position.

The inclination of each bar was measured in the usual way by means of the attached sectors.

Table No. 3 contains the data for the length of 20 bars of the duplex apparatus, obtained at the beginning of the season on the Shelton 100-meter comparator. The first column gives the number of the measure; the second and third, the date and hour of the day; the fourth, the direction of the measure; the fifth shows whether the face of the apparatus was up or down; the sixth gives the mean temperature as indicated by the three thermometers in each bar; the seventh and eighth, the length of 20 bars of steel minus 100 meters at the temperature of observation and after reducing to the duplex temperature 26°.45; columns nine and ten furnish the same information for the brass bars; while eleven and twelve furnish the gain of brass in the 100 meters, and the consequent length of the 20 bars when the steel and brass components are of equal length. In these determinations and those at Seguin, the coefficients of expansion, 11.54μ per meter for steel, 18.45μ per meter for brass, and the duplex coefficient 1.668, were used. These coefficients were determined from 32 measures of the Office 50-meter comparator in November, 1896.*

The duplex coefficient is the ratio of the coefficient of expansion of steel to the difference of the coefficients of brass and steel. Necessarily it is independent of any temperature. The duplex length is the length of the bar when the steel and brass components are of equal length and at the same temperature. It is evident that the duplex length can be determined without reference to any thermometer indication by the application of the duplex coefficient to the difference between the brass and steel set-ups in the measurement of the comparator interval. When the duplex length is once known, the length of any section may be computed from the gain of brass over steel as measured by the readings of the scales which show the relative positions of the

*See "Transcontinental Triangulation," pp. 196 and 197.

brass and steel bars. This can be most readily shown by a numerical example. In the first measure, on October 16, of the west half of section 8 of the El Reno Base (see Table 6), the brass component lost during the measurement $30^{mm}.84$, as compared with steel. In other words, during this measure the length of 100 brass bars was $30^{mm}.84$ less than the lenth of 100 steel bars. The length of the 100 steel bars was less than that of the 100 bars at duplex length by the duplex coefficient times $30^{mm}.84$.

Length of the section = 100 (duplex length of bar) − $30^{mm}.84$ (duplex coef.) − Σgrade corr's.
= 100 (5^{m} + $0^{mm}.0715$) − $30^{mm}.84$ (1.668) − $17^{mm}.45$.
= $499^{m}.9382$.

The derivation of the last two columns of Tables Nos. 3 and 4 furnishes a further illustration of the use of the duplex coefficient. The first value, −4.89, in column 11, is the +9.38 of column 7 minus the +14.27 in column 9. This value, −4.89, is both the difference between steel and brass set-ups and the difference between the length of 20 bars of steel and the 20 bars of brass during the measurement. The first value in the last column, namely, $+1^{mm}.22$, is $+9^{mm}.38 - 4^{mm}.89$ (1.668), the factor 1.668 being the duplex coefficient.

SEGUIN DETERMINATION OF THE LENGTH OF THE DUPLEX BARS.

At the conclusion of the base measures, four measures of the Seguin 100-meter comparator were made with the duplex bars. These four measures were made on two different days and in the same manner as described for the Shelton determinations. The temperature ranged from 23° to 12° and, although the first two measures were made under a cloudless sky, the thermometers were more consistent than at Shelton. The last measures were made in cloudy weather with the temperature nearly constant.

Table No. 4 contains the results of these measures.

TABLE No. 3.—*Standardization of the bars Nos. 15 and 16 of the Duplex Apparatus over the 100-meter Comparator at Shelton.*

No.	Date.	Hour.	Direction of measure.	Face.	Mean temperature.	Steel. Length of 20 bars.	Steel. Length of 20 bars reduced to 26°.45 C.	Brass. Length of 20 bars.	Brass. Length of 20 bars reduced to 26°.45 C.	Duplex. Scale S−B.	Duplex. Length of 20 bars when equal.
					C.	100 meters	100 meters	100 meters	100 meters		100 meters
	1900.				°	mm.	mm.	mm	mm.	mm.	mm.
1	July 26	5.5 p. m.	E	U	33.26	+9.38	+1.52	+14.27	+1.71	−4.89	+1.22
2	" 27	11.8 a. m.	W	U	27.60	+3.13	+1.80	+ 3.68	+1.56	−0.55	+2.21
3	" 28	10.3 a. m.	W	D	26.18	+0.98	+1.29	+ 0.51	+1.01	+0.47	+1.76
4	" 28	11.5 a. m.	E	D	30.74	+6.26	+1.31	+ 9.12	+1.20	−2.86	+1.49
5	Aug. 4	5.8 a. m.	W	U	22.23	−3.92	+0.95	− 6.61	+1.18	+2.69	+0.57
					Means	....	+1.37	....	+1.33	....	+1.45

TABLE NO. 4.—*Standardization of the bars Nos. 15 and 16 of the Duplex Apparatus over the 100-meter Comparator at Seguin.*

No.	Date.	Hour.	Direction of measure.	Face.	Mean temperature.	Steel.		Brass.		Duplex.	
						Length of 20 bars.	Length of 20 bars reduced to 26°.45 C.	Length of 20 bars.	Length of 20 bars reduced to 26°.45 C.	Scale S−B.	Length of 20 bars when equal.
					C.	100 meters	100 meters	100 meters	100 meters		100 meters
	1901.				°	mm.	mm.	mm.	mm.	mm.	mm.
1	Jan. 14	3.8 p.m.	E	U	22.52	− 3.08	+1.46	− 5.75	+1.50	+ 2.67	+1.37
2	" 14	4.9 p.m.	W	D	22.89	− 2.61	+1.50	− 4.96	+1.61	+ 2.35	+1.31
3	" 16	9.5 a.m.	E	D	11.95	−15.09	+1.66	−25.16	+1.59	+10.07	+1.71
4	" 16	10.5 a.m.	W	U	12.03	−15.22	+1.42	−25.09	+1.51	+ 9.87	+1.24
					Means........		+1.51	....	+1.55	....	+1.41
					Mean of all, from Tables Nos. 3 and 4...		+1.43	....	+1.43	....	+1.43

DISCUSSION OF RESULTS OF DUPLEX COMPARISONS.

It seemed desirable to examine the results first to discover whether or not any modification in the coefficients already adopted was necessary. If the assumed coefficients were wrong the lengths reduced to a fixed temperature should vary with the temperatures at which they were determined, or in the case of the duplex with the amount of the scale difference. At Shelton no such grouping of the results was found. At Seguin a most satisfactory check was obtained. For the twenty bars of steel the mean of the two values determined at 12° only differs by $0^{mm}.06$ from the mean of those at 22°.7 when reduced to 26°.45, as shown in Table No. 4. For the twenty bars of brass these two results are identical, and from the scale readings alone the two results differ only $0^{mm}.13$. As these facts showed that any change in the coefficients would be minute and not authorized by the probable error of these results, the temperature at which the steel and brass components are of equal length, called the duplex temperature, was computed from the nine comparisons on the two comparators taken as one group. The results were then reduced to this temperature, 26°.45, for the steel and brass components, and the mean result, $100^{m}+1^{mm}.43$ for twenty bars of steel and brass, has a probable error of $\pm 0^{mm}.05$, or 1 part in 2 000 000. Computing the length of the twenty bars independently of thermometers, we get an identical result, $100^{m}+1^{mm}.43$, but with a probable error of $\pm 0^{mm}.10$, or 1 part in 1 000 000.

It should be noted that the use of the bars during the season has apparently lengthened the twenty bars of steel by $0^{mm}.14$, and of brass by $0^{mm}.20$, but when computed independently of thermometers they seem to have shortened $0^{mm}.04$. The range in the results at Shelton being great enough to contain the entire group of results at Seguin, it is uncertain that any change has taken place. The duplex bars had not been in use since the determination of their lengths in September, 1896, when the lengths of the twenty steel and brass components reduced to the temperature 26°.45 were $+1^{mm}.44$ for steel and $+2^{mm}.04$ for brass. No reason has been discovered for this shortening of the brass component equivalent to 1 part in 170 000.

FIELD PROCEDURE WITH THE DUPLEX BARS.

The *modus operandi* so carefully described by Assistant Eimbeck on pages 763–764, Appendix No. 12, and the directions for the use of the apparatus on pages 747–751, Appendix No. 11, Coast and Geodetic Survey Report for 1897, were carefully studied. In certain particulars it was decided to modify these to suit the changed conditions and to omit many readings in order to increase the speed. On starting a measurement, the trestles having been arranged at the convenient height but in the rear of the section mark, the zero bar (No. 15 in every instance) was aligned and in position "face up," the front end of the component which is in line of the base brought over the section mark. Transit No. 149, in both direct and reversed position, was used at a distance of about 30 feet and at right angles to the bar, in referring to the section mark. The other component was then set normal, either by the plane mirror or with the front scale, whose reading when normal was known. The components are said to be set normal when their front agates are in the same plane normal to the bars. The bar scales on this bar were then read, recorded, and checked. The temperature was noted, and if higher or lower than the duplex temperature, 26°.45, the brass component was shifted backward or forward by an amount sufficient to permit the measuring of 250 meters if possible without another set-back or set-up. This was done to make as few delays as possible in the measurement. Next, the first bar of the measure was placed on the trestles and simultaneously with the rough alignment by the observer at the forward end, the rear end of the bar was raised or lowered by means of the sliding wedge (see illustration No. 6), and securely clamped when at the correct height. The preliminary contact was then established by seizing the bar under the left arm and sliding it backward bodily while the contact slides are held back and protected as much as possible with the forefinger of the left hand. The signal "Ready for line" was given when this approximate contact was begun, and generally with its completion the perfect alignment was completed by the forward observer, who bisected the line flag at the next section post ahead, which had previously been set five-eighths of an inch from the line, which is one-half the space between the components. It will thus be seen that one of the components traveled in the exact line of the base. The final contacts were then established between the components as quickly as possible by means of the contact screws (see illustration No. 7), and at the same time the mercurial thermometers and the inclination sectors were read and recorded. This completed the laying of the first bar.

Unless a set-up or set-back of brass became necessary no more scale readings were taken until the end of the half section, usually after the laying of the hundredth bar.

Next the zero bar was launched (see illustration No. 8) and carried ahead by the two men (see illustration No. 9), called "bar men," and brought into line and contact as the second bar of the measure. The inclination sectors were read, checked, and recorded, and the thermometers again read and recorded.

On the third bar and until the ninth was reached the thermometer readings were omitted, the mean temperature from eight sets not differing materially from that from twenty.

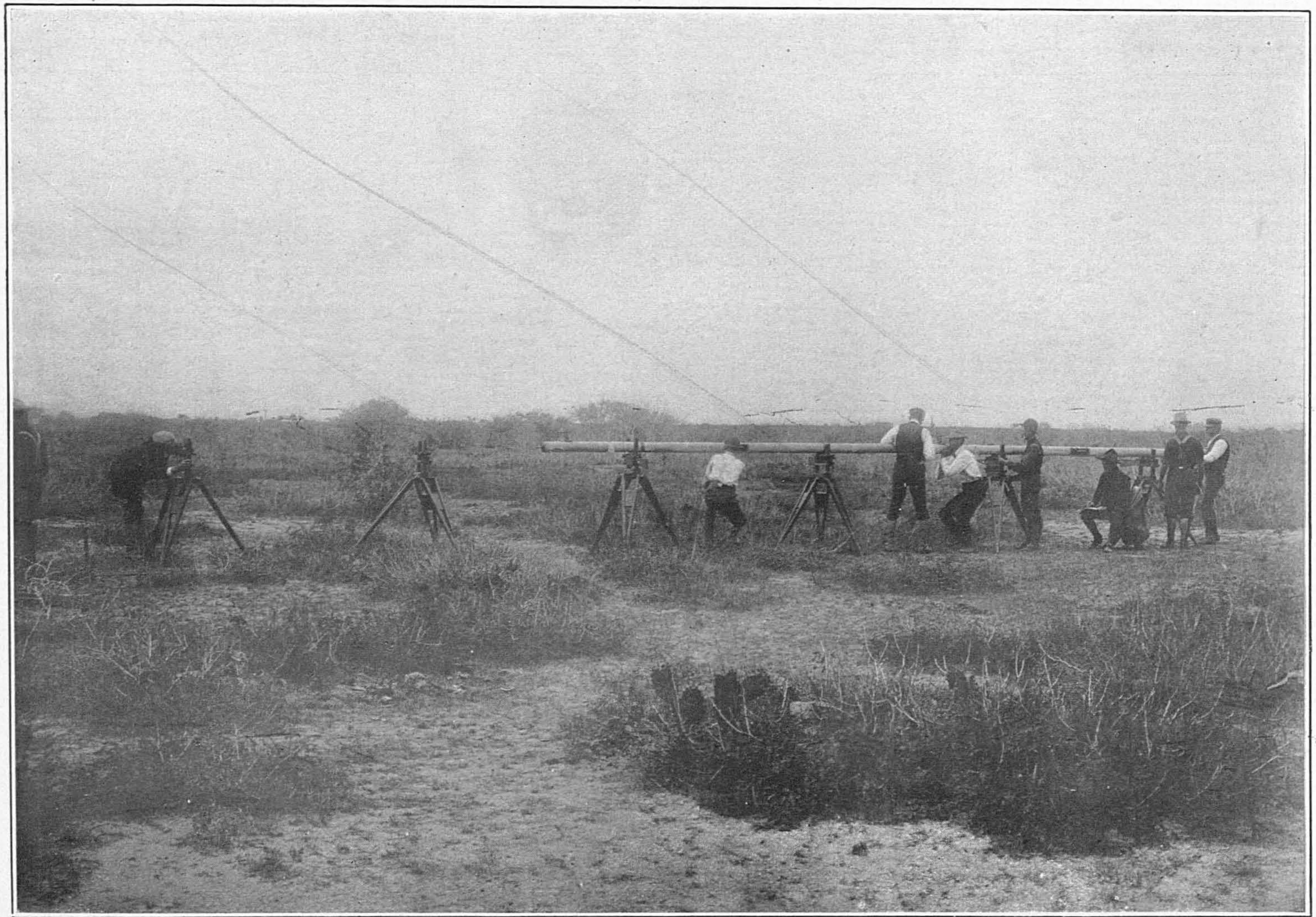
The observer in charge of the trestles spaced them and made them stable. The gain in speed over former bar measures was in a great measure due to the observer aligning the trestles simultaneously with the rough bar alignment, so that when he

DUPLEX MEASURES. ALIGNING BAR HORIZONTALLY AND VERTICALLY.

NO. 7.

DUPLEX MEASURES. MAKING FINAL CONTACT.

NO. 8.



DUPLEX MEASURES. READY TO LAUNCH REAR BAR.

DUPLEX MEASURES. CARRYING BAR AHEAD.

finally left the bar it was certain that the trestles ahead were in line. He then went to the front trestle, and by sighting under the fixed bar set its roller at the general grade of the ground. This enabled the forward bar man to immediately clamp his forward trestle and assist in the work at the rear trestle. At the conclusion of the measurement of 250 meters (or a quarter section), and at 750 meters, the bars were both reversed with care but no scale readings were made unless a shift of brass was required to equalize the amount of projection of the components beyond the protecting case.

At the end of the half section, where a stop was usually made, the forward agate of the steel component was referred to the ground and the scales of the last bar were read and checked. The brass component was then shifted to normal with steel, the scales read, and the bars left standing.

On resuming the measure the front agate was referred to the ground mark and the start made as described for the beginning of the section. When transferring to the ground the readings were never made on a scale, but the end of the measurement was preserved by a mark on a copper tack so that the set-ups (or set-backs) could be checked at any time with a quarter-meter scale and dividers.

RESULTS OF DUPLEX MEASURES OF NINE TEST KILOMETERS.

One kilometer of each base called the *test kilometer* was measured once with the duplex bar apparatus and once with each of the four steel tapes. The duplex measures of these nine test kilometers, the first of them made August 1 and 2, 1900, and the last January 5, 1901, will first be treated. Table No. 5 contains the data resulting from these measures. The first column gives the name of the base; the second the date; the third the mean temperature as indicated by six thermometers, whose bulbs were midway between the components; the fourth and fifth the temperature at the beginning and end of each half section; the sixth the length of the section computed independently of the thermometers; the seventh the length from the steel bars in conjunction with the thermometer readings; the eighth the length from the brass bars and thermometers; while in the ninth and tenth are the differences between the results, steel minus duplex, and brass minus steel, respectively.

TABLE No. 5.

Name of base.	Date.	Observed temperature. Corrected mean from six thermometers. C.	At beginning. C.	At end. C.	Length of section. From duplex.	From steel.	From brass.	Differences. S−D.	B−S.
	1900–1901.	°	°	°	m.	m.	m.	mm.	mm.
Shelton	Aug. 1, 2	26.92	21.0 20.9	33.7 31.5	1 000.2579	1 000.2612	1 000.2631	+3.3	+1.9
Page	Aug. 31	31.82	27.5 33.3	32.0 34.0	1 000.2081	.2093	.2101	+1.2	+0.8
Anthony	Sept. 15, 17	26.32	38.3 13.5	34.3 18.9	999.9192	.9187	.9185	−0.5	−0.2
El Reno	Oct. 13	20.64	11.8 26.0	19.6 26.0	1 000.0816	.0821	.0825	+0.5	+0.4
Bowie	Nov. 3	20.30	11.5 23.2	18.7 26.2	999.7866	.7889	.7904	+2.3	+1.5
Stephenville	Nov. 14	21.96	16.1 24.5	21.3 25.3	999.9428	.9461	.9481	+3.3	+2.0
Lampasas ...	Dec. 1	20.36	14.1 21.5	19.2 23.1	999.8524	.8555	.8573	+3.1	+1.8
Alice	Dec. 14	15.28	*14.9	*15.0	999.9810	.9809	.9809	−0.1	0.0
Seguin	Jan. 5	17.95	13.9 20.0	17.2 21.3	999.9222	.9219	.9218	−0.3	−0.1
							Means=	1.62	0.97

*No stop was made at the middle of this kilometer.

A full discussion of these results and the adoption of a mean for each section must be postponed until the 13 sections on which duplicate measures were made can be treated.

RESULTS OF REMAINING DUPLEX MEASURES.

Table No. 6 contains the data for the length of 22 sections and half sections with an average length of 543 meters. The table is identical with Table No. 5 in form, except that in the seventh, ninth, and eleventh columns are added the differences between the two measures.

TABLE NO. 6.

Base and section.	Date.	Observed temperature. Corrected mean from six thermometers.	Observed temperature. At beginning.	Observed temperature. At end.	Length of section or half section. Duplex.	Diff. 1st minus 2nd.	Steel.	Diff. 1st minus 2nd.	Brass.	Diff. 1st minus 2nd.	S—D.	B—S.
		C.	C.	C.								
	1900.	°	°	°	m.	mm.		mm		mm.	mm.	mm.
Shelton:												
3	July 30	37.94	33.9	38.8	600.1211		.1226		.1234		+1.5	+0.8
	31	38.32	28.7, 43.4	39.4, 40.8	.1224	−1.3	.1243	−1.7	.1253	− 1.9	+1.9	+1.0
6, E. half	Aug. 8	27.60	25.0	29.4	499.9965		.9967		.9968		+0.2	+0.1
	10	26.30	24.1	28.8	.9965	0.0	.9970	−0.3	.9973	− 0.5	+0.5	+0.3
6, W. half	8, 9	33.89	33.8	35.2	584.0456		.0454		.0453		−0.2	−0.1
	9	31.31	27.2	35.2	.0439	+1.7	.0462	−0.8	.0476	− 2.3	+2.3	+1.4
Page:												
7, SW. half	24	28.14	27.6	28.0	499.9538		.9546		.9550		+0.8	+0.4
	30, 31	27.36	31.7, 23.2	32.2, 25.7	.9514	+2.4	.9522	+2.4	.9526	+ 2.4	+0.8	+0.4
7, NE. half	25	32.59	30.8	33.4	500.1520		.1545		.1560		+2.5	+1.5
	30	26.48	23.7	28.8	.1490	+3.0	.1504	+4.1	.1512	+ 4.8	+1.4	+0.8
8, SW. half	27	24.96	21.2	30.1	599.9543		.9592		.9621		+4.9	+2.9
	29	33.25	33.6	32.5	.9552	−0.9	.9548	+4.4	.9544	+ 7.7	−0.4	−0.4
8, NE. half	28	27.48	23.2, 30.8	27.6, 31.1	600.9864		.9894		.9912		+3.0	+1.8
	28, 29	30.30	25.5, 33.2	28.6, 33.5	.9885	−2.1	9893	+0.1	.9898	+ 1.4	+0.8	+0.5
Anthony:												
6, SE. half	Sept. 21	20.50	19.4	21.3	499.8812		.8808		.8806		−0.4	−0.2
	22	30.67	29.4	31.0	.8818	−0.6	.8822	−1.4	.8824	− 1.8	+0.4	+0.2
6, NW. half	21	23.27	22.1	23.9	486.9240		.9239		.9238		−0.1	−0.1
	22	21.72	20.4	24.3	.9241	−0.1	.9241	−0.2	.9242	− 0.4	0.0	+0.1
El Reno:												
7	Oct. 15	16.88	16.0	18.2	444.3211		.3206		.3204		−0.5	−0.2
	16	16.16	15.4	16.7	.3199	+1.2	.3193	+1.3	.3191	+ 1.3	−0.6	−0.2
8, W. half	16	17.42	17.2	17.8	499.9382		.9376		.9372		−0.6	−0.4
	18	19.66	17.5	21.5	.9366	+1.6	.9368	+0.8	.9370	+ 0.2	+0.2	+0.2
8, E. half	17	14.35	14.2	14.5	500.2746		.2739		.2735		−0.7	−0.4
	18	15.78	14.6	17.0	.2735	+1.1	.2734	+0.5	.2733	+ 0.2	−0.1	−0.1
Bowie:												
7, SE. half	Nov. 1	14.67	12.3	17.2	499.8466		.8485		.8496		+1.9	+1.1
	2	21.49	20.0	23.2	.8508	−4.2	.8484	+0.1	.8470	+ 2.6	−2.4	−1.4
7, NW. half	1	22.96	20.9	24.9	598.2989		.3019		.3035		+3.0	+1.6
	2	12.04	6.6	15.6	.2954	+3.5	.2929	+9.0	.2914	+12.1	−2.5	−1.5
Stephenville:												
6, N. half	15	18.43	16.0	21.4	549.9115		.9139		.9154		+2.4	+1.5
	16	25.33	25.3	25.3	.9143	−2.8	.9144	−0.5	.9145	+ 0.9	+0.1	+0.1
6, S. half	15	26.96	26.6, 27.3	27.3, 26.8	606.2750		.2751		.2751		+0.1	0.0
	16	19.63	16.8	23.1	.2736	+1.4	.2748	+0.3	.2755	− 0.4	+1.2	+0.7
Lampasas:												
4	30	19.76	19.2	20.3	514.7229		.7237		.7242		+0.8	+0.5
	30	19.90	20.3	19.1	.7266	−3.7	.7257	−2.0	.7252	− 1.0	−0.9	−0.5
Alice:												
5, E. half	Dec. 15	16.00	13.9	18.4	499.7597		.7621		.7636		+2.4	+1.5
	18	24.49	23.8	25.1	.7617	−2.0	.7621	0.0	.7623	+ 1.3	+0.4	+0.2
5, W. half	15	25.34	24.6	25.2	471.5653		.5665		.5672		+1.2	+0.7
	18	23.24	22.7	23.6	.5655	−0.2	.5661	+0.4	.5664	+ 0.8	+0.6	+0.3
Seguin:												
6	Jan. 2, 3	7.56	6.8, 6.6	7.9, 8.8	895.1720		.1732		.1740		+1.2	+0.8
	3, 4	10.76	10.2, 12.5	10.4, 11.5	.1749	−2.9	.1740	−0.8	.1734	+ 0.6	−0.9	−0.6
7, W. half	4	12.95	11.6	15.0	499.9137		.9145		.9150		+0.8	+0.5
	7	23.56	23.4	23.6	.9133	+0.4	.9123	+2.2	.9117	+ 3.3	−1.0	−0.6
7, E. half	4	19.75	19.3	19.7	499.9366		.9375		.9381		+0.9	+0.6
	7	18.33	18.1	19.1	.9351	+1.5	.9364	+1.1	.9373	+ 0.8	+1.3	+0.9

In Table No. 7 the thirteen sections as they enter the base computation are treated. These are the same measures shown in Table No. 6, where they were treated in the shortest possible sections to display the residuals most completely. The tenth column contains the adopted length of the sections, obtained by taking a weighted mean of the results from duplex, steel, and brass. The weights assigned to the results from duplex, steel, and brass, namely, 10, 5, and 2, respectively, were determined as shown in the discussion which follows.

TABLE No. 7.

Base and section.	Date.	Corrrected mean temp. from six thermometers. C.	Length from duplex.	Diff. 1st minus 2d.	Length from steel.	Diff. 1st minus 2d.	Length from brass.	Diff. 1st minus 2d.	Final length of section.	Diff. 1st minus 2d.
Shelton:	1900-1901.	°	m.	mm.		mm.		mm.		mm.
3......	July 30	37.94	600.1211		.1226		.1234		600.1218	
	31	38.32	.1224	−1.3	.1243	−1.7	.1253	−1.9	.1233	−1.5
6......	Aug. 8, 9	30.74	1 084.0421		.0421		.0421		1 084.0421	
	9, 10	28.80	.0404	+1.7	.0432	−1.1	.0449	−2.8	.0418	+0.3
Page:										
7......	24, 25	30.36	1 000.1058		.1091		.1110		1 000.1074	
	30, 31	26.92	.1004	+5.4	.1026	+6.5	.1038	+7.2	.1014	+6.0
8......	27, 28	26.22	1 200.9407		.9486		.9533		1 200.9445	
	28, 29	31.78	.9437	−3.0	.9441	+4.5	.9442	+9.1	.9439	+0.6
Anthony:										
6......	Sept. 21	21.88	986.8052		.8047		.8044		986.8050	
	22	26.20	.8059	−0.7	.8063	−1.6	.8066	−2.2	.8061	−1.1
El Reno:										
7......	Oct. 15	16.88	444.3211		.3206		.3204		444.3209	
	16	16.16	.3199	+1.2	.3193	+1.3	.3191	+1.3	.3196	+1.3
8......	16, 17	15.88	1 000.2128		.2115		.2107		1 000.2122	
	18	17.72	.2101	+2.7	.2102	+1.3	.2103	+0.4	.2102	+2.0
Bowie:										
7......	Nov. 1	19.19	1 098.1455		.1504		.1531		1 098.1478	
	2	16.34	.1462	−0.7	.1413	+9.1	.1384	+14.7	.1438	+4.0
Stephenville:										
6......	15	22.90	1 156.1865		.1890		.1905		1 156.1877	
	16	22.34	.1879	−1.4	.1892	−0.2	.1900	+0.5	.1885	−0.8
Lampasas:										
4......	30	19.76	514.7229		.7237		.7242		514.7233	
	30	19.90	.7266	−3.7	.7257	−2.0	.7252	−1.0	.7262	−2.9
Alice:										
5......	Dec. 15	20.67	971.3250		.3286		.3308		971.3267	
	18	23.86	.3272	−2.2	.3282	+0.4	.3287	+2.1	.3277	−1.0
Seguin:										
6......	Jan. 2, 3	7.56	895.1720		.1732		.1740		895.1726	
	3, 4	10.76	.1749	−2.9	.1740	−0.8	.1734	+0.6	.1745	−1.9
7......	4	16.35	999.8503		.8520		.8531		999.8511	
	7	20.94	.8484	+1.9	.8487	+3.3	.8490	+4.1	.8486	±2.5

DISCUSSION OF RESULTS FROM DUPLEX MEASURES.

An inspection of the results in Tables Nos. 5, 6, and 7 reveals one specially important feature of the results from duplex, steel, and brass, namely, that they are always arranged in a certain order, with the result from steel between that from duplex and that from brass. Moreover, the differences, steel minus duplex and brass minus steel, bear a fixed relation to each other. This mean ratio in the case of Table No. 5 is $\frac{S-D}{B-S}=1.67$, and in Table No. 6 $=1.66$, and the individual values of this ratio in the tables agree closely with this mean. Under the section *Temperature errors of the duplex measures* (p. 291) this discussion is continued at some length. At this point it is deemed sufficient to compute the probable error of a single measure from the double measures of each section, first neglecting the thermometers, second using the steel bars with the thermometers, and third the brass bars with the thermometers. The probable error of a single measure of a mean section (543 meters) in Table No. 6 becomes $\pm 1^{mm}.0$ for duplex, $\pm 1^{mm}.2$ for steel, and $\pm 1^{mm}.7$ for brass.

In Table No. 7 (921 meters) these probable errors increase to $\pm 1^{mm}.2$ for duplex, $\pm 1^{mm}.7$ for steel, and $\pm 2^{mm}.6$ for brass.

The weights assigned were inversely proportional to the squares of the probable errors derived from Table No. 7, namely: For duplex 10, for steel 5, and for brass 2.

A weighted mean, derived in the same manner as in Table No. 7, can now be taken and adopted for the duplex lengths of the nine test kilometers shown in Table No. 5, as follows:

Shelton	1 000.2595
Page	1 000.2087
Anthony	999.9190
El Reno	1 000.0819
Bowie	999.7877
Stephenville	999.9444
Lampasas	999.8539
Alice	999.9810
Seguin	999.9221

As a further check on the values adopted for the coefficients of expansion, the relative results on section 6 of the Seguin Base and section 6 of the Shelton Base should be noted. The lowest temperatures of the season were encountered on the section at Seguin, with the result that on the first measure, when the total rise of temperature was $3^{\circ}.3$, the result from brass was 2^{mm} *above* the duplex, but on the second measure, when the total fall of temperature was $0^{\circ}.8$, the result from brass was $1^{mm}.5$ *lower* than the duplex. On the west half of section 6 at Shelton the temperature was practically constant, and 25° above that on the Seguin section, but the duplex and brass differ only $0^{mm}.3$. Therefore the coefficients can not be appreciably in error.

THE STEEL TAPE APPARATUS.

The 100-meter tapes Nos. 85 and 88 were used in the measurement of the Holton and St. Albans base lines in 1891 and 1892. Their cross section is $6^{mm}.34$ by $0^{mm}.47$, and the weight per meter of length was 22.32 grams originally, and had decreased to 22.29 for T_{85} and 22.07 for T_{88} when tested after the completion of the nine bases under discussion.

The 50-meter tapes Nos. 247 and 248 were cut from a steel ribbon of the same approximate cross section as the 100-meter tapes. They are about $51^m.0$ meters in length, and No. 247 weighs 21.8 grams per meter, and No. 248 20.9 grams. Instead of graduations ruled on the tape itself there are end graduations ruled on silver sleeves riveted to the tape. These tapes carry no intermediate graduations.

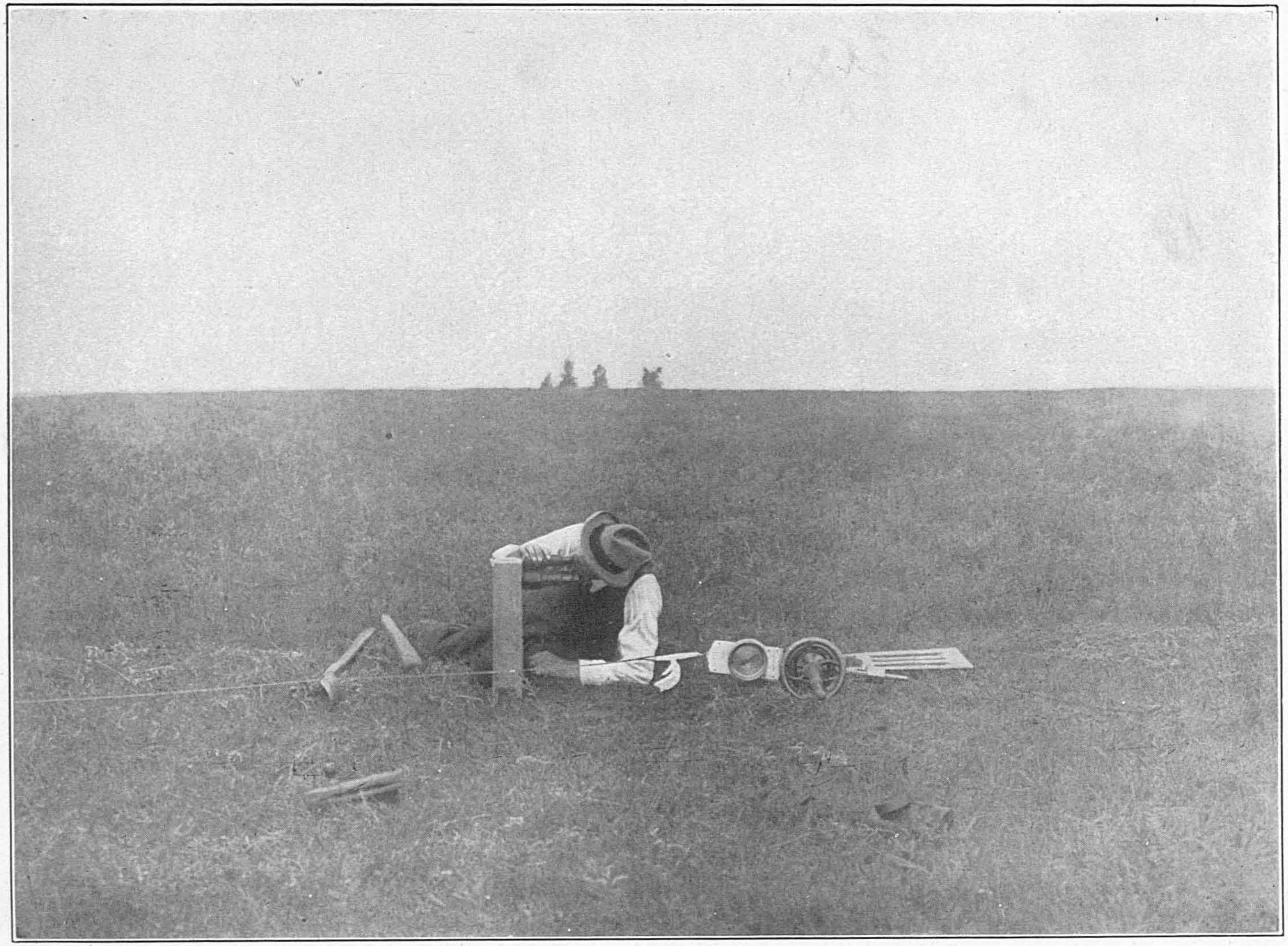
The tape stretchers used to give tension and alignment to the tape are described and illustrated on pages 414 and 415 of Appendix No. 8, Coast and Geodetic Survey Report for 1892. The spring balance attached to the stretcher was similar to the one there described, except that it was a metric balance reading directly to 25 grams, and which could be easily held to 12 grams. Only one stretcher was used, the end of the tape being held by a simple staff in the rear. As a tension of 15 kilograms was applied to the tape, the breaking link could safely be omitted, because there was little danger of a tension over 15 kilograms being applied in carrying and manipulating the tape. A strip of cotton cloth, which would not twist, was substituted for the breaking link.

The thermometers, which have already been described, were tied in a horizontal position, with their metal backs in contact with the tape, and about 1 meter from the marking sleeve.

A comparison of thermometers attached in this way with thermometers whose bulbs were inclosed in steel sheaths was made in October, 1897, on the 50-meter office test line, and continued through twenty-four hours. The thermometers with protected bulbs were hung with these bulbs at the height of the tape alongside those tied to the tape, as described. The length of the tape from thirty-seven determinations, as indicated by the thermometers with protected bulbs, was $0^{mm}.08$ less than that from thirty-eight determinations with thermometers tied to the tape. Moreover, the maximum residual was $0^{mm}.50$ (and four residuals exceeded $0^{mm}.40$) in the first case and only $0^{mm}.28$ in the second, while the signs of corresponding residuals from the two sets of thermometers were nearly always the same. The $0^{mm}.08$ showed that the indicated temperatures differed $0^{\circ}.15$ centigrade, and the residual $0^{mm}.50$ is equivalent to $0^{\circ}.92$ in temperature.

When in use for measuring a line or for a determination of its length, the tape was supported at equal intervals of 25 meters throughout its length. The intermediate supports consisted of steel wire nails driven into 2 by 4 inch stakes set at these intervals along the line. These support nails were ranged into a straight line for any tape length by means of one telescope of the binoculars brought to the right height at the forward end of the tape (see illustration No 10). At the forward end the tape was supported and aligned over the marking stake by the tape stretcher. These marking stakes were wooden posts 4 by 4 inches in cross section, securely driven to the proper height and with the top surface about parallel with the surface of the ground. Instead of the zinc plates, as used at Holton, copper strips* 55^{mm} by 11^{mm} and with a thickness of $1^{mm}.4$ were nailed on top of these posts parallel to the line of the base and distant from it half the width of the marking sleeve of the tape. The height of these strips brought their top surfaces into the plane of the marking sleeve and allowed the tape graduation to be prolonged onto this strip by means of a sharp awl and without the use of a try-square. The rear-end graduation of the tape was supported and held by a plain staff and brought into coincidence with these successive marks.

*These strips were first used in the Coast and Geodetic Survey by the writer in 1897, on the Versailles Base.



ALIGNING SUPPORT NAILS FOR TAPES.

NO. 11.

CONTACT AT REAR END OF TAPE

NO. 12.

FORWARD END OF TAPE MOVING AHEAD.

NO. 13.

CUT-OFF IN USE AT NIGHT.

THE FIELD PROCEDURE WITH THE STEEL TAPES.

The marking and support stakes for the measuement were ranged out and adjusted beforehand. For this alignment an 8-inch theodolite was used.

The measurements were all made at night. Eight men for the 50-meter tapes and twelve for the 100-meter tapes were used when possible in the measurement.*

A description of the personnel for measuring with the 50-meter tapes will suffice for the 100-meter tapes when four extra men are added to carry the tape ahead. There were required two observers, one at the front and one at the rear end of the tape, who also read the thermometers, and the observer at the front end helped to carry the tape ahead; one recorder, who also furnished the light for reading the tension and led the party to the next marking post ahead; two men to apply the tension at the front end and hold it in the rear; and three men to handle lamps and carry the tape ahead. The cooperation of the observers was secured by word of mouth, passed along by the man in the center when the wind was unfavorable. When the stretcher at the front end had brought his balance to the proper height and nearly to the proper reading the observer at the front end called "Tension." As soon as the rear-end observer had adjusted the rear-end graduation of the tape to coincidence with the proper mark on the copper strip he called "Contact." The tension was made perfect, and when the position of the front graduation had been marked he called "All done," and both observers read the thermometers. The thermometer readings were repeated by the recorder when he entered them in the record. The observer at the front end unhooked the tape from the balance, and at the command "Come ahead" each carried the tape above his head as it was moved to the next marking stake. The mean speed attained in this process was 2 kilometers per hour and a single kilometer was measured in 15 minutes. The copper strips were put in position when the marking tables were set and aligned. When a displacement, called set-up or set-back, became necessary or desirable by reason of the expansion or contraction of the tape, a new mark was made and noted by the recorder. By daylight these set-ups and set-backs were measured with a quarter-meter scale and dividers.

The record of the tape measures consisted, for each tape length of the designation of that tape length with the corresponding readings of thermometers, and a record of the set-ups and set-backs, with an occasional record of the time and weather conditions.

METHOD OF DETERMINING LENGTHS OF TAPES.

The lengths of the 100-meter and 50-meter tapes were determined by measuring the interval of the 100-meter comparator, already described, in the same way as any similar section of the base was measured, except that with the end microscopes pointings were made on the end graduations of the tape, after making the readings on the cut-off (see illustration No. 13).

The tape stretcher was mounted on a section of the car track and the graduated surface of the tape brought into the focus of the microscope, while the rear end was so fixed in position by tying it to a fixed staff that its graduation could be observed. The tapes were supported at intervals of 25 meters in the focal plane of the microscopes.

*It was seldom possible to use this number without delay to the leveling, and eight men were often used when measuring with the 100-meter tapes and only six with the 50-meter tapes.

The thermometers were tied to the tape in the manner described for the actual base measurement. When the tape was put under tension on its supports and aligned it was first brought to focus under the microscopes. At the signal "Ready" from the observer at the front end both observers made pointings, and at the word "Contact" from the rear observer (see illustration No. 14), the front observer calling "Finished," the thermometers were immediately read and recorded. The observers then exchanged places, each checking the other's micrometer reading on arriving at the new position. These pointings were repeated and one determination of the tape length was completed, depending on two sets of readings and thermometer indications.

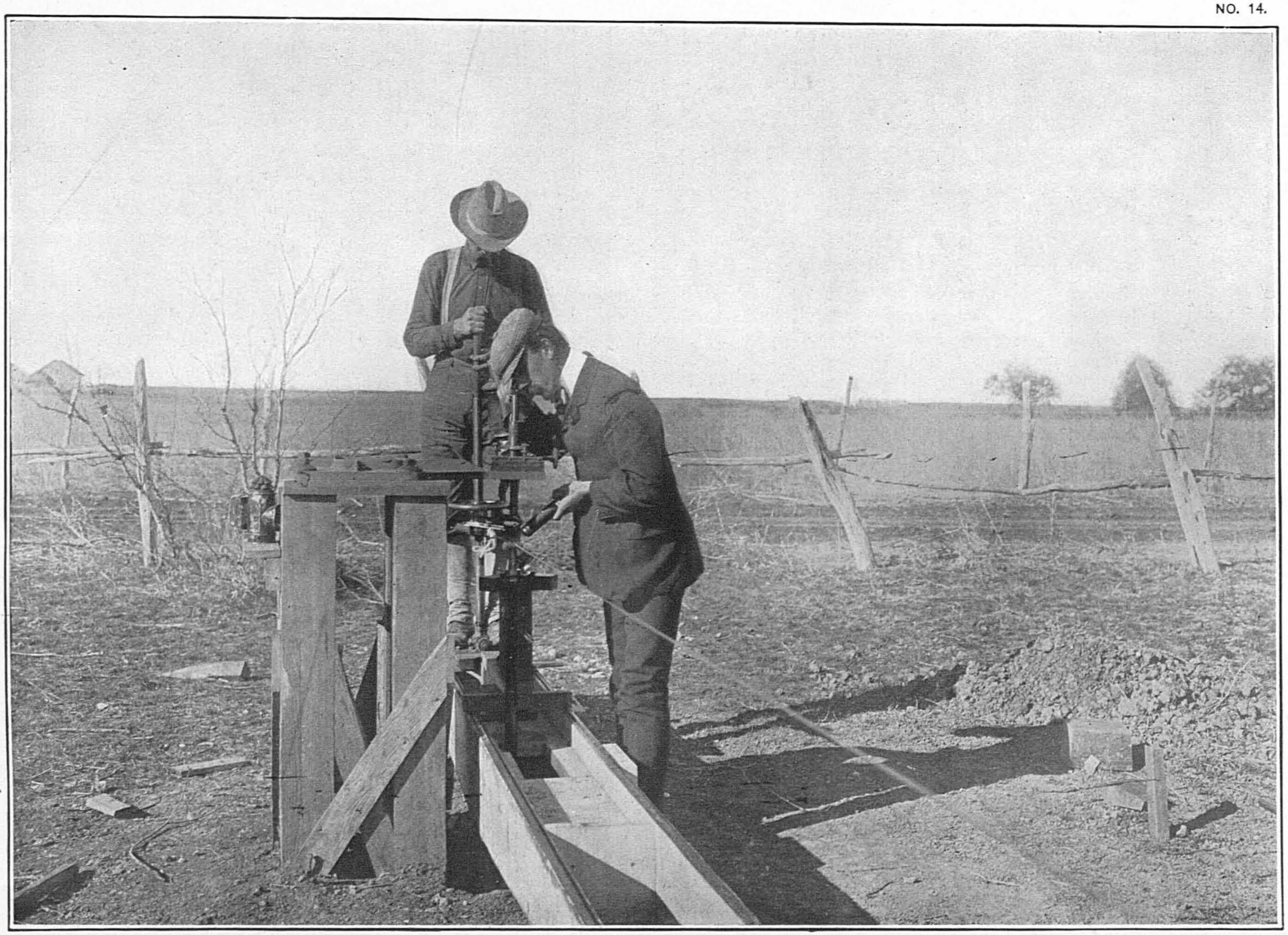
The programme for the 50-meter tapes was necessarily modified. A mark on the usual copper strip was made in the center of the comparator and a contact made by an observer as at the rear end of the tape in actual measurement. To relieve a man from holding contact here a staff that could be swung out of the way was provided, and after the tension had been applied the final contact was obtained by driving a small wedge alongside this staff (see illustration No. 15). When the tape was under tension and the contact made perfect by the observer in the center of the comparator (or rear end of the tape) a pointing was made on the graduation, the reading recorded, and both thermometers were read. The observers exchanged places and the same operation was repeated. The tape was then moved to the other end of the comparator, the tension applied at the opposite end of the comparator, and the same exchange of observers occurred here. A single determination of a double tape length was thus obtained, which depended on four contacts, four microscope pointings, and eight thermometer readings.

The standard tension adopted for all the steel tapes was 15.0 kilograms. Before it left Washington, spring balance No. 100 was set in accordance with determinations by the Weights and Measures Office so as to give a correct tension of 15 kilograms when in a horizontal position, and was carefully kept throughout the season as a standard. The working balances were tested by this one at the beginning of each night's work and at its close, if the index reading showed that a new comparison was desirable.

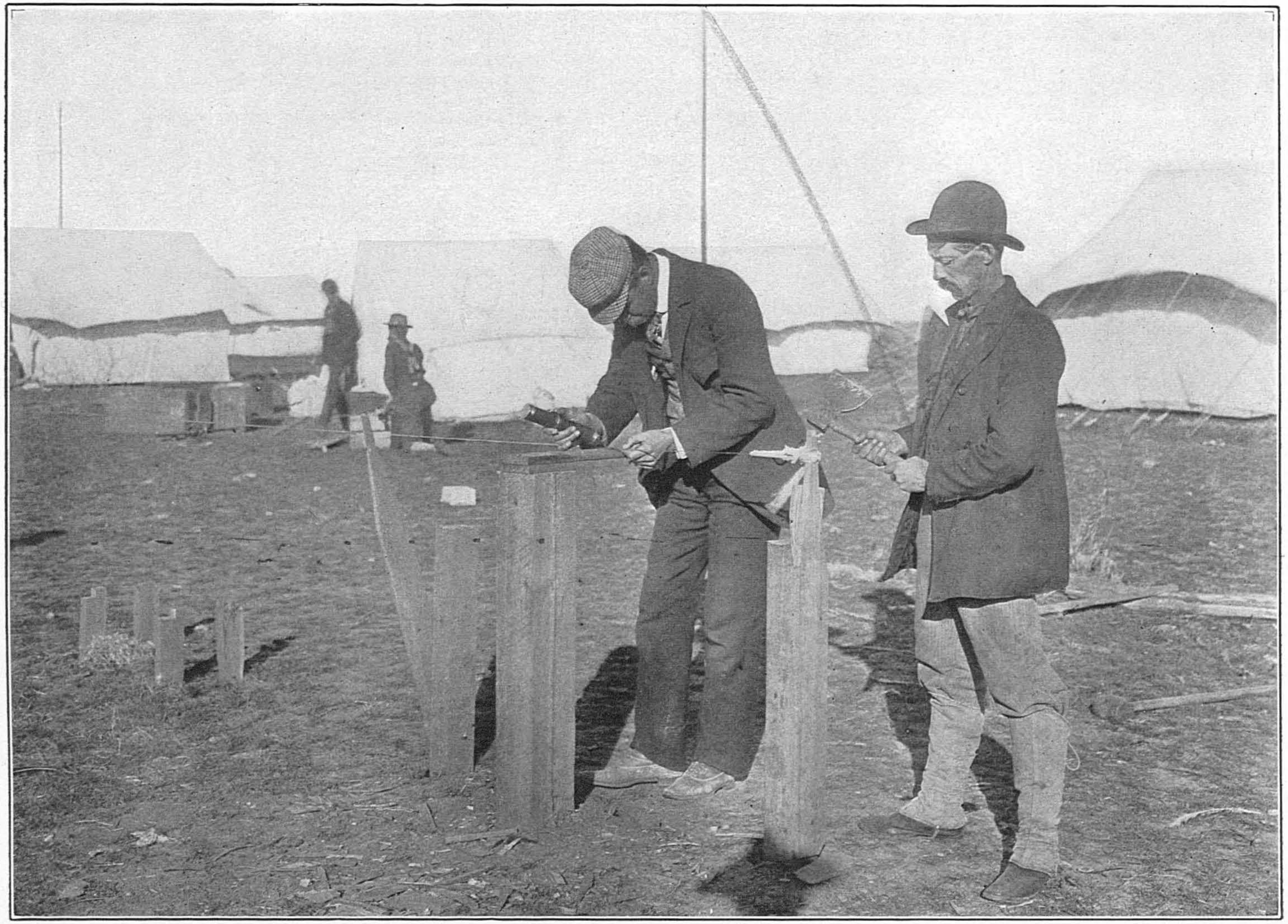
In February, after the return of the party from the field, a new determination by the Office of Weights and Measures showed that at the close of the season a tension in excess of 15 kilograms had been applied, amounting to 33 grams. This extra tension means that on the last measures the derived length for the 100-meter tape or double 50-meter tape is $0^{mm}.08$, or one part in 1 250 000, too great. To avoid the labor of distributing this amount through the season, one-half this quantity was added to the length from the Shelton and one-half subtracted from the length from the Seguin comparisons.

DETERMINATION OF LENGTHS OF TAPES.

The first column of Tables Nos. 8, 9, 10, and 11 contains the date; the second the time of day; the third the mean temperature as indicated by two thermometers; the fourth the observed length of the tape (or of two tapes in the case of the 50-meter tapes); the fifth the residuals in the sense of computed minus observed value, which result from the equations of the tapes deduced later, and the sixth, the remarks as to location and weather conditions.



TAPE CONTACT AT END OF COMPARATOR.



TAPE CONTACT AT MIDDLE OF COMPARATOR.

TABLE NO. 8.—*Results of observations for length of 100-meter steel tape No. 88.*

Date.		Time of day.	Corrected temperature from two thermometers. C.	Observed length of tape. 100 meters+	Residual (computed minus observed value).	Remarks.
1900.		h. m.	°	mm.	mm	
July	27	12 05 a. m.	21.40	32.21	−0.01	At beginning of season on Shelton comparator. Moderate wind. No dew.
		12 13	21.07	32.31	−0.46	
		12 15	21.60	32.53	−0.12	
		12 26	21.60	32.57	−0.16	
July	28	9 00 p. m.	15.51	25.19	+0.81	Calm.
		9 14	15.26	25.36	+0.38	
		9 21	15.58	25.88	+0.19	Wind rising.
		9 25	15.11	25.66	−0.08	Heavy dew.
		9 30	14.78	25.46	−0.23	
1901.						
Jan.	14	7 38 p. m.	12.00	22.22	+0.08	At end of season on Seguin comparator.
		7 49	11.86	22.02	+0.14	
		7 59	11.80	22.04	+0.05	No dew.
		8 11	11.31	21.52	+0.06	Clear and calm.
Jan.	15	8 31 p. m.	13.15	23.75	−0.24	
		8 38	13.47	23.96	−0.11	Partly cloudy, with light wind.
		8 45	13.90	24.37	−0.07	
		8 53	14.53	25.19	−0.23	

TABLE NO. 9.—*Results of observations for length of 100-meter steel tape No. 85.*

Date.		Time of day.	Corrected temperature from two thermometers. C.	Observed length of tape. 100 meters+	Residual (computed minus observed value).	Remarks.
1900.		h. m.	°	mm.	mm.	
July	27	9 30 p. m.	23.27	31.29	−0.17	At beginning of season on Shelton comparator. Moderate wind. No dew.
		9 48	22.62	30.61	−0.19	
		10 00	22.51	30.44	−0.14	
		10 15	22.64	30.37	+0.07	
		10 24	22.51	30.42	−0.12	
		10 35	22.38	30.24	−0.07	
July	28	9 55 p. m.	14.96	21.57	+0.67	Calm.
		10 05	14.79	21.33	+0.73	
		10 12	14.92	21.66	+0.54	Heavy dew.
		10 18	14.74	21.62	+0.39	
		10 23	14.56	21.60	+0.21	
		10 27	14.64	21.60	+0.30	
1901.						
Jan.	14	8 52 p. m.	10.18	17.27	−0.13	At end of season on Seguin comparator.
		9 02	10.25	17.33	−0.12	
		9 08	10.45	17.55	−0.13	No dew.
		9 25	10.55	17.65	−0.12	Clear with light wind.
Jan.	15	7 44 p. m.	13.15	20.71	−0.40	
		7 51	13.31	20.84	−0.36	Clear with light wind.
		7 59	13.31	20.81	−0.33	
		8 06	13.70	21.44	−0.54	

TABLE NO. 10.—*Results of observations for double length of 50-meter steel tape No. 247.*

Date.	Time of day.	Corrected temperature from two thermometers. C.	Observed length of two tapes. 100 meters+	Residual (computed minus observed value).	Remarks.
1900.	h. m.	°	mm.	mm.	
July 30	10 10 p. m.	20.90	+ 9.31	−0.37	At beginning of season on Shelton comparator.
	10 23	20.85	+ 9.19	−0.30	
	10 25	21.01	+ 9.27	−0.21	
	10 40	20.60	+ 9.04	−0.41	
July 31	10 20 p. m.	21.47	+ 8.98	+0.56	
	10 30	21.17	+ 8.36	+0.87	
	10 38	20.90	+ 8.45	+0.49	
	10 47	20.66	+ 8.11	+0.58	
Aug. 1	8 35 p. m.	25.32	+13.83	−0.26	
	8 55	24.99	+13.41	−0.18	
	8 57	24.81	+13.12	−0.08	
	9 03	24.74	+13.18	−0.22	
1901.					
Jan. 12	7 15 p. m.	8.03	− 4.63	+0.10	At end of season on Seguin comparator.
	7 33	7.32	− 5.15	−0.12	
	7 53	6.42	− 6.21	−0.01	Partly cloudy with light wind.
	8 05	6.28	− 6.31	−0.06	
Jan. 15	10 25 p. m.	13.70	+ 1.43	−0.02	No dew.
	10 35	13.49	+ 1.26	−0.07	Cloudy with light wind.
	10 46	12.99	+ 0.72	−0.06	
	10 56	12.59	+ 0.47	−0.23	Calm.

TABLE NO. 11.—*Results of observations for double length of 50-meter steel tape No. 248.*

Date.	Time of day.	Corrected temperature from two thermometers. C.	Observed length of two tapes. 100 meters+	Residual (computed minus observed value).	Remarks.
1900.	h. m.	°	mm.	mm.	
July 30	9 13 p. m.	21.38	+ 8.43	−0.40	At the beginning of season on Shelton comparator.
	9 25	21.77	+ 8.93	−0.49	
	9 40	21.57	+ 8.46	−0.23	
	9 55	21.19	+ 8.05	−0.22	Clear.
July 31	9 03 p. m.	23.27	+10.04	−0.02	
	9 26	22.51	+ 8.75	+0.47	Clear.
	9.38	22.07	+ 8.52	+0.23	
	9 45	21.98	+ 8.66	+0.15	
Aug. 1	9 20 p. m.	24.93	+11.73	+0.04	
	9 28	25.18	+11.90	+0.13	
	9 39	25.28	+12.00	+0.14	
	9 48	25.32	+12.04	+0.14	
1901.					
Jan. 12	8 42 p. m.	6.71	− 7.49	+0.06	At end of season on Seguin comparator.
	8 53	6.06	− 8.27	+0.15	
	9 10	5.23	− 9.14	+0.14	Some dew. Partly cloudy with light winds.
	9 19	4.88	− 9.42	+0.05	
Jan. 15	9 18 p. m.	14.47	+ 0.82	−0.08	Cloudy with light wind.
	9 39	14.07	+ 0.38	−0.06	
	9 51	13.48	− 0.29	−0.01	No dew.
	10 03	13.43	− 0.19	−0.16	

In order to simplify the computation it will be assumed that there was no change in length of the tapes during the season.

It is then possible to take a mean of all the observed lengths (x_0) for the mean of all temperatures (t_0) and leave the coefficient of expansion to be settled by a later discussion. The following values are thus derived for the four tapes from Tables Nos. 8, 9, 10, and 11:

$$T_{88} = 100^{m.} + 26^{mm}.01 \text{ at } 15^{\circ}.52 \text{ C.}$$
$$T_{85} = 100 + 23^{mm}.32 \text{ at } 15.97 \text{ C.}$$
$$2T_{247} = 100 + 5^{mm}.29 \text{ at } 17.41 \text{ C.}$$
$$2T_{248} = 100 + 4^{mm}.19 \text{ at } 17.74 \text{ C.}$$

DETERMINATION OF COEFFICIENTS* OF EXPANSION OF THE STEEL TAPES.

The coefficient of expansion for the two 100-meter tapes was determined by Prof. R. S. Woodward in 1891, at Holton, Ind., and the results found, with their probable errors, were, for Tape No. 88, $y=1^{mm}.0914\pm0^{mm}.0032$, and for No. 85, $y=1^{mm}.0947 \pm0^{mm}.0021$. Although the probable errors were small, these coefficients, when applied to the results in Tables 8, 9, 10, and 11, are evidently too large. The discussion of the 1891 results seemed to tend toward greater uncertainty and larger residuals for determinations made during the daylight hours, doubtless due to radiation effects. It had been the experience of the writer that these uncertainties of temperature during the day were not eliminated by the protection of a shed, as on the office test line and on the Holton 100-meter comparator. It was therefore determined to again solve the observation equations (from the Tables V and VI†), omitting the day observations. From Table V there remain 26 observations on 9 different nights. These, treated in exactly the manner in which the full group of observations was originally treated, give the following equation:

$$T_{85}=20B_{17}+16^{mm}.42\pm0^{mm}.023+(1^{mm}.068\pm0^{mm}.0040)\ (t-11^{\circ}.53 \text{ C.})$$

From Table VI, 24 remaining observations on 8 different nights give

$$T_{88}=20B_{17}+16^{mm}.62\pm0^{mm}.028+(1^{mm}.048\pm0^{mm}.0056)\ (t-9^{\circ}.49 \text{ C.})$$

It will be noted that when only the night observations, approximately one-third the whole group, are used, the probable error of the length is scarcely affected, being increased from $\pm0^{mm}.020$ to $\pm0^{mm}.023$ in the case of T_{85}, and from $\pm0^{mm}.024$ to $\pm0^{mm}.028$ in the case of T_{88}. Moreover, the probable error of a single determination is decreased from $\pm0^{mm}.22$ to $\pm0^{mm}.14$ for T_{88}, and from $\pm0^{mm}.17$ to $\pm0^{mm}.13$ for T_{85}. The writer believes that he can not be justly criticised, therefore, for using this newly determined coefficient in conjunction with others, as all the measures and determinations with these steel tapes were made at night during the measurement of the 9 bases under discussion.

When similarly treated, the data in Tables Nos. 8, 9, 10, and 11 of this Appendix give for the coefficients of the 4 tapes the following results:

For T_{88}, $y=1^{mm}.075\pm0^{mm}.012$
For T_{85}, $y=1.069\pm0.011$
For T_{247}, $y=1.044\pm0.008$
For T_{248}, $y=1.056\pm0.005$

* This term as used in the following discussion must be understood to mean the amount of expansion per hundred meters per degree centigrade.

† Pages 424-427 of Appendix No. 8 of the Report for 1892.

By comparison with the duplex bars, on the nine test kilometers, it is possible to get still another determination of this coefficient. Using the data from the abstracts of these test kilometers, which are found in their proper places in succeeding pages, equations of the form $(t-t_0)y+c=(l-l_0)$ where t is the observed temperature; t_0 is the mean temperature of standardization; c is an unknown, representing the constant difference between the bar length and the tape length under consideration; l is the length of a tape at the observed temperature, as given by one-tenth of the kilometer, and l_0 is the corresponding length x_0 from Tables Nos. 8, 9, 10 and 11, so corrected for inclinations and set-ups as to be comparable with l. For Tape No. 88 the following equations were formed:

		Residuals.
	mm.	mm.
Shelton	$-0.44y+c=-1.80$	-0.50
Page	$+2.70y+c=+2.30$	-0.30
Anthony	$+3.69y+c=+3.50$	-0.44
El Reno	$-9.00y+c=-10.59$	$+0.29$
Bowie	$+3.64y+c=+3.48$	-0.49
Stephenville	$-6.07y+c=-7.58$	$+0.36$
Lampasas	$-6.80y+c=-7.58$	-0.41
Alice	$-1.05y+c=-3.15$	$+1.21$
Seguin	$-11.74y+c=-12.52$	-0.66

The resulting values of c and y are: $c=-0^{mm}.84$ and $y=1^{mm}.051 \pm 0^{mm}.028$.

For Tape No. 85 the following equations were formed:

		Residuals.
	mm.	mm.
Shelton	$-0.34y+c=-1.17$	$+0.19$
Page	$+1.33y+c=+0.84$	-0.05
Anthony	$+2.26y+c=+2.15$	-0.37
El Reno	$-8.87y+c=-9.97$	-0.05
Bowie	$+2.60y+c=+2.48$	-0.34
Stephenville	$-9.62y+c=-10.78$	-0.04
Lampasas	$-6.16y+c=-7.37$	$+0.22$
Alice	$-1.18y+c=-2.56$	$+0.69$
Seguin	$-12.52y+c=-13.62$	-0.27

The resulting values of c and y are: $c=-0^{mm}.62$ and $y=1^{mm}.060 \pm 0^{mm}.015$.

For Tape No. 247 the following equations were formed:

		Residuals.
	mm.	mm.
Shelton	$+6.79y+c=+6.30$	$+0.30$
Page	$+1.15y+c=+0.36$	$+0.26$
Anthony	$-5.98y+c=-6.64$	-0.30
El Reno	$-9.48y+c=-10.99$	$+0.34$
Bowie	$+2.59y+c=+2.83$	-0.68
Stephenville	$-7.46y+c=-8.67$	$+0.16$
Lampasas	$-9.35y+c=-10.25$	-0.26
Alice	$-2.98y+c=-4.26$	$+0.50$
Seguin	$-4.62y+c=-5.21$	-0.29

The resulting values of c and y are: $c=-0^{mm}.60$ and $y=1^{mm}.060 \pm 0^{mm}.018$.

For Tape No. 248 the following equations were formed:

		mm.	Residuals. mm.
Shelton	$+4.28y+c=$	$+2.96$	$+0.59$
Page	$+1.12y+c=$	$+0.91$	-0.56
Anthony	$-5.91y+c=$	-6.43	-0.35
El Reno	$-9.17y+c=$	-10.72	$+0.63$
Bowie	$+1.51y+c=$	$+0.99$	-0.25
Stephenville	$-4.04y+c=$	-4.96	$+0.07$
Lampasas	$-9.27y+c=$	-9.98	-0.21
Alice	$-3.18y+c=$	-3.98	-0.03
Seguin	$-4.24y+c=$	-5.09	0.00

The resulting values of c and y are: $c=-0^{mm}.79$ and $y=1^{mm}.014\pm0^{mm}.022$.

Collecting the several values of y, we have for the four tapes the following coefficients of expansion with their probable errors:

	No. 88.	No. 85.	No. 247.	No. 248.
	mm.	mm.	mm.	mm.
Observations on comparators..	1.075±0.012	1.069±0.011	1.044±0.008	1.056±0.005
1891 observations............	1.048±0.0056	1.068±0.004		
Nine test kilometers..........	1.051±0.028	1.060±0.015	1.060±0.018	1.014±0.022
Weighted means..........	1.053±0.005	1.068±0.001	1.047±0.004	1.054±0.006

ADOPTED EQUATIONS OF TAPES.

Adopting, then, these weighted means as the respective coefficients for the four steel tapes, and using these values in Tables Nos. 8, 9, 10, and 11, the residuals in the fifth column are obtained.

The probable error of a single determination of a tape length (or of two tape lengths in the case of the 50-meter tapes) from these residuals becomes for T_{88}, $\pm0^{mm}.19$; for T_{85}, $\pm0^{mm}.24$; for T_{247}, $\pm0^{mm}.24$; and for T_{248}, $\pm0^{mm}.15$.

From these residuals any change in the length of the apparatus from use during the season may be detected. Tape No 88, for instance, has a sum of the residuals at Shelton equal to $+0^{mm}.32$, or an average of $0^{mm}.03$, while at Seguin the residuals sum up to $-0^{mm}.32$, or an average of $-0^{mm}.04$. This tends to show a lengthening of the tape equal to $0^{mm}.07$, or 1 part in 1 400 000. In like manner Tape No. 85 has an average plus residual of $0^{mm}.18$ at Shelton and an average minus one of $0^{mm}.27$ at Seguin. This seems to be good evidence that No. 85 has increased in length $0^{mm}.45$, or one part in 220 000. However, the residuals from the test kilometers display no apparent change, and for this reason it seems desirable to accept the mean. The residuals for No. 247 indicate a slight elongation of a double tape amounting to $0^{mm}.10$, or 1 part in 1 000 000, while No. 248 by its residuals shows no appreciable change.

The equation for each tape may now be written as follows:

$$T_{88}=100^{m}+26^{mm}.01\pm0^{mm}.045+(1^{mm}.053\pm0^{mm}.005)(t-15^{\circ}.52\text{ C.})$$
$$T_{85}=100^{m}+23^{mm}.32\pm0^{mm}.054+(1^{mm}.068\pm0^{mm}.001)(t-15^{\circ}.97\text{ C.})$$
$$2T_{247}=100^{m}+5^{mm}.29\pm0^{mm}.052+(1^{mm}.047\pm0^{mm}.004)(t-17^{\circ}.41\text{ C.})$$
$$2T_{248}=100^{m}+4^{mm}.19\pm0^{mm}.034+(1^{mm}.054\pm0^{mm}.006)(t-17^{\circ}.74\text{ C.})$$

At the mean temperature of standardization the largest probable error for any tape is 1 part in 1 900 000. At the extreme temperatures of observation the largest probable error for any tape is 1 part in 1 100 000.

SHELTON BASE LINE.

The site of the Shelton Base Line was selected in April, 1899, by Assistant F. D. Granger. It is located in the valley of the Platte River and is parallel to the Union Pacific Railroad track, between the towns of Shelton and Gibbon, in Buffalo County, Nebr. Its middle point is in latitude 40° 46′ and in longitude 98° 47′, and its elevation above the ocean is about 608 meters. The length of the base is approximately 7.89 kilometers and its mean azimuth is 70° 02′.

The terminal markings, which are 56.3 feet north of the north rail of the railroad track, were put in position when the line was connected with the triangulation in May, 1899. The tripods and scaffolds were in place when the measuring party reached the line, so that the surface marks, consisting of copper bolts with cross lines in limestone posts 8 inches square and 2.5 feet long, were undisturbed. Since 1899 a fence, 8 feet from the line, had been erected, which placed it in the public highway for its entire length.

East Base monument was used as a bench mark in a line of precise levels run in 1899 and the connection with the West Base monument was made by Prof. L. S. Smith, a member of the base line party. It would be hard to imagine a more perfect base site when considered topographically, no 100-meter length having a difference of elevation as much as a meter. The only impediment to the progress of the measurement was the team traffic along the line and the high winds encountered when measuring with the duplex bar apparatus. Several thermometer readings over 44°.5 C. were recorded while working with the bars.

The base was divided into eight sections, five of which were 1 kilometer in length; the third (from East Base), 600 meters; the fifth, 1 200 meters, and the sixth, 1 084 meters. Between sections 3 and 4, and 5 and 6, permanent marks were established by using duplicates of the stone marking the ends of the 100-meter comparator. Instead of the brass, spherical-headed bolts, brass screws were cemented into the top surface of the stones. The other section marks were crosses in copper rivets in the top of 6 by 6 inch pine posts, set with 4 feet of their length below the surface.

Sections 3 and 6 (aggregating 1 684 meters) were measured in each direction with the duplex bar apparatus. Sections 2 and 7 (2 000 meters) were measured in one direction with 50-meter tape No. 247 and in the opposite direction with No. 248. Sections 4, 5, and 8 (3 200 meters) were similarly measured with 100-meter tapes Nos. 85 and 88.

The test kilometer, section 1, was measured once with each apparatus. Of the entire base, therefore, 0.24 depends upon the length of the duplex bar apparatus; 0.23 on each 100-meter tape, and 0.15 on each 50-meter tape. The fractional part of a bar length on section 6 was measured with 3-meter steel bar No. 1, whose corrections are known. Table 12 contains the results of the measures of the Shelton Base.

TABLE No. 12.—*Results of measures of Shelton Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.	h. m. h. m.			° C.	°			m.	mm.
1. E. B. to 20	July 27	8 24– 9 00	E. to W.	Tape 247	24.20	0.4	R. F.	C. W.	1 000.2676	+0.9
	27	10 48–11 22	W. to E.	Tape 248	22.02	0.7	F.	C. W.	.2750	−6.5
	28	8 30– 9 04	E. to W.	Tape 85	15.63	0.6	F.	F. D.	.2676	+0.9
	28	9 50–10 25	E. to W.	Tape 88	15.08	0.6	F.	F. D.	.2729	−4.4
	Aug. 1, 2	a. m.	E. to W.	Duplex.	26.92	23.3	R.	F. W.	.2595	+9.0
2. 20 to 40	July 27	9 02– 9 55	E. to W.	Tape 247	23.01	1.9	F.	C. W.	1 000.0573	−1.1
	27	10 12–10 45	W. to E.	Tape 248	22.38	0.4	R. F.	C. W	.0551	+1.1
3. 40 to 52	July 30	p. m.	E. to W.	Duplex.	37.94	4.9	R.	F.	600.1218	+0.8
	31	a. m. & p. m.	W. to E.	Duplex.	38.32	13.3	R. F.	F.	.1233	−0.7
4. 52 to 72	July 24	7 55– 8 45	E. to W.	Tape 85	18.98	2.6	F.	F.	1 000.3057	+0.3
	24	10 50–11 33	W. to E.	Tape 88	15.96	1.1	R.	F.	.3062	−0.2
5. 72 to 96	July 24	8 50– 9 36	E. to W.	Tape 85	17.26	0.5	F.	F.	1 200.4019	−1.3
	24	10 00–10 45	W. to E.	Tape 88	16.36	0.4	F.	F.	.3994	+1.2
6. 96 to 118	Aug. 8, 9	a. m. & p. m.	E. to W.	Duplex.	30.74	5.8	R	C. and F. W.	1 084.0421	−0.1
	9, 10	a. m.	W. to E.	Duplex.	28.80	12.7	R.	F. W.	.0418	+0.2
7. 118 to 138	Aug. 11	8 07– 8 38	W. to E.	Tape 248	22.36	0.9	F.	F.	1 000.1523	+0.:
	11	8 48– 9 20	E. to W.	Tape 247	21.66	0.3	R. F.	F.	.1526	−0.2
8. 138 to W. B.	Aug. 11	9 33–10 00	E. to W.	Tape 85	21.51	0.4	R. F.	F. W.	1 000.1431	−0.7
	11	10 18–10 50	W. to E.	Tape 88	21.09	1.0	F.	F. W.	.1418	+0.6
Total length									7 885.4907	

* The hours of tape measures refer to p. m.

To reduce the measured length to the sea level, the height of Shelton East Base is taken from the precise leveling as 616.1 meters. The levelings of the base in July and August, 1900, gives the mean height of the eight sections and the corresponding reduction to sea level.

	m.	mm.		m.	mm.
Sec. 1.	617.4	96.7	Sec. 5.	621.5	116.8
2.	618.6	96.9	6.	624.7	106.1
3.	620.1	58.3	7.	626.1	98.1
4.	620.1	97.2	8.	627.3	98.3

And the total reduction for the entire base becomes −0.7684 meters.

An inspection of the residuals developed on the test kilometer, where five apparatus are involved, in comparison with the residuals on the other seven sections, where but two, or in the case of the duplex but one, apparatus was used, is sufficient to decide how the probable error should be computed. The errors of manipulation are evidently very small compared with those which are constant for each apparatus.

Therefore, two measures with any single apparatus are regarded as one, and from the probable error of a single measure of a kilometer section, determined from the residuals on the test kilometer, the probable error of the entire length is computed. This probable error of a single measure from the test kilometer is $\pm 4^{mm}.0$, and the probable error of the whole length, therefore, is $\pm 8^{mm}.5$.

Thus, p. e. of whole base=

$$\left(\frac{(4.0)^2}{5}+\frac{(4.0)^2}{2}+\frac{0.6\ (4.0)^2}{1}+\frac{(4.0)^2}{2}+\frac{1.2\ (4.0)^2}{2}+\frac{1.1\ (4.0)^2}{1}+\frac{(4.0)^2}{2}+\frac{(4.0)^2}{2}\right)^{\frac{1}{2}}=\pm 8^{mm}.5.$$

If, on the other hand, the probable errors of the single measures had been taken from the discord of the measures on each section and each divided by the square root of the number of apparatus involved, the total probable error for the base would then become only $\pm 2^{mm}.3$, a quantity which is without doubt too small.

It is quite possible that in the case of the probable error $\pm 2^{mm}.3$ for the base, computed from the discord of the individual measures on each section, there should be added the uncertainty of the comparisons of each apparatus with the 100-meter comparator. Moreover, it is evident that these uncertainties are already measured in the probable error of a single measure of the test kilometer $\pm 4^{mm}.0$, and therefore should not be combined with the probable error $\pm 8^{mm}.5$, which is already a combination of the probable error of measurement, and the probable error of measuring the comparator interval with the different apparatus.

Summing up, the adopted probable error of the entire base becomes,

	mm.
Probable error of standardization and measurement	±8.5
Probable error of reduction to sea level	±0.1
Probable error of 78.9 times comparator, 78.9 ($0^{mm}.037$)	±2.9
Adopted probable error	±9.0

which is about 1/876 000 of the length.

Length of the Shelton Base	7884.7223 meters. ±90
And its logarithm	3.8967864 ± 5

PAGE BASE LINE.

In the valley of the Elkhorn River north of the town of Page, in Holt County, Nebr., the site of the Page Base Line was chosen. A reconnaissance by F. D. Granger, Assistant, Coast and Geodetic Survey, in May, 1900, decided its exact location. Its middle point is in latitude 42° 27′ and longitude 98° 24′ west, and about 592 meters above the sea level. At its southwest end it attains its greatest elevation, 627 meters. There is a general slope of the ground downward toward its northeast terminus of nearly 46 meters. The length is approximately 8.25 kilometers, and the mean azimuth $39^c.9$. At 2.40 kilometers from southwest base a small ridge was crossed, on the northeast face of which the maximum grade was encountered. The correction to the 50-meter tape at this point for the 3.03 meters difference of elevation was 92.1 millimeters. The major part of the line was unbroken prairie used either as pasture or meadow. Twelve barbed-wire fences and five cornfields were crossed in the measurement.

The terminal marks were placed in position before the measurement began. They consist of limestone blocks 6 by 6 by 8 inches in dimensions, set below the surface, while blocks 24 by 24 inches and 14 inches deep, mark the stations at the surface. These monuments, securely set in cement, are lettered and have copper bolts inserted at the centers of their upper surfaces with cross lines marking the ends of the base. The ends of the sections were marked with copper rivets in the top of 4 by 6 inch posts set at least 3 feet in the ground. Exceptions to this marking were made at each end of the "test kilometer" section 6, where limestone blocks 54 inches long, dressed to 6 by 6 inches at the top, carrying copper bolts with cross lines were used.

After the surface monument at Southwest Base had been placed in position, it was connected with bench mark M_2 (1900), thus becoming a bench mark of the precise level line. By means of a forward and backward line the Northeast Base monument was connected with it by Aid O. M. Leland, using precise level No. 5.

The base was divided into eight sections for convenience of measurement. The first, second, fourth, fifth, sixth, and seventh from the southwest end are each 1 kilometer in length, the third 1 050 meters, and the eighth 1 201 meters.

The first three sections were measured in one direction with one 50-meter tape and in the opposite direction with the other 50-meter tape. Sections 4 and 5 were similarly measured with the 100-meter tapes. Sections 7 and 8 were measured in each direction with the duplex bars, while section 6 became the test kilometer. Of the length 0.29, therefore, depends on the duplex bar apparatus; 0.21 on each 50-meter tape, and 0.15 on each 100-meter tape. An extra measure of section 4 with Tape No. 88 was made to detect a supposed error in the first measure. A mean of the two was accepted and no extra weight assigned the result.

Table No. 13 contains the results of the measures made on the Page Base.

TABLE NO. 13.—*Results of measures of Page Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.	h. m. h. m.			°C.	°			m.	mm.
1. SW. B. to 20	Aug. 24	8 15- 9 08	SW. to NE.	Tape 248	15.59	1.2	F.	F. D.	999.8666	−0.5
	24	10 55-11 38	NE. to SW.	Tape 247	14.64	1.5	F.	F. D.	.8656	+0.5
2. 20 to 40	Aug. 24	9 12- 9 50	SW. to NE.	Tape 248	14.30	1.6	F. R.	F. D.	1 000.0560	−0.4
	24	10 15-10 50	NE. to SW.	Tape 247	14.13	1.7	R.	F. D.	.0553	+0.3
3. 40 to 61	Aug. 25	7 28- 8 11	NE. to SW.	Tape 248	18.27	2.2	R.	F.	1 049.8157	+4.7
	25	8 30- 9 15	SW. to NE.	Tape 247	18.68	2.2	F.	F.	.8251	−4.7
4. 61 to 81	Aug. 25	9 35-10 10	SW. to NE.	Tape 88	17.46	4.0	F.	F.	1 000.3079	−1.3
	28	7 40- 8 09	SW. to NE.	Tape 88	19.44	0.8	F.	F.		
	27	10 00-10 33	NE. to SW.	Tape 85	16.59	2.0	R.	F. D.	.3052	+1.4
5. 81 to 101	Aug. 27	7 14- 7 40	SW. to NE.	Tape 88	18.33	1.5	F. R.	F.	1 000.4470	−0.6
	27	9 17- 9 58	NE. to SW.	Tape 85	16.22	1.3	F.	F. D.	.4459	+0.5
6. 101 to 121	Aug. 27	7 43- 8 20	SW. to NE.	Tape 88	18.22	1.1	F.	F.	1 000.2141	−0.9
	27	8 45- 9 15	NE. to SW.	Tape 85	17.30	1.0	F.	F. D.	.2145	−1.3
	28	8 40- 9 24	NE. to SW.	Tape 248	18.86	0.6	R. F.	F.	.2114	+1.8
	28	9 33-10 25	SW. to NE.	Tape 247	18.56	0.4	F. R.	F.	.2171	−3.9
	31	a. m. & p. m.	NE. to SW.	Duplex	31.82	5.2	R.	F.	.2087	+4.5
7. 121 to 141	Aug. 24, 25	p. m.	SW. to NE.	Duplex	30.36	3.0	R.	F. W.	1 000.1074	−3.0
	30, 31	a. m. & p. m.	NE. to SW.	Duplex	26.92	8.1	R.	F. W.	.1014	+3.0
8. 141 to NE. B.	Aug. 27, 28	a. m. & p. m.	SW. to NE.	Duplex	26.22	14.6	R.	F.	1 200.9445	−0.3
	28, 29	p. m.	NE. to SW.	Duplex	31.78	2.3	R. F.	F.	.9439	+0.3
Total length.									8 251.7569	

* The hours of tape measures refer to p. m.

To reduce the measured length to the sea level, the height of Page Southwest Base, taken from the precise leveling, is 626.6 meters. From the levelings of the base in August and September the mean heights of the eight sections and the corresponding reductions to sea level are as follows:

	m.	mm.		m.	mm.
Sec. 1.	614.2	96.4	Sec. 5.	590.4	92.7
2.	602.4	94.5	6.	587.8	92.2
3.	599.4	98.7	7.	583.9	91.6
4.	594.2	93.2	8.	582.0	109.6

and the total reduction for the entire base becomes −0.7689 meters.

In the same manner as at Shelton Base the probable error of a single apparatus on a kilometer as derived from the residuals on the test kilometer is $\pm 2^{mm}.1$, and likewise the probable error of the whole base is $\pm 4^{mm}.7$. The probable error of the base from the discord of the measures on each section is also $\pm 4^{mm}.7$. Combining this probable error with the uncertainty in reduction to sea level and the length of the comparator, the adopted probable error of the whole base becomes:

	mm.
Probable error of standardization and measurement	±4.7
Probable error of reduction to sea level	±0.1
Probable error of 82.5 times comparator, 82.5 ($0^{mm}.037$)	±3.1
Adopted probable error	±5.6

which is about 1/1 473 000 part of the length.

Length of Page Base	8 250.9880 meters.
	± 56
And its logarithm	3.9165060
	± 3

ANTHONY BASE LINE.

The site of the Anthony Base was determined in a reconnaissance by Stehman Forney, Assistant, Coast and Geodetic Survey, in the summer of 1899. The base is about parallel to Bluff Creek in Harper County, Kans. Its southeast terminal is directly north of the schoolhouse in the town of Anthony and 1⅛ miles from it. The northwest terminal is on land belonging to W. W. Millican, of Thorntown, Ind., about equally distant from the towns of Anthony and Harper. The permanent marks at the base ends were put in position when the base was located. Below the surface a limestone block 6 by 6 inches in cross section and 1 foot long (21 inches long at Northwest Base) was set in concrete with its top 4 feet below the surface. Into the top surface of this post a copper bolt was secured, and the center of the station (underground) is a millimeter hole in this bolt.

At the surface a hard limestone block 23 by 23 inches and 16 inches high, weighing 700 pounds, set in a mass of concrete 4 feet square and 4 feet deep, carries at the center of its top surface a bronze station mark, the millimeter hole in the center of which marks the end of the base.

These station marks are made of a composition of copper and brass, and have a shank $7^{mm}.6$ long with a slit in its lower end into which a brass wedge is inserted, so that when the bolt is driven home it bulges out at the bottom of the hole, which is made larger there than at the top, and in this manner is securely fastened in place. The top of the station mark is 80^{mm} in diameter, with an inner circle (countersunk) 37^{mm} in diameter. The letters "U. S. C. & G. S." are cast on the space between the inner and outer circles.

Between the bottom of the surface monument and the bolt marking the point below the surface there is an earthenware drainpipe 7 inches in diameter and 25 inches long. This drainpipe is embedded in the upper mass of concrete and covered with a piece of galvanized iron to prevent anything from falling on the underground mark.

The latitude of the middle point of the base is 37° 11′, and the longitude 98° 03′. The height of its highest point is 423 meters above the sea level, while the azimuth of the line is about 142°.5. The length is approximately 6.03 kilometers. At 2.40 kilometers and again at 2.70 kilometers from Southeast Base the measurement crossed sharp ravines with the tape hung on tall supports 15 to 18 feet in height, and at 3.9 kilometers crossed Spring Creek.

The approach to this creek from the southeast is comparatively gentle, but to leave it necessitated the breaking of the grade of the 100-meter tape length between stakes 79 and 81, where the difference in elevation on 75 meters of the length is 6.57 meters, requiring a grade correction of $96^{mm}.1$ for a 25-meter span. These sections of the line could not have been measured with any form of bar apparatus without expensive preparations. In general, the line traversed cultivated fields except at the northwest end, where there was some unbroken prairie.

It was divided into six sections—sections 1, 3, and 5 being a kilometer in length; section 2, 1 052 meters; section 4, 996 meters, and section 7, 987 meters.

Section 1, though by no means level, was used as the test kilometer, and its northwest end was permanently marked by a stone 3.5 feet long and 6 by 6 inches in cross section, set on solid rock and cemented in position with 1 foot of its height projecting above the surface. A cross in a copper rivet set in the stone marks the exact point. Section 2 was measured once with each of the 50-meter tapes. Sections 3, 4, and 5 were similarly measured with the 100-meter tapes, except that on section 3 two measures with each tape were made. Section 6 was measured in each direction with the duplex bar apparatus. The fractional measures—less than 5 meters—on sections 2, 4, and 6 were made with the 3-meter fractional bar No. 1.

The monuments at Southeast Base and at the end of the test kilometer were used as bench marks in a precise level line (1900) and, incidental to the work of determining the tape grades, the pier at Northwest Base was connected with the levels during the progress of the work by Mr. R. S. Ferguson, Recorder, using precise level No. 5.

Table No. 14 contains the results of the measures of the Anthony Base.

TABLE NO. 14.—*Results of measures of Anthony Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.	h. m. h. m.			°C.	°			m.	mm.
1. SE. B. to 20	Sept. 16	7 25– 7 58	NW. to SE.	Tape 248	11.83	0.4	R. F.	C. W.	999.9262	−2.7
	16	8 11– 8 43	SE. to NW.	Tape 247	11.43	0.8	F.	C. W.	.9280	−4.5
	15–17	p. m. & a. m.	NW. to SE.	Duplex.	26.32	1.4	F. R.	F. W.	.9190	+4.5
	17	7 27– 7 57	NW. to SE.	Tape 88	19.21	0.8	F.	C.	.9229	+0.6
	17	8 16– 8 50	SE. to NW.	Tape 85	18.23	0.8	F.	C.	.9216	+1.9
2. 20 to 41	Sept. 17	9 18– 9 59	SE. to NW.	Tape 248	16.82	0.8	F.	C.	1 052.3314	+1.2
	17	10 18–10 56	NW. to SE.	Tape 247	16.20	0.5	F.	C.	.3338	−1.2
3. 41 to 61 †	Sept. 19	7 32– 7 55	SE. to NW.	Tape 85	15.45	3.5	R.	F.	999.9630	+4.8
	22	7 20– 7 45	SE. to NW.	Tape 85	19.96	0.4	F.	F.		
	19	10 42–11 08	NW. to SE.	Tape 88	15.06	1.6	R. F.	F.	.9726	−4.8
	22	8 05– 8 30	NW. to SE.	Tape 88	19.31	0.6	F.	F.		
4. 61 to 81	Sept. 19	8 00– 8 30	SE. to NW.	Tape 85	14.68	3.1	R. F.	F.	995.9068	−0.4
	19	10 10–10 40	NW. to SE.	Tape 88	13.34	3.5	F. R.	F.	.9059	+0.5
5. 81 to 101	Sept. 19	8 34– 9 00	SE. to NW.	Tape 85	13.93	3.0	F.	F.	1 000.1640	+1.2
	19	9 27–10 07	NW. to SE.	Tape 88	14.24	1.5	R. F.	F.	.1663	−1.1
6. 101 to NW. B.	Sept. 21	a. m. & p. m.	SE. to NW.	Duplex.	21.88	3.7	R.	C.	986.8050	+0.6
	22	a. m. & p. m.	NW. to SE.	Duplex.	26.20	5.5	R.	C.	.8061	−0.5
Total length									6 035.1011	

* The hours of tape measures refer to p. m.

† The individual results from the measures of this section are as follows: Tape 85, 999.9628 and 999.9633. Tape 88, 999.9728 and 999.9723.

The probable error of a single measure from the residuals on the test kilometer is $\pm 2^{mm}.4$, and therefore the probable error of the whole base becomes $\pm 4^{mm}.3$.

From the discord of the individual measures on each section the probable error of the whole base, $\pm 3^{mm}.9$, is deduced. Adopting the larger value and combining this with the uncertainty in the sea level reduction and in the length of the comparator, the adopted probable error of the whole base reduced to sea level becomes:

	mm.
Probable error of standardization and measurement	±4.3
Probable error of reduction to sea level	±0.1
Probable error of 60.3 times comparator, 60.3 ($0^{mm}.037$)	±2.2
Adopted probable error	±4.8

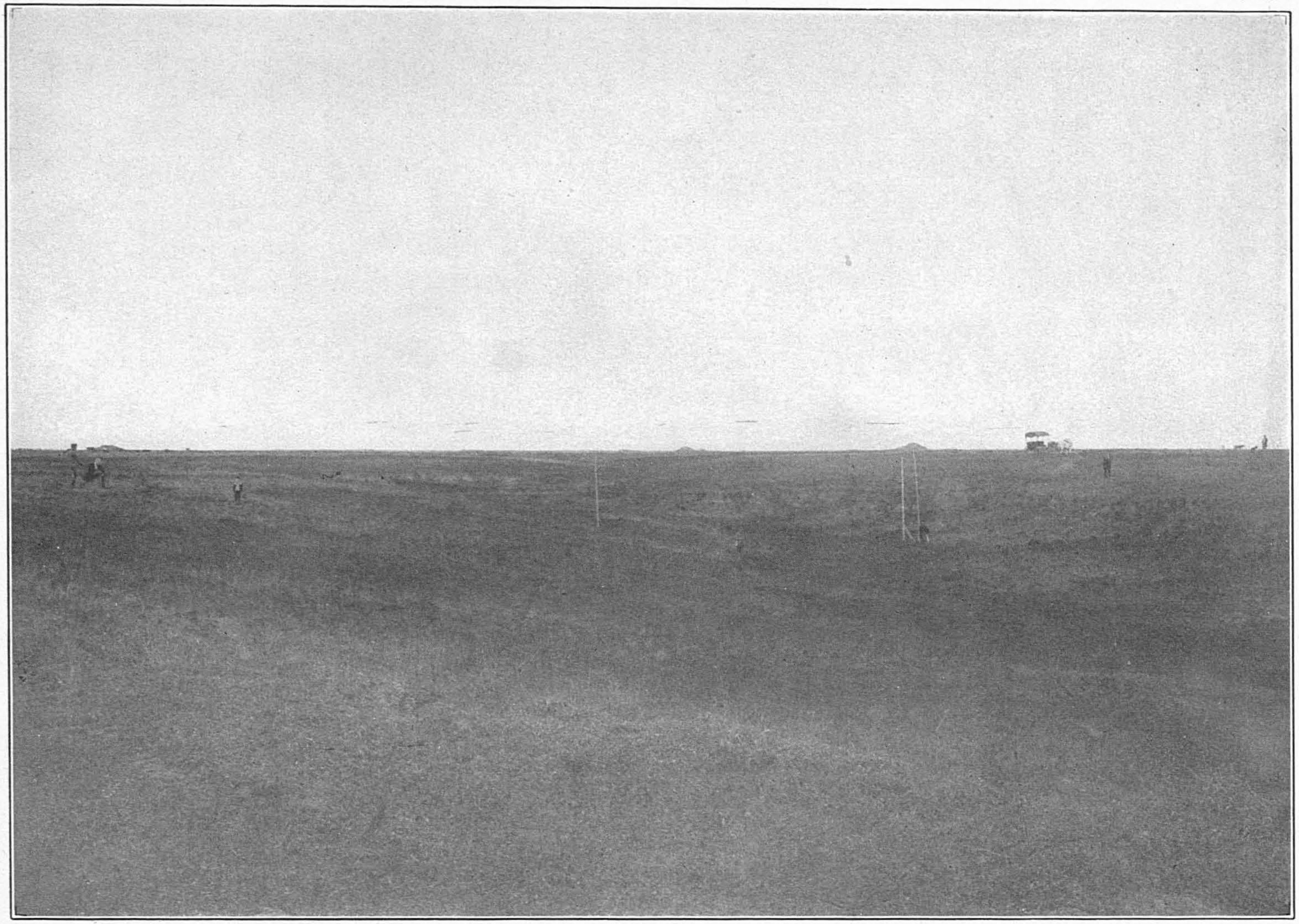
which is about 1/1 257 000 part of the length.

The unreduced length is 6035.1011 meters.
± 48

From the levelings of the base in September, the mean heights of the six sections and corresponding reductions to sea level are as follows:

	m.	mm.		m.	mm.
Sec. 1.	419.6	65.9	Sec. 4.	413.1	64.6
2.	420.0	69.4	5.	418.4	65.7
3.	414.9	65.2	6.	422.8	65.5

NO. 16.



CROSSING RAVINE WITH 100-METER TAPE.

and the total reduction for the entire base becomes $-396^{mm}.3$.

Length of the Anthony Base reduced to sea level	6034.7048 meters.
	± 48
And its logarithm	3.7806560
	± 3

EL RENO BASE LINE.

On the divide between the Canadian River and the North Fork of the Canadian is located the longest base in the ninty-eighth meridian triangulation—the El Reno Base.

The reconnaissance by Stehman Forney, Assistant, in 1899, decided its location, and the terminals were permanently marked by him. It is in Canadian County, Okla., southwest of the city of El Reno.

Its middle point is in approximate latitude 35° 28′ and longitude 98° 02′ west and is about 425 meters above sea level. The length is 12.9 kilometers and the azimuth of the line is roughly 110°.

The western terminal is the highest point on the line, and the descent from this point is 36 meters in the first kilometer. From this point the line retains this general elevation for 7 kilometers. The last 5 kilometers are comparatively smooth, with a rise in the last kilometer of 13 meters to East Base. The western half is broken by two sharp ravines, where 18-foot supports were needed for the 100-meter tapes. At the approach to one of these ravines on section 4 the steepest grade was encountered, where the difference in elevation in a 25-meter span was 2.85 meters and the corresponding correction for grade was $162^{mm}.7$. About fifty wire fences intersect the line and two large straw piles had to be removed before the measurement was made. At 1.2 kilometers from East Base the line crosses the track of the Chicago, Rock Island and Pacific Railway.

East Base is on the land of Mr. G. L. Newman, and the piers are similar to those described for the Anthony Base. The surface monument is a red sandstone 2 by 2 feet in cross section, 1 foot high, and weighs 600 pounds. A bronze station mark similar to that used at Anthony in the center of this stone marks the end of the base. This mark is 48 inches above the bolt in the limestone block which marks the station below the surface.

At West Base a similar monument on the land of Mr. J. T. Seawell marks the end of the base. It is on the summit of a prominent hill 2½ miles south and 6¾ west of the Rock Island depot in El Reno.

The leveling for the tape grades and for the mean height of the thirteen sections was not connected with any known bench mark. The end monuments, which are bench marks of the most permanent character, will ultimately be connected with the precise level net of the Coast and Geodetic Survey.

The base was divided into thirteen sections, numbered from West Base. Section 7 is 444 meters, and section 9, 1 450 meters long, while the other eleven sections are approximately 1 kilometer in length.

Sections 1, 2, 3, 4, and 5 were measured once with each 100-meter tape; sections 9, 10, 11, 12, and 13 were similarly measured, using the 50-meter tapes, and sections 7 and 8 were measured in each direction with the duplex bars. Section 6 was chosen as the test kilometer, being most easily accessible from the camp, and was measured with each apparatus in the usual way, except that two extra measures were made with 100-meter tape No. 88, as additional checks on the constancy of its length, but the mean of the three results used as one.

The base therefore depends for its length as follows: 0.13 on the duplex bar apparatus, 0.21 on each 100-meter tape, and 0.23 on each 50-meter tape.

Table No. 15 contains the results of the base measures.

TABLE NO. 15.—*Results of measures of El Reno Base.*

No. of section and stakes.	Date.		Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.		h. m. h. m.			°C.	°			m.	mm.
1. W. B. to 20	Oct.	5	8 43- 9 18	E. to W.	Tape 85	21.62	0.8	R.	F. W.	999.2040	+2.7
		5	9 35-10 02	W. to E.	Tape 88	22.06	0.8	R. F.	F. W.	.2094	-2.7
2. 20 to 40	Oct.	5	8 03- 8 37	E. to W.	Tape 85	20.09	0.7	R.	F. W.	996.4257	+2.1
		5	10 10-10 40	W. to E.	Tape 88	21.83	0.8	F.	F. W.	.4300	-2.2
3. 40 to 60	Oct.	5	7 35- 8 00	E. to W.	Tape 85	21.82	1.2	F.	F. W.	999.7729	+2.7
		5	10 45-11 10	W. to E.	Tape 88	21.27	0.5	F.	F. W.	.7783	-2.7
4. 60 to 80	Oct.	6	7 37- 8 20	E. to W.	Tape 88	19.13	1.1	F.	F. W.	994.6343	-1.1
		6	8 30- 9 08	W. to E.	Tape 85	18.26	1.0	F.	F. W.	.6320	+1.2
5. 80 to 100	Oct.	6	7 10- 7 34	E. to W.	Tape 88	19.95	0.6	F.	F. W.	1 000.3244	-2.7
		6	9 10- 9 45	W. to E.	Tape 85	17.34	1.0	F.	F. W.	.3190	+2.7
6. 100 to 120†	Oct.	8	7 10- 7 42	W. to E.	Tape 248	8.57	1.4	R. F.	F.	1 000.0924	-3.1
		8	7 52- 8 25	E. to W.	Tape 247	7.93	0.8	R. F.	F.	.0925	-3.2
		8	8 38- 9 03	W. to E.	Tape 85	7.10	0.7	R. F.	F.	.0869	+2.4
		8	9 22- 9 50	E. to W.	Tape 88	6.86	1.0	R. F.	F.		
		8	9 55-10 17	W. to E.	Tape 88	6.64	0.9	R. F.	F. D.	.0930	-3.7
		8	10 22-10 50	E. to W.	Tape 88	6.07	1.0	R. F.	F. D.		
		13	a. m. & p. m.	W. to E.	Duplex	20.64	7.8	R.	C.	.0819	+7.4
7. 120 to 128	Oct.	15	a. m.	E. to W.	Duplex	16.88	2.2	R.	C.	444.3209	-0.7
		16	a. m.	W. to E.	Duplex	16.16	1.3	R.	C.	.3196	+0.6
8. 128 to 148	Oct.	16, 17	p. m.	W. to E.	Duplex	15.88	0.9	R.	C.	1 000.2122	-1.0
		18	a. m.	E. to W.	Duplex	17.72	6.4	R.	C.	.2102	+1.0
9. 148 to 177	Oct.	11	8 11- 8 45	W. to E.	Tape 248	9.18	3.1	F. R.	F.	1 449.8521	+2.9
		11	10 07-10 32	E. to W.	Tape 247	7.65	2.9	R. F.	F.	.8578	-2.8
10. 177 to 197	Oct.	11	9 00- 9 35	W. to E.	Tape 248	9.54	4.4	F.	F.	999.9762	-1.0
		11	9 38-10 05	E. to W.	Tape 247	8.35	3.3	R. F.	F.	.9743	+0.9
11. 197 to 217	Oct.	9	7 55- 8 20	W. to E.	Tape 248	8.06	1.1	R.	C. D.	999.9038	+1.2
		9	10 42-11 08	E. to W.	Tape 247	7.45	0.7	F. R.	C. D.	.9062	-1.2
12. 217 to 237	Oct.	9	8 22- 8 50	W. to E.	Tape 248	8.94	0.6	R. F.	C. D.	1 002.9765	+1.5
		9	10 07-10 40	E. to W.	Tape 247	7.10	0.9	R.	C. D.	.9796	-1.6
13. 237 to E. B.	Oct.	9	8 52- 9 25	W. to E.	Tape 248	8.55	1.6	F. R.	C. D.	999.8387	+1.7
		9	9 37-10 05	E. to W.	Tape 247	7.50	2.5	F.	C. D.	.8422	-1.8
Total length										12 887.5393	

*The hours of tape measures refer to p. m.

†The individual results from the measures of this section with Tape 88 are as follows: $1000^{m}.0962$, $1000^{m}.0927$, and $1000^{m}.0902$.

The probable error of a single measure from the residuals on the test kilometer is $\pm 3^{mm}.2$, and therefore the probable error of the length of the whole base becomes $\pm 8^{mm}.4$.

From the discord of the individual measures on each section the probable error of the whole base, $\pm 5^{mm}.0$, is deduced.

Adopting the larger value and combining with the uncertainty in the comparator, the adopted probable error of the base becomes

	mm.
Probable error of standardization and measurement	±8.4
Probable error of 128.9 times comparator, 128.9 ($0^{mm}.037$)	±4.8
Adopted probable error	±9.7

which is about 1/1 329 000 part of the length.

The length not reduced to sea level is 12887.5393 meters
±97

A provisional height was assumed for West Base of 461 meters, and the resulting heights and corrections to reduce the thirteen sections to sea level are:

	m.	mm.		m.	mm.
Sec. 1.	437.2	68.5	Sec. 8.	423.9	66.4
2.	425.5	66.4	9.	419.0	95.2
3.	423.6	66.4	10.	415.9	65.2
4.	423.4	66.0	11.	414.7	65.0
5.	426.6	66.9	12.	417.3	65.6
6.	427.5	67.0	13.	428.8	67.2
7.	427.5	29.8			

and the total reduction for the entire base becomes −0.8556 meters.

The provisional length of the El Reno Base then becomes 12886.6837 meters
±97

And its logarithm 4.1101411
± 3

BOWIE BASE LINE.

During a reconnaissance by Stehman Forney, Assistant, in 1899, a site for the Bowie Base was located on the divide south of the Red River in Clay and Montague counties, Tex. It is west of the city of Bowie and south of the town of Bellevue. Its middle point is in approximate latitude 33° 36′ and very near the meridian of 98° west. The length of the line is 8.20 kilometers and its azimuth about 160°.

The northeast terminal is 1 mile southeast of the town of Bellevue, in Clay County, on a prominent knoll on the farm belonging to the Orton Brothers. It is almost exactly 6 meters below the southeast terminal which is on the highest part of a prominent ridge on the farm of C. H. Bodeker.

The marks at the ends of the base are of the most permanent character. The piers at the surface and the marks underground are duplicates of those described for the El Reno Base, with a single exception. At Northwest Base the native rock was found at 3 feet below the surface and a copper bolt in this rock was made the underground mark.

Nothing unusual in the topography was encountered. Beginning at the southeast end, the line falls 20 meters in the first 700 meters, rises gradually for the next kilometer, crosses several little creeks, and falls to its minimum height where it crosses a small creek at 5.7 kilometers. The heaviest grades are on section 8 approaching Northwest base, where in 1 100 meters there is a rise of 27 meters. The maximum grade occurs in a 25-meter span on which the difference in elevation is 1.64 meters and the corresponding correction $54^{mm}.0$.

The grades and profile were determined by leveling in duplicate with precise level No. 5, but as there were no bench marks in the immediate vicinity, the end piers preserve the base height for future determinations. The height of the northwest terminal is about 317 meters above the sea level.

The base was divided into eight sections, beginning at Southeast Base, the first six being 1 kilometer in length, the seventh 1 098 meters, and the eighth 1 099 meters.

Sections 1, 2, and 3 were measured once with each 100-meter tape. Sections 4, 6, and 8 were similarly measured with the 50-meter tapes. Section 7 was measured in each direction with the duplex bar apparatus. Section 5 became the test kilometer on account of its convenient location rather than its topography. The measurement of this section with the bar apparatus involved the necessity of using very heavy grades, amounting in one instance to 4° 41′. With the tapes, it became necessary to have a different grade for the 50-meter tape from that of the 100-meter tape in order to cross two small ravines without high marking stakes.

The base depends for its length as follows: 0.16 on the duplex bar apparatus; 0.21 on each 100-meter tape, and 0.21 on each 50-meter tape.

Table No. 16 contains the results of all the various measures made on the Bowie Base.

TABLE NO. 16.—*Results of measures of Bowie Base.*

No. of section and stakes.	Date.		Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.		h. m. h. m.			°C.	°			m.	mm.
1. SE. B. to 20	Oct.	25	9 26– 9 47	NW. to SE.	Tape 88	19.41	0.5	R.	F.	999.8493	−1.7
		25	10 02–10 28	SE. to NW.	Tape 85	19.08	0.3	F.	F.	.8459	+1.7
2. 20 to 40	Oct.	25	9 03– 9 24	NW. to SE.	Tape 88	19.51	0.4	F.	F.	999.9549	+0.6
		25	10 30–10 56	SE. to NW.	Tape 85	18.70	0.6	F.	F.	.9561	−0.6
3. 40 to 60	Oct.	25	8 42– 9 02	NW. to SE.	Tape 88	19.78	0.5	F.	F.W.	999.9375	−3.3
		25	10 58–11 26	SE. to NW.	Tape 85	18.42	0.1	F.	F.	.9310	+3.2
4. 60 to 80	Oct.	27	8 41– 9 09	NW. to SE.	Tape 248	19.38	0.7	F.R.	C.	999.6868	−0.8
		27	9 20– 9 55	SE. to NW.	Tape 247	19.27	0.3	F.R.	C.	.6851	+0.9
5. 80 to 100	Oct.	27	8 00– 8 25	NW. to SE.	Tape 85	18.57	2.0	R.	C.	999.7905	−0.7
		27	10 11–10 47	SE. to NW.	Tape 88	19.16	0.4	F.R.	C.	.7910	−1.2
		29	8 22– 8 53	NW. to SE.	Tape 248	19.25	1.3	R.	F.	.7934	−3.6
		29	9 04– 9 40	SE. to NW.	Tape 247	20.00	0.7	R.	F.	.7862	+3.6
	Nov.	3	a.m. & p.m.	NW. to SE.	Duplex.	20.30	10.2	R.	F.	.7877	+2.1
6. 100 to 120	Oct.	29	7 51– 8 20	NW. to SE.	Tape 248	19.21	1.4	F.	F.	999.4917	−0.9
		29	9 42–10 14	SE. to NW.	Tape 247	19.52	0.3	F.R.	F.	.4900	+0.8
7. 120 to 142	Nov.	1	a.m. & p.m.	SE. to NW.	Duplex	19.19	8.9	R.	F.	1 098.1478	−2.0
		2	a.m. & p.m.	NW. to SE.	Duplex	16.34	12.2	R.	F.	.1438	+2.0
8. 142 to NW. B.	Oct.	31	7 38– 8 06	NW. to SE.	Tape 247	8.00	4.0	F.	F.	1 099.5830	−2.8
		31	8 22– 8 57	SE. to NW.	Tape 248	7.00	2.8	R.	F.	.5774	+2.8
Total length										8 196.4299	

*The hours of tape measures refer to p. m.

The probable error of a single measure from the residuals on the test kilometer is $\pm 1^{mm}.9$, and therefore the probable error of the length of the whole base becomes $\pm 4^{mm}.0$.

From the discord of the individual measures on each section, the probable error of the whole base, $\pm 3^{mm}.9$, is deduced.

Adopting the larger value and combining it with the uncertainty in the comparator, the adopted probable error of the whole base becomes:

	mm.
Probable error of standardization and measurement	±4.0
Probable error of 82 times comparator, 82.0 ($0^{mm}.037$)	±3.0
Adopted probable error	±5.0

which is about 1/1 639 000 part of the length.

The length before reducing to sea level is 8 196.4299 meters ± 50

Assuming a height for Northwest Base equivalent to 316.68 meters, the resulting heights of and corrections to reduce the eight sections to sea level are:

	m.	mm.		m.	mm.
Sec. 1.	310.2	48.8	Sec. 5.	292.0	45.9
2.	314.1	49.4	6.	285.8	44.9
3.	309.1	48.6	7.	292.6	50.5
4.	302.3	47.5	8.	300.9	52.0

and the total reduction for the entire base becomes −0.3876 meters.

The provisional length of the Bowie Base then becomes . . . . 8 196.0423 meters ± 50

And its logarithm . . . . 3.9136041 ± 3

STEPHENVILLE BASE LINE.

The Stephenville Base was located by Stehman Forney, Assistant, Coast and Geodetic Survey, in the summer of 1899. It is on the eastern side of the Bosque River, Erath County, Tex. Its southern end is about three-fourths mile west of the town of Selden, on a ridge between Indian and Simms creeks. It follows closely the crest of this ridge until it culminates at North Base in a prominent knoll known locally as Bunker Hill. The line is 7 miles southeast of the town of Stephenville. Its middle point has an approximate latitude of 32° 10′ and is close to the ninety-eighth meridian. Its azimuth is roughly 4° 15′ and its highest point is North Base, which is 442 meters above sea level. Its length is 6.3 kilometers. The grades over the entire length were gentle, the maximum being 1.42 meters in a span of 25 meters with a correction of $4^{mm}.0$.

The permanent marks at the ends of the base were put in position by the reconnaissance party in 1899. The underground marks are small drill holes in the end of copper bolts cemented into the tops of hard limestone posts. These posts are 14 inches long and 6 inches square, and are set with their tops 34 inches below the surface, with a mass of concrete 24 inches square surrounding them. Above the top of this mark the mass of concrete is 4 feet square, and embedded in it, at the surface, is a hard limestone block 24 inches square and 14 inches thick, weighing 600 pounds. The center of the station at the surface is secured by a metal station mark, a duplicate of that described for the marks at the Anthony Base (page 270). North Base is 5½ miles east of the Court-House in Stephenville, and a half mile north of the road leading to Skippers Gap. It is on the summit of Bunker Hill, on land belonging to Geo. W. Gentry, of Selden, Tex. South Base is located on land of Mr. Willie Funk, of Midland, Tex., and is near the public road between Stephenville and Hyco, Tex. A line cleared through the timber, made by the measuring party, will readily guide one to the station.

The grades and profile of the line were determined by leveling in duplicate with precise level No. 5. There being no bench marks in the vicinity, the end piers preserve the height of the base for future determinations. The base was divided into six sections. Beginning at North Base, the first three were each 1 000 meters, the fourth 1 100 meters, the fifth 1 000 meters, and the sixth 1 156 meters in length. Sections 1 and 2 were measured once with each 100-meter tape. Sections 3 and 4 were measured with each 50-meter tape. Section 6 was measured in each direction with the duplex bar apparatus. Section 5 was used as the test kilometer and was therefore measured once with each apparatus.

The base depends for its length as follows: 0.21 on the duplex bar apparatus, 0.20 on each 50-meter tape, and 0.19 on each 100-meter tape.

Table No. 17 contains the results of all the measures made on the Stephenville base.

TABLE NO. 17.—*Results of measures of Stephenville Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind W.	Length of section.	Residual (mean minus observed).
	1900.	h. m. h. m.			°C.	°			m.	mm.
1. N. B. to 20	Nov. 12	7 50- 8 12	S. to N.	Tape 85	8.06	2.0	F. R.	F.	999.9668	+1.6
	12	8 40- 9 09	N. to S.	Tape 88	7.86	1.9	R. F.	F.	.9700	−1.6
2. 20 to 40	Nov. 12	7 23- 7 47	S. to N.	Tape 85	8.12	1.4	R.	F.	999.8875	−0.3
	12	9 11- 9 35	N. to S.	Tape 88	7.44	1.0	F.	F.	.8868	+0.4
3. 40 to 60	Nov. 13	7 36- 8 01	S. to N.	Tape 248	11.05	4.2	F. R.	F.	999.6872	+1.5
	13	8 14- 8 40	N. to S.	Tape 247	10.04	2.2	R.	F.	.6902	−1.5
4. 60 to 82	Nov. 13	7 04- 7 34	S. to N.	Tape 248	10.58	4.3	F. R.	F.	1 099.8098	−1.3
	13	8 42- 9 11	N. to S.	Tape 247	11.17	0.8	R. F.	F. W.	.8072	+1.3
5. 82 to 102	Nov. 12	10 50-11 11	S. to N.	Tape 85	6.35	1.8	R. F.	F.	999.9495	+1.4
	13	10 13-10 35	N. to S.	Tape 88	9.45	0.4	F. R.	F.	.9563	−5.4
	13	6 35- 7 02	S. to N.	Tape 248	13.70	3.7	R. F.	F.	.9513	−0.4
	13	9 13- 9 43	N. to S.	Tape 247	9.95	1.1	F.	F.	.9529	−2.0
	14	a. m. & p. m.	S. to N.	Duplex	21.96	6.2	R.	F. to C.	.9444	+6.5
6. 102 to S. B.	Nov. 15	a. m. & p. m.	N. to S.	Duplex	22.90	5.8	R. F.	C. to F.	1 156.1877	+0.4
	16	a. m. & p. m.	S. to N.	Duplex	22.34	6.5	R.	C. to F.	.1885	−0.4
Total length									6 255 4918	

* The hours of tape measures refer to p. m.

The probable error of a single measure, from the residuals on the test kilometer, is $\pm 3^{mm}.0$, and therefore the probable error of the length of the whole base becomes $\pm 5^{mm}.5$.

From the discord of the individual measures on each section the probable error of the whole base would be only $\pm 2^{mm}.3$.

Adopting the larger probable error and combining with the uncertainty in the length of the comparator, the adopted probable error for the Stephenville Base becomes:

	mm
Probable error of standardization and measurement	±5.5
Probable error of 62.5 times comparator, 62.5 ($0^{mm}.037$)	±2.3
Adopted probable error	±6.0

which is about 1/1 043 000 part of the length.

The length not reduced to sea level is .... 6 255.4918 meters
±60

A provisional height for North Base was assumed at 442 meters and the resulting heights and corrections to reduce the six sections to sea level are:

	m	mm		m	mm
Sec. 1.	435.5	68.5	Sec. 4.	420.5	72.8
2.	424.9	66.9	5.	419.1	66.0
3.	422.5	66.5	6.	416.6	75.8

and the total reduction for the entire base becomes −0.4165 meter.

The provisional length of the Stephenville Base then becomes .... 6 255.0753 meters
±60

And its logarithm 3.7962326
± 4

LAMPASAS BASE LINE.

The problem of the selection of a site for a primary base along the arc of the ninety-eighth meridian near the thirty-first parallel of latitude was solved by Assistant Stehman Forney in 1899. The Lampasas Base lies across the drainage, with its northeastern terminal about 2 miles east of the city of Lampasas, in Lampasas County, Tex. The southwestern end is on the brow of a prominent hill about 2 miles south of the city and nearly a mile west of the Austin road. The character of the topography along the line of measurement makes it the *roughest base* yet selected in the meridian arc, while its length, 6 kilometers, makes it also the *shortest*. The middle point of the line is in latitude 31° 02′ and its azimuth is 215°.

The highest point of the base is its southwest terminal, and the difference of elevation between the two ends exceeds 66 meters. Appended to this report is a profile of the line and a sketch of the base figure. Although this base is the roughest and shortest of the nine measured, its accuracy in proportional parts is exceeded by only two of the nine. This indicates that the principle on which the reconnaissance party acted is correct, namely, that it was more desirable to secure good geometric conditions in the base net than to get the most favorable topography for the base.

While the abruptness of the grades may seem startling, the results show that such inequalities of the line are easily surmounted when the measuring apparatus consists of long tapes. The maximum grade occurs in the first section, where it exceeds 3.1 meters in a 25-meter span and has a corresponding correction equal to 200^{mm}. For 1 mile at the northeast end the line required clearing, as it was covered with low, scrubby oaks.

The permanent marks were already in place when the measuring party arrived. At Northeast Base, the sub-surface mark is a metal station mark, as described under the heading Anthony Base (page 270), cemented into solid rock. A similar mark in the top of a limestone block 24 by 24 inches and 13 inches thick marks the station at the surface. This surface block is securely set in a body of concrete 48 by 48 inches, the solid rock being cut away a few inches to allow the upper surface of the block to be placed even with the ground.

At the southwest terminal, the underground mark is 6 by 6 inches and 12 inches long, embedded in concrete with its top surface 24 inches below the top of the surface stone.

This surface stone is of limestone and 24 inches square and 14 inches deep. It is embedded in a mass of concrete 48 by 48 inches, 22 inches deep. Both stones carry the station marks, the lower one being protected by a wooden box 8 inches long with a board over the top. Northeast Base is about 250 meters north of the Belton road in a pasture belonging to Mr. Howard, of Lampasas, and is near the northeastern brow of a timbered hill. Southwest Base is in what is known as the Craft pasture.

As no bench marks exist in the vicinity, the grades and profile were determined by leveling in duplicate with precise level No. 5 between the end piers, which will preserve the provisional height of the base for future determination.

The base was divided into six sections beginning at Southwest Base; the first, second, fifth, and sixth were each 1 000 meters, the third 1 449 meters, and the fourth 515 meters in length.

Sections 1 and 2 were measured once with each 50-meter tape; sections 3 and 6 once with each 100-meter tape; section 4 was measured in each direction with the duplex bar apparatus. Section 5 became the test kilometer, and was measured once with each of the tapes and once with the duplex bar apparatus.

The base depends for its length as follows: 0.12 on the duplex bar apparatus; 0.24 on each 100-meter tape, and 0.20 on each 50-meter tape.

Table No. 18 contains the results of the measures made on the Lampasas Base.

TABLE NO. 18.—*Results of measures of Lampasas Base.*

No. of section and stakes.	Date.		Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; cloudy, C.; dew, D.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.		h. m. h. m.			°C.	°			m.	mm.
1. SW. B. to 20	Dec.	1	8 28– 9 03	NE. to SW.	Tape 248	7.59	2.3	R	F	998.7428	+0.2
		1	9 13– 9 58	SW. to NE.	Tape 247	7.92	1.0	F	F	.7432	−0.2
2. 20 to 40	Dec.	1	7 57– 8 25	NE. to SW.	Tape 248	7.43	3.0	F	F	999.3494	+0.6
		1	9 59–10 30	SW. to NE.	Tape 247	7.32	1.2	R	F	.3509	−0.7
3. 40 to 69	Nov.	28	7 45– 8 25	SW. to NE.	Tape 85	12.63	0.3	RF	C	1449.3423	+1.2
		28	8 39– 9 20	NE. to SW.	Tape 88	12.28	0.4	F	C	.3447	−1.2
4. 69 to 79	Nov.	30	a. m.	SW. to NE.	Duplex	19.76	0.9	R	F	514.7233	+1.5
		30	p. m.	NE. to SW.	Duplex	19.90	1.2	F	F	.7262	−1.4
5. 79 to 99	Nov.	27	8 01– 8 19	SW to NE.	Tape 85	9.81	1.6	R	F	999.8616	−4.1
		27	9 27– 9 55	NE. to SW.	Tape 88	8.72	1.9	F	F	.8579	−0.4
		27	10 08–10 40	SW. to NE.	Tape 248	8.47	2.6	FR	F	.8558	+1.7
		27	10 47–11 29	NE. to SW.	Tape 247	8.08	1.5	FR	FD	.8585	−1.0
	Dec.	1	a.m. & p.m.	SW. to NE.	Duplex	20.36	7.2	R	F	.8539	+3.6
6. 99 to NE. B.	Nov.	27	8 21– 8 44	SW. to NE.	Tape 85	9.49	2.6	F	F	999.4769	+1.4
		27	9 01– 9 25	NE. to SW.	Tape 88	10.23	1.8	R	F	.4797	−1.4
Total length										5961.4973	

* The hours of tape measures refer to p. m.

The probable error of a single measure from the residuals on the test kilometer is $\pm 2^{mm}.0$, and thus the probable error of the whole base becomes $\pm 3^{mm}.4$.

From the discord of the individual measures on each section the probable error of the whole base would be but $\pm 2^{mm}.5$.

Adopting the larger probable error and combining with it the uncertainty in the length of the comparator, the adopted probable error of the Lampasas Base becomes:

	mm.
Probable error of standardization and measurement	± 3.4
Probable error of 60 times comparator, 60 ($0^{mm}.037$)	± 2.2
Adopted probable error	± 4.1

which is about 1/1 454 000 part of the length.

The length not reduced to sea level is 5 961.4973 meters. ± 41

A provisional height was assumed for Southwest Base equal to 420 meters, and the resulting heights and corrections to reduce the six sections to sea level are:

	m.	mm.		m.	mm.
Sec. 1.	420.4	63.2	Sec. 4.	384.4	31.1
2.	394.8	62.0	5.	381.5	60.0
3.	392.1	89.3	6.	363.0	57.0

and the total reduction for the entire base becomes -0.3626 meters.

The provisional length of the Lampasas Base then becomes	5 961.1347 meters. ± 41
And its logarithm	3.7753289 ± 3

ALICE BASE LINE.

About 7 miles south of the town of Alice, in Nueces County, Tex., the Alice Base Line was located in 1899 by Assistant Stehman Forney. Its middle point is in latitude 27° 46′ near the ninety-eighth meridian, and its azimuth is approximately 90°.

The height of the base above sea level is approximately 64 meters, and its length 7 kilometers.

The line is smooth, traversing pasture land covered with scattering mesquite brush and cactus. There is a very gradual slope from west to east, amounting to but 9.44 meters in the whole length of the line. The terminals were perpetuated in the same manner as at Lampasas Southwest Base, and these piers were made bench marks for future connection with the level net of the United States.

The West Base pier is only 300 meters from the house of Luciano Garcia, to whom the land belongs, and is 3 888 meters west of the center of the Alice and Brownsville stage road.

There are no prominent objects in the vicinity of East Base, which is 3 083 meters east of the center of the stage road.

The base was divided into seven sections, beginning at the east end. The first four and the last two sections are each 1 kilometer long, while the fifth is 971 meters.

Sections 1, 2, and 3 were measured once with each 100-meter tape, sections 6 and 7 were measured once with each 50-meter tape, section 5 was measured in each direction with the duplex bar apparatus, while the test kilometer, section 4, was measured once with each of the tapes and once with the duplex bar apparatus.

The base depends for its length as follows: 0.17 on the duplex bar apparatus, 0.24 on each 100-meter tape, and 0.17 on each 50-meter tape.

Table No. 19 contains the results of the measures made on the Alice Base.

TABLE No. 19.—*Results of measures of Alice Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; dew, D.; cloudy, C.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.	h. m h. m.			°C	°			m	mm.
1. E. B. to 20	Dec. 8	8 22- 8 47	W. to E.	Tape 88	4.95	2.0	F.	F.	1 000.1029	− 2.6
	8	9 04- 9 27	E. to W.	Tape 85	3.74	0.7	F. R.	F.	.0978	+ 2.5
2. 20 to 40	Dec. 8	7 59- 8 20	W. to E.	Tape 88	6.72	2.4	F.	F.	1 000.1807	+ 1.3
	8	9 29- 9 52	E. to W.	Tape 85	3.76	1.2	R. F.	F.	.1833	− 1.3
3. 40 to 60	Dec. 10	9 13- 9 28	W. to E.	Tape 85	14.35	0.1	R.	C.	1 000.1430	+ 1.3
	10	9 42-10 03	E. to W.	Tape 88	14.49	0.2	F.	C.	.1456	− 1.3
4. 60 to 80	Dec. 10	8 05- 9 10	W. to E.	Tape 85	14.79	1.0	F.	C.	999.9939	− 2.6
	10	10 05-10 28	E. to W.	Tape 88	14.47	0.1	F. R.	C.	1 000.0013	−10.0
	10	10 40-11 10	W. to E.	Tape 247	14.50	0.2	F.	C.	999.9930	− 1.7
	10	11 22-11 51	E. to W.	Tape 248	14.56	0.4	F.	C.	.9872	+ 4.1
	14	p. m.	W. to E.	Duplex	15.28	0.5	R. F.	C.	.9810	+10.3
5. 80 to 100	Dec. 15	a. m. & p. m.	E. to W.	Duplex	20.67	5.2	R.	F. W.	971.3267	+ 0.5
	18	p. m	W. to E.	Duplex	23.86	2.6	R.	C.	.3277	− 0.5
6. 100 to 120	Dec. 15	7 14- 8 55	E. to W.	Tape 248	15.65	0.6	F.	C. W.	1 000.0026	+ 1.3
	15	9 57-10 22	W. to E.	Tape 247	15.24	0.1	F.	C. W.	.0052	− 1.3
7. 120 to W. B.	Dec. 15	8 57- 9 24	E. to W.	Tape 248	15.32	0.1	F.	C. W.	1 000.0065	+ 2.5
	15	9 29- 9 55	W. to E.	Tape 247	15.33	0.2	R. F.	C. W.	.0115	− 2.5
Total length									6 971.7581	

*The hours of tape measures refer to p. m.

The probable error of a single measure from the residuals on the test kilometer is $\pm 5^{mm}.1$, and thus the probable error of the whole base becomes $\pm 9^{mm}.8$. This probable error is larger than that of any other of the nine base lines measured, although the conditions of topography and weather were most nearly perfect.

From the discord of the individual measures on each section the probable error would be but $3^{mm}.7$. Adopting the larger probable error and combining with it the uncertainty in the length of the comparator, the adopted probable error of the Alice Base becomes:

	mm.
Probable error of standardization and measurement	± 9.8
Probable error of 70 times comparator, 70 ($0^{mm}.037$)	± 2.6
Adopted probable error	±10.1

which is about 1/690 000 part of the length.

The length not reduced to sea level is 6 971.7581 meters.
±101

A provisional height was assumed for the station mark at east base equal to 60 meters and the resulting heights and corrections to reduce the seven sections to sea level are:

	m.	mm.		m.	mm.
Sec. 1.	59.9	9.4	Sec. 5.	65.3	9.9
2.	62.0	9.7	6.	66.7	10.5
3.	63.0	9.9	7.	68.3	10.7
4.	63.0	9.9			

and the total reduction for the entire base becomes −0.0700 meters.

The provisional length of the Alice Base then becomes	6 971.6881 meters.
	±101
And its logarithm	3.8433386
	±6

SEGUIN BASE LINE.

The site of the Seguin Base Line was chosen in 1899 by Assistant Stehman Forney, in the valley of the Guadalupe River, in Guadalupe County, Tex. It is about midway between the cities of Seguin and New Braunfels and on the east side of the river. Its middle point is in latitude 29° 40′ and its eastern terminal is very near the meridian of 98°.

The height of the base above sea level approximates 165 meters, and its length is 6.8 kilometers. While lying at right angles to the course of the drainage, the entire range in the elevations along the line is less than 14 meters. The maximum grade was 3.56 meters in 50 meters, necessitating a correction of $127^{mm}.0$. The western terminal is on a small hill, covered with scattering mesquite brush, on the land of Henry Steinman, 1 100 meters west of the Seguin-New Braunfels road and about 400 meters east of the Guadalupe River. The eastern terminal is on the land of Henry Soefje, at the western edge of the live-oak timber about 2 miles northwest of Von Beckman's store and gin. It is 1 050 meters east of the main road between Von Beckman's and New Braunfels, and the line crosses the road at the northwest corner of Mr. Soefje's dooryard.

During the year, between the location of the base and its measurements an enterprising farmer erected a barn directly on the line 1 464 meters from west base, but being on a slope where the line of sight was not interrupted, it was a simple matter to remove a board on the line and measure with the tape through the barn. Twenty-six fences, most of them of barbed wire, were crossed by the line.

The permanent marks were put in position when the location was chosen and are similar to those described for the Anthony Base (p. 270), with the exception that at East Base the underground mark is a copper bolt cemented into the natural sandstone rock about 32 inches below the surface. The mass of concrete in which the capstone was set was kept clear of the bolt by means of a box 9 inches square.

The base was divided into seven sections, beginning at West Base, sections 1, 2, 5, and 7 being each 1 kilometer in length, section 3, 700 meters, section 4, 1 200 meters, and section 6, 895 meters in length. Between sections 6 and 7 and on the line a hole in the top of a stone post 6 by 6 by 12 inches and 0.6 meter below the surface serves as a witness mark for the recovery of the eastern terminal. The other section marks were copper rivets in 4 by 6 inch posts securely set in the ground.

Sections 1, 2, and 3 were measured once with each 50-meter tape and section 4 similarly measured using the 100-meter tapes. Sections 6 and 7 were measured in each direction with the duplex bar apparatus, and section 5 was adopted as the test kilometer, and a single measure with each tape and the bar apparatus was made over it.

It was impracticable to connect the terminal monuments with any precise level bench marks, and the surface monuments were therefore left to preserve the provisional height of the base for future connection with the precise level net of the Survey. The connection between the two terminals was made in duplicate (by running in each direction) using precise level No. 5, as such leveling was necessary to determine the tape grades as well as the mean height of the base.

The base depends for its length as follows: 0.31 on the length of the duplex bar apparatus, 0.23 on each 50-meter tape, and 0.12 on each 100-meter tape.

Table No. 20 contains the results of the measures of the base.

TABLE No. 20.—*Results of measures of Seguin Base.*

No. of section and stakes.	Date.	Time of day.*	Direction.	Apparatus.	Mean temperature.	Temperature range.	Temperature—Rising, R.; falling, F.	Weather—Fair, F.; cloudy, C.; dew, D.; wind, W.	Length of section.	Residual (mean minus observed).
	1900.	h. m. h. m.			°C.	°			m.	mm.
1. W. B. to 20	Dec. 29	8 25– 8 55	E. to W.	Tape 248	4.05	0.3	R.	C. W.	999.8345	−3.1
	29	9 08– 9 40	W. to E.	Tape 247	4.14	0.6	F.	C. W.	.8406	−3.0
2. 20 to 40	Dec. 29	7 53– 8 23	E. to W.	Tape 248	4.13	0.3	R.	C. W.	999.7870	+1.2
	29	9 42–10 15	W. to E.	Tape 247	4.05	0.2	R.	C. W.	.7893	−1.1
3. 40 to 54	Dec. 29	7 30– 7 51	E. to W.	Tape 248	4.03	0.2	F.	C. W.	700.0327	+2.2
	29	10 17–10 34	W. to E.	Tape 247	3.93	0.2	F.	C. W.	.0371	−2.2
4. 54 to 78	Dec. 29	6 48– 7 15	E. to W.	Tape 85	4.02	0.3	R.	C. W.	1 200.1798	+1.0
	29	10 47–11 10	W. to E.	Tape 88	3.86	0.4	F.	C.	.1819	−1.1
5. 78 to 98	Dec. 29	6 21– 6 45	E. to W.	Tape 85	3.45	0.6	F. R.	C. W.	999.9245	+1.1
	29	11 12–11 38	W. to E.	Tape 88	3.78	0.3	F.	C.	.9236	+2.0
	1901.									
	Jan. 4	7 02– 7 28	E. to W.	Tape 248	13.49	0.3	F.	C.	.9281	−2.5
	4	7 40– 8 13	W. to E.	Tape 247	13.19	0.5	F.	C.	.9299	−4.3
	5	a.m. & p.m.	E. to W.	Duplex	17.95	4.6	R.	F. C.	.9221	+3.5
6. 98 to 116	Jan. 2, 3	p.m. & a.m.	E. to W.	Duplex	7.56	3.3	R.	C.	895.1726	+1.0
	3, 4	p.m. & a.m.	W. to E.	Duplex	10.76	0.8	F.	C.	.1745	−0.9
7. 116 to E. B.	Jan. 4	a.m. & p.m.	W. to E.	Duplex	16.35	3.8	R.	C.	999.8511	−1.3
	7	a.m. & p.m.	E. to W.	Duplex	20.94	1.2	F. R.	C.	.8486	+1.2
Total length									6 794.7905	

* The hours of tape measures refer to p. m.

The probable error of a single measure as deduced from the residuals on the test kilometer is $\pm 2^{mm}.2$, and therefore the probable error of the length of the whole base becomes $\pm 4^{mm}.4$.

From the discord of the individual measures on each section a smaller probable error for the whole base, namely, $\pm 3^{mm}.4$, may be deduced.

Adopting the probable error as first deduced and combining with the uncertainty in the length of the comparator, the adopted probable error of the base becomes:

	mm.
Probable error of standardization and measurement	±4.4
Probable error of 68 times comparator, 68 ($0^{mm}.037$)	±2.5
Adopted probable error	±5.1

which is about 1/1 333 000 part of the length.

The length not reduced to sea level is 6 794.7905 meters.
±51

A provisional height was assumed for West Base of 170 meters, and the resulting heights and corrections to reduce the seven sections to sea level are here given to correspond to this assumption:

	m.	mm.		m.	mm.
Sec. 1.	165.8	26.0	Sec. 5.	171.2	26.8
2.	165.9	26.0	6.	167.9	23.6
3.	170.8	18.7	7.	165.2	25.9
4.	172.0	32.4			

and the total reduction for the entire base becomes −0.1794 meters.

The provisional length of the Seguin Base reduced to sea level then becomes 6 794.6111 meters.
±51

And its logarithm 3.8321639
±3

SUMMARY OF RESULTS.

To aid the reader in judging the value and extent of the work accomplished in this field season of six months a brief summary is added.

B_{17}, whose length when immersed in melting ice was known with a probable error of 1 part in 4 500 000, became the unit of length for all these measures. From this unit of length two 100-meter comparators were prepared, 750 miles apart, and their lengths determined with an average probable error of 1 part in 2 700 000.

Five sets of apparatus were determined on each of these comparators, with an average probable error of approximately 1 part in 2 000 000.

The nine base lines here tabulated were measured in such a way that on the average one-fifth of each base depends on the length of each apparatus.

Name of base.	Probable error.	Length.	Probable error as proportional part.
	mm.	m.	
Shelton	± 9.0	7 884.72	1/876 000
Page	± 5.6	8 250.99	1/1 473 000
Anthony	± 4.8	6 034.70	1/1 257 000
El Reno	± 9.7	12 886.68	1/1 329 000
Bowie	± 5.0	8 196.04	1/1 639 000
Stephenville	± 6.0	6 255.08	1/1 042 000
Lampasas	± 4.1	5 961.13	1/1 454 000
Alice	±10.1	6 971.69	1/690 000
Seguin	± 5.1	6 794.61	1/1 333 000

These bases, aggregating 69.2 kilometers, with an average length of 7.7 kilometers, have an average probable error of 1 part in 1 200 000, which was attained without the expenditure of either time or money in excess of that necessary for the lesser accuracy required by the instructions, namely, 1 part in 500 000. They, in connection with the Salina Base of the transcontinental triangulation, control the lengths on 1 100 miles of the arc of the ninety-eighth meridian.

COST OF THE BASE LINE MEASUREMENTS.

It is now deemed advisable to show the total cost of the work which has just been summarized. The total amount expended for field expenses was $7 511.65. These field expenses include all items of transportation, freight, etc., beginning and ending in Washington, all material, camp equipage, and pay and subsistence of entire party, except salaries of officers. Adding the pay of the officers, which is the only item of expense not included in the field expenses, $2 546.84,* there results $10 058.50, which is the entire amount expended for field expenses on the nine bases. Approximately 25 per cent of the $7 500 was spent for transportation of the party and outfit by train and wagon, but this proportion of necessary travel and freight would have been considerably greater if all the bases had not been measured in one season's work. The cost of preparing the results for printing, including all computations made at the Office, $1,016.28, would bring the total cost of the bases to $11,074.78, which would be $1,230.53 per base, or $160 per kilometer. The above amounts include all the cost of standardizing the apparatus.

SPEED ATTAINED WITH BARS AND TAPES.

The actual speed of measurement during this season can be most readily shown in tabular form. In Table No. 21 all the bar measurements where 400 meters or more were measured consecutively have been tabulated. In column 3 there is shown the total time which elapsed between the completion of the reference to the ground mark at the start and the beginning of the reference at the end of the section. In column 6 the average number of bars per hour for each of the seven months in which measurements were made is shown.

In Tables Nos. 22 and 23 similar information is tabulated for the 100-meter and 50-meter tapes. In columns 5 and 6 the speed is expressed in kilometers per hour.

TABLE No. 21.—*Showing the increasing speed of duplex measurements.*

Date.	Name of base.	Time of measurement, including all delays, except as noted.	Number of bars laid.	Bars per hour.	Mean bars per hour for each month.	Remarks.
1900.		*hrs.*				
July 30	Shelton	4.73	120	25.3	26.9	Three shifts of brass, but no stop.
31	.....do	4.18	120	28.7		A stop for lunch deducted.
Aug. 1	.....do	3.87	100	25.8		
2	.....do	2.60	100	38.5		
8	.....do	2.82	100	35.5		
8	.....do	2.68	100	37.3		
9	.....do	3.07	117	38.1		
10	.....do	2.07	100	48.3		
24	Page	2.67	100	37.5		
25	.....do	2.07	100	48.3	43.1	
27	.....do	2.52	120	47.6		Crossed very rough ground.
28	.....do	1.57	80	51.0		
29	.....do	2.35	120	51.5		
30	.....do	1.68	100	59.5		
31	.....do	1.07	60	56.1		
31	.....do	1.73	100	57.8		
31	.....do	1.97	100	50.8		

*In computing this, one-eleventh was added to the actual pay, as shown by the salary tables, to cover the one month allowed for annual leave each year.

TABLE NO. 21.—*Showing the increasing speed of duplex measurements.*—Continued.

Date.		Name of base.	Time of measurement, including all delays, except as noted.	Number of bars laid.	Bars per hour.	Mean bars per hour for each month.	Remarks.
			hrs.				
1900. Sept.	15	Anthony	2.92	100	34.2		Encountered heavy grades.
	17	....do	2.13	100	46.9		
	21	....do	1.92	100	52.1	46.3	
	21	....do	2.07	97	46.9		
	22	....do	1.97	97	49.2		
	22	....do	1.83	100	54.6		
Oct.	13	El Reno	2.45	100	40.8		
	13	....do	2.03	100	49.3		
	15	....do	2.05	89	43.4		
	16	....do	2.35	89	37.9	49.5	
	16	....do	1.82	100	54.9		
	17	....do	1.73	100	57.8		
	18	....do	3.30	200	60.6		Deducting 39 minutes for lunch.
Nov.	1	Bowie	2.07	100	48.3		
	1	....do	2.33	120	51.5		
	2	....do	2.50	120	48.0		Deducting 18 minutes uniting broken column in thermometer.
	2	....do	1.65	100	60.6		
	3	....do	2.12	100	47.2		Steep grades on this section.
	3	....do	1.98	100	50.5		
	14	Stephenville	1.68	100	59.5		
	14	....do	1.68	100	59.5	54.5	
	15	....do	1.87	110	58.8		
	15	....do	2.15	121	56.3		
	16	....do	2.18	121	55.5		
	16	....do	1.62	110	67.9		
	30	Lampasas	1.92	103	53.6		
	30	....do	1.90	103	54.2		
Dec.	1	....do	1.47	80	54.4		
	1	....do	2.15	120	55.8		
	14	Alice	2.25	200	88.9		
	15	....do	1.47	100	68.0	67.8	
	15	....do	1.40	94	67.1		
	18	....do	2.88	194	67.4		Deducting 12 minutes referring to ground at middle of section.
1901. Jan.	3	Seguin	2.52	129	51.2		
	3	....do	2.35	129	54.9		NOTE.—The slow speed of Jan. 3 and the a. m. of Jan. 4 and 5 was due to the low temperature, 6° to 14° C.
	4	....do	1.75	100	57.1		
	4	....do	1.28	100	78.1	61.2	
	5	....do	1.98	100	50.5		Deducting 32 minutes repairing trestle.
	5	....do	1.68	100	59.5		
	7	....do	1.00	100	100.0		
	7	....do	1.47	100	68.0		
		Mean	....	....	52.9		

TABLE No. 22.—*Showing speed of measurement with 100-meter tapes.*

Date.		Name of base.	Time of measurement, including delays except as noted.	Length of continuous measurement.	Kilometers per hour.	Mean kilometers per hour for each month.	Remarks.
1900.			*hrs.*	*km.*			
July	24	Shelton	1.68	2.20	1.31		
	24	....do	1.55	2.20	1.42	1.46	
	28	....do	0.57	1.00	1.75		
	28	....do	0.58	1.00	1.72		
Aug.	11	....do	0.45	1.00	2.22		
	11	....do	0.53	1.00	1.89		
	25	Page	0.58	1.00	1.72	1.90	
	27	....do	1.10	2.00	1.82		
	27	....do	1.60	3.00	1.88		
	28	....do	0.48	1.00	2.08		
Sept.	17	Anthony	0.50	1.00	2.00		
	17	....do	0.73	1.00	1.37		
	19	....do	1.47	3.00	2.04	1.92	
	19	....do	1.68	3.00	1.78		
	22	....do	0.42	1.00	2.38		
	22	....do	0.42	1.00	2.38		
Oct.	5	El Reno	1.72	3.00	1.74		
	5	....do	1.58	3.00	1.90		
	6	....do	1.17	2.00	1.71		
	6	....do	1.25	2.00	1.60		
	8	....do	0.42	1.00	2.38	1.98	
	8	....do	1.47	3.00	2.04		
	25	Bowie	1.08	3.00	2.78		
	25	....do	1.40	3.00	2.14		
	27	....do	0.42	1.00	2.38		
	27	....do	0.60	1.00	1.67		
Nov.	12	Stephenville	0.82	2.00	2.44		
	12	....do	0.92	2.00	2.17		
	12	....do	0.35	1.00	2.86		
	13	....do	0.37	1.00	2.70	2.42	
	27	Lampasas	0.72	2.00	2.78		
	27	....do	0.75	2.00	2.67		
	28	....do	0.67	1.40	2.10		
	28	....do	0.68	1.40	2.06		
Dec.	8	Alice	0.80	2.00	2.50		
	8	....do	0.80	2.00	2.50		
	10	....do	0.78	2.00	2.56	2.45	Deducted 36 minutes to get new thermometer.
	10	....do	0.77	2.00	2.60		
	29	Seguin	0.90	2.20	2.44		
	29	....do	0.85	2.20	2.59		
		Mean			2.13		

TABLE NO. 23.—*Showing speed of measurement with 50-meter tapes.*

Date.		Name of base.	Time of measurement, including delays except as noted.	Length of continuous measurement.	Kilometers per hour.	Mean kilometers per hour for each month.	Remarks.
1900			*hrs.*	*km.*			
July	27	Shelton	1.22	2.00	1.64	1.67	Delayed 18 minutes to reset support.
	27	....do	1.17	2.00	1.71		
Aug.	11	....do	0.52	1.00	1.92	1.46	
	11	....do	0.53	1.00	1.89		
	24	Page	1.58	2.00	1.27		
	24	....do	1.38	2.00	1.45		
	25	....do	0.72	1.05	1.46		
	25	....do	0.75	1.05	1.40		
	28	....do	0.73	1.00	1.37		
	28	....do	0.87	1.00	1.15		
Sept.	16	Anthony	0.55	1.00	1.82	1.70	
	16	....do	0.55	1.00	1.82		
	17	....do	0.68	1.05	1.54		
	17	....do	0.63	1.05	1.67		
Oct.	8	El Reno	0.53	1.00	1.89	1.93	
	8	....do	0.53	1.00	1.89		
	9	....do	1.50	3.00	2.00		
	9	....do	1.52	3.00	1.97		
	11	....do	1.40	2.45	1.75		
	11	....do	1.13	2.45	2.17		
	27	Bowie	0.47	1.00	2.13		
	27	....do	0.58	1.00	1.72		
	29	....do	1.03	2.00	1.94		
	29	....do	1.17	2.00	1.71		
	31	....do	0.47	1.10	2.13		
	31	....do	0.58	1.10	1.72		
Nov.	13	Stephenville	1.43	3.10	2.17	1.96	
	13	....do	1.48	3.10	2.09		
	27	Lampasas	0.53	1.00	1.89		
	27	....do	0.70	1.00	1.43		
Dec.	1	....do	1.10	2.00	1.82	1.90	1 hour 8 minutes deducted.
	1	....do	1.28	2.00	1.56		
	10	Alice	0.50	1.00	2.00		
	10	....do	0.48	1.00	2.08		
	15	....do	1.03	2.00	1.94		
	15	....do	0.88	2.00	2.27		
	29	Seguin	1.42	2.70	1.90		
	29	....do	1.43	2.70	1.89		
1901							
Jan.	4	....do	0.43	1.00	2.33	2.04	
	4	....do	0.55	1.00	1.82		
		Mean			1.81		

ERRORS OF THE DUPLEX MEASURES.

At the conclusion of his consideration* of the behavior of the duplex bar apparatus the designer says: "The duplex may be regarded as equally perfect and efficient both as a bimetallic and a thermometric apparatus." This conclusion was necessarily based on results from the use of the apparatus when fully protected from the sun and wind by means of the "Salt Lake sled," which was a movable tent. The errors which were not apparent under these ideal circumstances must now be considered as well as errors which may have been in those measures and which are indicated by the additional evidence of this season.

There was, during all of the duplex bar measurements of 1900–01 now under discussion, no protection from the wind or from the direct rays of the sun except when an umbrella was held to shade the contact ends to enable the observer to see the contact lines more clearly.

The three sources of error described by Assistant Schott (p. 200, "Transcontinental Triangulation") can here be neglected as practically nil. The first, due to the push of the contact slide spring at the time of contact, was diminished to less than one-half by the strengthening of the cradle arms, page 249. Furthermore, the pressure of the springs was throughout the season the same during the base measures as during the standardization. The same trestles were used in the standardization measures, at about the average height used on the bases, and any push of the contact springs would have had the same effect on the duplex measures of the comparator intervals as they had on the field measures of the bases. Finally, the springs were used with much less strength than heretofore, being only strong enough to insure a contact between the agates when in use. No oil was applied to these contact slides, and in consequence very little trouble from an accumulation of dirt was encountered even on the days when the wind and dust were troublesome.

As to the second source of error, due to the wear of the knife edges during the season, the restandardization at the end of the season revealed no such wearing away, or an amount so small as to be absorbed in the errors of standardization. Formerly such wear was plainly discernible in the blunt appearance of the knife edges, whereas, at the conclusion of this season the agate knife edges presented the same appearance under the microscope as at the beginning of the season.

The third source of error is that due to the change in position of the components relative to the point of support of the metallic casing during the time of laying the bar. This source of error was rendered less effective by increasing materially the rapidity of the base measure, and by reading thermometers at the time of contact at the front end of the bar instead of at the rear, as has been the practice heretofore. It is evident that the change in the time of reading the thermometers affects only the results from the bars as a thermometric apparatus. The amount of this error is dependent on the rate of change of the temperature and on the manner of yielding of the trestles. Its effect on the duplex result may be readily computed, if we assume that the friction on the roller is so great as to preclude the possibility of the brass casing of the bar advancing on the roller with the small increases in temperature. In other words, the center of expansion of the brass casing is at the center of the bar instead of at the knife edge of the rear trestle. The

*See Appendix No. 12 of the Coast and Geodetic Survey Report for 1897, "Report on the Measurement of the Salt Lake Base," in Utah, p. 774.

steel and brass components are held against the rear end of the casing by springs at a point 2.44 meters from the center of the bar. Between the beginning of any measure and the end, an increase of temperature of the brass casing will pull back the front end of the bars an amount equal to the expansion of the brass casing for this 2.44 meters and for the whole range of temperature during the measure. As an example: During the measure of the test kilometer at Shelton, p. 254, the temperature rose 23°.3. The correction to the measured length of the kilometer from this source of error would be:

$$\text{corrn.} = -.0000185\ (2.44)\ 23.3 = -1^{\text{mm}}.05$$

Thus, in one of the most extreme cases of the season, the error from this source is only one part in a million.

At this point it should be noted that the accuracy is greater for the thermometric results than for the duplex result, when only the measures of the comparator interval are considered. In the actual measures the probable errors for a single duplex measure of a mean section of 543 meters (Table No. 6) was $\pm 1^{\text{mm}}.0$, from which would be expected a corresponding probable error of $\pm\frac{1.0}{\sqrt{5.43}}$ mm., or $\pm 0^{\text{mm}}.43$ for any section 100 meters long. In a similar manner from the probable error of a single duplex measure of a mean section of 921 meters (Table No. 7), equal to $\pm 1^{\text{mm}}.2$, we would expect $\pm\frac{1.2}{\sqrt{9.21}}$ mm., or $\pm\ 0^{\text{mm}}.40$ for any section 100 meters long. The probable error of such a single measure actually deduced from the nine observations on the 100-meter comparators in Tables Nos. 3 and 4 was $\pm 0^{\text{mm}}.30$.

Let the probable error of the steel be treated in the same manner, and the probable error of a single measure of 100 meters from the nine observations on the comparators is $\pm 0^{\text{mm}}.15$; deduced from 543-meter sections is $\pm\frac{1.2}{\sqrt{5.43}}$ mm. or $\pm 0^{\text{mm}}.52$, and deduced from sections 921 meters long is $\pm\frac{1.7}{\sqrt{9.21}}$ mm. or $\pm 0^{\text{mm}}.56$. Treating the probable errors of the brass in the same manner, the three corresponding probable errors are $\pm 0^{\text{mm}}.15$, $\pm 0^{\text{mm}}.73$, and $\pm 0^{\text{mm}}.86$.

The only conclusion possible from these figures is that the results from the duplex follow closely the laws of the accidental errors, the probable errors increasing but little faster than the square root of the lengths. With the steel and brass it is quite different. In the case of the steel, the errors increase very closely as the length, while with the brass the errors increase more rapidly than the length. The evidence of systematic or constant errors is therefor greatest in the results from brass and steel, while the duplex result is apparently not entirely free from such errors.

TEMPERATURE ERRORS OF THE DUPLEX MEASURES.

The discussion of the results shown in detail in Tables Nos. 5, 6, and 7 may now be resumed. It is certainly true that the part of the accidental errors which would affect the measure from brass differently from that of steel, such as faulty contacts, a lack of contact between either set of components, and errors in reading and setting the scales on which the set-ups and set-backs are measured, would make the ratio $\frac{S-D}{B-S}$ vary from its mean value 1.67 (see p. 257). Referring to Tables Nos. 5 and 6, we may see that in the fifty-three sets of differences there displayed, in not one case is there a reversal of sign (S–D is always plus when B–S is plus) even when these differences are less than $0^{mm}.5$, and in all the results of the duplex bar measures (see Tables Nos. 5 and 6) there is not a single case in which a correction of less than $0^{mm}.2$ to one of the results will not produce exactly the ratio 1.67. This feature can hardly fail to surprise anyone familiar with the use of any measuring bars where the contact slide is involved, and when it is remembered that from 200 to 400 contacts are involved.

Attention should here be called to the fact that this peculiarity of the ratio also checks the computation. For instance, if one tries to compute the length of a section, where 199 bars had been laid, as if it had been an entire kilometer, the result from the scale reading (the gain or loss of brass over steel) would be so wild as to detect an error at once. Again, suppose an error equivalent to $0^{\circ}.1$ centigrade or more was made in reducing the length of the steel from the mean temperature to the temperature of observation, the changed ratio would detect the error. As a curious example of this, the reader is referred to the "abstract of field results" on the Salt Lake Base (p. 774 of Appendix No. 12, Coast and Geodetic Survey Report for 1897), where the observer rejected the result from the duplex on the second measurement of Section VI in computing the probable error, doubtless because the residual was suspiciously large. An examination of the ratio shows something obviously wrong in the value of the ratio $\frac{S-D}{B-S} = \frac{9802-9779}{9804-9802} = 10.5$. But the office computation showed that an error had been made in the field computation of the length from the steel component, and that the rejected duplex value was correct.

An inspection of the results of the Salt Lake Base (pp. 198 and 199 of the "Transcontinental Triangulation") reveals this same ratio, even when the bars were carefully protected from inequalities of weather. The correction to preserve exactly this ratio $\frac{S-D}{B-S} = 1.67$ in any one of the twenty-two single measures would not exceed $0^{mm}.2$. These results, in conjunction with those of this season, make up all that have been obtained with the duplex bar apparatus. It is obvious, therefore, that the accidental errors which affect the two components differently, such as faulty contacts, errors of reading scales, etc., are of a much smaller magnitude than those which affect the bar as a whole, such as are due to transfer measures, the inclination of the bars, etc.

What then has been the effect of removing the protection (movable tent) and subjecting the bars to steep gradients (even exceeding $4^{\circ}\ 40'$) in all conditions of weather?

In the Salt Lake measures the probable error of a single measure of a section (1 000 meters) is for the duplex $\pm 1^{mm}.14$, and for the steel and brass somewhat less, but on the thirteen sections (averaging 921 meters) measured during the past season, on the nine different lines, the probable error of a single measure of a section is very little greater for the duplex, $\pm 1^{mm}.2$, but the probable errors from steel and brass increased to $\pm 1^{mm}.7$ and $\pm 2^{mm}.6$, respectively.

It is the opinion of the writer that a computation of the Salt Lake measures by half sections, where the temperature was in one case rising and in the other falling, would show probable errors much more favorable to the duplex result than to those from steel and brass.

The evidence that the duplex result deserves more weight than the results from steel and brass is convincing. First, because the probable errors of the results of the field measures from Tables Nos. 6 and 7 are much less than for either steel or brass. Second, because the probable errors of the duplex results follow more closely the laws of accidental errors, while for steel and brass the probable errors follow the laws of constant errors more nearly, varying in direct proportion to the length. And lastly, because by the removal of the tent and the subjection of the bars to different conditions of the weather, the probable errors have not been much affected for the duplex result, but the probable errors of the steel and brass have increased greatly.

In Tables Nos. 5 and 6 it is apparent that wherever the range in the temperature is least the results from the three methods are most nearly in accord. In special cases, such as the test kilometer at Alice Base, section 6 at Stephenville Base, and the northwest half of section 6 at Anthony Base, where the temperature was either stationary or varied little, the accord is perfect. With the one exception of November 2, when the canvas jacketing had become wet with dew during the preceding night, there was a decided tendency to have a large result from brass and steel when the temperature was rising and the reverse when the temperature was falling. In other words, when the temperature is rising the results stand in the order brass, steel, duplex, the brass being the highest.

It may occur to the reader to inquire why the evidence does not require the steel and brass results to be rejected and show the assumption true that the thermometers record the temperature in advance of the brass and steel components, but that these bars are of the same temperature. Let us first assume seven cases when the temperature is rising, where at least two of three involved temperatures are alike. In the first one, let the thermometers and the brass component have equal temperatures, both above that of steel, thus: $\dfrac{\text{Thermometer} = \text{Brass}}{\text{Steel}}$. As the thermometer indication is higher than the steel temperature, it follows that the result from steel would be greater than that from the brass, which in this case is the correct result. Also, the temperature of the brass being higher than that of steel, the gain of the brass component is too great, and when multiplied by the factor 1.668, or duplex coefficient, would give a result from the duplex method greater than either. The three results would stand $\begin{matrix}\text{Duplex}\\ \text{Steel}\\ \text{Brass}\end{matrix}$. This order and the ratio of these results may be shown by a numerical example: Suppose the thermometer and brass temperature to be 0°.2 above that of steel. The resulting value of the ratio would be

$$\frac{\text{Error}_{\text{steel}} - \text{Error}_{\text{duplex}}}{\text{Error}_{\text{brass}} - \text{Error}_{\text{steel}}} = \frac{0.2(1.15) - 0.2(1.84)\left(\dfrac{1.15}{1.84 - 1.15}\right)}{-0.2(1.15)} = 1.67.$$

The seven assumptions with the order of their results are given below.

Ther. = Brass Steel. (1)	Steel Ther. = Brass. (2)	Ther. = Steel Brass. (3)	Brass Ther. = Steel. (4)	Brass = Steel Ther. (5)	Ther. Brass = Steel. (6)	All alike. (7)
Duplex Steel Brass	Brass Steel Duplex	Brass Steel Duplex	Duplex Steel Brass	Duplex Steel Brass	Brass Steel Duplex	Agree

The ratio $\frac{\text{Error}_{\text{steel}}-\text{Error}_{\text{duplex}}}{\text{Error}_{\text{brass}}-\text{Error}_{\text{steel}}}$ would in every case reduce to 1.67, which is the ratio between results actually obtained (see p. 257), and is identical with the duplex coefficient. Moreover, assumptions 2, 3, and 6 would therefore correspond with the facts, the results having the right order and the same ratio. In a similar manner, by assuming the temperatures all different, two cases out of a possible eight were found where the order of the results and this ratio of the differences between the results would agree with the facts.

In view of the fact that with a rising temperature five out of a total of fifteen assumptions of the relation of the three involved temperatures would agree with the relation as found, it would seem to the writer too radical to assert that assumption No. 6, where the duplex result is correct and the thermometer is in error, is the only one possible, and reject the other four as impossible. Not being certain, then, that the two metals have exactly equal temperatures, it is not certain that the steel and brass measures should be rejected and the duplex results alone retained. The three results have been tried on their merits and the weights assigned inversely as the squares of the probable errors.

CONSTANT TEMPERATURE ERRORS OF THE DUPLEX MEASURES.

The presence of constant errors in any base measure due to a defective knowledge of the temperature of the bars has been explained in previous base measures by assuming a lag of the mercurial or bimetallic thermometers. The variety of temperatures encountered in the Shelton comparisons affords an opportunity to look for evidence of such a lag of either themometric or bar temperature. On July 27, and the first measure of July 28 (Table No. 3, p. 250), the temperature was rising at the rate of $0^{\circ}.05$ centigrade or more per minute, and these are the only two determinations of eithei comparator interval with the duplex apparatus made with rapidly rising temperature. Comparing the mean of these results with the mean of all for each method, the result from steel is $0^{mm}.12$ higher than the mean, the brass result $0^{mm}.14$ lower and the mean of the two determinations for the duplex method, becomes $100^{m}+1^{mm}.99$ for the 20 bars, independently of thermometers. This is $0^{mm}.56$ longer than the adopted value.

The evidence of these two determinations with rapidly rising temperature indicates that the temperatures as given by the thermometers on the 27th were too low and on the 28th too high, but on both days the brass temperature is apparently, from giving the shorter result, greater than that of steel. On the other hand, with falling temperatures, as on July 26 and August 4, the brass temperature is lower than that of steel (shown by the greater result). In other words, brass seems to take the temperature in advance of steel. This would mean that the duplex result, which is dependent on an equality of temperature between the brass and steel components, is also affected by a constant error from this cause.

Now, in the actual measurement on the nine test kilometers, the temperature conditions at Shelton and Bowie Bases and on half of the section at Page, El Reno, Stephenville, Lampasas, and Seguin Bases were the same as those on July 27 and 28. The duplex length of these sections would be, therefore, increased in millimeters as follows, to correspond with the fact that the comparator determinations show the bars under these conditions to be $0^{mm}.56$ per 100 meters longer than usual: at Shelton and

Bowie Bases by $5^{mm}.6$, and at Page, El Reno, Stephenville, Lampasas and Seguin Bases by $2^{mm}.8$. Such a change would place the duplex result among the tape results in three of the seven cases, and the agreement of the bars and tapes would be improved in each case.

ERRORS OF STEEL TAPE MEASURES.

The errors affecting measurements with long steel tapes have been fully treated in the pages discussing the tape measures of the Holton Base (Appendix No. 8, Coast and Geodetic Survey Report for 1892, Part II).

As to errors in grade corrections they are of the compensating class. Errors in determining the differences in altitude of consecutive marking tables are as likely to be of one sign as another. Throughout this season's work the interval between support nails has been 25 meters, and on nearly all the bases the differences of elevation were determined for each 25-meter interval, and thus the small cumulative error due to imperfections in the alignment of these support nails to a uniform slope has been eliminated.

The errors of alignment are necessarily very minute, as a lack of parallelism with the base of any 50-meter tape to the extent of a decimeter would give rise to an error of only $0^{mm}.10$. A decimeter is an impossible quantity, as each marking table and support nail was aligned with an 8-inch theodolite to within 1 centimeter. Any departure of the intermediate supports of the tape from a vertical plane through its ends would give rise to errors of the same sort and sign. Supposing an extreme and impossible case of a centimeter out of alignment on each support, the total accumulation could be but $0^{mm}.8$ on a kilometer, or 1 part in 1 200 000.

The question of economy, presented to the Superintendent when the plans were made for measuring the Versailles Base, brought about a change in the interval between supports from 10 meters to 25 meters. This was made possible by the increase in the applied tension from 11.5 kilograms to 15.

TEMPERATURE ERRORS OF THE TAPE MEASURES.

The method of attaching the thermometers directly to the tape in horizontal position was first used in measurements of primary bases at the Versailles Base.

This departure from the exact duplication of the Holton Base methods, it is believed, has at least not increased the uncertainties in the tape temperatures.

That the day measures are more uncertain than the night measures has been thoroughly established. Without doubt this is due to the differing capacities of the tape and thermometer for absorbing and radiating heat under varying conditions. Some evidences of errors of this sort may therefore be expected even where all measures and standardization are carried on between sunset and daylight. These may be distinguished as errors due to time of night. As the aim of the party was to attain results which should conform in accuracy to the limits prescribed in the instructions and not to experiment, there may not be data sufficient to come to any definite conclusion. Whatever errors of temperature are present in the actual measurement on the base ought also to be present in the standardization, which was made at similar times and under similar conditions.

Referring to the results in Tables Nos. 8, 9, 10, and 11, the reader needs to be reminded that in these determinations of length there was no protection from the weather, and the results show considerable effect of the wind during the Shelton comparisons. But the Seguin comparisons are all free from wind effect and these alone should be used in discussing temperature errors. The maximum residual at the Seguin comparator is $0^{mm}.17$ for Tape 85, $0^{mm}.20$ for 88, $0^{mm}.16$ for 248 and $0^{mm}.17$ for 247, without any rejected observation and including observations on three nights which were quite different in their atmospheric conditions. On the 12th of January there was dew and a few clouds, the 14th was perfectly clear with no dew, and on the 15th it began clear but became entirely overcast with storm clouds during the observations. The probable error of a single determination of a tape length from the Seguin comparisons only, in the case of the 100-meter tape, or of two tape lengths in the case of the 50-meter tapes, is therefore $\pm 0^{mm}.09$ for T_{85}, $\pm 0^{mm}.10$ for T_{88}, $\pm 0^{mm}.07$ for T_{248}, and $\pm 0^{mm}.06$ for T_{247}. The largest probable error of a single determination at Seguin is only one part in 1 000 000. When compared with the probable error of a single determination, where only the night comparisons at the Holton comparator were used (p. 263), the temperature errors here displayed are less.

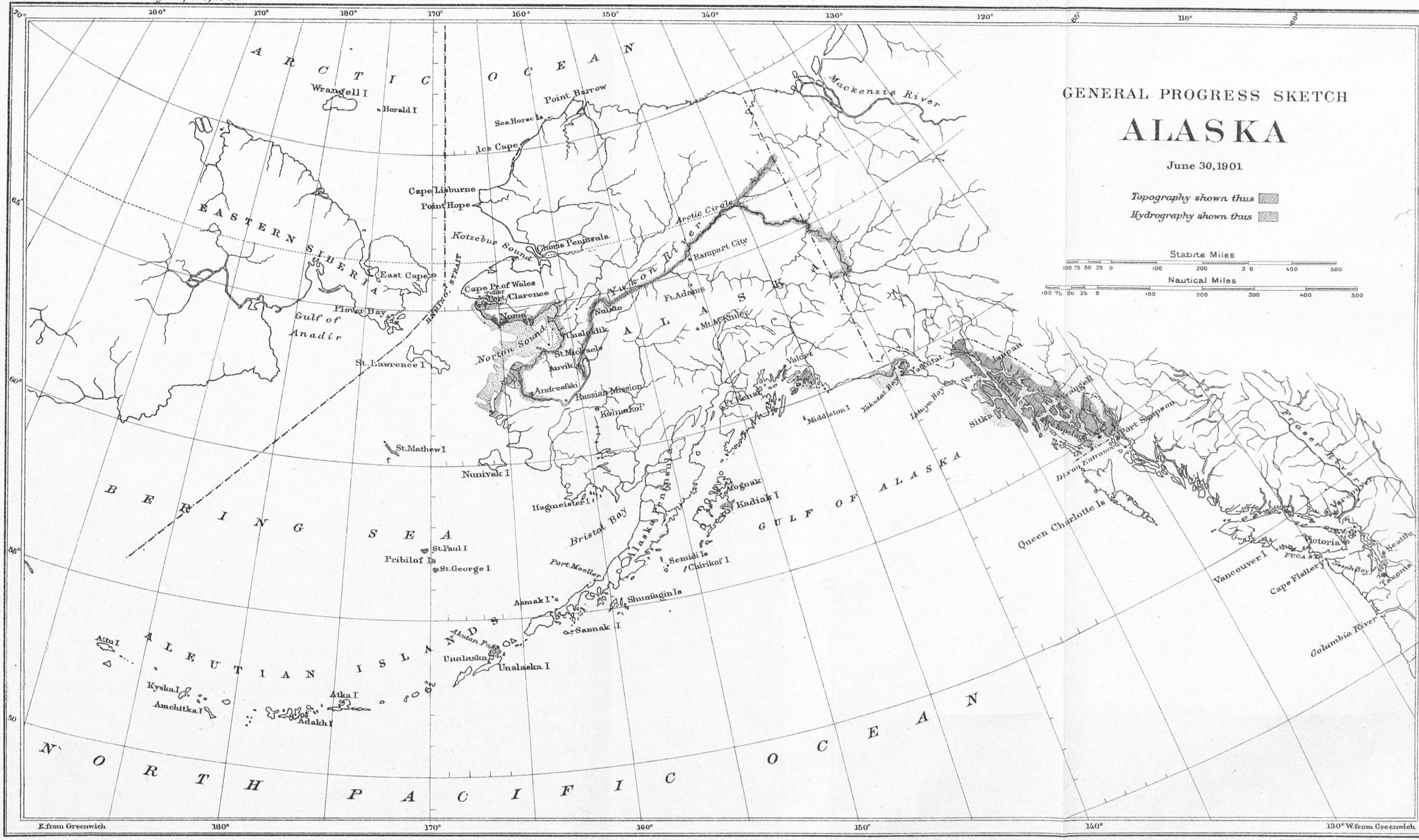
The probable error of a single measure of a kilometer as deduced for the measures on the Holton Base was $\pm 1^{mm}.74$. In a similar manner the probable error of a single measure of a kilometer from the tape measures on the Versailles Base was $\pm 1^{mm}.20$. From the results of all the measurements on the nine base lines under discussion the probable error of a single measure of a kilometer section can be computed, for the 50-meter tapes $\pm 1^{mm}.7$, and for the 100-meter tapes $\pm 1^{mm}.8$. It is shown, then, that even though these probable errors are computed from sections which have been repeated by a second tape and involve errors of standardization, the probable errors have not increased over that attained in the Holton Base measures.

A comparative test of the two methods of handling the thermometers has already been made on p. 258, which is entirely favorable to the method of attaching the thermometer to the tape in a horizontal position, as compared with the Holton Base method of incasing the bulbs in steel sheaths and holding at the height of the tape.

The departure, therefore, from the Holton Base method of handling the thermometers, and of increasing the tension and distance between supports, is justified by the resulting probable errors.

The liability of showing a constant error in tape measures from a lag of the mercurial thermometers is not great, because the range of temperature during the measure of a section is small.

An unsuccessful attempt was made to discover a lag of thermometers with respect to the tape. There is apparently no decided lag effect either in the Versailles Base measures or in the measures during this season. The results of the comparator determinations and on the sections where measures were made on different nights show a tendency to constant errors which does not correspond to an assumed lag of the mercurial thermometer, but is probably due to a changed relation or persistent difference between the thermometer and tape temperature due to atmospheric conditions. The magnitude of these errors is hard to determine, but from the residuals on the test kilometers, on sections involving measures on different nights and on the comparators, they are of about the size indicated for the duplex result on the comparators (Tables Nos. 3 and 4). The maximum residual for any one of the four tapes is $0^{mm}.87$, and for the duplex result it is $0^{mm}.86$. For 50-meter Tape No. 248 the maximum residual is $0^{mm}.47$, and the



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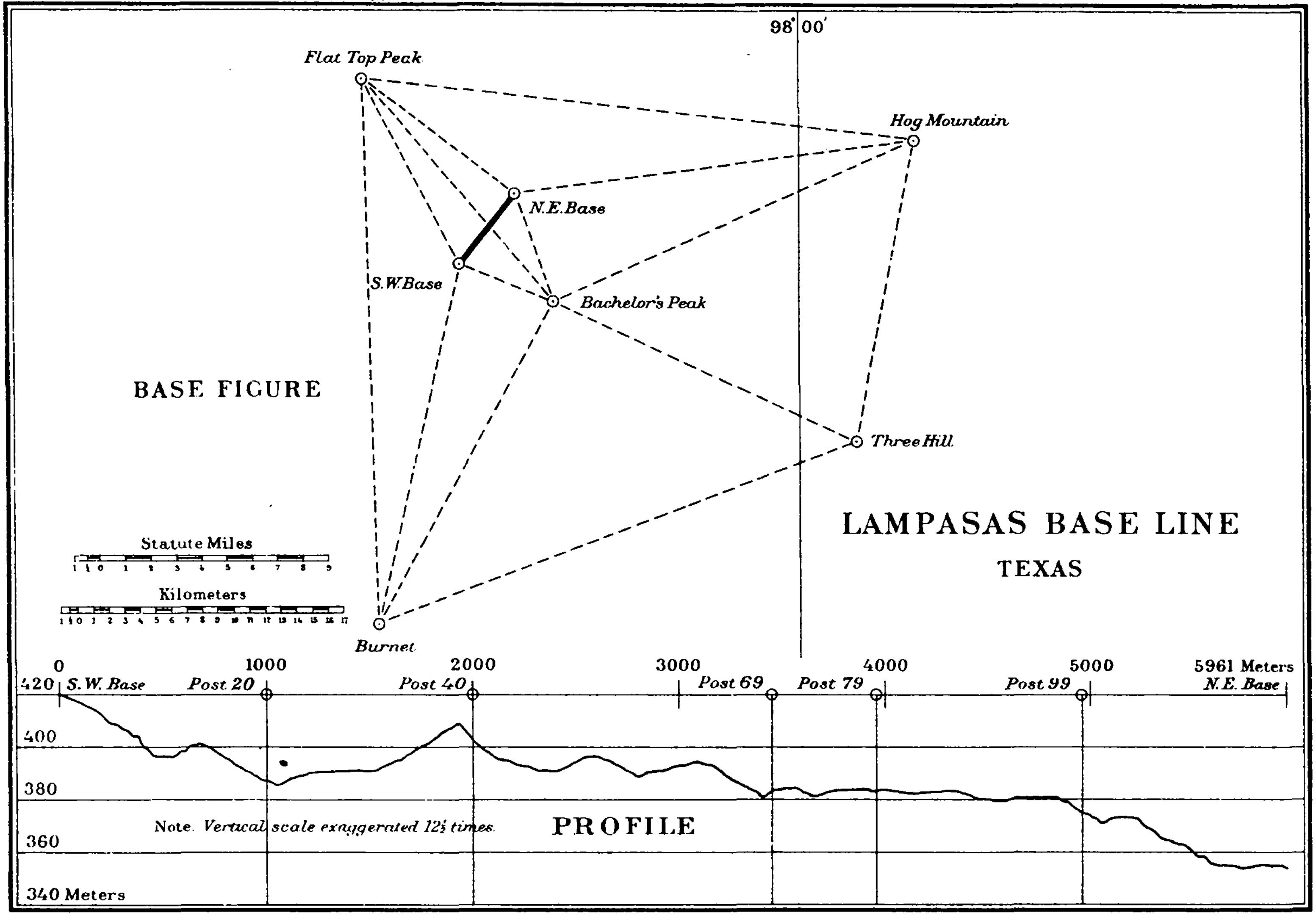

98° 00′
Flat Top Peak
Hog Mountain
N.E. Base
S.W. Base
Bachelor's Peak
BASE FIGURE
Three Hill
LAMPASAS BASE LINE
TEXAS
Statute Miles
Kilometers
Burnet
0
1000
2000
3000
4000
5000
5961 Meters
420
S. W. Base
Post 20
Post 40
Post 69
Post 79
Post 99
N.E. Base
400
380
360
340 Meters
Note. Vertical scale exaggerated 12½ times.
PROFILE

probable error of a single determination of 100 meters is $\pm 0^{mm}.15$, the same as for the steel and brass components of the duplex.

It seems desirable to examine the tape results with a view to discovering constant errors peculiar to different nights. On July 28 measures were made with Tapes 88 and 85 on the same night as the comparisons. Referring to Tables Nos. 8 and 9, the observations on 85 for this night make the tape $0.^{mm}47$ shorter than the mean, while on 88 this night's observations make the tape $0^{mm}.21$ shorter than the mean. Applying these two corrections to the measures of the Shelton test kilometer and the correction* $+5^{mm}.6$ to the duplex result (p. 254) there result these values:

Tape 88............	1000.2708
Tape 85............	.2629
Duplex	.2635

The range in the results from these three sets of apparatus in Table No. 12, $13^{mm}.4$, is thus reduced to $7^{mm}.9$, the result from Tape 85 agreeing closely with that from the duplex.

CONSTANCY OF STEEL TAPES.

Although the 100-meter tapes used at the Holton and St. Albans Bases were again used in this work, their equations can not be directly compared. The tension has been increased from 11.5 kilograms to 15.0 kilograms, and the interval between supports from 10 meters to 25. On July 19, before any of the standardizing of this season began, when unreeling tape No. 85 an undiscovered defect in the reel caused a kink in the tape which could not be entirely removed. The difference between the tapes, $T_{88}-T_{85}$, was at Holton $2^{mm}.45$, at St. Albans $2^{mm}.57$, and throughout this season $3^{mm}.16$. The test of constancy is greatest in this season's work, extending as it does through six months and involving nine base lines. The reader is again referred to the section, "Adopted lengths of tapes" to note that three of the tapes, 88, 247, and 248, show no change during the season over 1 part in 1 000 000, while Tape 85 apparently increased in length $0^{mm}.45$, or 1 part in 220 000. Again 50-meter Tape No. 204 was tested both before and after the measurement of the Versailles Base (p. 226, "Transcontinental Triangulation"), with almost identical values for its length, which indicates that the tension of 15 kilograms is not excessive.

MAXIMUM GRADES FOR STEEL TAPES, AND BREAKING OF GRADES.

The rather unusual topography for a base line encountered on four of the nine lines, as shown by the maximum grade corrections, mentioned in connection with each base, will cause comment, and the manner in which it was overcome should be explained and justified. As an exhibition of this the reader is referred to illustration No. 17, the profile of the Lampasas Base. No grading to ease the grades on any of the lines was attempted, and the 25-meter spans of the tape measurement are nearly parallel to the surface of the ground traversed, except where such parallelism would necessitate placing an intermediate tape support below the grade of the marking tables, a tall support being substituted in all such cases. On section 1 of the Lampasas line it was necessary to break the grade (have the middle support above the grade of the marking tables) on three-fifths of the section. Also, on this section the maximum grade of the entire season was encountered, 3.15 meters in 25 meters, involving a correction to the measured length

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* As derived on pp. 294, 295.

equivalent to 201 millimeters. An improbable error of 5 millimeters in determining this difference of elevation would cause an uncertainty of $0^{mm}.3$. As has been pointed out these errors are not cumulative and moreover occur but seldom.

When tapes are inclined in this manner it is plain that the distance between the terminal marks will be greater than when the line is horizontal. The investigation of this question, pages 487,488, Report for 1892, Part II, shows that for grades of 5 per cent or differences of elevation of less than 1.25 meters for each 25-meter span this correction may be regarded as insensible, being considerably less than 1 part in 1 000 000. On this, the extreme of all sections measured during this season, only thirteen of the forty spans exceed this 5 per cent grade, and for these the corrections due to such slope could be readily computed and applied. The correction would be about $0^{mm}.8$ in the extreme case.

Any possible criticism of the method of breaking the tape grades may be most readily disposed of by referring the reader to the test kilometer of the Bowie Base. On this section the 100-meter tapes were practically unbroken from end to end of the section, but for the 50-meter tape four broken grades occur, making the grade corrections for the 50-meter tapes $234^{mm}.1$, and for the 100-meter tapes $197^{mm}.2$, yet the mean of the length from the 50-meter tapes differs only $0^{mm}.9$ from the length from the 100-meter tapes. It may be concluded from this and other similar cases that the increased friction on the support nails has not produced errors of appreciable magnitude. In perfecting the tension for the final contact it is as probable in a given case that the man applying the tension will have to slack off a few grams as to take it up, and thus the errors from the increased friction on the supports would be as likely of one sign as the other.

WIND EFFECT ON TAPES.

Very little attention has been paid to the effect of wind on tape measurements, except to avoid making measures while a strong breeze was blowing, such measures being not at all trustworthy. At the Shelton comparator delays were caused by high winds which failed to subside with the setting of the sun. Observations were made on the tapes for determinations of their lengths when the wind was disturbing the tape very much. The effect seems to be that the results are erratic and necessarily not as trustworthy as those on calm nights. Experience soon taught the observers that when using the tape under the conditions of tension and supports here used any wind which did not set the tape to vibrating violently would not seriously affect the results. When it is explained that during the five months after the completion of the Shelton Base practically no delays to the progress of the base measurement were made necessary by the wind, the liability of delays from wind will not be urged as an objection to measures with long tapes.

ERRORS DUE TO TENSION ON THE TAPES.

The errors due to erroneously holding the pointer of the dial to the exact tension are obviously not of the cumulative class. Any personal equation of the man applying the tension in persistently applying too much (or too little) tension is eliminated by having the same man apply the tension in the determinations on the comparator as in the base measures, which was the practice during the season, with two or three minor exceptions.

TEN-METER INTERVALS FOR TAPE SUPPORTS VERSUS TWENTY-FIVE METER INTERVALS.

Very little discussion is required to point out the advantage of the longer interval of twenty-five meters over that of ten meters. The evidence already produced is deemed sufficient to prove that there was no loss of accuracy from the change.

On the work of setting stakes and preparing for tape measurement a direct comparison can be made by taking the figures in the table on page 332 of Coast and Geodetic Survey Report for 1892. According to this table, for the 5.5 kilometers of the Holton Base 53.5 days for one man were required, or 9.7 days per kilometer. In the work under discussion, where the interval was 25 meters between tape supports, 201 days for one man were spent in cutting and setting the tape supports for measuring 57 kilometers, or 3.5 days per kilometer. As a matter of economy this change, then, shows a reduction in labor of preparation of something over one-half by reducing the number of tape supports in a kilometer from 100 to 40. If the reduction in the lumber and cost of transporting it were added, the comparison would become still more favorable to the long interval between supports.

The setting of the tape supports was done by a party of from four to five persons, consisting of one officer who had immediate charge of the work and handled the forward end of the tape, one officer who aligned the tape supports, and two or three men. The time necessary for such a party to set one kilometer of tape supports varied from two to six hours.

TAPES VERSUS BARS.

For a proper discussion of the relative merits of the duplex bar apparatus and the long steel tapes, it is necessary to state the relative cost of the two.

The cost, when computed in terms of a day of labor for an officer or laborer, of measuring 57 kilometers of double measure with steel tapes was 406 days. For measuring 16½ kilometers of double measure with the duplex apparatus the cost was 321 days; that is, 7.1 days' work for one man was required to measure a kilometer twice with the tapes and 19.5 days' with the duplex apparatus. In making this comparison one-half of all the time required for the leveling was charged to the tape measures and none to the duplex measures, because the profile of the line necessary when bar measures only were made would require much less time than the leveling for the grade of the tape.

The item of 406 days is made up of three parts, as follows: 201 days in cutting and setting the tape supports, 112 days in the actual measurement, and 93 days for the extra leveling required. There were 61 days spent in opening the lines and aligning the few points required on the base, which were necessary for either type of apparatus. The three to five hours during the evening were called a half day in making this comparison. From these figures the labor of the bar measurement is two and three-quarter times as great as that of the tape measurement.

When comparison is made of the probable errors of a single measure of a kilometer section, that from the Salt Lake Base, $\pm 1^{mm}.14$, and from this season, $\pm 1^{mm}.2$, for the duplex result, are practically identical with that attained in the measurement of the Versailles Base for the 50-meter tape, $\pm 1^{mm}.2$. It is true, however, that viewed in the light of these probable errors the accuracy is greater from the duplex, for two reasons, viz, the duplex gives three results which, although they are not independent, are desirable checks on a portion of the accidental errors to which the apparatus is subject, and, second, because the errors due to determinations of the grade are displayed in the case of the bar apparatus, while in the case of the tape measures such errors would affect both measures alike.

FIFTY-METER TAPES VERSUS ONE-HUNDRED-METER TAPES.

The probable errors may be expected to reveal the relative merits of using a 50-meter and a 100-meter tape. The probable error of a single determination of the comparator interval was for the two 100-meter tapes $\pm 0^{mm}.19$ and $\pm 0^{mm}.24$, respectively, and for the 50-meter tapes $\pm 0^{mm}.24$ and $\pm 0^{mm}.15$, respectively, which is slightly favorable to the shorter tape. Again, the probable error of a single measure of a kilometer when computed from all sections was $\pm 1^{mm}.7$* in the case of the 50-meter tapes, and $\pm 1^{mm}.8$* in the case of the 100-meter tapes.

While this gain in accuracy is small for the 50-meter tape over the 100-meter tape, it is nevertheless instructive as showing that the accidental errors of the thermometer indications are not decreased with a multiplication of the thermometer readings. As the accidental errors of making twice the number of contacts made necessary by the use of the 50-meter tape instead of the 100-meter tape are so small† as to make no showing in the probable error, it would naturally be supposed that the double number of thermometer indications recorded for the 50-meter tapes would have a great effect on the probable error. Such is not the case, however.

The ease with which 50-meter tapes may be adapted to obstructions of topography makes the labor of setting the supports about equal to that required for the 100-meter tapes.

The choice between the two must be made, then, in the comparison of the number of operatives required with each length of tape. The minimum number of operatives for the 100-meter tape is eight, and for the 50-meter tape six, which means that it always takes one-third more help to manipulate the longer tape.

While the speed of measurement with the 100-meter tape is about one-fifth faster than with the 50-meter tape (see Tables Nos. 22 and 23), this is unimportant for two reasons: First, because the time required for the measurement is much less than that required for the preparation of the line for measurement; and, second, it is always desirable to keep the measurement following closely the setting of the supports. In measurements through pasture the tape supports were so frequently disturbed that it was found convenient to complete the measurement as soon as 3 kilometers had been prepared for measurement. The work of measuring 3 kilometers in each direction was readily accomplished during an evening without regard to whether it was with the 100-meter or 50-meter tape.

The conclusion therefore is that the 100-meter tape has few if any advantages over the 50-meter tape, and requires a party at least one-third larger for its manipulation.

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*These probable errors involve the errors of standardization and the constant errors of each tape, so are not comparable with the probable errors stated on page 296, and therefore were not used in discussing the relative accuracy of bars and tapes.

†See page 474, Report for 1892.

CONCLUSIONS.

The history of geodesy presents few if any examples of a base measured with more than one apparatus which do not show outstanding differences very large in comparison with those which are displayed by repeating the measurement with the same apparatus. These constant errors, which are only detected by the use of several sets of apparatus, have been revealed in this season, and it may be inferred that the absolute accuracy is therefore at least as great as in previous bases where but one type of apparatus is involved. These constant errors are shown in the results of the measures of the nine test kilometers. The maximum range in the results was 20^{mm}, the tapes, as would be expected, agreeing among themselves more often than with the bars. The bars give a smaller result than the mean, ranging in the kilometer from $2^{mm}.1$ to $10^{mm}.3$. This outstanding difference between the duplex result and the mean of all is 1 part in 175 000 on the average. In like manner, 100-meter tape No. 88 shows a tendency to give the largest result, being above the mean in seven of the nine cases and averaging 1 part in 385 000 on the entire 9 kilometers. The source of these constant errors is still problematic.

In concluding this report of a geodetic operation of this magnitude, in which in a single season of six months nine primary bases were measured, the opinions of the writer may not be amiss.

The accomplishment of the work was made easy by the complete cooperation of every member of the party, and its success is due in great measure to their untiring support. Special acknowledgment of the valuable advice and assistance of Assistant Bowie should be made.

The benefits accruing from keeping the same party throughout the season are incalculable. Evidences of the increasing efficiency of the party were the rapid preparation of the base sites; the record of the stub-setting party in setting 1 300 meters of marking posts and intermediate supports at proper intervals and in accurate alignment for the 50-meter tapes in one hundred and forty-three minutes on the Alice Base; and, finally, the attainment of the unprecedented speed of 100 bars (500 meters) in sixty minutes for the duplex measurement at Seguin was the culmination of the increasing experience on the eight bases which preceded.

The general conclusion, from a consideration of all the work done with the iced-bar apparatus, must be its superiority over all types of base-measuring apparatus, displaying no errors of the systematic or constant class. Also, that two to six measures under the most trying conditions and without the protection of a shed will give an accuracy equal to that represented by a probable error of 1 part in 2 500 000.

The duplex apparatus in use under the most trying conditions has shown itself to be entitled to probably first rank among contact-slide bar apparatus. Its double contact feature has proved no hindrance, and the results have shown that it is possible to use it in high winds in which the secondary apparatus could not be used. This greater stability is probably due to the greater weight of the duplex. An examination of the results from duplicate measures and in competition with the tapes reveals constant errors of some magnitude. These constant errors can be most nearly overcome by duplicating the field conditions of temperature and atmosphere on the comparator determinations.

In summing up all the errors of tape measurements, except those involving the grades, and which are necessarily small, the real criterion is the probable error of a single measure of a section where the observations extend through more than one day or a variety of weather. Such a test occurred on nearly every section of the Versailles Base,* and these errors were shown to be small. During this season such tests occurred on but few sections, but the indications from these agreed with the Versailles experience. It is not maintained that no constant errors are in evidence in the results of the tape measures, but it is not believed that they are larger than those which affect the duplex bar measures.

It is apparent that a field comparator whose interval should be measured with the iced-bar apparatus is a positive necessity when an absolute accuracy of 1 part in 500 000 is desired. It is also necessary with either the duplex bar or tape apparatus to have the conditions of temperature and weather the same in the actual measures as in the standardization. This duplication of conditions could be more readily attained with the tape apparatus than with the duplex bars.

In future base measures with a field comparator at each base it would be feasible to measure the comparator interval with the tape on each of the two to four nights when measures were made on the base. In this manner a party no larger than the one of this season could use two or three 50-meter tapes and have a 50-meter comparator at *each* base with no greater cost than in these measures, and attain an absolute accuracy still greater than here attained.

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*Page 230, "Transcontinental Triangulation."

APPENDIX No. 4.

REPORT 1901.

EXTENSION OF TABLES FOR THE COMPUTATION OF GEODETIC POSITIONS TO THE EQUATOR.

CONTENTS.

EXTENSION OF TABLES FOR THE COMPUTATION OF GEODETIC POSITIONS TO THE EQUATOR.

By JOHN F. HAYFORD, *Chief of Computing Division.*

These tables are an extension of those published in Appendix No. 9, of the Report for 1894, which are applicable between latitudes 18° and 72°. The tables here printed extend from 18° to the equator. They are based on the same constants as the tables in the 1894 Report, namely, upon the Clarke Spheroid of 1866, of which the equatorial radius is 6 378 206.4 meters, and the polar semiaxis 6 356 583.8 meters.

For the purpose of making these tables complete in themselves the derivation of the formulæ on which they are based is reproduced from the 1894 Report.

To apply these tables to the computation of positions south of the equator it is only necessary to bear in mind in using the formulæ that all south latitudes are negative. Whenever $\triangle\varphi$ as computed in these formulæ is negative it indicates a numerical increase in the latitude. In using the formula for $\triangle\alpha$ it should be noted that for the Southern Hemisphere the term $\sin \frac{1}{2}(\varphi+\varphi')$ is always negative and therefore $\triangle\alpha$ and $\triangle\lambda$ always have the same sign in the Southern Hemisphere, whereas they have opposite signs in the Northern Hemisphere.

To apply these tables to the computation of positions in east longitude it is only necessary to consider that all east longitudes are negative.

These formulæ and tables, with those in 1894 Report, keeping in mind the above statements, apply to the computation of geodetic positions over the whole sphere, except in latitudes greater than 72° north or south.

In the logarithms given in the tables a minus sign over the characteristic indicates that 10 is to be subtracted from the characteristic as printed, and a double minus sign indicates that 20 is to be subtracted from the characteristic as printed.

FORMULÆ FOR THE COMPUTATION OF GEODETIC LATITUDES, LONGITUDES, AND AZIMUTHS.

When the geographical coordinates of latitude and longitude of a point on the earth's surface and the distance and azimuth to another point are known, the problem of computing the latitude and longitude of the second point and the reverse azimuth may be treated in two different ways.

We may either solve the spheroidal triangle formed by the two points and the pole, as a whole, arriving at trigonometrical functions of the required co-latitude, azimuth, and difference of longitude, or we may develop expressions for the differences of the required and the given quantities.

The former or direct method has the inconvenience of requiring the use of ten places of decimals in the computation, in order to give the positions with a degree of exactness corresponding to that of the known distance between the two points, while the second leads to very convenient expressions, on account of the smallness of the differential arcs in ordinary triangulation.

When, however, the arc between the two points reaches several degrees in length, the direct method must be resorted to. This solution has been very completely and elegantly effected by Bessel, and is given in Astronomische Nachrichten, No. 86, 1826.

Adopting the second method, we follow in the main Puissant (Traité de Géodésie)* in the development of the difference of latitude of two points on the spheroid in terms of the distance, azimuth, and latitude of the given point. It will be desirable first to recall the expressions of several lines of an ellipse in terms involving the latitude φ which is the angle the normal to any point on the ellipse makes with the major axis.

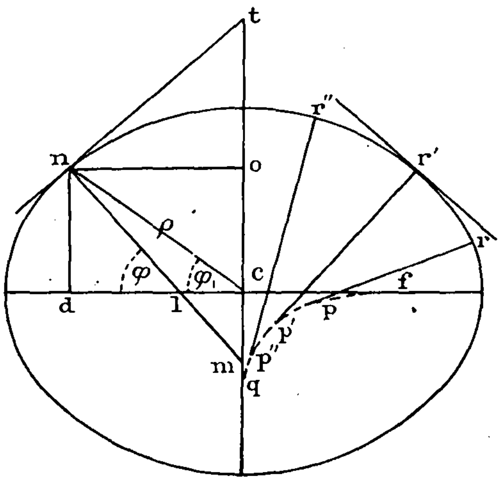

Fig. 1.

Designating the major or equatorial semiaxis by a and the minor or polar semiaxis by b then the ellipticity ε or the ratio of their differences to the former is

$$\varepsilon = \frac{a-b}{a}$$

The eccentricity e is expressed by

$$e^2 = \frac{a^2 - b^2}{a^2}$$

and shown in fig. 1 by cf, the distance from the center to the focus.

The normal nl terminating at the major axis equals

$$\frac{a\ (1-e^2)}{(1-e^2 \sin^2 \varphi)^{1/2}}$$

The normal nm produced to the minor axis is

$$N = \frac{a}{(1-e^2 \sin^2 \varphi)^{1/2}}$$

* Traité de Géodésie, par L. Puissant, troisième édition, Tome I, Chapter XV, page 347 and fol., Paris, 1842.

The abscissa *cd* or *no* equals $N \cos \varphi$. This is the radius of a parallel on the spheroid.
The tangent *nt* ending at the minor axis equals $N \cot \varphi$.
The ordinate *nd* equals

$$\frac{a\,(1-e^2)\sin\varphi}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

The reduced latitude being ψ, we have

$$\tan\psi = \frac{b}{a}\tan\varphi$$

The radius vector $\rho = a\,(1-e^2\sin^2\psi)^{\frac{1}{2}}$,
The radius of curvature rp, $r'p'$, $r''p''$ . . . at any point of the ellipse r, r', r'' . . . is

$$R = \frac{a\,(1-e^2)}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}$$

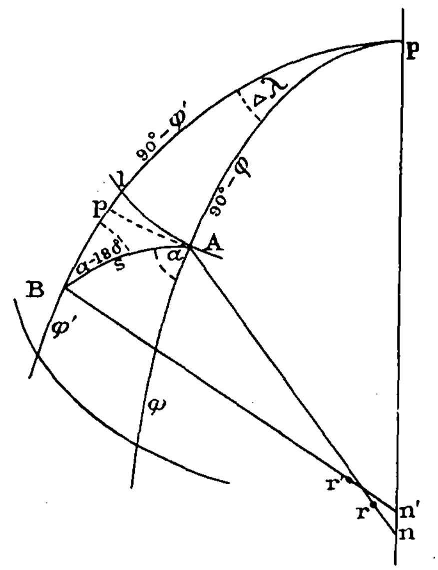

Fig. 2.

The terminal points f, p, p', p'', q form an evolute; at the equator where $\sin\varphi = 0$, $R = \frac{b^2}{a}$ and the center of curvature is in the focus; at the pole, where $\sin\varphi = 1$, $R = \frac{a^2}{b}$.

The radius of curvature R and the normal N are principal quantities used in geodesy. It will be observed that radii of curvature for different latitudes do not intersect unless produced, and that when they lie in different meridional planes on the spheroid they will not intersect at all.

A and B in Fig. 2 are two points on a spheroid of revolution, having the latitudes φ, φ', and joined by the geodetic line $AB = s$, making the angles with the meridian $PAB = 180° - \alpha$, and $PBA = \alpha' - 180°$. The azimuths α, α' are reckoned from south around by west in consequence of the latitudes being reckoned, by settled custom, from the equator toward the poles, otherwise the meridional coordinate of a point would be more properly measured from the pole and the azimuth of a line reckoned from the north. The angle APB between the two meridional planes passing through A and B is the difference of their longitudes λ, λ', which being reckoned positive to the westward we have $\lambda'-\lambda=\Delta\lambda$. Furthermore, An, Bn', Ar, Br' indicate the normals N, N', and the radii of curvature in the meridian R, R', at the points A and B.

This being premised and the latitude φ of the point A being given, as well as the length s of the geodetic line AB and its azimuth α, we propose to find the latitude φ' of the point B, the angle $\Delta\lambda$, and the reverse azimuth α', by solving the geodetic triangle ABP. Writing γ, γ', for the co-latitudes, ξ for $180-\alpha$, and σ for the arc AB referred to radius $=1$, we have in a spherical triangle for γ' the following equation:

$$\cos\gamma'=\cos\gamma\cos\sigma+\sin\gamma\sin\sigma\cos\xi$$

Observing now that σ is always a small arc, rarely exceeding $1°$, and generally less than $30'$, we can develop the increment of γ with reference to that of σ in a rapidly converging series, and will have, by Taylor's theorem,

$$\gamma'=\gamma+\frac{d\gamma}{d\sigma}\sigma+\tfrac{1}{2}\frac{d^2\gamma}{d\sigma^2}+\tfrac{1}{6}\frac{d^3\gamma}{d\sigma^3}\sigma^3+\quad\ldots \tag{a}$$

In order to determine the differential coefficients, we consider a differential spherical triangle having the sides γ, $d\sigma$, and $\gamma+d\gamma$, in which

$$\cos(\gamma+d\gamma)=\cos\gamma\cos d\sigma+\sin\gamma\sin d\sigma\cos\xi,$$

and developing, as usual, by the differential calculus, we find

$$\frac{d\gamma}{d\sigma}=-\cos\xi,\quad \frac{d^2\gamma}{d\sigma^2}=\sin^2\xi\cot\gamma,\quad \frac{d^3\gamma}{d\sigma^3}=\sin^2\xi\cos\xi(1+3\cot^2\gamma)$$

Introducing these values in (a) we obtain

$$\gamma'-\gamma=-\sigma\cos\xi+\tfrac{1}{2}\sigma^2\sin^2\xi\cot\gamma+\tfrac{1}{6}\sigma^3\sin^2\xi\cos\xi(1+3\cot^2\gamma)+\quad\ldots\ldots$$

and substituting φ, φ', and α in this expression, we have for the difference of latitude

$$\varphi-\varphi'=\sigma\cos\alpha+\tfrac{1}{2}\sigma^2\sin^2\alpha\tan\varphi-\tfrac{1}{6}\sigma^3\sin^2\alpha\cos\alpha(1+3\tan^2\varphi)+\quad\ldots\ldots \tag{b}$$

It will be readily seen that the first term expresses the distance on the meridian PB from B to p, the foot of the perpendicular from A; the second term, the distance, very nearly, from p to the parallel passing through A; while the third term is a further approximation, and so on.

Referring now our case to an imaginary sphere of radius equal to N, with its center at the point where the normal An intersects the polar diameter of the spheroid, we have

$$\sigma=\frac{s}{N}$$

substituting which, we get

$$\varphi-\varphi'=\frac{s\cos\alpha}{N}+\tfrac{1}{2}\frac{s^2\sin^2\alpha\tan\varphi}{N^2}-\tfrac{1}{6}\frac{s^3\sin^2\alpha\cos\alpha}{N^3}(1+3\tan^2\varphi)+\quad\ldots \tag{c}$$

This difference of latitude is, however, referred to a sphere whose radius is N and requires still to be transformed by referring it to one whose radius is R_m, the radius of curvature in the meridian for the middle latitude. Since we do not at first know the middle latitude, it is more convenient to refer to the radius of curvature R of the starting point, the latitude of which is known, and then find the small correction due to the ratio of R to R_m.

Multiplying then equation (c) by $\frac{N}{R}$ and dividing, moreover, by arc $1''$ in order to express $\varphi-\varphi'$ in seconds of arc, we get

$$-\delta\varphi=\frac{s}{R \operatorname{arc} 1''}\cos\alpha+\tfrac{1}{2}\frac{s^2}{RN \operatorname{arc} 1''}\sin^2\alpha\tan\varphi-\tfrac{1}{6}\frac{s^3}{RN^2 \operatorname{arc} 1''}\sin^2\alpha\cos\alpha(1+3\tan^2\varphi)$$
$$+\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\quad.\qquad (d)$$

The computation of this series is facilitated by tables giving the logarithms of the following factors to the argument of φ, viz:

$$B=\frac{1}{R \operatorname{arc} 1''} \qquad\qquad C=\frac{\tan\varphi}{2\,RN \operatorname{arc} 1''}$$

Moreover, substituting in the third term the value of the first term, designated by h, we can write it

$$\tfrac{1}{6}h.\frac{s^2\sin^2\alpha}{N^2}(1+3\tan^2\varphi)$$

and tabulate another factor

$$E=\frac{1+3\tan^2\varphi}{6\,N^2},$$

when our formula for computation becomes

$$-\delta\varphi=s\cos\alpha\,.\,B+s^2\sin^2\alpha\,.\,C-h\,.\,s^2\sin^2\alpha\,.\,E+\quad.\quad.\quad. \qquad (e)$$

In order, finally, to obtain the true $\Delta\varphi$ referred to R_m we must increase $\delta\varphi$ by $\frac{R-R_m}{R_m}\delta\varphi$

Now

$$R-R_m=a\,(1-e^2)\left(\frac{1}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}-\frac{1}{(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}\right)$$
$$=a\,(1-e^2)\frac{\frac{3}{2}\,e^2\,(\sin^2\varphi-\sin^2\varphi_m)}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}\,(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}$$

by developing and neglecting terms involving higher powers of e^2; but

$$\sin^2\varphi-\sin^2\varphi_m=\sin(\varphi-\varphi_m)\sin(\varphi+\varphi_m)=\delta\varphi\sin 1''\sin\varphi\cos\varphi$$

very nearly, because $\frac{1}{2}\sin 2\varphi=\sin\varphi\cos\varphi$; hence we write

$$\frac{R-R_m}{R_m}=\frac{a(1-e^2)\frac{3}{2}\,e^2\,\delta\varphi\sin 1''\sin\varphi\cos\varphi}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}\,(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}\times\frac{(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}{a\,(1-e^2)}=\frac{\frac{3}{2}\,e^2\,\delta\varphi\sin 1''\sin\varphi\cos\varphi}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}$$

nearly, but making

$$D=\frac{\frac{3}{2}\,e^2\sin\varphi\cos\varphi \operatorname{arc} 1''}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}$$

we get for the desired corrective term*

$$\frac{R-R_m}{R_m}\delta\varphi=(\delta\varphi)^2D$$

and we finally have for the true difference of latitude

$$-\Delta\varphi=s\cos\alpha\,.\,B+s^2\sin^2\alpha\,.\,C+(\delta\varphi)^2.\,D-h.\,s^2\sin^2\alpha\,.\,E \qquad (1)$$

*In his "The Theory and Practice of Surveying" Prof. J. B. Johnson develops this corrective term in a direct manner as contrasted with the approximate and laborious method given in the text, and points out that the $\frac{3}{2}$-power in the denominator of D should be replaced by unity. This has been done in the appended tables; although the defect is not more than 0.001 of the value of this term, which is itself very small.—C. A. S.

which formula, although of a somewhat complicated derivation, is very simple and convenient in practical computation with the aid of the tabulated log. factors B, C, D, E. The term* $(\delta\varphi)^2 D$ is here interposed between the second and third terms of the series proper, because the latter is frequently not required, being insensible when the distance s is less than about 10 statute miles or log s, in meters, less than 4.23. The term $(\delta\varphi)^2 D$ should be used whenever log h exceeds 2.31, and h^2 may be substituted for $(\delta\varphi)^2$ in all cases where log s does not exceed 4.93.

The term depending on the fourth differential coefficient, neglected in equation (a) never exceeds $0''.002$ for $\sigma = 1^\circ$ or $s = 100$ kilometers, and may therefore be safely neglected in practice. †

* This term was devised by the writer of this article in 1846, while arranging the formulæ for use in the Coast Survey and putting them into the form above given, in which they have been employed ever since.—J. E. H.

† This additional term has, however, been lately developed by Mr. M. H. Doolittle, of the Computing Division, who finds that it can be given as a function of the factors A, C, and E of the tables, thus requiring no special tabulation. It is as follows:

The additional term of Taylor's theorem

$$\frac{1}{24}\frac{d^4\gamma}{d\sigma^4}\sigma^4 = -\frac{1}{24}\sigma^4 \sin^2\xi \cot\gamma\left[(1-3\cos^2\xi)(1+3\cot^2\gamma)-6\cos^2\xi\operatorname{cosec}^2\gamma\right]$$

Substituting $90^\circ-\varphi$ for γ, $180^\circ-\alpha$ for ξ, $\frac{s}{N}$ for σ, and multiplying by $\frac{N}{R \operatorname{arc} 1''}$ in the same manner as for the other terms

$$\begin{aligned}\frac{1}{24}\frac{d^4\gamma}{d\sigma^4}\sigma^4 = &-\frac{1}{24}\frac{s^4}{RN^3\operatorname{arc} 1''}\sin^2\alpha\tan\varphi(1+3\tan^2\varphi)\\ &+\frac{1}{8}\frac{s^4}{RN^3\operatorname{arc} 1''}\sin^2\alpha\cos^2\alpha\tan\varphi(1+3\tan^2\varphi)\\ &+\frac{1}{4}\frac{s^4}{RN^3\operatorname{arc} 1''}\sin^2\alpha\cos^2\alpha\tan\varphi\sec^2\varphi\end{aligned}$$

Denoting the second term $s^2 \sin^2\alpha\, C$ in formula (e) by C_1

$$C_1 E = \frac{s^2\sin^2\alpha\tan\varphi(1+3\tan^2\varphi)}{12\, RN^3\operatorname{arc} 1''}$$

$$A^2 C_1 = \frac{s^2\sin^2\alpha\tan\varphi}{2\, RN^3\operatorname{arc}^3 1''}$$

and we finally obtain

$$-\Delta\varphi = s\cos\alpha\, B + s^2\sin^2\alpha\, C + (\delta\varphi)^2 D - h\,.\, s^2\sin^2\alpha\, E$$

$$-\frac{1}{2}s^2 C_1 E + \frac{3}{2}s^2\cos^2\alpha\, C_1 E + \frac{1}{2}s^2\cos^2\alpha\sec^2\varphi\,.\, A^2 C_1 \operatorname{arc}^2 1''$$

In the line from Ibepah to Ogden, in Utah, 230 kilometers long, the additional term amounted to $0''.038$. In Puissant's time no such long lines had to be provided for as have since been observed in triangulations; e. g., in California, Nevada, Utah, and Colorado, where several sides reach to nearly 2° in length, or slightly surpass this limit, with a maximum sight of 2¾°. The formulæ applicable for the computation of the largest triangles that it is possible to measure, given in Clarke's Geodesy (Oxford, 1880) and in Appendix No. 9, Coast and Geodetic Survey Report for 1885, pages 462-464, and employed in the British Ordnance Survey, also in the extension of La Caille's arc in South Africa, may be employed for a check computation, but they demand the use of not less than 9-place logarithms.

For distances greater than any that can be directly observed, see development of formulæ in series by Dr. F. R. Helmert, "Theorieen der Höheren Geodäsie, Leipzig, 1880," Vol. I, pages 296-298. It includes terms of the fifth order.

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For secondary triangulation and when the sides do not exceed about 12 statute miles, or say 20 kilometers, the formula (1) may be advantageously reduced to the following:

$$-\varDelta\varphi = s \cos\alpha \,.\, B + s^2 \sin^2\alpha \,.\, C + h^2 \,.\, D \tag{2}$$

In order next to deduce the angle APB (Fig. 2) between the meridional planes passing through A and B and intersecting in the polar axis, or the difference $\varDelta\lambda$ of the longitudes λ and λ' of the points A and B, counted from east to west, we avail ourselves of the latitude φ' of B, which has become known by the previous calculation, and have simply, using the same notation as before,

$$\sin\gamma' : \sin\xi = \sin\sigma : \sin\varDelta\lambda$$

Referring σ to a sphere the radius of which is the normal $Bn' = N'$, we have $\sigma = \frac{s}{N'}$, and assuming for the present the small arcs σ and $\varDelta\lambda$ proportional to their sines, we obtain

$$\varDelta\lambda = \frac{s \sin\alpha}{N' \cos\varphi' \operatorname{arc} 1''} \quad \ldots \tag{3}$$

dividing by arc 1″ in order to obtain $\varDelta\lambda$ expressed in seconds of arc. The table gives the logarithm of the factor $A = \frac{1}{N' \operatorname{arc} 1''}$, which must be taken out for φ'. We have

$$\varDelta\lambda = \frac{s \sin\alpha}{\cos\varphi'} A$$

In order to correct for the assumption that the small arcs s and $\varDelta\lambda$ are proportional to their sines we use a table giving the differences of the logarithms of the arcs and sines. This table is given before the tabulation of the factors A to F. In using it take out the differences for the arguments log s and log $\varDelta\lambda$, the first with a negative, the second with a positive sign, and add their algebraic sum to log $\varDelta\lambda$.

We obtain finally the reverse azimuth α' by considering that in the spherical triangle APB (Fig. 2) we have the following relation

$$\cot \tfrac{1}{2}(\xi + \xi') = \tan \tfrac{1}{2}(\varDelta\lambda) \frac{\cos \frac{1}{2}(\gamma' + \gamma)}{\cos \frac{1}{2}(\gamma' - \gamma)} = \tan \tfrac{1}{2}(\varDelta\lambda) \frac{\sin \frac{1}{2}(\varphi' + \varphi)}{\cos \frac{1}{2}(\varphi' - \varphi)}$$

but $\xi = 180° - \alpha$, therefore

$$\cot \tfrac{1}{2}(180° - \alpha + \xi') = -\tan \tfrac{1}{2}(\xi' - \alpha)$$

and

$$-\tan \tfrac{1}{2}(\varDelta\alpha) = \tan \tfrac{1}{2}(\varDelta\lambda) \frac{\sin \frac{1}{2}(\varphi' + \varphi)}{\cos \frac{1}{2}(\varphi' - \varphi)}$$

Assuming the tangents of $\frac{1}{2}\varDelta\alpha$ and $\frac{1}{2}\varDelta\lambda$ proportional to their arcs, and writing $\varphi_m = \frac{1}{2}(\varphi + \varphi')$ for the middle latitude, we have

$$-\varDelta\alpha = \varDelta\lambda \frac{\sin\varphi_m}{\cos \frac{1}{2}(\varDelta\varphi)} \quad \text{and} \quad \alpha' = \alpha + 180° + \varDelta\alpha$$

When the difference of longitude is very large it becomes necessary to correct for the error in the assumption that tan ½ $(\Delta\alpha)$: tan ½ $(\Delta\lambda) = \Delta\alpha : \Delta\lambda$. By an obvious transformation we find the correction to be $\frac{1}{12} (\Delta\lambda)^3 \sin \varphi_m \cos^2 \varphi_m \sin^2 1''$, for which we write $(\Delta\lambda)^3 F$ where log. F is to be taken from the table (see last column of table of factors). This term is only 0''.01 when log. $\Delta\lambda = 3.36$ and need never be used for secondary triangulation. A convenient table for finding the reciprocal of cos ½ $(\Delta\varphi)$ is appended.

The following examples will illustrate the use of the formulæ and tables:

The formulæ for the computation of the geodetic differences in latitude $\Delta\varphi$, in longitude $\Delta\lambda$, and in azimuth $\Delta\alpha$ are as follows:

$$\begin{cases} -\Delta\varphi = s \cos \alpha \,.\, B + s^2 \sin^2 \alpha \,.\, C + (\delta\varphi)^2 D - h \,.\, s^2 \sin^2 \alpha \,.\, E \\ \Delta\lambda = s \sin \alpha \sec \varphi' \,.\, A \\ -\Delta\alpha = \Delta\lambda \sin \tfrac{1}{2} (\varphi + \varphi') \sec \tfrac{1}{2} (\Delta\varphi) + (\Delta\lambda)^3 F \end{cases}$$

where

$$\begin{cases} \varphi' = \varphi + \Delta\varphi \\ \lambda' = \lambda + \Delta\lambda \\ \alpha' = \alpha + \Delta\alpha + 180^\circ \end{cases} \quad \text{and} \begin{cases} -\delta\varphi = s \cos \alpha \,.\, B + s^2 \sin^2 \alpha \,.\, C - h \,.\, s^2 \sin^2 \alpha \,.\, E \\ \text{also } h = s \cos \alpha \,.\, B \end{cases}$$

For subordinate triangulation when the sides do not exceed say 25 kilometers, or about 15 statute miles, the term involving E in $\Delta\varphi$ and the factor sec ½ $(\Delta\varphi)$, as well as the term involving F in $\Delta\alpha$, may be omitted.

Our formulæ can also be used for the solution of the inverse problem, viz, given the positions of two points on the spheriod, to find their distance and mutual azimuths, i. e., given φ, λ, φ', λ' (or φ, φ', $\Delta\lambda$), to find s, α, and α'. For its direct solution put

$$\begin{cases} s \cos \alpha = x = -\frac{1}{B}[\Delta\varphi + C \,.\, y^2 + D\,(\Delta\varphi)^2 + E\,(\Delta\varphi)\, y^2 + E \,.\, C \,.\, y^4] \\ s \sin \alpha = y = \dfrac{\Delta\lambda \cos \varphi'}{A} \end{cases}$$

whence

$$\tan \alpha = y : x \text{ and } s = x \sec \alpha = y \operatorname{cosec} \alpha$$

Position computation: Given, φ, λ, s, and α; required, φ', λ', α'.

FORM FOR PRIMARY TRIANGULATION.

		°	′	″
α	Mount Blue to Mount Pleasant	26	19	28.69
$\angle$	Ragged Mountain and Mount Pleasant	− 85	35	25.78
α	Mount Blue to Ragged Mountain	300	44	02.91
$\Delta\alpha$		+	50	03.88
		180		
α'	Ragged Mountain to Mount Blue	121	34	06.79

	°	′	″			°	′	″
φ	44	43	41.437	Mount Blue	λ	70	20	33.157
$\Delta\varphi$	−	30	56.052	s=110 743.7 meters *	$\Delta\lambda$	− 1	11	27.830
φ'	44	12	45.385	Ragged Mountain	λ'	69	09	05.327

s $\cos\alpha$ B	5.044 3191 9.708 4678 8.510 4887	s^2 $\sin^2\alpha$ C	10.08864 9.86854 1.39991	$(\delta\varphi)^2$ D	6.5372 2.3926	h $s^2\sin^2\alpha$ E	3.2633 9.9572 6.2069
h	3.263 2756		1.35709		8.9298		9.4274
	″		″				
1st term	+1 833.478	3d term	+ 0.0851			$\Delta\lambda^3$	10.897_n
2d term	+ 22.756	4th term	− 0.2675			F	7.844
	+1 856.234						8.741_n
3d and 4th terms	− 0.182						
$-\Delta\varphi$	+1 856.052						
		s	5.044 3191				
	° ′ ″	$\sin\alpha$	$9.934\ 2701_n$	Arg.		$\Delta\lambda$	$3.632\ 237_n$
$\frac{1}{2}(\varphi+\varphi')$	44 28 13.4	A	8.509 0107	s	− 218	$\sin\frac{1}{2}(\varphi+\varphi')$	9.845 433
$\frac{1}{2}\Delta\varphi$	0 15 28.0	$\sec\varphi'$	0.144 6280	$\Delta\lambda_u$	+ 314	$\sec\frac{1}{2}(\Delta\varphi)$	0.000 004
			$3.632\ 2375_n$	Corr.	+ 96		$3.477\ 674_n$
		$\Delta\lambda$	″ −4 287.830			1st term	−3 003.82
						2d term	− 0.06
						$-\Delta\alpha$	− 3003.88

*68.8 statute miles, nearly.

N. B.—Take out A from table for φ'.

Position computation: Given, φ, λ, s, and α; required, φ', λ', α'.—Continued.

FORM FOR SUBORDINATE TRIANGULATION.

		°	′	″
α	Tomales Bay to Sonoma Mountain	244	08	30.9
$\angle$	Bodega and Sonoma Mountain	− 83	14	34.7
α	Tomales Bay to Bodega	160	53	56.2
$\Delta\alpha$		−	2	01.9
		180		
α'	Bodega to Tomales Bay	340	51	54.3

	°	′	″			°	′	″
φ	38	10	47.982	Tomales Bay	λ	122	56	47.301
$\Delta\varphi$	+	7	28.222	s = 14 626.8 meters	$\Delta\lambda$	+	3	16.993
φ'	38	18	16.204	Bodega	λ'	123	00	04.294

$\frac{1}{2}(\varphi+\varphi')$	° ′ ″ 38 14 32	s cos α B	4.165 1480 9.975 4055n 8.510 9892	s^2 sin² α C	8.3303 9.0297 1.3003	h^2 D	5.303 2.380
1st term 2d and 3d terms	″ −448.273 + 0.051	h	2.651 5427n		8.6603 0.046		7.683 0.005
$-\Delta\varphi$	−448.222						

s sin α A sec φ'	4.165 1480 9.514 8602 8.509 1611 0.105 2810	$\Delta\lambda$ sin ½ $(\varphi+\varphi')$	2.29445 9.79168
	2.294 4503		2.08613
$\Delta\lambda$	″ +196.993	$-\Delta\alpha$	″ +121.9

N. B.—Take out A from table for φ'.

The inverse problem.—Cases frequently occur where the distance and mutual azimuths are demanded of two points whose latitudes and longitudes only are known. It has not been found necessary to prepare special formulæ and blank forms for this computation, as it can readily be made with the help of the preceding forms. It is done by dividing $\Delta\lambda = s \sin\alpha \,.\, A \,.\, \sec\varphi'$ by the first term for $\Delta\varphi$, $h = s\cos\alpha \,.\, B$, whence we get

$$\tan\alpha = \frac{\Delta\lambda \,.\, B}{A \sec\varphi' \, h}$$

This would give the azimuth at once, provided we knew h, since $\Delta\lambda$ is given. We therefore compute the smaller terms for the difference of latitude in order to obtain h by subtracting them from the known value of $\Delta\varphi$. The only addition to the usual form is the term log tan $\alpha = \log (s \sin \alpha) - \log (s \cos \alpha)$. The value of s will best be taken from the term h when $\sin \alpha$ exceeds $\cos \alpha$, and from the term $\Delta\lambda$ when the reverse is the case. When the distance s is large, as in primary triangulation, it will be necessary to introduce the correction for $\Delta\lambda$ due to difference of ratio between sine and arc, using the form for primary work, inversely, as indicated above.

Distance and azimuth computation: Given, φ, φ', λ, λ'; required, s, α, α'.

		°	′	″
α	Tomales Bay to Bodega	160	53	56.2
$\Delta\alpha$		—	2	01.9
		180		
α'	Bodega to Tomales Bay	340	51	54.3

		°	′	″				°	′	″
φ		38	10	47.982	Tomales Bay	λ		122	56	47.301
$\Delta\varphi$	+		7	28.222	s=14 626.8 meters	$\Delta\lambda$	+		3	16.993
φ'		38	18	16.204	Bodega	λ'		123	00	04.294

$\frac{1}{2}(\varphi+\varphi')$=38° 14′ 32″		s $\cos \alpha$ B	4.140 5535n 8.510 9892	s^2 $\sin^2 \alpha$ C	7.3600 1.3003	h^2 D	5.303 2.380
1st term 2d and 3d terms	″ −448.273 + 0.051	h	2.651 5427n		8.6603 0.046		7.683 0.005
$-\Delta\varphi$	−448.222	s $\sin \alpha$	3.680 0082			$s \sin \alpha$ $s \cos \alpha$	3.6800082 4.1405535n
		A $\sec \varphi'$	8.509 1611 0.105 2810	$\Delta\lambda$ $\sin \frac{1}{2}(\varphi+\varphi')$	2.29445 9.79168	$\tan \alpha$	9.5394547n
						α	160° 53′ 56″.2
			2.294 4503		2.08613		
		$\Delta\lambda$	″ +196.993	$-\Delta\alpha$	″ +121.9	$\sin \alpha$ s	9.514 8602 4.165 1480

*Table of corrections to longitude for difference in arc and sine.**

log s (−)	log difference.	log Δλ (+)	log s (−)	log difference.	log Δλ (+)	log s (−)	log difference.	log Δλ (+)
3.876	0.000 0001	2.385	4.871	0.000 0098	3.380	5.172	0.000 0392	3.681
4.026	02	2.535	4.882	103	3.391	5.178	402	3.687
4.114	03	2.623	4.892	108	3.401	5.183	412	3.692
4.177	04	2.686	4.903	114	3.412	5.188	422	3.697
4.225	05	2.734	4.913	119	3.422	5.193	433	3.702
4.265	06	2.774	4.922	124	3.431	5.199	443	3.708
4.298	07	2.807	4.932	130	3.441	5.204	453	3.713
4.327	08	2.836	4.941	136	3.450	5.209	464	3.718
4.353	09	2.862	4.950	142	3.459	5.214	474	3.723
4.376	10	2.885	4.959	147	3.468	5.219	486	3.728
4.396	11	2.905	4.968	153	3.477	5.223	497	3.732
4.415	12	2.924	4.976	160	3.485	5.228	508	3.737
4.433	13	2.942	4.985	166	3.494	5.233	519	3.742
4.449	14	2.958	4.993	172	3.502	5.238	530	3.747
4.464	15	2.973	5.002	179	3.511	5.242	541	3.751
4.478	16	2.987	5.010	186	3.519	5.247	553	3.756
4.491	17	3.000	5.017	192	3.526	5.251	565	3.760
4.503	18	3.012	5.025	199	3.534	5.256	577	3.765
4.526	20	3.035	5.033	206	3.542	5.260	588	3.769
4.548	23	3.057	5.040	213	3.549	5.265	600	3.774
4.570	25	3.079	5.047	221	3.556	5.269	613	3.778
4.591	27	3.100	5.054	228	3.563	5.273	625	3.782
4.612	30	3.121	5.062	236	3.571	5.278	637	3.787
4.631	33	3.140	5.068	243	3.577	5.282	650	3.791
4.649	36	3.158	5.075	251	3.584	5.286	663	3.795
4.667	39	3.176	5.082	259	3.591	5.290	674	3.799
4.684	42	3.193	5.088	267	3.597	5.294	687	3.803
4.701	45	3.210	5.095	275	3.604	5.299	702	3.808
4.716	48	3.225	5.102	284	3.611	5.303	716	3.812
4.732	52	3.241	5.108	292	3.617	5.307	729	3.816
4.746	56	3.255	5.114	300	3.623	5.311	743	3.820
4.761	59	3.270	5.120	309	3.629	5.315	757	3.824
4.774	63	3.283	5.126	318	3.635	5.319	771	3.828
4.788	67	3.297	5.132	327	3.641	5.323	785	3.832
4.801	71	3.310	5.138	336	3.647	5.327	800	3.836
4.813	75	3.322	5.144	345	3.653	5.331	814	3.840
4.825	80	3.334	5.150	354	3.659	5.335	829	3.844
4.834	84	3.343	5.156	364	3.665	5.339	845	3.848
4.849	89	3.358	5.161	373	3.670	5.343	861	3.852
4.860	94	3.369	5.167	383	3.676	5.347	877	3.856

*From $\sin x = x - \frac{x^3}{6} + \frac{x^5}{120} - \ldots$ we have with sufficient accuracy for our purpose $\log \sin x = \log x - M\frac{x^2}{6}$, and $\log(\log x - \log \sin x) = \log\left(M\frac{x^2}{6}\right)$.

Substituting the value of M or modulus of common log's, and putting $x \sin 1''$ for x, when expressed in seconds, we get $\log\left(M\frac{x^2}{6}\right) = 2 \log x + 8.23078$; hence the expression log (log diff.) $= 3.2308 + 2 \log \Delta\lambda$. By taking an average value for $\log A$, say 8.5090, we get by means of $\log s$ (in seconds) $= \log A + \log s$ (in meters), the corresponding expression log (log diff.) $= 2 \log s + 5.2488$, and the numerical difference of the corresponding tabular values of $\log s$ and $\log \Delta\lambda$ equals 1.4910.—J. F. H., March, 1902.

Table of values of log sec ½ (Δφ).

Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)
′		′		′		′		′	
10	0.000 000	28	0.000 004	46	0.000 010	64	0.000 019	82	0.000 031
11	1	29	4	47	10	65	19	83	32
12	1	30	4	48	11	66	20	84	32
13	1	31	4	49	11	67	21	85	33
14	1	32	5	50	11	68	21	86	34
15	1	33	5	51	12	69	22	87	35
16	1	34	5	52	12	70	22	88	36
17	1	35	6	53	13	71	23	89	36
18	1	36	6	54	13	72	24	90	37
19	2	37	6	55	14	73	24	91	38
20	2	38	7	56	14	74	25	92	39
21	2	39	7	57	15	75	26	93	40
22	2	40	7	58	15	76	26	94	41
23	2	41	8	59	16	77	27	95	41
24	3	42	8	60	16	78	28	96	42
25	3	43	8	61	17	79	29	97	43
26	3	44	9	62	18	80	29	98	44
27	3	45	9	63	18	81	30	99	45

To convert:				To convert:			
Meters to feet.		Feet to meters.		Kilometers to statute miles.		Statute miles to kilometers.	
1 =	3. 280 833	1 =	0. 304 8006	1 =	0. 621 3699	1 =	1. 609 347
2	6. 561 667	2	0. 609 6012	2	1. 242 7399	2	3. 218 694
3	9. 842 500	3	0. 914 4018	3	1. 864 1098	3	4. 828 042
4	13. 123 333	4	1. 219 2024	4	2. 485 4798	4	6. 437 389
5	16. 404 166	5	1. 524 0030	5	3. 106 8497	5	8. 046 736
6	19. 685 000	6	1. 828 8037	6	3. 728 2196	6	9. 656 083
7	22. 965 833	7	2. 133 6043	7	4. 349 5896	7	11. 265 430
8	26. 246 666	8	2. 438 4049	8	4. 970 9595	8	12. 874 778
9	29. 527 500	9	2. 743 2055	9	5. 592 3295	9	14. 484 125

FORMULA AND TABLE FOR COMPUTING THE SPHERICAL EXCESS OF TRIANGLES.

In every spherical triangle the excess of the sum of the three angles over 180° bears the same ratio to eight right angles as the area of the triangle bears to that of the whole sphere. Putting r for radius, ε for the excess, we have $\frac{\varepsilon}{4\pi} = \frac{area}{4r^2\pi}$, hence $\varepsilon = \frac{area}{r^2}$. In order to express ε in seconds of arc, we must divide the expression by $\sin 1''$. The area of the triangle, when it is small in relation to the whole sphere, as is the case in all geodetic triangles, may be expressed with sufficient accuracy for this purpose by $\frac{1}{2} a_1 b_1 \sin C_1$ where a_1 and b_1 are two sides and C_1 the included angle. We then have

$$\varepsilon = \frac{a_1 b_1 \sin C_1}{2 r^2 \sin 1''}$$

In determining ε in a triangle on the terrestrial spheroid, we can refer it to an osculating sphere, the radius of which is taken as $\sqrt{R N}$, where R equals radius of curvature in the meridian and N equals radius of curvature in the prime vertical at the center of the triangle. These are respectively

$$R=\frac{a\ (1-e^2)}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}\qquad N=\frac{a}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

using the notation of the preceding formulæ for position computation.

We have, therefore, for the spherical triangle,

$$\varepsilon=\frac{a_1\ b_1\sin C_1}{2\ R\ N\sin 1''}=\frac{a_1\ b_1\sin C_1}{2\ a^2\ (1-e^2)\sin 1''}[1-e^2\sin^2\varphi]^2$$

for which we write $\varepsilon=a_1\ b_1\sin C_1\times m$, and tabulate the logarithms of $m=\frac{[1-e^2\sin^2\varphi]^2}{2\ a^2\ (1-e^2)\sin 1''}$ for different latitudes.

Table of log m.

Lat. ° ′	log m	Lat. ° ′	log m
0 00	1.40695	9 30	1.40679
0 30	1.40695	10 00	1.40677
1 00	1.40695	10 30	1.40675
1 30	1.40694	11 00	1.40673
2 00	1.40694	11 30	1.40671
2 30	1.40694	12 00	1.40669
3 00	1.40693	12 30	1.40667
3 30	1.40693	13 00	1.40665
4 00	1.40692	13 30	1.40663
4 30	1.40691	14 00	1.40660
5 00	1.40690	14 30	1.40658
5 30	1.40689	15 00	1.40655
6 00	1.40688	15 30	1.40653
6 30	1.40687	16 00	1.40650
7 00	1.40686	16 30	1.40647
7 30	1.40685	17 00	1.40644
8 00	1.40683	17 30	1.40642
8 30	1.40682	18 00	1.40639
9 00	1.40680	18 30	1.40636

CONSTANTS.

$$A=\frac{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}{a\ \text{arc}\ 1''}$$

$$B=\frac{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}{a\ (1-e^2)\ \text{arc}\ 1''}$$

$$C=\frac{(1-e^2\sin^2\varphi)^2\tan\varphi}{2a^2\ (1-e^2)\ \text{arc}\ 1''}$$

$$D=\frac{\frac{3}{2}\ e^2\sin\varphi\cos\varphi\ \text{arc}\ 1''}{1-e^2\sin^2\varphi}$$

$$E=\frac{(1+3\tan^2\varphi)\ (1-e^2\sin^2\varphi)}{6a^2}$$

$$F=\tfrac{1}{12}\sin\varphi\cos^2\varphi\ \text{arc}^2\ 1''$$

$\log a=6.804\ 698\ 57$

$\log b=6.803\ 223\ 78$

$\log e^2=\bar{7}.830\ 502\ 57$

$\log\frac{1}{a\ \text{arc}\ 1''}=\bar{8}.509\ 726\ 56$

$\log\frac{1}{a\ (1-e^2)\ \text{arc}\ 1''}=\bar{8}.512\ 676\ 15$

$\log\frac{1}{2a^2\ (1-e^2)\ \text{arc}\ 1''}=\bar{1}.406\ 947\ 6$

$\log\ (\frac{3}{2}\ e^2\ \text{arc}\ 1'')=\bar{2}.692\ 168\ 7$

$\log\frac{1}{6a^2}=\bar{5}.612\ 45$

$\log\ (\frac{1}{12}\ \text{arc}^2\ 1'')=\bar{8}.291\ 96$

The constants as printed above were those used in computing the tables given in the report for 1894. For greater convenience in computation they have been transformed as indicated below, by Mr. M. H. Doolittle, Computer.

$$N=\frac{a}{(1-e^2 \sin^2 \varphi)^{\frac{1}{2}}}, \text{ (see p. 320), hence } (1-e^2 \sin^2 \varphi)^{\frac{1}{2}}=\frac{a}{N}$$

$$\log\frac{N}{a} = \log\frac{1}{(1-e^2 \sin^2 \varphi)^{\frac{1}{2}}}=-\tfrac{1}{2}\log(1-e^2 \sin^2 \varphi)$$

$$= \tfrac{1}{2} Me^2 \sin^2 \varphi+\tfrac{1}{4} Me^4 \sin^4 \varphi+\tfrac{1}{6} Me^6 \sin^6 \varphi \text{ \&c, in which } M=\text{modulus of logarithms.}$$

Let $\frac{1}{2} Me^2 \sin^2 \varphi=m$; $\frac{1}{4} Me^4 \sin^4 \varphi=n$; $\frac{1}{6} Me^6 \sin^6 \varphi=p$

$\log \frac{1}{2}=9.6989700$	$\log \frac{1}{4}=9.397940$	$\log \frac{1}{6}=9.2218$
$\log M=9.6377843$	$\log M=9.637784$	$\log M=9.6378$
$\log e^2=7.8305026$	$\log e^4=5.661005$	$\log e^6=3.4915$
7.1672569	4.69673	2.351

$$\log m=2 \log \sin \varphi+7.1672569$$
$$\log n=4 \log \sin \varphi+4.69673 \quad =2 \log m+0.36222-10$$
$$\log p=6 \log \sin \varphi+2.351 \quad =3 \log m+0.849 \quad -20$$
$$\log\frac{N}{a}=m+n+p$$

$$\log A=\log\frac{1}{a \text{ arc } 1''}+\log\frac{a}{N}=8.50972656-\log\frac{N}{a}$$

$$\log B=\log\frac{1}{a(1-e^2) \text{ arc } 1''}+3\log\frac{a}{N}=8.51267615-3\log\frac{N}{a}$$

$$\log C=\log\frac{1}{2a^2(1-e^2) \text{ arc } 1''}+\log \tan \varphi+4\log\frac{a}{N}$$
$$=1.4069476+\log \tan \varphi-4\log\frac{N}{a}$$

$$\log D=\log \sin 2\varphi-\log 2+\log(\tfrac{3}{2} e^2 \text{ arc } 1'')-2\log\frac{a}{N}$$
$$=2.3911387+\log \sin 2\varphi+2\log\frac{N}{a}$$

$$\log E=\log\frac{1}{6a^2}+\log(1+3\tan^2 \varphi)+2\log\frac{a}{N}$$
$$=5.6124516+\log(1+3\tan^2 \varphi)-2\log\frac{N}{a}$$

LATITUDE 0°.

Lat.	log A	log B	log C	log D	log E	log F
° ′						
00 00	8.509 7266	8.512 6761	−∞	−∞	$\bar{\bar{5}}$.6125	−∞
1	66	61	$\bar{\bar{7}}$.8707	$\bar{9}$.156	5	
2	66	61	$\bar{\bar{8}}$.1717	457	5	
3	66	61	3477	633	5	
4	66	61	4727	758	5	
05	66	61	5696	855	5	
6	66	61	6488	$\bar{9}$.934	5	
7	66	61	7158	0.001	5	
8	66	61	7740	059	5	
9	66	61	8249	110	5	
10	8.509 7266	8.512 6761	8.8707	0.156	5.6125	
11	65	61	9121	197	5	
12	65	61	9499	235	5	
13	65	61	8.9846	270	5	
14	65	61	9.0168	302	5	
15	65	61	0468	332	5	
16	65	61	0748	360	5	
17	65	60	1011	386	5	
18	65	60	1259	411	5	
19	65	60	1494	435	5	
20	8.509 7265	8.512 6760	9.1717	0.457	5.6125	6.057
21	65	60	1929	478	5	
22	65	60	2131	498	5	
23	65	60	2324	518	5	
24	65	59	2509	536	5	
25	65	59	2686	554	5	
26	65	59	2857	571	5	
27	65	59	3020	587	5	
28	65	59	3178	603	5	
29	65	58	3331	618	5	
30	8.509 7265	8.512 6758	9.3478	0.633	5.6126	
31	64	58	3620	647	6	
32	64	58	3758	661	6	
33	64	57	9.3892	674	6	
34	64	57	9.4022	687	6	
35	64	57	4148	700	6	
36	64	57	4270	712	6	
37	64	56	4389	724	6	
38	64	56	4505	736	6	
39	64	56	4618	747	6	
40	8.509 7264	8.512 6756	9.4728	0.758	5.6126	6.358
41	64	55	4835	769	6	
42	64	55	9.4939	779	6	
43	64	55	9.5042	789	6	
44	63	54	5141	799	7	
45	63	54	5239	809	7	
46	63	54	5335	819	7	
47	63	53	5428	828	7	
48	63	53	5519	837	7	
49	63	53	5609	846	7	
50	8.509 7263	8.512 6752	9.5697	0.855	5.6127	
51	63	52	5783	863	7	
52	62	51	5866	872	7	
53	62	51	9.5950	880	7	
54	62	51	9.6031	888	8	
55	62	50	6111	896	8	
56	62	50	6189	904	8	
57	62	49	6266	912	8	
58	61	49	6341	919	8	
59	61	49	6416	927	8	
60	8.509 7261	8.512 6748	9.6489	0.934	5.6128	6.534

LATITUDE 1°.

Lat.	log A	log B	log C	log D	log E	log F
° ′						
1 00	$\bar{8}$.509 7261	$\bar{8}$.512 6748	$\bar{9}$.6489	$\bar{0}$.934	$\bar{\bar{5}}$.6128	6.534
1	61	48	560	941	29	
2	61	47	631	948	29	
3	61	47	701	955	29	
4	61	46	769	962	29	
05	60	46	836	969	29	
6	60	45	903	975	29	
7	60	45	9.6968	982	29	
8	60	44	9.7032	988	30	
9	60	44	096	0.995	30	
10	8.509 7260	8.512 6743	9.7158	1.001	5.6130	
11	59	43	220	007	30	
12	59	42	281	013	30	
13	59	42	341	019	30	
14	59	41	400	025	31	
15	59	41	458	031	31	
16	58	40	516	037	31	
17	58	39	572	042	31	
18	58	39	628	048	31	
19	58	38	684	053	31	
20	8.509 7258	8.512 6738	9.7738	1.059	5.6132	6.658
21	57	37	792	064	32	
22	57	36	846	070	32	
23	57	36	898	075	32	
24	57	35	9.7950	080	32	
25	57	35	9.8002	085	32	
26	56	34	053	090	33	
27	56	33	103	095	33	
28	56	33	152	100	33	
29	56	32	202	105	33	
30	8.509 7256	8.512 6731	9.8250	1.110	5.6133	
31	55	31	298	115	34	
32	55	30	346	119	34	
33	55	29	393	124	34	
34	55	29	439	129	34	
35	54	28	485	133	34	
36	54	27	531	138	35	
37	54	26	576	142	35	
38	54	26	620	147	35	
39	53	25	664	151	35	
40	8.509 7253	8.512 6724	9.8708	1.156	5.6136	6.755
41	53	23	751	160	36	
42	53	23	794	164	36	
43	52	22	836	168	36	
44	52	21	878	173	36	
45	52	20	920	177	37	
46	52	20	961	181	37	
47	51	19	9.9002	185	37	
48	51	18	042	189	37	
49	51	17	082	193	38	
50	8.509 7251	8.512 6716	9.9122	1.197	5.6138	
51	50	16	161	201	38	
52	50	15	200	205	38	
53	50	14	239	209	39	
54	49	13	277	212	39	
55	49	12	315	216	39	
56	49	11	353	220	39	
57	49	10	390	224	40	
58	48	10	427	227	40	
59	48	09	464	231	40	
60	8.509 7248	8.512 6708	9.9500	1.2347	5.6140	6.834

LATITUDE 2°.

Lat. ° ′	log A	log B	log C	log D	log E	log F
2 00	8.509 7248	$\bar{8}$.512 6708	$\bar{\bar{9}}$.95002	$\bar{1}$.2347	$\bar{\bar{5}}$.6140	$\bar{\bar{6}}$.834
1	47	.07	5363	383	41	
2	47	06	5721	419	41	
3	47	05	6076	454	41	
4	47	04	6428	489	41	
05	46	03	6777	524	42	
.6	46	02	7123	559	42	
7	46	01	7467	593	42	
8	45	6700	7808	627	43	
9	45	6699	8146	661	43	
10	8.509 7245	8.512 6698	$\bar{\bar{9}}$.98482	1.2694	5.6143	
11	44	97	8815	727	43	
12	44	97	9145	760	44	
13	44	96	9473	793	44	
14	43	95	$\bar{9}$.99799	826	44	
15	43	94	$\bar{0}$.00122	858	45	
16	43	93	0443	890	45	
17	42	91	0762	922	45	
18	42	90	1078	953	45	
19	42	89	1392	1.2984	46	
20	8.509 7241	8.512 6688	0.01703	1.3015	5.6146	6.901
21	41	87	2013	046	46	
22	41	86	2320	077	47	
23	40	85	2625	107	47	
24	40	84	2928	138	47	
25	40	83	3229	168	48	
26	39	82	3528	197	48	
27	39	81	3825	227	48	
28	38	80	4119	256	49	
29	38	79	4412	285	49	
30	8.509 7238	8.512 6678	0.04703	1.3314	5.6149	
31	37	76	4992	343	50	
32	37	75	5279	372	50	
33	37	74	5564	400	50	
34	36	73	5847	428	51	
35	36	72	6129	456	51	
36	35	71	6408	484	51	
37	35	70	6686	512	52	
38	35	68	6962	539	52	
39	34	67	7237	567	52	
40	8.509 7234	8.512 6666	0.07509	1.3594	5.6153	6.959
41	33	65	7780	621	53	
42	33	64	8050	648	53	
43	33	62	8317	674	54	
44	32	61	8583	701	54	
45	32	60	8848	727	54	
46	31	59	9111	753	55	
47	31	58	9372	779	55	
48	31	56	9631	805	56	
49	30	55	0.09890	831	56	
50	8.509 7230	8.512 6654	0.10146	1.3856	5.6156	
51	29	52	0401	882	57	
52	29	51	0655	907	57	
53	28	50	0907	932	57	
54	28	49	1158	957	58	
55	28	47	1407	1.3982	58	
56	27	46	1655	1.4007	59	
57	27	45	1902	031	59	
58	26	43	2147	055	59	
59	26	42	2390	080	60	
60	8.509 7225	8.512 6641	0.12633	1.4104	5.6160	7.010

LATITUDE 3°.

Lat.	log A	log B diff. 1″ = −0.03	log C	log D	log E	log F
° ′						
3 00	$\bar{8}$.509 7225	$\bar{8}$.512 6641	$\bar{0}$.12633	$\bar{1}$.4104	$\bar{\bar{5}}$.6160	$\bar{\bar{7}}$.010
1	25	39	2874	28	61	
2	24	38	3113	52	61	
3	24	37	3352	75	61	
4	24	35	3589	1.4199	62	
05	23	34	3825	1.4222	62	
6	23	33	4059	46	62	
7	22	31	4293	69	63	
8	22	30	4525	1.4292	63	
9	21	28	4756	1.4315	64	
10	8.509 7221	8.512 6627	4985	1.4338	64	
11	20	26	5214	60	65	
12	20	24	5441	1.4383	65	
13	19	23	5667	1.4405	65	
14	19	21	5892	28	66	
15	18	20	6116	50	66	
16	18	18	6338	72	67	
17	17	17	6560	1.4494	67	
18	17	15	6780	1.4516	68	
19	16	14	6999	38	68	
20	8.509 7216	8.512 6612	0.17217	1.4560	5.6168	$7.0\bar{5}\bar{5}$
21	15	11	7434	1.4581	69	
22	15	09	7650	1.4603	69	
23	14	08	7665	24	70	
24	14	06	8079	45	70	
25	13	05	8292	66	71	
26	13	03	8504	1.4687	71	
27	12	02	8715	1.4708	72	
28	12	6600	8925	29	72	
29	11	6599	9133	50	72	
30	8.509 7211	8.512 6597	0.19341	1.4770	5.6173	
31	10	96	9548	1.4791	73	
32	10	94	9754	1.4811	74	
33	09	92	19959	32	74	
34	09	91	20163	52	75	
35	08	89	0366	72	75	
36	08	88	0568	1.4892	76	
37	07	86	0769	1.4912	76	
38	07	84	0969	32	77	
39	06	83	1168	52	77	
40	8.509 7206	8.512 6581	0.21367	1.4971	5.6178	7.096
41	05	80	1564	1.4991	78	
42	04	78	1761	1.5011	79	
43	04	76	1956	30	79	
44	03	75	2151	49	80	
45	03	73	2345	68	80	
46	02	71	2538	1.5088	81	
47	02	69	2731	1.5107	81	
48	01	68	2922	26	81	
49	01	66	3113	45	82	
50	8.509 7200	8.512 6564	0.23302	1.5163	5.6182	
51	7199	63	3491	1.5182	83	
52	99	61	3680	1.5201	84	
53	98	59	3867	19	84	
54	98	58	4053	38	85	
55	97	56	4239	56	85	
56	96	54	4424	75	86	
57	96	52	4608	1.5293	86	
58	95	50	4792	1.5311	87	
59	95	49	4974	29	87	
60	8.509 7194	8.512 6547	0.25156	1.5347	5.6188	7.133

LATITUDE 4°.

Lat.	log A.	log B diff. 1″ = −0.04	log C	log D	log E	log F
° ′						
4 00	$\bar{8}$. 509 7194	$\bar{8}$. 512 6547	$\bar{0}$. 25156	$\bar{1}$. 5347	$\bar{\bar{5}}$. 6188	$\bar{\bar{7}}$. 133
1	93	45	5337	65	88	
2	93	43	5518	1. 5383	89	
3	92	42	5697	1. 5401	89	
4	92	40	5376	18	90	
05	91	38	6055	36	90	
6	91	36	6232	54	91	
7	90	34	6409	71	91	
8	89	32	6585	1. 5489	92	
9	89	31	6760	1. 5506	92	
10	8. 509 7188	8. 512 6529	0. 26935	1. 5523	5. 6193	
11	87	27	7109	40	93	
12	87	25	7282	58	94	
13	86	23	7455	75	95	
14	86	21	7627	1. 5592	95	
15	85	19	7798	1. 5609	96	
16	84	17	7968	25	96	
17	84	16	8138	42	97	
18	83	14	8308	59	97	
19	82	12	8476	76	98	
20	8. 509 7182	8. 512 6510	0. 28644	1. 5692	5. 6199	7. 168
21	81	08	8812	1. 5709	5. 6199	
22	80	06	8978	25	5. 6200	
23	80	04	9144	42	00	
24	79	02	9310	58	01	
25	78	6500	9475	74	01	
26	78	6498	9639	1. 5791	02	
27	77	96	9802	1. 5807	03	
28	76	94	0. 29965	23	03	
29	76	92	0. 30128	39	04	
30	8. 509 7175	8. 512 6490	0. 30290	1. 5855	5. 6204	
31	74	88	0451	71	05	
32	74	86	0611	1. 5887	05	
33	73	84	0771	1. 5902	06	
34	72	82	0931	18	07	
35	72	80	1090	34	07	
36	71	78	1248	50	08	
37	70	76	1406	65	08	
38	70	74	1563	81	09	
39	69	72	1719	1. 5996	10	
40	8. 509 7168	8. 512 6470	0. 31875	1. 6011	5. 6210	7. 200
41	67	68	2031	27	11	
42	67	65	2186	42	12	
43	66	63	2340	57	12	
44	66	61	2494	73	13	
45	65	59	2647	1. 6088	13	
46	64	57	2800	1. 6103	14	
47	63	55	2953	18	15	
48	63	53	3104	33	15	
49	62	51	3255	48	16	
50	8. 509 7161	8. 512 6448	0. 33406	1. 6163	5. 6216	
51	60	46	3556	77	17	
52	60	44	3706	1. 6192	18	
53	59	42	3855	1. 6207	18	
54	58	40	4004	21	19	
55	57	38	4152	36	20	
56	57	35	4300	51	20	
57	56	33	4447	65	21	
58	55	31	4594	80	22	
59	55	29	4740	1. 6294	22	
60	8. 509 7154	8. 512 6427	0. 34885	1. 6308	5. 6223	7. 229

LATITUDE 5°.

Lat.	log A	log B diff. 1″=−0.04	log C	log D diff. 1″=+0.22	log E	log F
° ′						
5 00	$\bar{8}$.509 7154	$\bar{8}$.512 6427	$\bar{0}$.34885	$\bar{1}$.6308	$\bar{\bar{5}}$.6223	$\bar{\bar{\bar{7}}}$.229
1	53	24	5030	23	24	
2	53	22	5175	37	24	
3	52	20	5320	51	25	
4	51	18	5464	65	26	
05	50	15	5607	79	26	
6	49	13	5750	1.6393	27	
7	49	11	5892	1.6407	28	
8	48	08	6034	21	28	
9	47	06	6176	35	29	
10	8.509 7146	8.512 6404	0.36317	1.6449	5.6230	
11	46	6402	6457	63	30	
12	45	6399	6597	77	31	
13	44	97	6737	1.6491	32	
14	43	95	6876	1.6504	32	
15	43	92	7015	18	33	
16	42	90	7154	32	34	
17	41	88	7292	45	34	
18	40	85	7429	59	35	
19	39	83	7566	72	36	
20	8.509 7139	8.512 6381	0.37703	1.6586	5.6236	7.256
21	38	78	7839	1.6599	37	
22	37	76	7975	1.6612	38	
23	36	73	8111	26	38	
24	35	71	8246	39	39	
25	35	69	8380	52	40	
26	34	66	8514	65	41	
27	33	64	8648	78	41	
28	32	61	8781	1.6692	42	
29	31	59	8914	1.6705	43	
30	8.509 7131	8.512 6356	0.39047	1.6718	5.6243	
31	30	54	9179	31	44	
32	29	52	9311	44	45	
33	28	49	9442	56	46	
34	27	47	9573	69	46	
35	27	44	9704	82	47	
36	26	42	9834	1.6795	48	
37	25	39	0.39964	1.6808	48	
38	24	37	0.40094	20	49	
39	23	34	0223	33	50	
40	8.509 7122	8.512 6332	0.40351	1.6846	5.6251	7.282
41	21	29	0480	58	51	
42	21	27	0608	71	52	
43	20	24	0735	83	53	
44	19	21	0863	1.6896	54	
45	18	19	0990	1.6908	54	
46	17	16	1116	21	55	
47	16	14	1242	33	56	
48	16	11	1368	45	57	
49	15	09	1493	58	57	
50	8.509 7114	8.512 6306	0.41619	1.6970	5.6258	
51	13	03	1743	82	59	
52	12	6301	1868	1.6994	60	
53	11	6298	1992	1.7006	60	
54	10	96	2115	19	61	
55	09	93	2239	31	62	
56	09	90	2362	43	63	
57	08	88	2484	55	63	
58	07	85	2607	67	64	
59	06	82	2729	79	65	
60	8.509 7105	8.512 6280	0.42850	1.7090	5.6266	7.306

LATITUDE 6°.

Lat.	log A diff. 1″ = −0.02	log B diff. 1″ = −0.05	log C	log D diff. 1″ = +0.18	log E	log F
° ′						
6 00	$\bar{8}$.509 7105	$\bar{8}$.512 6280	$\bar{0}$.42850	$\bar{1}$.7090	$\bar{\bar{\bar{5}}}$.6266	$\bar{\bar{\bar{7}}}$.306
1	04	77	2972	7102	67	
2	03	74	3093	14	67	
3	02	72	3213	26	68	
4	01	69	3334	38	69	
05	01	66	3454	50	70	
6	7100	64	3573	61	70	
7	7099	61	3693	73	71	
8	98	58	3812	85	72	
9	97	55	3931	1.7196	73	
10	8.509 7096	8.512 6253	0.44049	1.7208	5.6274	
11	95	50	4167	19	74	
12	94	47	4285	31	75	
13	93	44	4402	42	76	
14	92	42	4519	54	77	
15	91	39	4636	65	78	
16	91	36	4753	76	78	
17	90	33	4869	88	79	
18	89	31	4985	1.7299	80	
19	88	28	5101	1.7310	81	
20	8.509 7087	8.512 6225	0.45216	1.7322	5.6282	7.329
21	86	22	5331	33	83	
22	85	19	5446	44	83	
23	84	16	5560	55	84	
24	83	14	5674	66	85	
25	82	11	5788	78	86	
26	81	08	5902	1.7389	87	
27	80	05	6015	1.7400	88	
28	79	6202	6128	11	88	
29	78	6199	6241	22	89	
30	8.509 7077	8.512 6196	0.46353	1.7433	5.6290	
31	76	94	6465	44	91	
32	75	91	6577	54	92	
33	74	88	6689	65	93	
34	73	85	6800	76	93	
35	72	82	6911	87	94	
36	71	79	7022	1.7498	95	
37	70	76	7132	1.7508	96	
38	70	73	7242	19	97	
39	69	70	7352	30	98	
40	8.509 7068	8.512 6167	0.47462	1.7541	5.6299	7.351
41	67	64	7571	51	5.6299	
42	66	61	7681	62	5.6300	
43	65	58	7789	73	01	
44	64	55	7898	83	02	
45	63	52	8006	1.7594	03	
46	62	49	8114	1.7604	04	
47	61	46	8222	15	05	
48	60	43	8330	25	06	
49	59	40	8437	36	06	
50	8.509 7058	8.512 6137	0.48544	1.7646	5.6207	
51	57	34	8651	56	08	
52	56	31	8757	67	09	
53	55	28	8864	77	10	
54	53	25	8970	87	11	
55	52	22	9075	1.7698	12	
56	51	19	9181	1.7708	13	
57	50	16	9286	18	13	
58	49	13	9391	28	14	
59	48	10	9496	38	15	
60	8.509 7047	8.512 6107	0.49600	1.7749	5.6216	7.371

LATITUDE 7°.

Lat. ° ′	log A diff. 1″ = −0.02	log B diff. 1″ = −0.06	log C	log D diff. 1″ = +0.16	log E	log F
7 00	8.509 7047	$\bar{8}$.512 6107	$\bar{0}$.49600	$\bar{1}$.7749	5.6316	$\bar{7}$.371
1	46	03	705	59	17	
2	45	6100	809	69	18	
3	44	6097	0.49913	79	19	
4	43	94	0.50016	89	20	
05	42	91	119	1.7799	21	
6	41	88	222	1.7809	22	
7	40	85	325	19	23	
8	39	82	428	29	23	
9	38	78	530	39	24	
10	8.509 7037	8.512 6075	0.50632	1.7849	5.6325	
11	36	72	734	59	26	
12	35	69	836	68	27	
13	34	66	0.50937	78	28	
14	33	62	0.51039	88	29	
15	32	59	140	1.7898	30	
16	30	56	240	1.7908	31	
17	29	53	341	17	32	
18	28	50	441	27	33	
19	27	46	541	37	34	
20	8.509 7026	8.512 6043	0.51641	1.7946	5.6335	7.391
21	25	40	741	56	36	
22	24	37	840	66	37	
23	23	33	0.51939	75	37	
24	22	30	0.52038	85	38	
25	21	27	137	1.7994	39	
26	20	23	236	1.8004	40	
27	19	20	334	13	41	
28	17	17	432	23	42	
29	16	14	530	32	43	
30	8.509 7015	8.512 6010	0.52628	1.8042	5.6344	
31	14	07	725	51	45	
32	13	04	822	61	46	
33	12	6000	0.52919	70	47	
34	11	5997	0.53016	79	48	
35	10	94	113	89	49	
36	09	90	209	1.8098	50	
37	07	87	306	1.8107	51	
38	06	83	402	17	52	
39	05	80	497	26	53	
40	8.509 7004	8.512 5977	0.53593	1.8135	5.6354	7.409
41	03	73	688	44	55	
42	02	70	784	53	56	
43	01	66	879	63	57	
44	7000	63	0.53973	72	58	
45	6998	60	0.54068	81	59	
46	97	56	162	90	60	
47	96	53	257	1.8199	61	
48	95	49	351	1.8208	62	
49	94	46	444	17	63	
50	8.509 6993	8.512 5942	0.54538	1.8226	5.6364	
51	91	39	631	35	65	
52	90	35	725	44	66	
53	89	32	818	53	67	
54	88	28	0.54911	62	68	
55	87	25	0.55003	71	69	
56	86	21	096	80	70	
57	84	18	188	89	71	
58	83	14	280	1.8298	72	
59	82	11	372	1.8307	73	
60	8.509 6981	8.512 5907	0.55464	1.8315	5.6374	7.427

LATITUDE 8°.

Lat.	log A diff. 1″ = −0.02	log B diff. 1″ = −0.06	log C	log D diff. 1″ = +0.14	log E diff. 1″ = +0.02	log F
° ′						
8 00	$\bar{8}$. 509 6981	8. 512 5907	$\bar{0}$. 55464	$\bar{1}$. 8315	$\bar{\bar{5}}$. 6374	$\bar{\bar{7}}$. 427
1	80	04	555	24	75	
2	79	5900	646	33	76	
3	77	5897	738	42	77	
4	76	93	829	50	78	
05	75	90	0. 55919	59	79	
6	74	86	0. 56010	68	80	
7	73	82	100	77	81	
8	71	79	191	85	82	
9	70	75	281	1. 8394	83	
10	8. 509 6969	8. 512 5872	0. 56371	1. 8403	5. 6384	
11	68	68	460	12	85	
12	67	64	550	20	86	
13	65	61	639	28	87	
14	64	57	728	37	88	
15	63	54	817	45	90	
16	62	50	906	54	91	
17	61	46	0. 56995	62	92	
18	59	43	0. 57083	71	93	
19	58	39	172	79	94	
20	8. 509 6957	8. 512 5835	0. 57260	1. 8488	5. 6395	7. 444
21	56	32	348	1. 8496	96	
22	54	28	436	1. 8505	97	
23	53	24	523	13	98	
24	52	20	611	21	99	
25	51	17	698	30	5. 6400	
26	49	13	785	38	5. 6401	
27	48	09	872	46	02	
28	47	06	0. 57959	55	03	
29	46	5802	0. 58045	63	04	
30	8. 509 6945	8. 512 5798	0. 58132	1. 8571	5. 6406	
31	43	94	218	80	07	
32	42	91	304	88	08	
33	41	87	390	1. 8596	09	
34	39	83	476	1. 8604	10	
35	38	79	562	13	11	
36	37	75	647	21	12	
37	36	72	732	29	13	
38	34	68	818	37	14	
39	33	64	903	45	15	
40	8. 509 6932	8. 512 5760	0. 58987	1. 8653	5. 6416	7. 461
41	31	56	0. 59072	61	18	
42	29	53	157	69	19	
43	28	49	241	77	20	
44	27	45	325	85	21	
45	25	41	409	1. 8693	22	
46	24	37	493	1. 8701	23	
47	23	33	577	09	24	
48	22	29	660	17	25	
49	20	26	744	25	26	
50	8. 509 6919	8. 512 5722	0. 59827	1. 8733	5. 6428	
51	18	18	910	41	29	
52	16	14	0. 59993	49	30	
53	15	10	0. 60076	57	31	
54	14	06	159	65	32	
55	12	5702	241	73	33	
56	11	5698	324	81	34	
57	10	94	406	89	35	
58	09	90	488	1. 8796	37	
59	07	86	570	1. 8804	38	
60	8. 509 6906	8. 512 5682	0. 60652	1. 8812	5. 6439	7. 476

LATITUDE 9°.

Lat.	log A diff. 1″ = −0.02	log B diff 1″ = −0.07	log C	log D diff. 1″ = +0.12	log E diff. 1″ = +0.02	log F
° ′						
9 00	8.509 6906	8.512 5682	$\bar{0}$.60652	$\bar{1}$.8812	$\bar{\bar{5}}$.6439	$\bar{\bar{7}}$.476
1	05	78	733	20	40	
2	03	74	815	27	41	
3	02	70	896	35	42	
4	6901	66	0.60977	43	44	
05	6899	62	0.61058	51	45	
6	98	58	139	58	46	
7	97	54	220	66	47	
8	95	50	301	74	48	
9	94	46	881	81	49	
10	8.509 6893	8.512 5642	0.61461	1.8889	5.6450	
11	91	38	542	1.8897	52	
12	90	34	622	1.8904	53	
13	89	30	702	12	54	
14	87	26	781	19	55	
15	86	22	861	27	56	
16	84	18	0.61941	34	57	
17	83	14	0.62020	42	59	
18	82	10	099	50	60	
19	80	06	178	57	61	
20	8.509 6879	8.512 5602	0.62257	1.8964	5.6462	7.490
21	78	5598	336	72	63	
22	76	93	415	79	65	
23	75	89	493	87	66	
24	74	85	572	1.8994	67	
25	72	81	650	1.9002	68	
26	71	77	728	09	69	
27	69	73	806	17	70	
28	68	69	884	24	72	
29	67	64	0.62962	31	73	
30	8.509 6865	8.512 5560	0.63039	1.9039	5.6474	
31	64	56	117	46	75	
32	62	52	194	53	76	
33	61	48	271	61	78	
34	60	43	349	68	79	
35	58	39	426	75	80	
36	57	35	502	82	81	
37	55	31	579	90	83	
38	54	27	656	1.9097	84	
39	53	22	732	1.9104	85	
40	8.509 6851	8.512 5518	0.63808	1.9111	5.6486	7.505
41	50	14	885	19	87	
42	48	10	0.63961	26	89	
43	47	05	0.64037	33	90	
44	45	5501	112	40	91	
45	44	5497	188	47	92	
46	43	92	264	54	94	
47	41	88	339	61	95	
48	40	84	415	69	96	
49	38	80	490	76	97	
50	8.509 6837	8.512 5475	0.64565	1.9183	5.6498	
51	35	71	640	90	5.6500	
52	34	67	715	1.9197	01	
53	33	62	789	1.9204	02	
54	31	58	864	11	03	
55	30	54	0.64938	18	05	
56	28	49	0.65013	25	06	
57	27	45	087	32	07	
58	25	40	161	39	08	
59	24	36	235	46	10	
60	8.509 6822	8.512 5432	0.65309	1.9253	5.6411	7.518

LATITUDE 10°.

Lat.	log A diff. 1″ = −0.03	log B diff. 1″ = −0.08	log C	log D diff. 1″ = +0.11	log E diff. 1″ = +0.02	log F
° ′						
10 00	$\bar{8}$.509 6822	$\bar{8}$.512 5432	$\bar{0}$.65309	$\bar{1}$.9253	$\bar{\bar{5}}$.6511	$\bar{\bar{7}}$.518
1	21	27	383	60	12	
2	19	23	456	67	13	
3	18	19	530	74	15	
4	17	14	603	80	16	
05	15	10	677	87	17	
6	14	05	750	1.9294	18	
7	12	5401	823	1.9301	20	
8	11	5396	896	08	21	
9	09	92	0.65968	15	22	
10	8.509 6808	8.512 5388	0.66041	1.9322	5.6524	
11	06	83	114	28	25	
12	05	79	186	35	26	
13	03	74	259	42	27	
14	02	70	331	49	29	
15	6800	65	403	56	30	
16	6799	61	475	62	31	
17	97	56	547	69	33	
18	96	52	619	76	34	
19	94	47	691	82	35	
20	8.509 6793	8.512 5343	0.66762	1.9389	5.6536	7.532
21	91	38	834	1.9396	38	
22	90	33	905	1.9403	39	
23	88	29	0.66976	09	40	
24	87	24	0.67047	16	42	
25	85	20	118	23	43	
26	84	15	189	29	44	
27	82	11	260	36	46	
28	81	06	331	42	47	
29	79	5302	401	49	48	
30	8.509 6777	8.512 5297	0.67472	1.9456	5.6549	
31	76	92	542	62	51	
32	74	88	613	69	52	
33	73	83	683	75	53	
34	71	79	753	82	55	
35	70	74	823	88	56	
36	68	69	893	1.9495	57	
37	67	65	0.67962	1.9501	59	
38	65	60	0.68032	08	60	
39	64	55	102	14	61	
40	8.509 6762	8.512 5251	0.68171	1.9521	5.6563	7.544
41	60	46	240	27	64	
42	59	41	310	34	65	
43	57	37	379	40	67	
44	56	32	448	47	68	
45	54	27	517	53	69	
46	53	23	586	60	71	
47	51	18	654	66	72	
48	50	13	723	72	73	
49	48	08	791	79	75	
50	8.509 6746	8.512 5204	0.68860	1.9585	5.6576	
51	45	5199	928	91	78	
52	43	94	0.68996	1.9598	79	
53	42	89	0.69064	1.9604	80	
54	40	85	132	10	82	
55	38	80	200	17	83	
56	37	75	268	23	84	
57	35	70	336	29	86	
58	34	66	404	36	87	
59	32	61	471	42	88	
60	8.509 6730	8.512 5156	0.69539	1.9648	5.6590	7.556

LATITUDE 11°.

Lat.	log A diff. 1″ = −0.03	log B diff. 1″ = −0.08	log C	log D diff. 1″ = +0.10	log E diff. 1″ = +0.02	log F
° ′						
11 00	$\bar{8}$. 509 6730	8. 512 5156	$\bar{0}$. 69539	$\bar{1}$. 9648	$\bar{\bar{5}}$. 6590	$\bar{\bar{7}}$. 556
1	29	51	606	54	91	
2	27	46	673	61	93	
3	26	41	740	67	94	
4	24	37	807	73	95	
05	22	32	874	79	97	
6	21	27	0. 69941	86	98	
7	19	22	0. 70008	92	5. 6599	
8	18	17	074	1. 9698	5. 6601	
9	16	12	141	1. 9704	02	
10	8. 509 6714	8. 512 5108	0. 70208	1. 9710	5. 6604	
11	13	5103	274	16	05	
12	11	5098	340	23	06	
13	09	93	406	29	08	
14	08	88	473	35	09	
15	06	83	539	41	11	
16	05	78	604	47	12	
17	03	73	670	53	13	
18	01	68	736	59	15	
19	6700	63	802	65	16	
20	8. 509 6698	8. 512 5058	0. 70867	1. 9771	5. 6618	7. 568
21	96	53	933	77	19	
22	95	49	0. 70998	83	20	
23	93	44	0. 71063	89	22	
24	91	39	128	1. 9795	23	
25	90	34	194	1. 9801	25	
26	88	29	259	07	26	
27	86	24	323	13	27	
28	85	19	388	19	29	
29	83	14	453	25	30	
30	8. 509 6681	8. 512 5009	0. 71518	1. 9831	5. 6632	
31	80	04	582	37	33	
32	78	4999	647	43	35	
33	76	94	711	49	36	
34	75	89	775	55	37	
35	73	83	840	61	39	
36	71	78	904	67	40	
37	70	73	0. 71968	73	42	
38	68	68	0. 72032	79	43	
39	66	63	095	85	45	
40	8. 509 6665	8. 512 4958	0. 72159	1. 9890	5. 6646	7. 580
41	63	53	223	1. 9896	47	
42	61	48	286	1. 9902	49	
43	59	43	350	08	50	
44	58	38	413	14	52	
45	56	33	477	20	53	
46	54	28	540	25	55	
47	53	22	603	31	56	
48	51	17	666	37	58	
49	49	12	729	43	59	
50	8. 509 6647	8. 512 4907	0. 72792	1. 9949	5. 6661	
51	46	4902	855	54	62	
52	44	4897	918	60	64	
53	43	92	0. 72980	66	65	
54	41	86	0. 73043	72	66	
55	39	81	106	77	68	
56	37	76	168	83	69	
57	35	71	230	89	71	
58	34	66	293	94	72	
59	32	60	355	1. 9900	74	
60	8. 509 6630	8. 512 4855	0. 73417	2. 0006	5. 6675	7. 591

LATITUDE 12°.

Lat. ° ′	log A diff. 1″ = −0.03	log B diff. 1″ = −0.09	log C	log D diff. 1″ = +0.09	log E diff. 1″ = +0.04	log F
12 00	$\bar{8}$.509 6630	$\bar{8}$.512 4855	$\bar{0}$.73417	$\bar{2}$.0006	$\bar{\bar{5}}$.6675	$\bar{\bar{7}}$.591
1	29	50	479	11	77	
2	27	45	541	17	78	
3	25	39	603	23	80	
4	23	34	664	28	81	
05	21	29	726	34	83	
6	20	24	788	40	84	
7	18	18	849	45	86	
8	16	13	911	51	87	
9	14	08	0.73972	57	89	
10	8.509 6613	8.512 4803	0.74033	2.0062	5.6690	
11	11	4797	094	67	92	
12	09	92	156	73	93	
13	07	87	217	79	95	
14	06	81	278	84	96	
15	04	76	339	90	98	
16	02	71	399	2.0096	99	
17	6600	65	460	2.0101	5.6701	
18	6599	60	521	07	02	
19	97	55	581	12	04	
20	8.509 6595	8.512 4749	0.74642	2.0118	5.6705	7.601
21	93	44	702	23	07	
22	91	39	763	29	08	
23	90	33	823	34	10	
24	88	28	883	40	11	
25	86	23	0.74943	45	13	
26	84	17	0.75003	50	14	
27	82	12	063	56	16	
28	81	06	123	61	17	
29	79	4701	183	67	19	
30	8.509 6577	8.512 4696	0.75243	2.0172	5.6720	
31	75	90	302	77	22	
32	73	85	362	83	24	
33	72	79	422	88	25	
34	70	74	481	94	27	
35	68	68	540	2.0199	28	
36	66	63	600	2.0205	30	
37	64	57	659	10	31	
38	62	52	718	15	33	
39	61	46	777	21	34	
40	8.509 6559	8.512 4641	0.75836	2.0226	5.6736	7.611
41	57	35	895	32	37	
42	55	30	0.75954	37	39	
43	53	24	0.76013	42	41	
44	51	19	072	47	42	
45	50	13	130	53	44	
46	48	08	189	58	45	
47	46	4602	247	63	47	
48	44	4597	306	69	48	
49	42	91	364	74	50	
50	8.509 6540	8.512 4586	0.76422	2.0279	5.6751	
51	39	80	481	84	53	
52	37	75	539	90	55	
53	35	69	597	2.0295	56	
54	33	63	655	2.0300	58	
55	31	58	713	05	59	
56	29	52	771	10	61	
57	27	47	828	16	62	
58	25	41	886	21	64	
59	24	35	0.76944	26	66	
60	8.509 6522	8.512 4530	0.77001	2.0331	5.6767	7.621

LATITUDE 13°.

Lat.	log A diff. 1″ = −0.03	log B diff. 1″ = −0.10	log C diff. 1″ = +0.93	log D diff. 1″ = +0.08	log E diff. 1″ = +0.03	log F
° ′						
13 00	$\bar{8}$.509 6522	$\bar{8}$.512 4530	$\bar{0}$.77001	$\bar{2}$.0331	$\bar{\bar{5}}$.6767	$\bar{\bar{7}}$.621
1	20	24	059	36	69	
2	18	19	116	42	70	
3	16	13	174	47	72	
4	14	07	231	52	74	
05	12	4502	288	57	75	
6	10	4496	346	62	77	
7	09	90	403	67	78	
8	07	85	460	73	80	
9	05	79	517	78	82	
10	8.509 6503	8.512 4473	0.77574	2.0383	5.6783	
11	6501	67	630	88	85	
12	6499	62	687	93	86	
13	97	56	744	2.0398	88	
14	95	50	801	2.0403	90	
15	93	45	857	08	91	
16	91	39	914	13	93	
17	90	33	0.77970	18	94	
18	88	27	0.78027	23	96	
19	86	22	083	28	98	
20	8.509 6484	8.512 4416	0.78139	2.0433	5.6799	7.631
21	82	10	195	38	5.6801	
22	80	4404	251	44	03	
23	78	4399	307	49	04	
24	76	93	363	54	06	
25	74	87	419	59	07	
26	72	81	475	64	09	
27	70	76	531	69	11	
28	68	70	587	74	12	
29	66	64	642	78	14	
30	8.509 6464	8.512 4358	0.78698	2.0483	5.6816	
31	63	52	754	88	17	
32	61	46	809	93	19	
33	59	41	865	2.0498	20	
34	57	35	920	2.0503	22	
35	55	29	0.78975	08	24	
36	53	23	0.79030	13	25	
37	51	17	086	18	27	
38	49	11	141	23	29	
39	47	4305	196	28	30	
40	8.509 6445	8.512 4299	0.79251	2.0533	5.6832	7.640
41	43	94	306	38	34	
42	41	88	360	42	35	
43	39	82	415	47	37	
44	37	76	470	52	39	
45	35	70	525	57	40	
46	33	64	579	62	42	
47	31	58	634	67	44	
48	29	52	588	72	45	
49	27	46	743	76	47	
50	8.509 6425	8.512 4240	0.79797	2.0581	5.6849	
51	23	34	851	86	50	
52	21	28	905	91	52	
53	19	22	0.79960	2.0596	54	
54	17	16	0.80014	2.0601	55	
55	15	10	068	05	57	
56	13	4204	122	10	59	
57	11	4198	176	15	60	
58	09	92	230	20	62	
59	07	86	284	24	64	
60	8.509 6405	8.512 4180	0.80337	2.0629	5.6865	7.649

LATITUDE 14°.

Lat.	log A diff. 1″ = −0.03	log B diff. 1″ = −0.10	log C diff. 1″ = +0.87	log D diff. 1″ = +0.08	log E diff. 1″ = +0.03	log F
° ′						
14 00	$\bar{8}$.509 6405	$\bar{8}$.512 4180	$\bar{0}$.80337	$\bar{2}$.0629	$\bar{\bar{5}}$.6865	$\bar{\bar{7}}$.649
1	03	74	391	34	67	
2	6401	68	445	39	69	
3	6399	62	498	43	71	
4	97	56	552	48	72	
05	95	50	605	53	74	
6	93	44	659	58	76	
7	91	38	712	62	77	
8	89	32	765	67	79	
9	87	26	819	72	81	
10	8.509 6385	8.512 4120	0.80872	2.0676	5.6882	
11	83	14	925	81	84	
12	81	08	0.80978	86	86	
13	79	4101	0.81031	90	88	
14	77	4095	084	2.0695	89	
15	75	89	137	2.0700	91	
16	73	83	190	04	93	
17	71	77	243	09	94	
18	69	71	295	14	96	
19	67	65	348	18	98	
20	8.509 6365	8.512 4059	0.81401	2.0723	5.6900	7.658
21	63	52	453	28	01	
22	61	46	506	32	03	
23	58	40	558	36	05	
24	56	34	611	41	06	
25	54	28	663	46	08	
26	52	21	715	51	10	
27	50	15	767	55	12	
28	48	09	820	60	13	
29	46	4003	872	64	15	
30	8.509 6344	8.512 3997	0.81924	2.0769	5.6917	
31	42	90	0.81976	73	19	
32	40	84	0.82028	78	20	
33	38	78	080	83	22	
34	36	72	131	87	24	
35	34	65	183	92	26	
36	32	59	235	2.0796	27	
37	29	53	287	2.0801	29	
38	27	47	338	05	31	
39	25	40	390	10	33	
40	8.509 6323	8.512 3934	0.82441	2.0814	5.6934	7.667
41	21	28	493	19	36	
42	19	22	544	23	38	
43	17	15	596	28	40	
44	15	09	647	32	41	
45	13	3903	698	37	43	
46	11	3896	749	41	45	
47	08	90	800	46	47	
48	06	84	852	50	48	
49	04	77	903	54	50	
50	8.509 6302	8.512 3871	0.82954	2.0859	5.6952	
51	6300	65	0.83005	63	54	
52	6298	58	055	68	55	
53	96	52	106	72	57	
54	94	45	157	77	59	
55	92	39	208	81	61	
56	89	33	258	85	63	
57	87	26	309	90	64	
58	85	20	360	94	66	
59	83	13	410	2.0899	68	
60	8.509 6281	8.512 3807	0.83461	2.0903	5.6970	7.675

LATITUDE 15°

Lat.	log A diff. 1″=−0.04	log B diff. 1″=−0.11	log C diff. 1″=+0.82	log D diff. 1″=+0.07	log E diff. 1″=+0.03	Log F
° ′						
15 00	8.509 6281	$\bar{8}$.512 3807	$\bar{0}$.83461	$\bar{2}$.0903	$\bar{\bar{5}}$.6970	$\bar{\bar{7}}$.675
1	79	3801	.511	07	72	
2	77	3794	561	12	73	
3	74	88	612	16	75	
4	72	81	662	21	77	
05	70	75	712	25	79	
6	68	68	762	29	80	
7	66	62	813	34	82	
8	64	56	863	38	84	
9	62	49	913	42	86	
10	8.509 6259	8.512 3743	0.83963	2.0947	5.6988	
11	57	36	0.84012	51	89	
12	55	30	062	55	91	
13	53	23	112	59	93	
14	51	17	162	64	95	
15	49	10	212	68	97	
16	46	3704	261	72	5.6999	
17	44	3697	311	77	5.7000	
18	42	91	361	81	02	
19	40	84	410	85	04	
20	8.509 6238	8.512 3677	0.84460	2.0990	5.7006	7.683
21	35	71	509	94	08	
22	33	64	558	2.0998	09	
23	31	58	608	2.1002	11	
24	29	51	657	07	13	
25	27	45	706	11	15	
26	24	38	755	15	17	
27	22	31	804	19	19	
28	20	25	854	23	20	
29	18	18	903	28	22	
30	8.509 6216	8.512 3612	0.84952	2.1032	5.7024	
31	14	3605	0.85001	36	26	
32	11	3598	049	40	28	
33	09	92	098	44	30	
34	07	85	147	49	31	
35	05	79	196	53	33	
36	02	72	245	57	35	
37	6200	65	293	61	37	
38	6198	59	342	65	39	
39	96	52	390	69	41	
40	8.509 6194	8.512 3545	0.85439	2.1074	5.7042	7.691
41	91	39	487	78	44	
42	89	32	536	82	46	
43	87	25	584	86	48	
44	85	19	633	90	50	
45	82	12	681	94	52	
46	80	3505	729	2.1099	54	
47	78	3498	777	2.1103	55	
48	76	92	825	07	57	
49	73	85	874	11	59	
50	8.509 6171	8.512 3478	0.85922	2.1115	5.7061	
51	69	71	0.85970	19	63	
52	67	65	0.86018	23	65	
53	64	58	066	27	67	
54	62	51	113	31	69	
55	60	44	161	35	70	
56	58	38	209	39	72	
57	55	31	257	44	74	
58	53	24	304	48	76	
59	51	17	352	52	78	
60	8.509 6149	8.512 3411	0.86400	2.1156	5.7080	7.698

LATITUDE 16°

Lat.	log A diff. 1″ = −0.04	log B diff. 1″ = −0.12	log C diff. 1″ = +0.77	log D diff. 1″ = +0.06	log E diff. 1″ = +0.03	log F
° ′						
16 00	$\bar{8}$.509 6149	$\bar{8}$.512 3411	$\bar{0}$.86400	$\bar{2}$.1156	$\bar{\bar{5}}$.7080	$\bar{\bar{7}}$.698
1	46	3404	.447	60	82	
2	44	3397	495	64	84	
3	42	90	542	68	85	
4	40	83	590	72	87	
05	37	76	637	76	89	
6	35	70	684	80	91	
7	33	63	732	84	93	
8	30	56	779	88	95	
9	28	49	826	92	97	
10	8.509 6126	8.512 3342	0.86873	2.1196	5.7099	
11	24	35	921	2.1200	5 7101	
12	21	28	0.86968	04	03	
13	19	22	0.87015	08	04	
14	17	15	062	12	06	
15	14	08	109	16	08	
16	12	3301	156	20	10	
17	10	3294	202	24	12	
18	08	87	249	28	14	
19	05	80	296	32	16	
20	8.509 6103	8.512 3273	0.87343	2.1236	5.7118	7.705
21	6101	66	389	40	20	
22	6098	59	436	44	22	
23	96	52	483	47	24	
24	94	45	529	51	25	
25	91	39	576	55	27	
26	89	32	622	59	29	
27	87	25	669	63	31	
28	84	18	715	67	33	
29	82	11	.761	71	35	
30	8.509 6080	8.512 3204	0.87808	2.1275	5.7137	
31	77	3197	854	79	39	
32	75	90	900	83	41	
33	73	83	947	87	43	
34	70	76	0.87993	90	45	
35	68	69	0.88039	94	47	
36	66	62	085	2.1298	49	
37	63	55	131	2.1302	51	
38	61	48	177	06	52	
39	59	41	223	10	54	
40	8.509 6056	8.512 3133	0.88269	2.1314	5.7156	7.712
41	54	26	315	17	58	
42	52	19	360	21	60	
43	49	12	406	25	62	
44	47	3105	452	29	64	
45	45	3098	498	33	66	
46	42	91	543	37	68	
47	40	84	589	40	70	
48	37	77	634	44	72	
49	35	70	680	48	74	
50	8.509 6033	8.512 3063	0.88726	2.1352	5.7176	
51	30	56	771	56	78	
52	28	48	816	59	80	
53	26	41	862	63	82	
54	23	34	907	67	84	
55	21	27	952	71	86	
56	18	20	0.88998	74	88	
57	16	13	0.89043	78	90	
58	14	3006	088	82	92	
59	11	2998	133	86	94	
60	8.509 6009	8.512 2991	0.89178	2.1390	5.7196	7.719

LATITUDE 17°.

Lat.	log A diff. 1″=−0.04	log B diff. 1″=−0.12	log C diff. 1″=−0.73	log D diff. 1″=+0.06	log E diff. 1″=+0.03	log F
° ′						
17 00	$\bar{8}$. 509 6009	8. 512 2991	$\bar{0}$. 89178	$\bar{2}$. 1390	$\bar{5}$. 7196	$\bar{7}$. 719
1	06	84	223	93	97	
2	04	77	268	2. 1397	99	
3	6002	70	313	2. 1401	5. 7201	
4	5999	62	358	04	03	
05	97	55	403	08	05	
6	94	48	448	12	07	
7	92	41	493	16	09	
8	90	34	538	19	11	
9	87	26	583	23	13	
10	8. 509 5985	8. 512 2919	0. 89627	2. 1427	5. 7215	
11	82	12	672	30	17	
12	80	2905	717	34	19	
13	78	2897	761	38	21	
14	75	90	806	42	23	
15	73	83	850	45	25	
16	70	76	895	49	27	
17	68	68	939	53	29	
18	65	61	0. 89984	56	31	
19	63	54	0. 90028	60	33	
20	8. 509 5961	8. 512 2846	0. 90072	2. 1464	5. 7235	7. 726
21	58	39	117	67	37	
22	56	32	161	71	39	
23	53	24	205	75	41	
24	51	17	249	78	43	
25	48	10	294	82	45	
26	46	2802	338	85	47	
27	44	2795	382	89	49	
28	41	88	426	93	51	
29	39	80	470	2. 1496	53	
30	8. 509 5936	8. 512 2773	0. 90514	2. 1500	5. 7255	
31	34	66	558	04	57	
32	31	58	602	07	59	
33	29	51	646	11	61	
34	26	44	689	14	64	
35	24	36	733	18	66	
36	21	29	777	22	68	
37	19	21	821	25	70	
38	16	14	864	29	72	
39	14	2707	908	32	74	
40	8. 509 5912	8. 512 2699	0. 90952	2. 1536	5. 7276	7. 732
41	09	92	0. 90995	39	78	
42	07	84	0. 91039	43	80	
43	04	77	082	47	82	
44	5902	69	126	50	84	
45	5899	62	169	54	86	
46	97	55	212	57	88	
47	94	47	256	61	90	
48	92	40	299	64	92	
49	89	32	342	68	94	
50	8. 509 5887	8. 512 2625	0. 91386	2. 1571	5. 7296	
51	84	17	429	75	5. 7298	
52	82	10	472	78	5. 7300	
53	79	2602	515	82	02	
54	77	2595	558	85	04	
55	74	87	601	89	06	
56	72	80	644	92	08	
57	69	72	687	96	11	
58	67	65	730	2. 1599	13	
59	64	57	773	2. 1603	15	
60	8. 509 5862	8. 512 2550	0. 91816	2. 1606	5. 7317	7. 738

APPENDIX No. 5.

REPORT 1901.

DETERMINATION OF RELATIVE VALUE OF GRAVITY IN EUROPE AND THE UNITED STATES IN 1900.

BY

G. R. PUTNAM, Assistant.

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CONTENTS.

DETERMINATION OF RELATIVE VALUE OF GRAVITY IN EUROPE AND THE UNITED STATES IN 1900.

By G. R. PUTNAM, *Assistant*.

This work was carried out for the purpose of more definitely connecting Washington, used as a base for the American pendulum observations, with several of the more important European base stations. The cost of the field work was paid from a grant made by the International Geodetic Association, while the instruments and time of the observer were supplied by the United States Coast and Geodetic Survey, with the approval of the Secretary of the Treasury.

In accordance with the suggestions of Prof. F. R. Helmert, Director of the Central Bureau of the Geodetic Association, the European stations were restricted to the three localities, London, Paris, and Berlin, to some one of which most of the earlier observations had been referred, and with which more recent base stations in other countries have in general been carefully connected. In the vicinity of London observations were made at three stations: Greenwich Observatory, Kew Observatory, and the Polytechnic Institute (near Portland Place), so as to connect the three important English base stations, on which depend, often independently, extensive series of observations. The lack of a satisfactory connection between these three points has been a difficulty encountered in discussing pendulum observations. (See Clarke's Geodesy, p. 344.) Even the more recent connections have not given entirely accordant results. Observations were made at Potsdam, instead of Berlin, because of the present geodetic importance of the former station, which has also been most carefully connected with Berlin.

Acknowledgment is made of the great courtesy received from the Directors and Assistants of the various institutions visited, in the matter of accommodations and facilities for carrying on the work, and in the furnishing of clock rates and comparisons. In London the work was rendered practicable by the special arrangements made by the General Post Office (Telegraph Department) for transmission of time signals direct to the vicinity of the station. Acknowledgment is also due to the North German Lloyd Steamship Company for courtesy in the matter of transportation to Europe.

DESCRIPTIONS OF STATIONS.

Very favorable locations were obtained for the observations at all stations, both with respect to uniformity of temperature and stability of support. The total range of temperature at the six stations was 6°.85 C., so that the effect of any uncertainty in the temperature coefficient should be small. The extreme range of temperature during the observations at each individual station is given below, the largest being only 1°.3 C.

At each place the pendulum case was mounted on solid stone, masonry, or concrete foundations, as detailed under the separate descriptions. The flexure of the support, including case and foundation, is also given below, as measured statically by observing with a microscope the displacement of the knife edge in microns when a force of 1.5 kilograms was applied horizontally in the plane of oscillation of the pendulum. It is believed that the slight flexure observed was mostly due to the case itself, and that there was no considerable flexure in the foundations at any of the stations. The apparatus used for measuring the flexure is not sufficiently delicate to determine accurately very slight differences, and those obtained between these stations are not unlikely due to uncertainty of observation. As, however, the total range in the flexure corrections applied at these stations is less than one millionth of the period, it is practically a negligible quantity as far as the present work is concerned. The locations of the stations, in general well removed from the lines of heavy traffic, rendered them satisfactorily free from earth vibrations due to this cause, with the possible exception of London. Here the point of observation was but 48 meters from Regent street, an important thoroughfare, but no resulting effect on the oscillation of the pendulum was noticed, nor is there any marked discrepancy between the observations made during the night and during the day. The results with the separate pendulums are, however, somewhat less accordant at this station. (Table D.)

Station.	Extreme range of temperature.	Flexure, displacment of knife edge with force 1.5 kg.
	°C.	μ
Washington (May)	1.00	1.2
Kew	1.05	1.1
Greenwich	0.65	1.3
London	1.30	0.7
Potsdam	0.55	0.9
Paris	0.15	1.2
Washington (October)	1.05	1.1

Washington, D. C., Office of United States Coast and Geodetic Survey, pendulum room in southwest corner of lowest basement, north pier (a massive brick pier with capstone).—This station was connected with the former base station at the Smithsonian Institution in 1893. (See Report United States Coast and Geodetic Survey for 1894, Part II, p. 42.) The geographic position and the elevation of the station are derived from points established on the Survey Office building.

Kew Observatory, Old Deer Park, Richmond, Surrey, England.—This is now a part of the National Physical Laboratory. Observations were made in the seismograph room in the basement. This is a small room partitioned off from a large octagonal room in the center of the south side of the building. The apparatus was mounted on the concrete floor in the same position used by Mr. E. G. Constable in the pendulum observations of 1888 under direction of Gen. J. T. Walker, and slightly north of the position used by Capt. W. J. Heaviside, 1873–74. This room is immediately west of and at the same level as the southeast corner room used in the English observations of 1864 and 1873, and by Col. R. D. von Sterneck in 1893. The geographic position is from that given for the Observatory in the American Ephemeris, and the elevation is derived from an Ordnance Survey bench mark near the northeast corner of the building.

Greenwich Observatory, London, England.—Observations were made in the record room at the northeast corner of the old observatory building. The apparatus was mounted on a low brick and stone pier built on the stone floor. The pier is in the same position, but not so high as that used by Von Sterneck in 1893. Some of the later English pendulum observations have been made in this room, but other parts of the building have also been used for this purpose. The geographic position is from that given in the American Ephemeris, the pendulum station being about 19 meters east of the meridian circle. The elevation is derived from an Ordnance Survey bench mark near the entrance gate of the Observatory.

London Polytechnic Institute, 309 Regent street, London, W., England.—Observations were made near the south side of the plumber shop in the lowest basement of this building and about 48 meters west from the building line of Regent street. The apparatus was mounted on the concrete floor. The geographic position is taken from the Ordnance Survey map (London, Sheet VII S. W., scale 6 inches to 1 mile). The elevation is derived from that given on the large-scale Ordnance Survey map (London, Sheet VII 52, scale 5 feet to 1 mile). This station was selected as the nearest convenient locality to the former stations at Mr. Henry Browne's house in Portland Place (used by Sabine, Kater, and others), and at No. 1 All Souls Place (used by Herschel), both in private residences. (For locations of these stations see Philosophical Transactions, Royal Society, 1818, p. 93, and 1890 A, p. 558; also Sabine's "Account of Experiments to Determine the Figure of the Earth," p. 343.) The station at the Polytechnic Institute is 5".7 of latitude south of Herschel's station and 8".2 south of Sabine's station.

Potsdam, Germany, "Königliches Preussisches Geodätisches Institut."—Observations were made in the northeast basement room ("Nord-Ost-Keller"). The apparatus was mounted on a low stone pier built on the concrete floor. This room has been used for the relative pendulum observations made at the Geodetic Institute, but it is east of and lower than the inner room in which are being carried out the elaborate absolute determinations of the force of gravity. The geographic position and elevation of the station were furnished by the Director of the Institute.

Paris Observatory, France.—Observations were made in the octagonal room used by Commandant G. Defforges and described by him as "Observatoire, rez-de-chaussée de la tour de l'Est." It is a room with massive masonry walls, on the ground floor, southeast of the main north entrance to the Observatory, and west of the meridian circle. The apparatus was mounted on a massive cubical stone block near the center of the room. Observations have been made in other parts of the building by earlier observers. The geographic position is from that given in the American Ephemeris, and the elevation is derived from a bench mark of the Nivellement général de la France, east of the north entrance of the Observatory.

INSTRUMENTS AND METHODS OF OBSERVATION.

The half-second pendulum apparatus and pendulums A_4, A_5, and A_6 were used in this work. These pendulums have a record of extensive service and long voyages, and from their first use at Washington, in 1894, have shown a nearly constant period.

There has been in this time apparently a slight diminution of about one millionth of a second. This apparatus is described in the United States Coast and Geodetic Survey Reports for 1891, Appendix 15; 1894, Appendix 1; and 1897, Appendix 6. The methods of observation, as modified in 1895 and described in the last two of the above reports, were followed in this work, with the partial exception of the plan of swinging the pendulums for the entire interval between time observations. At the European stations the observer did not make his own observations for time, but in general depended on the regular work of the observatories for this service, and at Kew and London used the time signals sent out during the day by telegraph from Greenwich Observatory. In some cases, therefore, the pendulum swings did not cover the entire interval between the epochs of the star observations for time, but a study of the rates of the standard observatory clocks at Greenwich and Paris indicates that probably very little uncertainty is introduced by depending on them. At Potsdam and Washington special time observations were made and the pendulum swings cover the entire interval between these determinations (ninety-six hours at Potsdam).

Briefly stated, the method of observation was to swing successively three pendulums in two positions each, making in all six swings of eight hours each (twice this number were made at Potsdam). Pendulum A_4 was swung on knife edge II, and A_5 and A_6 on knife edge I. The swings were made with a nearly uniform arc, diminishing from about 55′ to 20′ (this is the total or double arc), and at a nearly uniform pressure, about 60^{mm} of mercury. The thermometer, inserted in a dummy pendulum in the case, had its corrections determined before and after the work. As a precaution a free thermometer was also suspended in the case.

RATES OF CHRONOMETERS.

The periods of the pendulums were obtained by means of coincidence observations made with two break-circuit chronometers, used alternately in the flash apparatus circuit. At Washington both chronometers were sidereal, but at the European stations one sidereal and one mean time chronometer were used, the latter giving a more convenient coincidence interval in the higher latitudes where the force of gravity is greater and the period of these pendulums more nearly approaches the sidereal half second. The separate observations and computations with the two chronometers afford a convenient check on the work, though in general increasing the accuracy of the final result but little, for at none of these stations do the mean periods derived from the two chronometers differ more than $0^s.0000002$. The rates of the chronometers used in the pendulum observations were obtained as detailed below:

Washington, D. C.—Star observations for time were made in the Coast and Geodetic Survey Office Observatory with an astronomic transit, the observations and chronometer comparisons being recorded chronographically. In June and October observations were obtained each night of the work, and the same star list was used throughout each group of observations.

Kew Observatory.—The standard mean time clock "French" of Kew Observatory was compared each day at 10 a. m. and 1 p. m. with time signals received by telegraph from Greenwich Observatory. The comparisons at Kew were made on a tape recorder, and at Greenwich the sending of the signals was compared with their standard clock by a chronographic record. The chronometers at Kew were compared with each other and with the clock "French" by eye and ear comparisons of coincidence of beats. The corrections to the signals sent from Greenwich, as resulting from the final time computations, were furnished by the Astronomer Royal. The mean of the two daily telegraphic comparisons was adopted in deriving the rate of the standard clock "French."

Greenwich Observatory.—Sidereal chronometer 1829 was compared chronographically each evening with the standard sidereal clock of the Observatory, the corrections to which were derived directly from the meridian circle observations. The two chronometers were compared by coincidences of beats. Meridian circle observations were obtained by the Observatory Assistants on the evenings of July 3, 4, and 6. The final clock corrections were furnished by the Astronomer Royal.

London Polytechnic Institute.—Mean time chronometer 1840 was compared twice daily with the time signals sent by telegraph from Greenwich Observatory, the comparisons being made on a tape recorder. The two chronometers were intercompared by coincidence of beats. The sending of the signals was recorded chronographically at Greenwich, and the corrections, as resulting from the final time computations, were furnished by the Astronomer Royal. Special arrangements for the sending of the time signals to a point convenient for this work, and for installing the necessary receiving apparatus, were made by the Engineer in Chief, General Post Office (telegraphs).

Potsdam, Geodetic Institute.—Star observations for time were made by Herr E. Borrass on the evenings of July 21, 24, and 25, from which were computed the corrections to the standard sidereal clock Dencker 27. The two chronometers were compared with this clock on the tape chronograph each evening. The corrections and rates of clock Dencker 27 were furnished by the Geodetic Institute.

Paris Observatory.—Star observations for time were made by the Observatory staff on the evenings of July 31, August 1 (partial set), August 3, and August 4. The chronometers were compared by coincidence of beats with the standard sidereal clock used in these observations. The computed corrections to the clock were furnished by the Director.

Some idea of the possible uncertainty of the chronometer rates may be obtained from the pendulum results themselves. A certain combination of pendulums was always swung during each twenty-four hours, either A_4R, A_4D, and A_5R; or A_5D, A_6R, and A_6D. A separate chronometer rate connection was used for the interval of each such group. Therefore, if the results be combined by these groups instead of by the separate pendulums, the discrepancies between such results may be attributed to errors in rate, though undoubtedly they also include other sources of error. An examination of the present observations in this manner shows discrepancies which if due entirely to rate would indicate an average uncertainty of rate of 0.05 second per day, and a maximum at any of the six stations of 0.10 second per day (corresponding to an uncertainty of about the 1/430,000 part in the resulting value of g).

TABLE A.—*Summary of rates of chronometers on sidereal time.*

[The rate of the mean time chronometer is given in sidereal seconds on sidereal time.]

Station.	Interval.		Daily rate.		
			+Losing.	−Gaining.	
			Chron. 1829.	Chron. 1828, 1840, M.T. 1818.	
	1900		s	s	
Washington	May	20–21	+1.17	− 4.42	1828
		21–22	+1.24	− 4.16	
Kew	June	28–29	+1.66	+238.80	1840 M. T.
		29–30	+1.64	+238.79	
Greenwich	July	3– 4	+1.38	+239.34	
		4– 5	+1.19	+239.07	
London	July	12–13	+0.36	+238.12	
		13–14	+0.52	+238.13	
Potsdam	July	21–22	+1.18	+239.15	
		22–23	+0.81	+238.92	
		23–24	+0.94	+238.91	
		24–25	+0.87	+239.20	
Paris	August	1– 2	+0.64	+238.96	
		2– 3	+0.73	+239.10	
Washington	October	5– 6	−0.36	− 0.37	1818
		6– 7	−0.46	− 0.73	

REDUCTION OF OBSERVATIONS.

The computations were made in the same manner as heretofore, the periods of the pendulums being reduced to the standard conditions, sidereal time, arc infinitely small, temperature 15° C., pressure 60^{mm} of mercury at 0° C., inflexible support. The following is a summary of the corrections applied to the observed period:

Rate correction $= +0.00001157\ R\ P$, where P is period and R is daily rate in sidereal seconds on sidereal time (+ if losing, − if gaining).

Arc correction $= -\dfrac{PM \sin(\varphi+\varphi') \sin(\varphi-\varphi')}{32 \log \sin\varphi - \log \sin\varphi'}$, where P is period, M is modulus of common logarithmic system, φ and φ' are initial and final semi-arcs (2φ and $2\varphi'$ are the quantities given in Table B).

Temperature correction $= +0.00000837\ P\ (15° - T°)$, where P is period, and T is observed temperature in degrees centigrade.

Pressure correction $= +0.000000202\ P\left(60 - \dfrac{Pr}{1+.00367.\ T°}\right)$ where P is period, Pr is observed pressure in millimeters, and T is centigrade temperature.

Flexure correction $= -0.00000130\ P\ D$, where P is period, and D is observed displacement of knife-edge in microns, when force of 1.5 kilograms is applied horizontally in the plane of oscillation.

The above temperature, pressure, and flexure coefficients were determined by experiment in 1894.

Table B gives a detailed summary of the observations and corrections, and in Table C are collected the mean periods of the pendulums and the differences of each from the mean, for the separate stations.

TABLE B.—*Pendulum observations and reductions.*

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY OFFICE).

Swing No.	Pendulum.	Position.	Knife-edge.	Date, 1900.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (7th decimal place).						Period corrected.		
							Initial.	Final.					Rate.		Arc.	Temperature.	Pressure.	Flexure.			
					Chr. 1829. s.	*Chr. 1828.* s.	′	′	°C.	mm.	*Chr. 1829.* s.	*Chr. 1828.* s.	*Chr. 1829.*	*Chr. 1828.*					*Chr. 1829.* s.	*Chr. 1828.* s.	*Mean.* s.
1	A4	R	II	May 20	294.20	283.42	52	20	19.00	61	.5008512	.5008836	+68	− 256	− 8	−168	− 1	−8	.5008395	.5008395	.5008395
2	A4	D	II	May 21	294.72	284.11	56	20	18.80	62	8497	8815	+68	− 256	− 9	−159	− 2	−8	8387	8381	8384
3	A5	R	I	May 21	370.08	352.98	52	19	18.76	60	6764	7092	+68	− 256	− 8	−158	0	−8	6658	6662	6660
4	A5	D	I	May 21	370.97	354.51	52	20	18.50	57	6748	7062	+72	− 241	− 8	−147	+ 3	−8	6660	6661	6660
5	A6	R	I	May 22	392.21	374.11	52	20	18.34	60	6382	6691	+72	− 241	− 8	−140	0	−8	6298	6294	6296
6	A6	D	I	May 22	391.88	373.22	52	19	18.34	60	6388	6707	+72	− 241	− 8	−140	0	−8	6304	6310	6307
																			.5007117	.5007117	.5007117

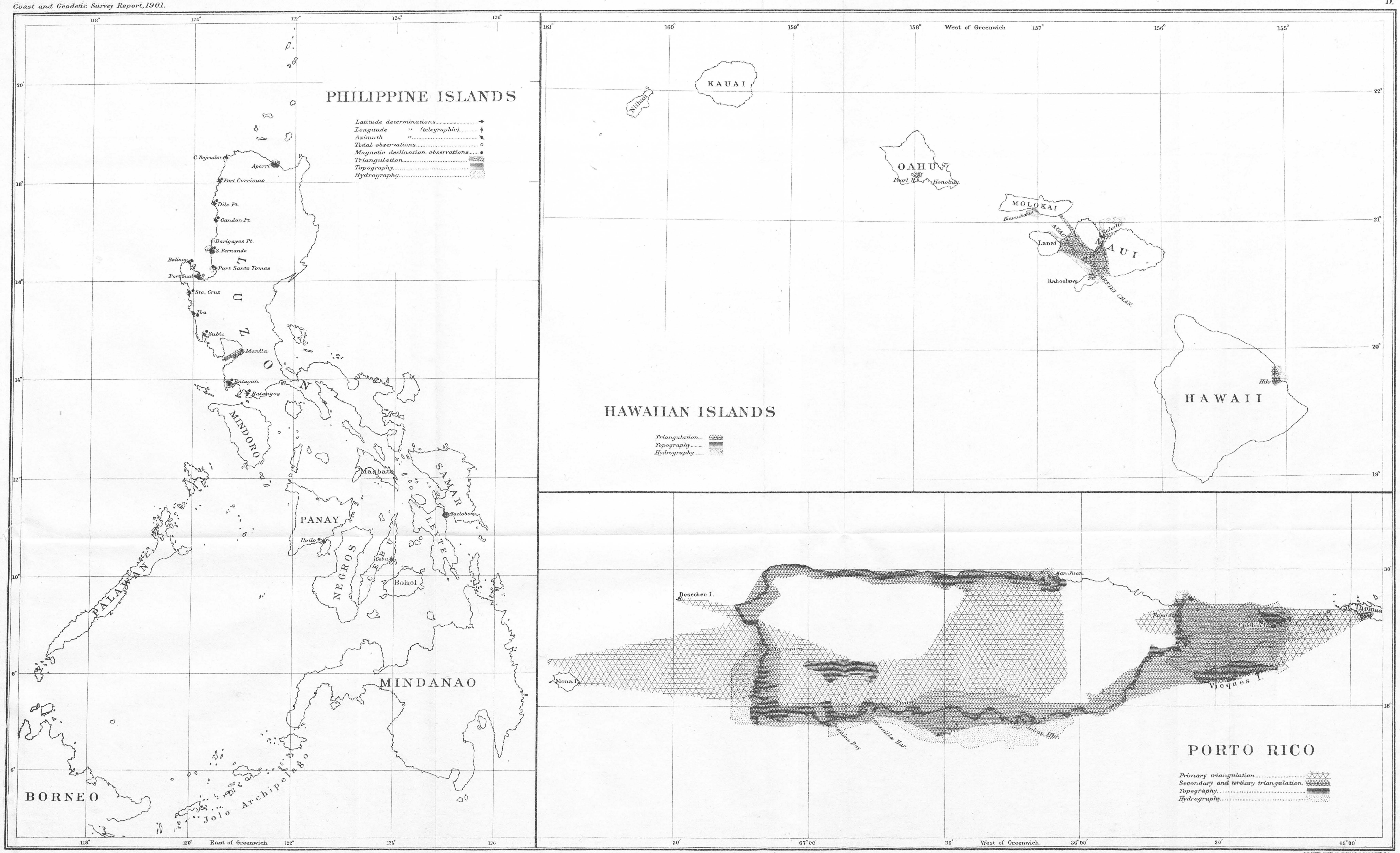
KEW OBSERVATORY, ENGLAND.

Swing No.	Pendulum.	Position.	Knife-edge.	Date, 1900.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (7th decimal place).						Period corrected.		
							Initial.	Final.					Rate.		Arc.	Temperature.	Pressure.	Flexure.			
					Chr. 1829. s.	*Chr. 1840.* s.	′	′	°C.		*Chr. 1829.* s.	*Chr. 1840.* s.	*Chr. 1829.* s.	*Chr. 1840.* s.					*Chr. 1829.* s.	*Chr. 1840.* s.	*Mean.* s.
1	A4	R	II	June 28	450.27	306.70	56	19	15.83	60	.5005558	.4991862	+96	+13797	− 9	− 35	0	−7	.5005603	.5005608	.5005606
2	A4	D	II	June 28	449.29	306.97	55	21	15.94	59	5570	91869	+96	+13797	− 9	− 39	+ 1	−7	5612	5612	5612
3	A5	R	I	June 29	646.72	253.81	57	23	16.34	52	3869	90169	+96	+13792	−10	− 56	+ 8	−7	3900	3896	3898
4	A5	D	I	June 29	647.09	253.93	52	19	16.75	61	3866	90174	+95	+13792	− 8	− 73	− 1	−7	3872	3877	3874
5	A6	R	I	June 29	712.79	244.74	53	20	16.66	59	3510	89806	+95	+13791	− 8	− 69	+ 1	−7	3522	3514	3518
6	A6	D	I	June 30	714.09	245.08	51	21	16.62	62	3503	89820	+95	+13791	− 8	− 68	− 2	−7	3513	3526	3520
																			.5004337	.5004339	.5004338

GREENWICH OBSERVATORY, ENGLAND.

Swing No.	Pendulum.	Position.	Knife-edge.	Date, 1900.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (7th decimal place).						Period corrected.		
							Initial.	Final.					Rate.		Arc.	Temperature.	Pressure.	Flexure.			
					Chr. 1829. s.	*Chr. 1840.* s.	′	′	°C.		*Chr. 1829.* s.	*Chr. 1840.* s.	*Chr. 1829.* s.	*Chr. 1840.* s.					*Chr. 1829.* s.	*Chr. 1840.* s.	*Mean.* s.
1	A4	R	II	July 3	447.02	306.35	56	19	15.55	62	.5005599	.4991853	+80	+13829	− 9	− 23	− 2	−8	.5005637	.5005640	.5005638
2	A4	D	II	July 4	447.36	305.98	53	21	15.36	62	5595	91842	+80	+13829	− 8	− 15	− 2	−8	5642	5638	5640
3	A5	R	I	July 4	644.17	253.08	53	21	15.56	62	3884	90141	+80	+13824	− 8	− 23	− 2	−8	3923	3924	3924
4	A5	D	I	July 4	643.86	253.19	52	19	15.53	63	3886	90145	+69	+13808	− 8	− 22	− 3	−8	3914	3912	3913
5	A6	R	I	July 5	710.11	244.07	52	22	15.40	63	3523	89778	+69	+13807	− 9	− 17	− 3	−8	3555	3548	3552
6	A6	D	I	July 5	710.41	244.34	52	21	15.65	58	3522	89789	+69	+13807	− 8	− 27	+ 2	−8	3550	3555	3552
																			.5004370	.5004370	.5004370

GENERAL PROGRESS SKETCH



LONDON, POLYTECHNIC INSTITUTE, ENGLAND.

					Chr. 1829. s.	Chr. 1840. s.	′	′	° C.		Chr. 1829. s.	Chr. 1840. s.	Chr. 1829. s.	Chr. 1840. s.					Chr. 1829. s.	Chr. 1840. s.	Mean. s.
1	A4	R	II	July 12	432.82	313.84	57	20	19.51	62	.5005783	.4992047	+21	+13758	−9	−189	−2	−5	.5005599	.5005600	.5005600
2	A4	D	II	July 12	432.59	313.31	58	19	19.55	61	5786	92033	+21	+13758	−9	−191	−1	−5	5601	5585	5593
3	A5	R	I	July 13	616.11	258.68	55	22	19.80	62	4061	90354	+21	+13753	−9	−201	−2	−5	3865	3890	3878
4	A5	D	I	July 13	608.74	259.30	55	20	20.48	61	4110	90377	+30	+13754	−9	−230	−1	−5	3895	3886	3890
5	A6	R	I	July 13	674.31	249.17	52	19	20.05	61	3710	89987	+30	+13753	−8	−211	−1	−5	3515	3515	3515
6	A6	D	I	July 14	675.67	249.19	53	22	19.67	58	3703	89988	+30	+13753	−9	−196	+2	−5	3525	3533	3529
																			.5004333	.5004335	.5004334

POTSDAM, GEODETIC INSTITUTE, GERMANY.

					Chr. 1829. s.	Chr. 1840. s.	′	′	° C.		Chr. 1829. s.	Chr. 1840. s.	Chr. 1829. s.	Chr. 1840. s.					Chr. 1829. s.	Chr. 1840. s.	Mean. s.
1	A4	R	II	July 21	462.16	299.25	52	17	16.17	60	.5005415	.4991660	+68	+13817	−8	−49	0	−6	.5005420	.5005414	.5005417
9	A4	R	II	July 24	460.43	300.13	53	20	16.32	61	5436	91684	+54	+13803	−8	−55	−1	−6	5420	5417	5418
2	A4	D	II	July 22	462.74	299.18	55	20	16.10	60	5408	91658	+68	+13817	−9	−46	0	−6	5415	5414	5414
8	A4	D	II	July 24	460.98	299.74	53	22	16.32	59	5429	91674	+54	+13803	−9	−55	+1	−6	5414	5408	5411
3	A5	R	I	July 22	676.47	248.57	55	20	16.27	63	3698	89963	+68	+13812	−9	−53	−3	−6	3695	3704	3700
7	A5	R	I	July 23	673.62	248.76	53	19	16.32	74	3714	89970	+54	+13798	−8	−55	−14	−6	3685	3685	3685
4	A5	D	I	July 22	673.08	248.55	53	20	16.22	61	3717	89962	+47	+13798	−8	−51	−1	−6	3698	3694	3696
10	A5	D	I	July 24	672.48	248.30	53	21	16.43	58	3720	89952	+50	+13814	−8	−60	+2	−6	3698	3694	3696
5	A6	R	I	July 23	746.12	239.90	53	21	16.29	62	3353	89601	+47	+13797	−8	−54	−2	−6	3330	3328	3329
11	A6	R	I	July 25	745.02	239.54	52	19	16.41	59	3358	89585	+50	+13813	−8	−59	+1	−6	3336	3326	3331
6	A6	D	I	July 23	746.33	240.07	55	21	16.27	59	3352	89608	+47	+13797	−9	53	+1	−6	3332	3338	3335
12	A6	D	I	July 25	746.06	239.81	53	21	16.43	62	3353	89597	+50	+13813	−8	−60	−2	−6	3327	3334	3330
																			.5004147	.5004146	.5004147

PARIS OBSERVATORY, FRANCE.

					Chr. 1829. s.	Chr. 1840. s.	′	′	° C.		Chr. 1829. s.	Chr. 1840. s.	Chr. 1829. s.	Chr. 1840. s.					Chr. 1829. s.	Chr. 1840. s.	Mean. s.
1	A4	R	II	Aug. 1	392.68	337.16	53	20	18.15	59	.5006375	.4992597	+37	+13808	−8	−132	+1	−8	.5006265	.5006258	.5006262
2	A4	D	II	Aug. 2	392.67	337.41	55	21	18.21	60	6375	2602	+37	+13808	−9	−134	0	−8	6261	6259	6260
3	A5	R	I	Aug. 2	537.85	274.23	52	19	18.22	59	4652	0900	+37	+13803	8	−135	+1	−8	4539	4553	4546
4	A5	D	I	Aug. 2	538.48	273.61	55	20	18.22	59	4647	0880	+42	+13811	9	−135	+1	−8	4538	4540	4539
5	A6	R	I	Aug. 3	583.09	263.08	53	20	18.18	58	4291	0515	+42	+13810	−8	−133	+2	−8	4186	4178	4182
6	A6	D	I	Aug. 3	582.67	263.33	52	20	18.18	60	4294	0524	+42	+13810	−8	−133	0	−8	4187	4185	4186
																			.5004996	.5004995	.5004996

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY OFFICE).

					Chr. 1829. s.	Chr. 1818. s.	′	′	° C.		Chr. 1829. s.	Chr. 1818. s.	Chr. 1829. s.	Chr. 1818. s.					Chr. 1829. s.	Chr. 1818. s.	Mean. s.
1	A4	R	II	Oct. 5	288.57	288.60	53	20	21.16	58	.5008678	.5008678	−21	−21	−8	−258	+2	−7	.5008386	.5008386	.5008386
2	A4	D	II	Oct. 6	287.97	288.06	53	20	21.46	61	8696	8694	−21	−21	−8	−271	−1	−7	8388	8386	8387
3	A5	R	I	Oct. 6	258.67	358.00	52	19	21.73	59	6980	6993	−21	−21	−8	−282	+1	−7	6663	6676	6670
4	A5	D	I	Oct. 6	258.58	358.03	53	20	21.81	59	6982	6992	−27	−42	−8	−285	+1	−7	6656	6651	6654
5	A6	R	I	Oct. 7	377.77	377.23	51	20	22.00	59	6627	6636	−27	−42	−8	−293	+1	−7	6293	6287	6290
6	A6	D	I	Oct. 7	377.53	376.42	53	19	21.99	59	6631	6650	−27	−42	−8	−293	+1	−7	6297	6301	6299
																			.5007114	.5007115	.5007114

TABLE C.—*Summary of corrected periods.*

Station.	Date.	Periods.				Differences from mean (seventh decimal place).		
		Pendulum A4, knife-edge II.	Pendulum A5, knife-edge I.	Pendulum A6, knife-edge I.	Mean of three pendulums.	A4.	A5.	A6.
	1900.	*s.*	*s.*	*s.*				
Washington	May 20–22	.5008390	.5006660	.5006302	.5007117	+1273	−457	−815
Kew	June 28–30	5609	3886	3519	4338	+1271	−452	−819
Greenwich	July 3– 5	5639	3918	3552	4370	+1269	−452	−818
London	July 12–14	5596	3884	3522	4334	+1262	−450	−812
Potsdam	July 21–25	5415	3694	3331	4147	+1268	−453	−816
Paris	Aug. 1– 3	6261	4542	4184	4996	+1265	−454	−812
Washington	Oct. 5– 7	8386	6662	6294	7114	+1272	−452	−820

RESULTS.

Table D gives for each station the value of g computed from the periods of each pendulum separately and from the means of the three pendulums, with the differences of the individual results from the mean. The latter are to some extent a measure of the accuracy of the work, but not entirely so, as there are errors, such as flexure, which might affect all three pendulums alike. These values of g are based, as indicated, on the value provisionally adopted for Washington in 1892. In Table E are given the data as to the positions of the stations and the values of g as above, and also those based on the result tentatively obtained at Potsdam in the elaborate determinations of the absolute force of gravity now in progress there, but not yet completed.* This, which is probably the best value of the absolute force of gravity now available, indicates that the provisional value for Washington and all values based thereon will need to be increased by about 0.013 dyne or centimeter, or about the 1/75000 part.

The connection between the three London stations indicates, in accordance with previous experience, that marked and sudden changes in the amount of the force of gravity are not likely to be found between near points. Greenwich is distant from Kew 21.6 kilometers (13.4 miles) and from London Polytechnic Institute 10.8 kilometers (6.7 miles). Greenwich is 42 meters (138 feet) higher than Kew and 24 meters (79 feet) higher than London. Greenwich is 0′ 32″ of latitude north of Kew and 2′ 21″ south of London. Resulting from these differences in elevation and latitude we should have the following theoretical differences in the force of gravity as compared with those found by the present observations:

	Differences in g (dynes or centimeters).	
	Theoretical.†	Observed 1900.
Kew–Greenwich	+.012	+.012
London–Greenwich	+.011	+.014

* "Bericht über die Thätigkeit des Centralbureaus der Internationalen Erdmessung im Jahre 1899" (Berlin, 1900), page 21, length of seconds pendulum at Potsdam, 994.2375 millimeters. The place where the relative observations were made at Potsdam is about 3.5 meters lower than where the above work is in progress. A slight correction is required on account of this difference of elevation.

† If the attraction term in Bouguer's formula is included, these theoretical differences become +.008.

TABLE D.—*Values of g computed from each pendulum.*

Station.	*g* in dynes or centimeters.				Differences from mean (third decimal place.)		
	Pendulum A_4.	Pendulum A_5.	Pendulum A_6.	Mean of three pendulums.	A_4.	A_5.	A_6.
Washington	....	....	....	(980.098)	....	....	....
Kew	981.187	981.185	981.187	981.186	+.001	−.001	+.001
Greenwich	981.175	981.173	981.174	981.174	+ 1	− 1	0
London	981.192	981.186	981.186	981.188	+ 4	− 2	− 2
Potsdam	981.263	981.260	981.261	981.261	+ 2	− 1	0
Paris	980.931	980.928	980.926	980.928	+ 3	0	− 2

TABLE E.—*Summary of results (not reduced to sea level).*

Station.	Latitude north.			Longitude from Greenwich.			Elevation.	*g* in dynes or centimeters.	
								Based on g=980.098 at Washington.	Based on g=981.274 at Potsdam.
	°	′	″	°	′	″	*Meters.*		
Washington, D. C. (Coast and Geodetic Survey Office).	38	53	13	77	00	32 W.	14	980.098	980.111
Kew Observatory, England.	51	28	06	0	18	46 W.	5	981.186	981.199
Greenwich Observatory, England.	51	28	38	0	00	01 E.	47	981.174	981.187
London Polytechnic Institute, England.	51	30	59	0	08	31 W.	23	981.188	981.201
Potsdam Geodetic Institute, Germany.	52	22	52	13	03	53 E.	83	981.261	981.274
Paris Observatory, France.	48	50	11	2	20	16 E.	62	980.928	980.941

APPENDIX No. 6.

REPORT 1901.

TRIANGULATION NORTHWARD ALONG THE NINETY-EIGHTH MERIDIAN IN KANSAS AND NEBRASKA.

BY

JOHN F. HAYFORD, Inspector of Geodetic Work.

CONTENTS.

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TRIANGULATION NORTHWARD ALONG THE NINETY-EIGHTH MERIDIAN IN KANSAS AND NEBRASKA.

By JOHN F. HAYFORD, *Inspector of Geodetic Work.*

GENERAL STATEMENT.

It is proposed to extend a chain of primary triangulation northward and southward from the transcontinental triangulation in the vicinity of the ninety-eighth meridian approximately along that meridian to the Canadian border to the northward and to the Rio Grande to the southward. This triangulation, which may for convenience be called the ninety-eighth meridian triangulation, when completed from Canada to Mexico, from latitude 49° to latitude 26°, will pass through North Dakota, South Dakota, Nebraska, Kansas, Oklahoma Territory, Indian Territory, and Texas. For the engineer, this triangulation will, in combination with the transcontinental triangulation, form the main framework for the control of all the triangulation in the United States. For the scientist it will furnish incidentally a great arc of a meridian having an amplitude of 23°, and passing over a region in which the surface indications are that the local deflections of the vertical are probably small. The Mexican Government has already in progress a triangulation along the same meridian which it is expected will extend the arc southward from latitude 26° to latitude 17°, at which point this meridian intersects the Pacific coast. It is also possible for the Canadian Government to extend this arc far to the northward.

The present state of the ninety-eighth meridian triangulation within the limits of the United States is as follows:

The reconnaissance is complete from the Rio Grande to points in North Dakota in latitude 43½°, over an arc of 17½°.

All the necessary bases between these points have been measured save one which is near the Rio Grande. The ten bases measured are, in order, from south to north: Alice Base (Texas), Seguin Base (Texas), Lampasas Base (Texas), Stephenville Base (Texas), Bowie Base (Texas), El Reno Base (Oklahoma), Anthony Base (Kansas), Salina Base (Kansas), Shelton Base (Nebraska), and Page Base (Nebraska), the name of the base indicating its location near a town of the same name in each case. A report on the measurement of nine of these bases during the season of 1900 may be found in Appendix No. 3 of this Report. The remaining base is that at Salina, in Kansas, which was measured in connection with the transcontinental triangulation*. As this base line lies near the intersection of the thirty-ninth parallel and the ninety-eighth meridian, it belongs essentially to both triangulations.

* See "The Transcontinental Triangulation" (Special Publication No. 4), pp. 174–190.

The measures of horizontal and vertical angles are complete from the transcontinental triangulation northward to latitude 43¼°, in South Dakota, three figures beyond the Page Base, and from the transcontinental triangulation southward to the vicinity of the Anthony Base near the Kansas-Oklahoma line in latitude 37°. The connection with the Anthony Base is not complete.

No astronomic determinations have yet been made, and hence the portion of the triangulation which has been completed is not yet available for use as an arc in determining the figure of the earth.

It is proposed to publish the results of the ninety-eighth meridian triangulation from time to time as complete sections between bases become available for that purpose. It is desirable to make the publication in such sections since the lengths between bases are not completely fixed until the second base has been connected with. This Appendix contains a complete statement of the results for the two sections from the Salina Base to the Shelton Base and from the Shelton Base to the Page Base*, including all secondary and tertiary points determined, as well as the primary points, and including the vertical as well as the horizontal measures. It includes the republication of certain information in regard to the triangulation between the Salina Base and the stations Meades Ranch and Waldo, which is common to the transcontinental triangulation and the ninety-eighth meridian triangulation.

The first reconnaissance for the triangulation to the northward was made during the autumn of 1896, between August 17 and November 9, and during the spring of 1897 between April 10 and June 20, by a party under the direction of Assistant F. D. Granger. Afterwards, during the seasons of 1897–1901, the comparatively little additional reconnaissance which was found necessary to supplement or extend this reconnaissance was done during the field seasons, which were devoted mainly to the measurement of horizontal and vertical angles.

The measures of horizontal and vertical angles in the triangulation to the northward were all made by Assistant F. D. Granger during the seasons of 1897, 1898, 1899, and 1900 with one exception. The station Walnut, which was necessary to complete the connection with the Page Base, was occupied by the same observer in 1901.

THE METHODS AND INSTRUMENTS USED IN THE MEASUREMENT OF HORIZONTAL ANGLES.

All of the angle measures were made by the direction method. Each series of observations consists of successive pointings on the various stations in order, from left to right, with corresponding readings of the horizontal circle with three micrometer microscopes followed immediately by pointings on the same stations in the reverse order after reversing the position of the telescope by transiting it through the wyes and turning the alidade 180° in azimuth, each pivot remaining in contact with the same wye as before. Each observation of an angle consists, therefore, of two pointings on each station involved, one in each position of the telescope, together with the corresponding micrometer readings, 24 in all, both a forward and a backward reading of each micrometer being made in each of its positions.

* See illustrations Nos. 1-4 at the end of this Appendix.

At each station in the triangulation under consideration which was occupied in 1890, 1891, or 1892, theodolite No. 10 was used in seventeeen positions and two series of observations were taken in each position, making the total number of measures of each angle thirty-four. The horizontal circle of this theodolite is 35^{cm} in diameter and carries a $10'$ graduation read directly by three micrometer microscopes to single seconds. The telescope has a clear aperture of $2\frac{1}{8}$ inches (equals $5^{cm}.4$) a focal length of $24\frac{1}{4}$ inches (equals $61^{cm}.6$) and a magnifying power of 36. At only one of these stations was it found necessary to place the instrument more than 50 feet above the ground—namely, at Heath (57 feet).

During the measures of 1896, all in the vicinity of the Salina Base and serving to connect it with the main triangulation, theodolite No. 118 was used in seventeen positions and two series of observations taken in each position, or thirty-four measures in all. The horizontal circle of this theodolite is 30^{cm} in diameter, is graduated to $5'$ spaces and is read directly to single seconds by three micrometer microscopes. The telescope has a clear aperture of 6^{cm}, a focal length of 58^{cm}, and a magnifying power of 35. The instrument was not elevated more than 35 feet above the ground at any station.

During the measures of 1897, commencing with the station Waldo and ending with Lebanon, theodolite No. 118 was used in eleven positions and two series of observations were taken in each position, or twenty-two measures in all. The instrument was less than 18 feet above the ground at each station.

During the season of 1898, commencing with station Brown and ending with Prosser, theodolite No. 118 was used in thirteen positions, two series being taken in each position, or twenty-six measures in all. At only three stations was the instrument elevated more than 50 feet above the ground, namely, at Brown (70 feet), Cooper (66 feet), Blue Hill (66 feet). In three cases, however, the pointings were made upon very tall poles. The pole observed at Cooper from Brown was 118 feet high. On the line Herrick–Sand Creek there is an obstructing ridge at about the middle of the line. In order to see from instrument to instrument, it would have been necessary to build each instrument tripod about 80 feet high. To save expense, instead of building the instrument tripods to this height, they were each made 50 feet high and a pole 126 feet high was observed at Sand Creek from Herrick; similarly, one 121 feet high was observed at Herrick from Sand Creek. In each of these cases the pole was supported by the scaffold upon which the observer stands and which is entirely independent of the instrument tripod and was held securely in position by suitable wire guys.

During 1899, at the six stations in the Shelton base net, theodolite No. 146 was used in thirteen positions, two series being taken in each position, or twenty-six observations in all upon each angle. Theodolite No. 146* carries a horizontal circle 30^{cm} in diameter, graduated to $5'$ spaces and read directly by three micrometer microscopes to single seconds. The clear aperture of the telescope is 61^{mm} and its focal length 74^{cm}. Three eye-pieces, magnifying 30, 45, and 60 diameters, respectively, were furnished with the telescope. The highest elevation for the instrument anywhere in the base net was 43 feet at Shelton East Base.

In all the observations thus far indicated the circle was used in seventeen, eleven,

*For a full description of this instrument, see Appendix No. 8 of the Report for 1894, "Notes on some instruments recently made in the Instrument Division of the Coast and Geodetic Survey Office."

or thirteen positions with the readings on the initial station uniformly distributed over 360°. Commencing at station Pompey in 1899, this plan was radically changed, as indicated below, and was again changed at the beginning of 1900.

Commencing with station Pompey in 1899, during the remainder of the season the instrument was used in the twenty-four positions indicated below, one measure only being made in each position.

Position.	Reading on initial.			Position.	Reading on initial.		
	°	′	″		°	′	″
No. 1	0	00	00	No. 13	187	32	30
2	15	00	00	14	202	32	30
3	30	00	00	15	217	32	30
4	45	00	00	16	232	32	30
5	62	30	50	17	250	03	20
6	77	30	50	18	265	03	20
7	92	30	50	19	280	03	20
8	107	30	50	20	295	03	20
9	125	01	40	21	312	34	10
10	140	01	40	22	327	34	10
11	155	01	40	23	342	34	10
12	170	01	40	24	357	34	10

The purpose of this change is indicated in the paragraphs following the instructions for 1900 and 1901, given below.

At Pompey and the five following stations occupied in 1899 and ending with Brayton the instrument was never more than 50 feet above the ground.

During the seasons of 1900 and 1901 theodolite No. 146 was again used and the observer was acting under the following instructions:

In making the measurements of horizontal directions, you will measure each direction in the primary scheme sixteen times, a direct and a reverse reading being considered one measurement, and sixteen positions of the circle are to be used, corresponding approximately to the following readings upon the initial signal:

Position.	Reading on initial.			Position.	Reading on initial.		
	°	′	″		°	′	″
No. 1	0	00	40	No. 9	128	00	40
2	15	01	50	10	143	01	50
3	30	03	10	11	158	03	10
4	45	04	20	12	173	04	20
5	64	00	40	13	192	00	40
6	79	01	50	14	207	01	50
7	94	03	10	15	222	03	10
8	109	04	20	16	237	04	20

When a broken series is observed the missing signals are to be observed later in connection with the chosen initial, or with some other one, and only one, of the stations already observed in that series. In selecting the conditions under which to observe, you should proceed upon the assumption that the maximum speed consistent with the requirement that the closing error of a triangle in the primary scheme shall seldom exceed three seconds, and that the average closing error shall be but little greater than one second, is what is desired rather than a greater accuracy than that indicated.

In regard to the positions specified in these instructions, it is important to note three points:

1. In each of the four groups of four positions each, the readings of the three microscopes on the circle corresponding to pointings on the initial station will be nearly uniformly spaced at intervals of approximately 15° over the whole 360°, and therefore the mean values of the angles from each group of four positions will be but little affected by periodic errors of graduation. In connection with this statement it is necessary to keep in mind that, during each measure, the alidade is turned 180° between the direct and reverse readings when the position of the telescope is changed, and therefore the three microscopes which are at intervals of 120° furnish readings at nearly uniform intervals of 60° during each measure.

2. In each group of four positions the micrometer readings corresponding to the initial station, and therefore those corresponding to each station, are nearly uniformly distributed over the 5′ interval covered by the micrometer. The effect of this is to insure that if a correction for run is applied, the algebraic sum of such corrections for each micrometer corresponding to pointings on each station will be nearly zero. In other words, the mean value of any angle from observations in four positions uncorrected for run is almost independant of the run. An examination in detail of the observations at two or three stations showed that it was entirely unnecessary to apply any correction for run to observations made under these instructions, and considerable time was thereby saved in making the computation.

3. No microscope ever returns for pointings on a given station to any position on the circle which it has formerly occupied. When the observations in sixteen positions have been completed, the circle has been read at ninety-six points, scattered at intervals of three or four degrees over the whole circumference for each station observed. This insures that the mean value of each angle from sixteen positions is still more completely freed from the effect of periodic errors than are the means from the separate groups of four positions each.

Looking back now to the statement of the twenty-four positions used during the latter part of the season of 1899, it will be seen that many of the good points of the 1900 programme had already been secured in 1899. In 1899 the effect of the run of the micrometers was not eliminated in each group of four positions but was almost completely eliminated from the mean of the twenty-four positions.

The total number of measures was reduced from twenty-four in 1899 to sixteen in 1900 after a careful study in detail of the 1899 observations, and a general study of the relation between the accuracy secured and the number of measures made in previous observations in the United States. It was concluded that the additional measures after sixteen are obtained increase the accuracy of the results very little.

At the stations occupied in 1900 the instrument was never placed more than 30 feet above the ground. At station Walnut in 1901 it was placed only 15 feet above the ground.

The preceding statements apply to observations at the primary stations only. In observing upon points determined by intersection from primary stations, which will for convenience be called tertiary points, from one to three positions were used. For a few secondary points which were occupied to reach other points, but which did not form a part of the primary scheme, an intermediate programme was used.

In all the triangulation here treated the pointings were made upon poles, as a rule, being supplemented by pointings upon heliotropes when much difficulty was encountered in seeing the poles.

PROGRAMME OF OCCUPATION OF STATIONS.

In the following table the stations are arranged approximately in the order in which they were occupied. The second column indicates the days on which observations on primary stations were taken, the third column the number of such days, and the fourth column is added here for convenience to indicate the height of signals. In general, the pole observed upon was but a few feet higher than the instrument at a given station. The few extraordinary cases in which the pole was extended far above the top of the instrument tripod are mentioned under the previous heading. The height of signal must be considered in connection with the rate of progress, both because the work may be delayed in waiting for the building of signals, and because there is likely to be more delay on account of wind when observing from a high signal than when observing from a low one.

It will be noted that the station Iron Mound was occupied twice, once during the progress of the main triangulation, and once for the purpose of connecting with the Salina Base. Similarly, Meades Ranch and Waldo were each occupied twice, first in connection with the transcontinental triangulation, and later at the beginning of the ninety-eighth meridian triangulation. Station Prosser was also occupied twice, once in 1898, and again after the signals at the Shelton Base had been built in 1899. In the table and in the statements following it, each new occupation of a station is counted as if it were an occupation of a new station, as it is virtually equivalent to a new station at which few directions were observed.

Station.	Days on which observations of primary horizontal angles were made.	Number of days.	Height of instrument above ground.
			Feet.
Vine Creek	1890 June 28–30, July 1, 2, 4, 6–8, 10, 12–14, 16–18, 20, 21.	18	20
Iron Mound	1890 July 30, 31, August 1, 3–13.	14	6
Iron Mound	1896 May 16, 19–22.	5	5
Salina West Base	1896 May 4–10.	7	20
Salina East Base	1896 May 26, 28–31.	5	35
North Pole Mound	1896 June 5, 7–10.	5	25
Heath	1891 July 8, 10, 12–17, 19–25.	15	57
Thompson	1891 August 6–10.	5	6
Lincoln	1891 August 22, 25, 27–31.	7	20
Golden Belt	1891 September 12, 13, 15–21, 23.	10	6
Wilson	1891 October 24–27, 30, 31, November 1, 4, 6, 7, 9.	11	50
Bunker Hill	1892 May 26, 28, 29, June 1–3, 6–8, 11, 13–16.	14	40
Allen	1892 July 13–25.	13	24
Blue Hill	1892 October 6, 13–19, 22–26.	13	15
Waldo	1892 June 23–25, 27–30, July 1, 2, 5–7.	12	6
Waldo	1897 July 8, 10, 11.	3	5
Meades Ranch	1891 September 29, October 2–10, 13–16.	14	5
Meades Ranch	1897 July 16, 18–22.	6	6
Dial	1897 July 28–31, August 1.	5	5
Kill Creek	1897 August 8–11.	4	17
Lawrence 2	1897 August 17–20, 27–31, September 1.	10	6
Old Well 2	1897 September 4, 7–16.	11	17
Lebanon	1897 September 22–26.	5	14
Brown	1898 May 20–26.	7	70
Lipps	1898 June 4–10, 13–16.	11	26
Cooper	1898 June 24–27, 29.	5	66
Blue Hill	1898 July 9–12, 14–16, 18–20.	10	66
Herrick	1898 July 26, 28–31, August 1, 2.	7	50
Lars	1898 August 16, 18, 19.	3	30
Sand Creek	1898 August 25–29, September 3, 4, 6.	8	50
Wanda	1898 September 13–20.	8	25
Mason	1898 September 28–30, October 2, 3.	5	40
Prosser	1898 October 28–31, November 1, 2, 4.	7	39
Prosser	1899 April 29, May 1, 3–5.	5	6
Shelton West Base	1899 May 8–12.	5	24
Shelton East Base	1899 May 15–18.	4	43
Lowell	1899 May 29–31, June 4–7.	7	20
Valley	1899 June 12, 14–16, 19–24, 27.	11	26
Cameron	1899 July 1, 3, 6–11.	8	35
Pompey	1899 July 19, 21, 22, 24–29.	9	21
Deer	1899 August 8–13, 16–20.	11	20
Divide	1899 August 26, 27, 29, September 2–5.	7	25
Yale	1899 September 12, 16, 17, 19–23, 25.	9	35
Elm	1899 October 3, 4, 7–10.	6	20
Brayton	1899 October 16–19, 22, 25, 26.	7	50
Daily	1900 May 29, 31, June 1, 2.	4	5
Custer	1900 June 9, 11–15.	6	21
Ono	1900 June 28, 29, July 2, 3, 5, 6.	6	30
Buffalo	1900 July 18–21.	4	30
McClure	1900 July 31, August 1–3, 6–8.	7	15
Deloit	1900 August 14–19.	6	14
Hall	1900 August 25, 27–31.	6	13
Page Southwest Base	1900 September 13, 15, 17, 19, 20.	5	21
Page Northeast Base	1900 September 22, 25–27.	4	15
Prairie	1900 October 5–7.	3	9
Old	1900 October 12, 13, 15, 16.	4	9
Walnut	1901 June 26, 28, 29, July 1–3, 5.	7	15

The following data, compiled from the above table and from the preceding statement of the number of observations at each station, show clearly how much reduction may be expected in the time spent at the station when the number of observations is reduced. A comparison between the heavy (thirty-four observations) and the light (sixteen observations) programme is especially fair in this case, since all the observations were made by one man who already had many years of experience, and were made under the same general conditions as to length of lines, height of signals, topography, and climatic conditions.

Period.	Number observations.	Total number days of observation.	Number stations.	Average number days of observation at a station.	Maximum number days of observation at any station.	Minimum number days of observation at any station.
1890–91–92, 96	34	168	16	10.5	18	5
1897–98–99	24	204	29	7.0	11	3
1900–01	16	62	12	5.2	7	3

It is evident that upon an average the reduction of the number of observations from 34 to 16 saved 5.3 observing days at each station. For the whole group of station here treated, 1890–1901, the total number of observing days was 434, and the total number of days from the first day of observation to the last day of observation inclusive at each station was 555. Hence the ratio of the number of observing days at a station to the total number of days at the station, exclusive of the time before the first observation and after the last observation, is 434 to 555, or 0.78. Therefore, the saving of 5.3 observing days at each station is equivalent on an average to a saving of nearly seven days of occupation at each station under the average conditions involved in this triangulation.

It is noteworthy that in the three separate groups of triangulation treated the percentage of observation days in each of the groups agrees with the above-mentioned percentage (0.78) within one-half of one per cent.

The question whether the reduction in the number of observations has appreciably affected the accuracy of the work, will be treated later.

There were eight stations at which the instrument was elevated 50 feet or more above the ground. At four of these, namely, Heath, Blue Hill, Sand Creek, and Wilson, the time of occupation was longer; at three, namely, Brown, Herrick, and Brayton, the time of occupation was the same, and at one, Cooper, the time of occupation was shorter than for the average of the group. It is thus evident that there is a slight tendency for the observations at the high stations to be slower than at the lower stations.

STATEMENT OF ADJUSTMENTS.

For the stations involved in the transcontinental triangulation local adjustments* were made.

From the stations from Meades Ranch–Waldo northward along the ninety-eighth meridian to the Page Base but few local adjustments have been made. The computer

*For a complete explanation of local adjustments, see "The Transcontinental Triangulation," pp. 36–46.

made local adjustments at a few stations where the proportion of broken series was greatest, these being the cases in which the local adjustment will in general produce the greatest changes in the angles. These extraordinary cases being carefully studied indicated that the effect of the local adjustment at the remaining stations would in general be simply to change the angles in the hundredths of seconds, the tenths being seldom affected. It was therefore considered that the time would not be well spent in making these local adjustments, the effects of which would be so small as to be entirely masked by the corrections inevitably applied in the figure adjustments. For the greater number of stations the directions used in the figure adjustments are therefore those resulting directly from the observations after the mere taking of means.

The figure adjustment was made in five sections, viz, the Salina base net, from the Salina base net to the El Paso base net, from Meades Ranch–Waldo to the Shelton base net, the Shelton base net, from the Shelton base net to the Page Base. The adjustment of the Salina base net is fully set forth in "The Transcontinental Triangulation," pages 182–188. The stations involved are Vine Creek, Iron Mound, Salina East Base, Salina West Base, North Pole Mound, Thompson, and Heath. (See illustration No. 1, at the end of this Appendix.) The only fixed line in the figure was the base. The number of observed directions involved was thirty. There were thirteen rigid conditions to be satisfied, nine relating to the closures of the triangles and four to the ratios of sides.

The stations west of the Salina base net to and including Blue Hill and Allen, as shown in illustration No. 1 at the end of this Appendix, form a part of the Kansas-Colorado series of triangles between the Salina and El Paso bases, of which the adjustment is shown in "The Transcontinental Triangulation," pages 514–551. Two hundred and twenty-five observed directions were involved, and these were connected by ninety-nine conditions, of which seventy related to closures of triangles, twenty-eight to ratios of sides, and the last condition was that the length carried through from Thompson–Heath at the edge of the Salina base net must agree with the length of the line Holcolm Hills–Big Springs at the edge of the El Paso base net.

The adjustment of the triangulation (see illustration No. 2) from the fixed line Meades Ranch–Waldo to the fixed line Lowell–Prosser of the Shelton base net, which had previously been adjusted, involves seventy-six observed directions connected by twenty-nine rigid conditions, as indicated below, of which twenty-two referred to closures of triangles and six referred to ratios of sides, and the last is that the length carried from Meades Ranch–Waldo must agree with the fixed length of Lowell–Prosser. In the following condition equations the numbers assigned to the directions correspond to those shown in illustration No. 2.

CONDITION EQUATIONS.

Meades Ranch–Waldo to Shelton base net.

No.	
1	$0=+0.83-(1)+(2)-(5)+(6)-(10)+(11)$
2	$0=-0.82-(4)+(5)+(7)-(11)-(13)+(14)$
3	$0=-0.58-(7)+(8)-(12)+(13)-(18)+(19)$
4	$0=-1.01-(2)+(3)-(9)+(10)-(20)+(21)$
5	$0=+1.42-(8)+(9)-(17)+(18)-(21)+(22)$
6	$0=-0.89-(16)+(17)-(22)+(23)-(26)+(27)$
7	$0=-0.05-(23)+(24)-(25)+(26)-(30)+(31)$
8	$0=-0.99-(15)+(16)-(27)+(28)-(41)+(42)$
9	$0=+0.55+(25)-(29)-(31)+(32)-(33)+(34)$
10	$0=-0.54-(28)+(29)-(34)+(35)-(40)+(41)$
11	$0=-0.43-(35)+(37(-(39)+(40)-(48)+(49)$
12	$0=+0.08-(36)+(37)-(45)+(46)-(48)+(50)$
13	$0=+0.07-(38)+(39)-(45)+(47)-(49)+(50)$
14	$0=+0.09-(44)+(45)-(50)+(51)-(58)+(59)$
15	$0=-0.63-(43)+(44)+(54)-(59)-(61)+(62)$
16	$0=-0.14-(54)+(55)-(60)+(61)-(64)+(65)$
17	$0=-0.47-(55)+(56)-(63)+(64)-(66)+(67)$
18	$0=-0.27-(51)+(53)-(57)+(58)-(71)+(72)$
19	$0=-0.08-(52)+(53)-(69)+(70)-(71)+(73)$
20	$0=-0.15-(56)+(57)+(66)-(69)-(72)+(73)$
21	$0=-0.64-(68)+(69)-(73)+(74)-(75)+(76)$
22	$0=+0.55+(63)-(67)+(68)-(76)$
23	$0=-10.3-4.89(1)+5.32(2)-0.43(3)-1.55(4)+3.58(5)-2.03(6)+0.34(12)+1.48(13)-1.82(14)$ $+0.28(17)+4.97(18)-5.25(19)-4.25(20)+6.40(21)-2.15(22)$
24	$0=-2.4-4.57(15)+6.82(16)-2.25(17)-0.40(22)+2.84(23)-2.44(24)-1.14(30)+1.05(31)$ $+0.09(32)-2.37(33)+3.10(34)-0.73(35)-1.37(40)+5.24(41)-3.87(42)$
25	$0=-7.1-1.17(35)+4.11(36)-2.94(37)-4.23(38)+4.74(39)-0.51(40)-0.95(48)+3.03(49)$ $-2.08(50)$
26	$0=+6.9-2.41(43)+3.24(44)-0.83(45)-1.37(50)+5.39(51)-4.02(52)-0.83(60)+2.37(61)$ $-1.54(62)-1.58(63)+3.17(64)-1.59(65)+2.91(66)-0.51(67)-2.40(70)$
27	$0=-7.7-4.02(51)+8.62(52)-4.60(53)-4.45(56)+3.63(57)+0.82(58)-0.25(71)+2.84(72)$ $-2.59(73)$
28	$0=-0.5-1.73(55)+5.36(56)-3.63(57)+4.43(63)-1.58(64)-2.84(72)+4.44(73)-1.60(74)$ $-1.44(75)+3.56(76)$
29	$0=-9.0-0.43(2)+0.43(3)-2.03(5)+2.03(6)-2.71(8)+2.71(9)-0.79(10)+0.79(11)-4.57(15)$ $+4.57(16)-0.28(17)+0.28(18)+4.25(20)-4.25(21)-0.40(22)+0.40(23)+1.33(26)-1.33(27)$ $-1.63(28)+1.63(29)+0.73(34)-0.73(35)-2.94(36)+2.94(37)-0.51(38)+0.51(40)+3.87(41)$ $-3.87(42)-0.83(44)+0.83(45)+2.29(46)-2.29(47)+0.95(48)-0.95(50)-4.02(51)+4.02(52)$ $-1.73(55)+1.73(56)+1.49(58)-1.49(59)+1.58(63)-1.58(64)-2.40(66)+0.33(67)-0.33(68)$ $+2.40(70)+2.12(76)$

In the adjustment of the Shelton base net (see illustration No. 3) the base was the only fixed line. For the measurement and length of this line, see Appendix No. 3 of this Report. The adjustment involves twenty-four directions between six stations connected by twelve rigid conditions shown below, of which eight relate to the closure of triangles and four to the ratios of sides.

CONDITION EQUATIONS.

Shelton base net.

No.	
1	$0=+0.77-(b)+(2)-(7)+(a)-(20)+(21)$
2	$0=+0.66-(6)+(7)-(16)+(18)-(21)+(22)$
3	$0=+1.63-(b)+(1)-(6)+(a)-(17)+(18)$
4	$0=-0.49-(5)+(7)-(10)+(12)-(21)+(23)$
5	$0=-0.61-(10)+(11)+(16)-(19)-(22)+(23)$
6	$0=-2.07-(1)+(3)-(9)+(11)+(17)-(19)$
7	$0=-0.56-(8)+(10)-(14)+(15)-(23)+(24)$
8	$0=-0.46-(2)+(4)-(13)+(14)+(20)-(24)$
9	$0=+0.76+0.12(b)-0.69(1)+0.57(2)+0.54(6)-0.78(7)+0.24(a)+0.37(16)-0.30(17)-0.07(18)$
10	$0=-0.41+0.34(5)-0.54(6)+0.20(7)+0.13(10)-0.33(11)+0.20(12)-0.09(16)+0.07(18)+0.02(19)$
11	$0=-0.31+0.01(1)-0.69(2)+0.68(3)+0.32(9)-0.33(10)+0.01(11)+0.16(20)+0.00(22)-0.16(23)$
12	$0=-0.78+0.69(1)-0.92(2)+0.23(4)+0.10(8)-0.43(10)+0.33(11)+0.33(13)-0.57(14)+0.24(15)-0.28(16)+0.30(17)-0.02(19)$

The adjustment of the triangulation northward from the Shelton base net starts with the two fixed lines Valley–Cameron and Cameron–Prosser at the edge of the Shelton base net and closes on the Page Base, of which the length was fixed by a measurement by a party under Mr. A. L. Baldwin in 1900. (See Appendix 3 of this Report.) The adjustment involves ninety-six directions connected by forty-three rigid conditions, as indicated below, of which No. 1 to No. 30 relate to triangle closures and No. 32 to No. 42 to ratios of sides. The thirty-first is the condition that the length of Cameron–Prosser as computed from Valley–Cameron shall agree with its fixed value, and the last condition is that the Page Base as computed from the line Valley–Cameron at the edge of the Shelton base net shall agree with its measured value.

CONDITION EQUATIONS.

Shelton base net to Page Base.

No.	
1	$0=+0.41+(1)-(6)-(7)+(8)$
2	$0=-0.34-(3)+(5)-(12)+(13)$
3	$0=+0.10-(5)+(6)-(8)+(9)-(11)+(12)$
4	$0=-0.81-(2)+(4)-(19)+(20)$
5	$0=-0.21-(2)+(3)-(13)+(14)-(18)+(20)$
6	$0=-0.10-(9)+(10)+(11)-(16)-(21)+(22)$
7	$0=-1.08-(14)+(15)-(17)+(18)-(30)+(31)$
8	$0=+0.56-(15)+(16)-(22)+(23)-(29)+(30)$
9	$0=-0.65-(23)+(24)-(28)+(29)-(33)+(34)$
10	$0=+0.43-(23)+(25)-(27)+(29)-(36)+(38)$
11	$0=+1.21-(24)+(25)-(32)+(33)-(36)+(37)$
12	$0=+0.18-(26)+(28)-(34)+(35)-(45)+(46)$
13	$0=+1.76-(26)+(27)-(38)+(39)-(44)+(46)$
14	$0=+1.07-(39)+(40)-(42)+(44)-(55)+(56)$
15	$0=-0.73-(39)+(41)-(43)+(44)-(47)+(48)$
16	$0=-0.46-(40)+(41)-(47)+(49)-(54)+(55)$
17	$0=-1.28-(49)+(51)-(53)+(54)-(62)+(63)$
18	$0=-0.92-(49)+(50)-(52)+(54)-(60)+(61)$

CONDITION EQUATIONS—Continued.

No.

19 $0=-0.20-(50)+(51)-(59)+(60)-(62)+(64)$

20 $0=+0.16-(58)+(59)-(64)+(66)-(67)+(68)$

21 $0=-0.04-(57)+(59)-(64)+(65)-(77)+(78)$

22 $0=-1.56-(65)+(66)-(67)+(69)-(76)+(77)$

23 $0=-0.38-(69)+(70)-(75)+(76)-(79)+(80)$

24 $0=-0.63-(69)+(71)-(74)+(76)-(84)+(86)$

25 $0=+0.78-(70)+(71)+(79)-(83)-(84)+(85)$

26 $0=-0.59-(72)+(75)-(80)+(82)-(90)+(92)$

27 $0=+0.21-(82)+(83)-(85)+(88)-(89)+(90)$

28 $0=-0.37-(73)+(75)-(80)+(81)+(93)-(96)$

29 $0=+0.12-(72)+(73)-(91)+(92)-(93)+(94)$

30 $0=+0.27-(81)+(83)-(85)+(87)-(95)+(96)$

31 $0=-1.3+3.85(1)+1.72(3)+3.42(7)-4.34(8)+0.92(9)-2.00(11)-5.59(12)+3.59(13)$

32 $0=-2.0-3.87(2)+5.59(3)+3.96(4)-4.29(5)-1.41(18)+1.83(19)-0.42(20)$

33 $0=-5.3-3.96(4)+4.84(5)-0.88(6)-0.92(8)+2.36(9)-1.44(10)-0.35(17)+2.18(18)-1.83(19)$
$-1.75(21)+3.00(22)-1.25(23)-1.61(29)+5.02(30)-3.41(31)$

34 $0=+3.42-0.143(23)+0.497(24)-0.354(25)-4.713(27)+5.212(28)-0.499(29)-0.127(36)$
$+1.434(37)-1.307(38)$

35 $0=+6.4-1.43(23)+4.97(24)-3.54(25)-2.38(26)+7.37(28)-4.99(29)-1.27(36)+3.01(37)$
$-1.74(39)-6.18(44)+6.51(45)-0.33(46)$

36 $0=-3.5+0.03(39)+1.88(40)-1.91(41)-1.95(42)+4.58(43)-2.63(44)-2.59(54)+2.56(55)$
$+0.03(56)$

37 $0=+4.8-0.63(49)+5.09(50)-4.46(51)-4.30(52)+5.30(53)-1.00(54)-1.61(59)+1.48(60)$
$+0.13(61)$

38 $0=-5.0-0.01(57)+2.09(58)-2.08(59)-3.25(67)+2.84(68)+0.41(69)-2.63(76)+5.96(77)$
$-3.33(78)$

39 $0=+16.1-3.18(69)+11.04(70)-7.86(71)-4.10(74)+5.15(75)-1.05(76)-5.93(84)+11.31(85)$
$-5.38(86)$

40 $0=-0.26-0.189(72)+0.573(73)+0.384(75)-0.227(80)+1.082(81)-0.855(82)-1.478(90)$
$+1.744(91)-0.266(92)$

41 $0=+0.044-0.019(72)+0.814(73)-0.795(74)-1.490(86)+1.523(87)-0.033(88)-0.013(89)$
$+0.040(91)-0.027(92)$

42 $0=-6.4-1.89(72)+5.73(73)-3.84(75)-2.27(80)+2.32(81)-0.05(83)-5.17(85)+8.42(87)$
$-3.25(88)-1.30(89)+3.96(91)-2.66(92)$

43 $0=+5.3-1.72(3)-0.88(5)+0.88(6)+0.92(8)-2.36(9)+1.44(10)+3.59(12)-3.59(13)-0.84(15)$
$+0.84(16)+1.75(21)-1.75(22)-0.12(23)+0.12(25)-2.61(26)+2.61(27)+1.61(29)-1.61(30)$
$+0.85(36)-0.85(38)-1.88(40)+1.88(41)-0.15(42)-0.21(44)+0.36(46)-0.09(47)-0.54(49)$
$+0.63(51)-4.30(52)+4.30(53)+1.68(55)-1.68(56)-2.14(57)+2.14(58)-0.13(59)+0.13(61)$
$+2.33(62)-2.33(63)+0.30(64)-0.30(66)+2.84(67)-2.84(68)-3.18(69)+3.18(70)+0.72(76)$
$-0.72(78)+0.26(79)-2.53(80)+2.27(81)+0.70(93)-0.70(96)$

The ordinary practice in the Coast and Geodetic Survey in adjusting a piece of triangulation comprising two base nets and the intervening triangulation has been, to first adjust each base net by itself independently, then to adjust the intervening triangulation to fit the fixed lines at the borders of the two base nets. In the adjustment indicated above there is a radical departure from this practice. The adjustment starts with the fixed lines on the edge of the Shelton base net, in accordance with the former practice, but ends at the Page Base itself, including both the intervening triangulation and the Page base net in a single adjustment without any distinction between them.

The advantages of the former practice were twofold. First, the adjustment was symmetrical. It began and ended with a border line, or lines, of a base net, whereas the new practice is unsymmetrical, beginning with a border line or lines of a base net and ending with a measured base in the midst of another base net. Second, the work of adjustment was somewhat lighter under the former practice than is the case now, since the smaller the number of equations dealt with in each group solved simultaneously the lighter is the computation. The new practice substitutes a single group for two groups of equations, namely, one corresponding to the intervening triangulation and one corresponding to the base net. The increase in computation thus produced is small, though doubtless real.

The advantage of the new practice is that greater accuracy is secured. In general, the larger the number of triangles dealt with in a single group of equations, the greater the accuracy attained, since the breaking into groups of triangles necessarily involves the neglect or mutilation of certain rigid conditions actually existing which must be fulfilled by the observed directions. In the case under consideration, the neglected condition is an important one. In the former practice the length equation, expressing the condition that the length of a given base, as computed from a preceding base, must agree with the measured length, is only used *between* the base nets. In other words, the distortion of the measured angles necessary to make the two bases agree is all forced into the triangulation intervening between base nets, whereas it is a well-known fact that errors in length accumulate more rapidly as a rule within the base net itself, where poor geometric conditions necessarily occur, than in the main chain of triangles between base nets. Thus, under the former practice, the error of length which had accumulated in the whole chain of triangles from base to base was in the adjustment dissipated by distorting the measured angles on the part of the chain in which the rate of accumulation of length error is probably least, leaving the part of the chain in which the rate of accumulation of length error was probably greatest without any adjustment in so far as the length equation is concerned. Under the new practice there is a length equation running through each base net.

ACCURACY AS INDICATED BY CORRECTIONS TO OBSERVED DIRECTIONS.

The corrections to directions resulting from the three adjustments of the ninety-eighth meridian triangulation and outlined above are as follows. The numbers of the directions refer to illustrations Nos. 2, 3, and 4.

Meades Ranch–Waldo to Shelton base net.

Number of direction.	Correction to direction.	Number of direction.	Correction to direction.
	″		″
1	−0.300	39	+0.440
2	+0.067	40	+0.001
3	+0.233	41	+0.050
4	−0.369	42	+0.111
5	+0.490	43	−0.176
6	−0.122	44	−0.058
7	−0.125	45	+0.148
8	+0.102	46	+0.250
9	+0.022	47	−0.164
10	+0.293	48	−0.177
11	−0.293	49	+0.422
12	−0.320	50	−0.379
13	+0.261	51	−0.431
14	+0.059	52	+0.567
15	−0.619	53	−0.002
16	+0.195	54	+0.046
17	+0.457	55	−0.186
18	+0.098	56	+0.005
19	−0.132	57	+0.303
20	−0.167	58	+0.039
21	+0.403	59	−0.207
22	−0.580	60	−0.139
23	+0.135	61	−0.060
24	+0.209	62	+0.199
25	−0.031	63	+0.014
26	−0.082	64	−0.142
27	−0.165	65	+0.153
28	−0.053	66	−0.289
29	+0.331	67	+0.145
30	−0.045	68	−0.137
31	−0.017	69	−0.120
32	+0.062	70	+0.401
33	+0.043	71	−0.138
34	−0.223	72	−0.034
35	−0.115	73	−0.011
36	+0.138	74	+0.183
37	+0.157	75	−0.145
38	−0.603	76	+0.282

Shelton base net.

	″		″
b	+0.099	12	+0.668
1	−0.176	13	+0.011
2	−0.457	14	−0.262
3	+0.285	15	+0.251
4	+0.249	16	0.000
5	+0.223	17	+0.875
6	−0.299	18	−0.592
7	+0.262	19	−0.284
a	−0.187	20	+0.023
8	−0.093	21	+0.259
9	−0.536	22	−0.370
10	+0.048	23	+0.090
11	−0.086	24	−0.003

Shelton base net to Page Base.

Number of direction.	Correction to direction.	Number of direction.	Correction to direction.
	″		″
1	−0.291	49	−0.423
2	−0.504	50	−0.114
3	+0.302	51	+0.316
4	+0.110	52	+0.090
5	+0.332	53	−0.422
6	+0.021	54	+0.048
7	+0.030	55	+0.871
8	−0.069	56	−0.588
9	+0.230	57	−0.410
10	−0.191	58	+0.509
11	−0.068	59	−0.049
12	−0.156	60	−0.351
13	+0.151	61	+0.301
14	−0.240	62	−0.068
15	+0.376	63	+0.001
16	−0.063	64	+0.003
17	−0.317	65	−0.047
18	+0.305	66	+0.111
19	−0.092	67	−0.413
20	+0.104	68	−0.123
21	−0.170	69	+0.300
22	+0.355	70	−0.106
23	−0.015	71	+0.342
24	+0.130	72	−0.266
25	−0.301	73	−0.062
26	+0.416	74	+0.193
27	+0.066	75	−0.388
28	−0.480	76	−0.196
29	−0.113	77	+0.495
30	+0.134	78	+0.224
31	−0.023	79	−0.532
32	−0.031	80	+0.063
33	−0.258	81	+0.206
34	−0.116	82	+0.468
35	+0.405	83	−0.205
36	+0.402	84	+0.358
37	−0.149	85	−0.547
38	+0.440	86	+0.072
39	−0.510	87	+0.171
40	−0.005	88	−0.053
41	−0.178	89	−0.106
42	+0.257	90	−0.139
43	+0.434	91	+0.075
44	+0.142	92	+0.170
45	−0.513	93	+0.238
46	−0.320	94	−0.182
47	−0.234	95	+0.260
48	+0.455	96	−0.316

The maximum correction to any direction is 0''.875 to Prosser observed from Shelton West Base.

The probable error of an adjusted direction is

$$d=0.674\sqrt{\frac{\Sigma v^2}{c}}$$

in which Σv^2 is the sum of the squares of the corrections to the directions and c is the number of conditions. For each of the three groups the value of d is

Meades Ranch-Waldo to Shelton base net	±0''.27 from	76 directions.
Shelton base net	±0''.33 from	26 directions.
Shelton base net to Page Base	±0''.29 from	96 directions.
Weighted mean	±0''.29 from	198 directions.

For the purpose of comparison it may be noted that the same quantity for the Salina base net was ±0''.44 and for the Kansas-Colorado series of triangles, which includes the triangulation westward from the Salina base net to Meades Ranch-Waldo, was ±0''.50.*

For comparison it may also be noted that in the twenty-one sections into which the transcontinental triangulation was divided the maximum value of d was ±0''.82 in the American Bottom base net; the minimum value was ±0''.23 in the Nevada-California series of triangles, and the average value was ±0''.44.*

By inspection of the formula for the probable error, d, of an adjusted direction given above it may be seen that if the ratio of the number of directions to the number of conditions is the same in two groups of adjusted triangles the values of d^2 are proportional to the average values of v^2. Under these conditions, then, the average value of the correction to a direction may be used as a rough means of comparing the accuracy of any one group with any part of some other group, since the probable error of an adjusted direction will be nearly proportional to the average value of corrections to directions in such groups.

The values of the ratio, number of directions divided by number of conditions, in the five groups of adjusted triangles here treated are: in the Salina base net, $\frac{30}{13}=2.3$; between Salina base net and the El Paso base net, $\frac{225}{99}=2.3$; between Meades Ranch-Waldo and the Shelton base net, $\frac{76}{29}=2.6$; in the Shelton base net, $\frac{26}{12}=2.2$, and between the Shelton base net and Page Base, $\frac{96}{43}=2.2$. Hence the mean value of a correction to a direction may be used as an approximate measure of the relative accuracy of the different parts of the triangulation.

It is desirable to determine whether the accuracy has been affected appreciably by the reduction in the number of observations of each direction, accompanied, as indicated on page 368, by a corresponding reduction in the number of days on which the observations were taken. Dividing the whole triangulation from Salina Base to Page Base

* The Transcontinental Triangulation, p. 613.

into three groups in order of decreasing number of observations, the following comparison is obtained:

	Number of observations of each direction.	Average number of days of observation.	Years.	Number of directions.	Average correction to a direction, without regard to sign.	Maximum correction to a direction.
					"	"
Group No. 1	34	10.5	1890–91–92, 96	76	0.416	1.374
Group No. 2	22 to 26	7.0	1897–98–99	135	0.217	0.875
Group No. 3	16	5.2	1900–01	57	0.266	0.871

This evidence is a strong indication that there has been no appreciable reduction in accuracy.

ACCURACY AS INDICATED BY CORRECTIONS TO ANGLES AND CLOSURES OF TRIANGLES.

The correction to each angle is the algebraic sum of the corrections to two directions. In order to make it possible to study the corrections to the separate angles, they are shown in the following table for every triangle in the primary scheme from the Salina Base to the Page Base, together with the error of closure of the triangles, the corrected spherical angles, and the spherical excess. The plus sign prefixed to the error of closure of a triangle indicates that the sum of the angles is less than 180° plus the spherical excess. The spherical excess is a convenient indication of the size of the triangle, since it is proportional to the area.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	"	"	°	′	"	"
Iron Mound	−0.34		44	16	26.78	
Salina West Base	−0.53	−0.93	52	50	52.02	0.12
Salina East Base	−0.06		82	52	41.32	
North Pole Mound	+0.09		34	23	08.78	
Salina East Base	+0.32	+0.38	74	29	25.53	0.18
Salina West Base	−0.03		71	07	25.87	
North Pole Mound	−0.30		25	14	27.73	
Iron Mound	−0.39	−1.25	30	47	14.60	0.22
Salina West Base	−0.56		123	58	17.89	
North Pole Mound	+0.40		9	08	41.06	
Salina East Base	+0.26	+0.70	157	22	06.85	0.08
Iron Mound	+0.04		13	29	12.17	
Heath	+1.12		22	19	31.82	
North Pole Mound	−0.14	+0.93	100	28	05.85	1.8[illegible]
Iron Mound	−0.05		57	12	24.14	
Thompson	+0.65		92	56	25.90	
North Pole Mound	+0.56	+0.18	51	50	59.36	1.85
Heath	−1.03		35	12	36.59	
Thompson	−0.67		80	49	10.90	
Iron Mound	−0.46	−1.04	41	38	43.86	3.17
Heath	+0.09		57	32	08.41	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	"	"	°	'	"	"
Thompson	+1.32		12	07	15.00	
North Pole Mound	+0.43	+2.15	152	19	05.22	0.49
Iron Mound	+0.40		15	33	40.27	
Vine Creek	−0.98		30	57	42.95	
Iron Mound	+0.41	−0.71	45	39	52.41	1.13
North Pole Mound	−0.14		103	22	25.77	
Thompson	−0.14		51	50	46.87	
Vine Creek	−0.02	+0.65	66	55	43.51	3.06
Iron Mound	+0.81		61	13	32.68	
Vine Creek	+0.95		35	58	00.55	
North Pole Mound	−0.29	−0.80	104	18	29.01	1.43
Thompson	−1.46		39	43	31.87	
Vine Creek	+0.73		14	40	50.83	
North Pole Mound	+0.27	+1.76	156	09	28.37	1.04
Heath	+0.76		9	09	41.84	
Thompson	−0.81		132	39	57.77	
Vine Creek	+0.23	−2.37	21	17	09.73	2.25
Heath	−1.79		26	02	54.75	
Vine Creek	−0.25		45	38	33.78	
Iron Mound	+0.35	+1.98	102	52	16.54	3.98
Heath	+1.88		31	29	13.66	
Lincoln	+0.87		75	35	24.17	
Thompson	+0.30	+0.98	58	20	09.39	1.60
Heath	−0.19		46	04	28.04	
Golden Belt	−0.77		47	38	58.45	
Thompson	+0.64	+0.94	38	54	03.07	2.15
Heath	+1.07		93	27	00.63	
Golden Belt	+0.32		68	30	27.33	
Lincoln	−0.77	+0.81	64	07	01.47	1.39
Heath	+1.26		47	22	32.59	
Lincoln	+0.10		139	42	25.64	
Thompson	−0.33	+0.86	19	26	06.33	0.85
Golden Belt	+1.09		20	51	28.88	
Wilson	+0.24		40	05	15.19	
Lincoln	+0.95	+1.73	62	10	34.15	2.62
Heath	+0.54		77	44	13.28	
Wilson	+1.15		42	11	49.43	
Golden Belt	+0.09	+0.52	107	26	31.19	1.31
Heath	−0.72		30	21	40.69	
Golden Belt	+0.41		175	56	58.52	
Lincoln	−1.72	−0.40	1	56	27.32	0.08
Wilson	+0.91		2	06	34.24	
Meades Ranch	+0.12		62	23	31.39	
Lincoln	−0.91	−0.44	57	53	14.39	3.71
Wilson	+0.35		59	43	17.93	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	//	//	°	′	//	//
Meades Ranch	+1.36		23	36	46.06	
Lincoln	+0.04	+0.88	120	03	48.54	2.50
Heath	−0.52		36	19	27.90	
Wilson	+0.59		99	48	33.12	
Meades Ranch	−1.25	+0.41	38	46	45.32	3.83
Heath	+1.07		41	24	45.39	
Golden Belt	−0.44		91	44	40.68	
Meades Ranch	−0.93	−0.56	32	18	34.14	1.89
Lincoln	+0.81		55	56	47.07	
Golden Belt	−0.12		160	15	08.01	
Meades Ranch	−2.30	−0.63	8	41	48.07	0.78
Heath	+1.79		11	03	04.70	
Wilson	−0.56		57	36	43.69	
Meades Ranch	+1.05	+0.52	30	04	57.25	1.74
Golden Belt	+0.03		92	18	20.80	
Bunker Hill	−0.75		72	27	18.10	
Meades Ranch	+0.32	−0.91	26	40	18.98	1.91
Wilson	−0.48		80	52	24.83	
Waldo	+0.73		62	59	56.95	
Meades Ranch	−0.16	+0.59	82	10	52.71	2.61
Wilson	+0.02		34	49	12.95	
Waldo	+0.06		86	20	54.50	
Meades Ranch	−0.48	+0.10	55	30	33.73	2.25
Bunker Hill	+0.52		38	08	34.02	
Bunker Hill	−0.23		110	35	52.12	
Waldo	−0.67	−1.40	23	20	57.55	1.55
Wilson	−0.50		46	03	11.88	
Blue Hill	+0.58		60	58	20.39	
Waldo	+0.19	−0.17	67	20	20.77	2.49
Bunker Hill	−0.94		51	41	21.33	
Blue Hill	+0.42		49	01	11.30	
Meades Ranch	−0.02	−0.02	41	08	57.19	3.84
Bunker Hill	−0.42		89	49	55.35	
Waldo	+0.25		153	41	15.27	
Meades Ranch	−0.46	−0.05	14	21	36.54	0.90
Blue Hill	+0.16		11	57	09.09	
Allen	−0.99		65	34	07.55	
Waldo	−1.51	−1.46	23	48	19.98	1.33
Bunker Hill	+1.04		90	37	33.80	
Allen	+1.11		54	05	00.20	
Blue Hill	−1.19	+1.62	82	23	01.05	2.04
Waldo	+1.70		43	32	00.79	
Allen	+0.11		119	39	07.74	
Blue Hill	−1.77	+0.33	21	24	40.66	0.88
Bunker Hill	+1.99		38	56	12.48	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	″	″	°	′	″	″
Dial	−0.59		110	45	14.94	
Meades Ranch	+0.37	−0.83	23	17	45.49	0.51
Waldo	−0.61		45	57	00.08	
Kill Creek	−0.20		49	04	30.14	
Dial	+0.16	+0.82	77	13	23.42	0.31
Waldo	+0.86		53	42	06.75	
Lawrence 2	−0.23		21	51	01.19	
Dial	+0.23	+0.58	59	02	43.51	0.78
Kill Creek	+0.58		99	06	16.08	
Old Well 2	+0.57		26	23	08.44	
Meades Ranch	+0.17	+1.01	78	27	04.84	2.12
Dial	+0.27		75	09	48.84	
Lawrence 2	−0.36		97	46	28.42	
Old Well 2	−0.98	−1.42	44	24	44.40	2.10
Dial	−0.08		37	48	49.28	
Brown	−0.08		57	46	36.35	
Old Well 2	+0.71	+0.89	79	06	16.20	1.47
Lawrence 2	+0.26		43	07	08.92	
Lebanon	+0.03		61	35	19.99	
Old Well 2	+0.07	+0.05	40	50	35.14	0.88
Brown	−0.05		77	34	05.75	
Lipps	+0.06		28	31	43.25	
Brown	+0.11	+0.99	126	43	24.95	1.76
Lawrence 2	+0.82		24	44	53.56	
Cooper	−0.27		41	39	12.34	
Lebanon	+0.08	−0.55	92	33	05.33	0.72
Brown	−0.36		45	47	43.05	
Lipps	+0.05		56	59	14.95	
Cooper	+0.11	+0.54	70	52	36.52	1.35
Brown	+0.38		52	08	09.90	
Herrick	−0.41		42	34	59.77	
Cooper	+0.25	+0.44	60	49	27.30	1.68
Lipps	+0.60		76	35	34.61	
Blue Hill	+0.60		30	55	08.46	
Cooper	+0.27	+0.43	96	26	24.46	2.06
Lipps	−0.44		52	38	29.14	
Blue Hill	−0.20		65	41	[illegible]3.44	
Cooper	+0.02	−0.08	35	36	57.16	1.74
Herrick	+0.10		78	42	01.14	
Herrick	−0.31		121	17	00.91	
Blue Hill	−0.80	−0.07	34	45	54.98	1.36
Lipps	+1.04		23	57	05.47	
Sand Creek	−0.25		54	33	54.73	
Blue Hill	−0.05	−0.09	57	00	20.11	1.08
Herrick	+0.21		68	25	46.24	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	"	"	°	′	"	"
Lars	+0.26		53	48	43.77	
Sand Creek	+0.25	+0.63	85	08	34.39	0.97
Herrick	+0.12		41	02	42.81	
Lowell	+0.29		52	56	45.55	
Sand Creek	−0.23	+0.14	58	37	52.92	0.79
Lars	+0.08		68	25	22.32	
Wanda	+0.43		76	22	46.47	
Sand Creek	+0.19	+0.47	50	28	31.41	0.68
Lowell	−0.15		53	08	42.80	
Wanda	−0.69		41	11	37.61	
Blue Hill	+1.00	+0.34	27	37	16.82	0.97
Sand Creek	+0.03		111	11	06.54	
Mason	+0.10		46	45	16.42	
Blue Hill	+0.43	+0.27	52	12	56.86	1.58
Sand Creek	−0.26		81	01	48.30	
Mason	+0.13		83	20	47.30	
Blue Hill	−0.57	+0.08	24	35	40.04	1.18
Wanda	+0.52		72	03	33.84	
Wanda	−0.17		113	15	11.45	
Mason	+0.02	+0.15	36	35	30.87	0.57
Sand Creek	+0.30		30	09	18.25	
Prosser	+0.43		55	34	07.17	
Mason	+0.19	+0.64	52	47	11.76	0.48
Wanda	+0.02		71	38	41.55	
Prosser	−0.28		44	47	25.06	
Wanda	−0.28	−0.55	98	43	20.53	0.57
Lowell	+0.01		36	29	14.98	
Shelton West Base	−1.47		73	47	49.73	
Prosser	−0.27	−1.63	43	04	33.76	0.85
Lowell	+0.11		63	07	37.36	
Shelton East Base	+0.24		78	20	41.39	
Prosser	−0.56	−0.77	60	04	17.66	0.78
Lowell	−0.45		41	35	01.73	
Shelton East Base	−0.39		127	48	20.31	
Prosser	−0.28	+0.21	16	59	43.91	0.25
Shelton West Base	+0.88		35	11	56.03	
Shelton East Base	−0.63		49	27	38.92	
Lowell	+0.56	−0.66	21	32	35.63	0.31
Shelton West Base	−0.59		108	59	45.76	
Valley	+1.20		46	40	12.62	
Prosser	+0.19	+0.98	60	26	37.01	1.53
Lowell	−0.41		72	53	11.90	
Valley	+0.62		46	16	25.93	
Shelton East Base	−0.17	+0.49	102	25	24.63	0.73
Lowell	+0.04		31	18	10.17	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	″	″	°	′	″	″
Valley	−0. 13		32	34	59. 51	
Shelton East Base	+0. 46	+0. 61	52	57	45. 71	0. 23
Shelton West Base	+0. 28		94	27	15. 01	
Valley	+0. 75		13	41	26. 42	
Shelton West Base	+0. 31	+0. 54	156	32	59. 23	0. 19
Lowell	−0. 52		9	45	34. 54	
Valley	+0. 45		32	58	46. 20	
Prosser	+0. 46	+2. 07	17	22	03. 25	0. 49
Shelton West Base	+1. 16		129	39	11. 04	
Valley	+0. 55		0	23	46. 66	
Prosser	+0. 74	+1. 25	0	22	19. 34	0. 01
Shelton East Base	−0. 04		179	13	54. 01	
Cameron	+0. 24		74	12	25. 15	
Prosser	−0. 03	−0. 22	42	32	20. 76	1. 45
Valley	−0. 43		63	15	15. 54	
Cameron	−0. 27		32	32	47. 08	
Prosser	+0. 71	+0. 46	42	54	40. 10	0. 75
Shelton East Base	+0. 02		104	32	33. 57	
Cameron	+0. 51		41	39	38. 07	
Shelton East Base	−0. 09	+0. 56	74	41	20. 41	0. 70
Valley	+0. 14		63	39	02. 22	
Pompey	−0. 10		31	35	29. 45	
Prosser	−0. 29	−0. 41	28	40	06. 73	1. 58
Cameron	−0. 02		119	44	25. 40	
Deer	+0. 31		30	26	23. 34	
Cameron	+0. 33	+0. 34	98	49	26. 37	1. 72
Valley	−0. 30		50	44	12. 01	
Pompey	+0. 30		66	18	56. 77	
Cameron	−0. 31	−0. 10	67	13	43. 08	1. 94
Deer	−0. 09		46	27	22. 09	
Divide	+0. 20		29	52	38. 07	
Cameron	+0. 11	+0. 81	70	49	44. 17	2. 12
Valley	+0. 50		79	17	39. 88	
Divide	−0. 20		78	53	52. 34	
Deer	−0. 39	+0. 21	72	32	41. 80	2. 01
Valley	+0. 80		28	33	27. 87	
Deer	−0. 08		102	59	05. 14	
Cameron	+0. 22	−0. 26	27	59	42. 20	1. 61
Divide	−0. 40		49	01	14. 27	
Brayton	+0. 52		50	12	18. 98	
Pompey	−0. 42	+0. 10	55	30	25. 31	2. 78
Deer	0. 00		74	17	18. 49	
Yale	−0. 16		31	38	52. 50	
Deer	+0. 62	+1. 08	67	56	09. 69	1. 79
Divide	+0. 62		80	24	59. 60	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	″	″	°	′	″	″
Yale	+0.25		52	31	05.77	
Brayton	−0.37	−0.56	59	08	52.75	3.12
Deer	−0.44		68	20	04.60	
Daily	+0.14		101	18	33.19	
Brayton	+0.14	+0.65	55	49	38.77	1.39
Yale	+0.37		22	51	49.43	
Custer	+0.04		68	00	38.18	
Brayton	−0.29	−0.43	86	34	06.75	1.97
Yale	−0.18		25	25	17.04	
Custer	−0.55		58	51	20.63	
Brayton	−0.43	−1.21	30	44	27.98	0.40
Daily	−0.23		90	24	11.79	
Daily	+0.08		168	17	15.01	
Yale	−0.55	+0.12	2	33	27.61	0.17
Custer	+0.59		9	09	17.55	
Elm	+0.19		81	05	14.24	
Daily	+0.52	−0.18	57	26	22.73	1.71
Yale	−0.89		41	28	24.74	
Elm	−0.46		99	52	55.37	
Custer	−0.95	−1.76	41	12	09.58	2.07
Yale	−0.35		38	54	57.12	
Custer	−0.36		50	21	27.13	
Daily	−0.44	−1.46	110	50	52.28	0.53
Elm	−0.66		18	47	41.12	
Buffalo	−1.46		51	24	14.46	
Custer	+0.50	−1.07	42	44	10.53	1.74
Elm	−0.11		85	51	36.75	
Ono	+0.69		50	24	22.18	
Custer	+0.33	+0.73	90	54	21.49	1.63
Elm	−0.29		38	41	17.96	
Ono	−0.19		92	24	14.23	
Custer	−0.17	+0.46	48	10	10.96	1.55
Buffalo	+0.82		39	25	36.36	
Buffalo	−0.64		90	49	50.82	
Ono	−0.88	−1.34	41	59	52.05	1.66
Elm	+0.18		47	10	18.79	
Deloit	+0.07		42	05	27.21	
Ono	+0.74	+1.28	73	16	18.00	2.34
Buffalo	+0.47		64	38	17.13	
McClure	+0.65		38	29	04.98	
Ono	+0.31	+0.92	50	47	38.98	2.26
Buffalo	−0.04		90	43	18.30	
McClure	+0.35		93	27	53.40	
Deloit	0.00	−0.16	60	27	06.85	1.42
Buffalo	−0.51		26	05	01.17	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations.	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	″	″	°	′	″	″
Deloit	+0.07		102	32	34.06	
Ono	+0.43	+0.20	22	28	39.02	1.50
McClure	−0.30		54	58	48.42	
Hall	+0.29		36	35	52.40	
Deloit	+0.11	−0.16	98	10	31.61	0.85
McClure	−0.56		45	13	36.84	
Page Southwest Base	−0.27		32	19	40.45	
Deloit	−0.05	+0.04	57	52	10.43	1.14
McClure	+0.36		89	48	10.26	
Page Southwest Base	+0.42		71	00	46.63	
Hall	+0.43	+1.77	64	24	41.28	1.33
McClure	+0.92		44	34	33.42	
Hall	+0.71		101	00	33.67	
Deloit	+0.16	+1.56	40	18	21.18	1.03
Page Southwest Base	+0.69		38	41	06.18	
Old	+0.60		83	06	09.38	
Hall	−0.41	+0.38	33	27	49.80	0.54
Page Southwest Base	+0.19		63	26	01.36	
Walnut	−0.28		40	53	48.88	
Hall	+0.04	−0.63	48	27	16.52	1.25
Page Southwest Base	−0.39		90	38	55.85	
Old	−0.33		145	28	51.30	
Walnut	−0.90	−0.78	19	31	42.37	0.39
Hall	+0.45		14	59	26.72	
Old	−0.27		131	24	59.32	
Page Southwest Base	−0.58	−0.23	27	12	54.49	0.32
Walnut	+0.62		21	22	06.51	
Prairie	+0.31		46	30	23.03	
Old	+0.40	+0.59	56	36	41.37	0.38
Page Southwest Base	−0.12		76	52	55.98	
Prairie	−0.03		50	04	48.01	
Walnut	+0.49	−0.21	55	06	54.59	0.55
Old	−0.67		74	48	17.95	
Prairie	+0.28		96	35	11.04	
Walnut	−0.13	+0.61	33	44	48.08	0.61
Page Southwest Base	+0.46		49	40	01.49	
Page Northeast Base	+0.56		108	29	18.81	
Old	+0.14	+0.37	42	46	43.91	0.12
Page Southwest Base	−0.33		28	43	57.40	
Page Northeast Base	−0.42		93	27	19.91	
Page Southwest Base	+0.20	−0.12	48	08	58.57	0.21
Prairie	+0.10		38	23	41.73	
Page Northeast Base	−0.13		158	03	21.29	
Prairie	+0.21	+0.34	8	06	41.30	0.05
Old	+0.26		13	49	57.46	

Accuracy as indicated by corrections to angles and closures of triangles—Continued.

Stations	Corrections to angles.	Error of closure of triangle.	Corrected spherical angles.			Spherical excess.
	″	″	°	′	″	″
Page Northeast Base	−0.58		69	11	04.26	
Walnut	+0.72	−0.27	22	10	40.54	0.21
Old	−0.41		88	38	15.41	
Page Northeast Base	+0.44		88	52	17.02	
Prairie	+0.18	+0.40	58	11	29.31	0.39
Walnut	−0.22		32	56	14.06	
Page Northeast Base	−0.02		177	40	23.07	
Walnut	+0.10	+0.33	0	48	34.03	00.1
Page Southwest Base	+0.25		1	31	02.91	

The maximum correction to any angle is $-2''.30$ to the angle at Meades Ranch between Heath and Golden Belt measured in 1891.

The triangles show 69 closing errors of the plus sign and 46 of the minus sign.

The average closing error of a triangle for this whole triangulation, without regard to sign, is $0''.68$ (115 triangles). For comparison it may be noted that the average closing error for the whole transcontinental triangulation is $1''.06$, and that the average closing error for the 21 sections into which that triangulation was divided varies from a minimum of $0''.57$ in the Nevada-California section to a maximum of $2''.22$ in the American Bottom base net (see "Transcontinental Triangulation," p. 16).

The mean error of an angle, namely, $\sqrt{\frac{\Sigma\Delta^2}{3n}}$, in which $\Sigma\Delta^2$ is the sum of the squares of the closing errors of the triangles, and n is the number of triangles, is for this triangulation and for the separate groups into which it is divided:

	″
For the whole triangulation, Salina Base to Page Base	±0.49
For the triangulation from Meades Ranch-Waldo to Page Base	±0.42
For Salina base net	±0.75
For triangulation from Salina base net to Meades Ranch-Waldo	±0.49
For the triangulation Meades Ranch-Waldo to the Shelton base net	±0.35
For the Shelton base net	±0.45
For the triangulation from the Shelton base net to the Page Base	±0.44

In the transcontinental triangulation the mean error of an angle, computed as indicated above, varies from $\pm 0''.42$ to $\pm 1''.59$, and its average value is $\pm 0''.77$. (See "Transcontinental Triangulation," p. 613.)

The mean error of an angle as thus computed from the triangle closures may be rendered comparable with the probable error of the resulting direction by multiplying it by $\sqrt{\tfrac{1}{2}}$ to take account of the fact that an angle is the difference of two directions, and by the factor 0.674, to reduce from a mean error to a probable error.

The mean error of an angle, a, for the triangulation between Meades Ranch-Waldo and Page Base, namely, $\pm 0''.42$, when reduced to a probable error of direction is $\pm 0''.20$, whereas the probable error of direction as computed from the figure adjustment for the same section is $\pm 0''.29$. (See page 375.) The excess of the second of these values over the first is an indication of the magnitude of the errors which were put in evidence by the rigid conditions relating to the ratios of sides and the accord in length between bases, and which do not appear from the triangle closures alone.

To secure further evidence as to whether the accuracy of the triangulation has been appreciably affected by the reduction of the number of observations of each direction, the following table, similar to that shown on page 376, has been compiled. Certain triangles belong to two different seasons. In such cases the triangle has been credited to the season during which two of its three stations were occupied.

	Number of observations of each direction.	Average number of days of observations.	Years.	Number of triangles.	Average closing error.	Maximum closing error.
					$''$	$''$
Group No. 1	34	10.5	1890–91–92, 96	37	0.83	2.37
Group No. 2	22 to 26	7.0	1897–98–99	50	0.59	2.07
Group No. 3	16	5.2	1900–01	28	0.63	1.77

This evidence again indicates clearly that no appreciable reduction in accuracy has occurred on account of the reduction in the number of observations.

No attempt has been made here to set forth the agreement of the separate measures of each direction as a criterion of accuracy, since it is well known that it is of little value for that purpose. A close agreement of the separate measures of a given direction is of little consequence, since such measures are usually subject to constant errors of considerable size, which become evident as soon as the closures of the triangles are studied or an attempt is made to adjust a figure. For example, the probable error of a direction computed from the figure adjustment, and therefore including the constant as well as the accidental errors of the measures, is for the observations of 1900–1901, $\pm 0''.29$ (see page 375). This probable error refers to the mean of 16 measures. Hence the probable error of a single measure of a direction should be four times as great, namely, $\pm 1''.16$, and for a single measure of an angle should be $\sqrt{2}$ times as large, namely, $\pm 1''.64$. If this probable error were due in the main to accidental errors in the angle measures, the range of such measures should occasionally approach or exceed seven times this value, or $11''.5$. As a matter of fact, the range of such measures at these stations never exceeds $7''.5$, and seldom exceeds $6''.5$. This triangulation is therefore no exception to the general rule that the accidental errors in the angle measures are less serious than the constant errors.

THE ACCORD OF THE BASES AND THE ACCURACY OF THE LENGTHS.

In solving the normal equations of the figure adjustment, between Meades Ranch–Waldo and the line Lowell–Prosser of the Shelton base net, the length equation was as usual assigned the last place, so that the discrepancy in length, after all the conditions relating to closures of triangles and ratios of lengths had been satisfied, became known. It thus became evident that the Shelton base, as computed from the line Meades Ranch–Waldo, which in turn depends for its length on the Salina and El Paso bases (but mainly on the former) was shorter by 1 part in 58 000 than its measured length (represented by 75 in the seventh decimal place of logarithms). In other words, after the angles have been adjusted to close all triangles and to make the computed length of each side the same, whatever one of the several possible chains of triangles are used, the best length which can be derived for the Shelton Base from the triangulation from the southward differs from its measured length by 1 part in 58 000.

Similarly the best length which can be derived for the Page Base as computed from the triangulation connecting it with the Shelton Base is 1 part in 270 000 longer than its measured length. (This discrepancy is represented by 16 in the seventh decimal place of logarithms.)

For comparison it may be noted that the nine discrepancies of this nature between bases on the transcontinental triangulation varied from 1 part in 724 000 to 1 part in 25 700.* Five out of the nine discrepancies were greater than that between the Salina and Shelton bases and seven greater than that between the Shelton and Page bases.

To put the accuracy with which the lengths are determined in evidence, the probable errors for certain lines have been computed from the probable errors of the base measures and of the angle measures.

The length of the line Thompson–Heath at the edge of the Salina base net, depending on the measures of the Salina Base and the angle measures in the base net, is $31\ 563^{m}.71 \pm 0^{m}.16$, its probable error being, therefore, 1 part in 200 000.

Similarly the length of the line Meades Ranch–Waldo from the adjustment is $25\ 783^{m}.11$ and its probable error is $\pm 0^{m}.204$, or 1 part in 126 000. This probable error has been computed as if Meades Ranch–Waldo depended for its length on the Salina Base alone, whereas its length is really dependent on both the Salina and El Paso bases. As the Salina Base is, however, very much nearer than the El Paso Base, the above probable error is but little too large.

The adjusted length of the line Lipps–Cooper which is about midway between Meades Ranch–Waldo and Lowell–Prosser, the two fixed lines in the adjustment, is $22\ 983^{m}.18$. The probable error of this line, when computed from the southward only, depends upon the probable error of Meades Ranch–Waldo, as shown above, and the additional errors accumulated in the intervening angle measures and is $\pm 0^{m}.227$, or 1 part in 101 000. Its probable error when computed from the northward alone depends upon the probable error of the line Lowell–Prosser, as shown below, and the errors accumulated in the intervening angle measures, and is $\pm 0^{m}.135$, or 1 part in 170 000. The length of the line Lipps–Cooper as fixed in the adjustment is necessarily nearly a mean between its two possible independent lengths, as computed from the southward and northward, respectively. Hence, with sufficient accuracy the probable error of the adjusted length of the line Lipps–Cooper is $\frac{1}{2}\sqrt{(0.227)^2+(0.135)^2}$, or 1 part in 174 000.

We may note here that twice 1 part in 174 000, or 1 part in 87 000, represents the probable error of the discrepancy between the two bases, Salina and Shelton, as brought together on this line, since the probable error of the difference of the two quantities is necessarily double the probable error of their mean. The actual discrepancy between the bases is 1 part in 58 000, not very different from its probable error, but somewhat in excess of it. The lengths of the lines Lowell–Prosser and Valley–Cameron at the edge of the Shelton base net are respectively 22 944.02 and 21 180.56 meters and their

*See the "Transcontinental Triangulation," pp. 613–614.

probable errors are $\pm0^{m}.069$ and $\pm0^{m}.051$, or 1 part in 333 000 and 1 part in 415 000, respectively. These probable errors are computed from the probable error of the Shelton base measures and the computed errors of the angle measures in the Shelton base net.

Similarly the length of the line Prairie–Walnut, near the Page Base, and its probable error, as computed from the uncertainties as in measures of the Page Base and in the angles concerned, are 18 $196^{m}.70$ and $\pm0^{m}.030$, or the probable error is 1 part in 607 000.

The line Buffalo–Ono is about midway between the two fixed lines in the adjustment covering this region. It is eight triangles from Valley–Cameron and six triangles from the Page Base. The probable error of its length, as computed from the southward only, including the uncertainty in the length of Valley–Cameron, shown above, is $\pm0^{m}.164$. The probable error of its length, as computed from the northward only, depending upon the uncertainties of the Page Base measures and the uncertainties in the angle measures in the intervening triangulation, is $\pm0^{m}.167$. The length of this line as fixed by the adjustment being necessarily nearly a mean between its two possible independent lengths, computed from the southward and northward, its probable error is $\pm0^{m}.117$, or 1 part in 229 000, its adjusted length being 26 $747^{m}.68$.

The probable error of the discrepancy between the Shelton and the Page bases is 2 parts in 229 000, or 1 part in 114 000. The actual discrepancy is 1 part in 270 000, very much smaller than its probable error.

ACCURACY AND ECONOMY.

In fixing the method of triangulation along the ninety-eighth meridian the aim has constantly been to hold the accuracy up to the standard fixed by the best half of the transcontinental triangulation, a standard of accuracy which compares very favorably with that actually attained in any country. With equal constancy there has been kept in view the desirability of reducing the cost of the triangulation and the time required for it as much as possible while holding the accuracy up to this high standard. The time required for, and the cost of, the office computations have been kept in mind.

That the accuracy has been kept up to the selected standard and above it is put in evidence by the corrections to directions, closures of triangles, accord between bases, and probable errors of lengths as set forth in the preceding pages. It is also noticeable that the accuracy has not decreased with the gradual change of methods as the triangulation proceeds northward.

A considerable amount of time has been saved in the office part of the work by omitting all corrections for run during the latter part of the work and by making very few local adjustments, the former being entirely unnecessary with the present programme of observation and the latter but seldom needed. A small amount of time has also been saved in the field by utilizing the field computation as an insurance against loss and making no duplicates of records except of the descriptions of stations.

The principal saving in the field in time and money has been in the reduction of the number of observations of each direction. The reduction from 34 to 16 observations saves on an average seven days at each station. During 1900 it took on an average fourteen days to make the observations at a station and to move to the next and prepare for observation. If the change were made back from the 16-observation programme of 1900 to the 34-observation programme of 1896 it would take seven days, or 50 per cent, longer at each station, the cost would be increased in nearly that ratio, and the increase in accuracy would be imperceptible. Even to go back to the programme of from 22 to 26 observations used in 1897–1899 would increase the time at each station by more than two days, or 14 per cent, with a corresponding increase of cost.

EXPLANATION OF POSITIONS, LENGTHS, AND AZIMUTHS, AND OF THE UNITED STATES STANDARD DATUM.

The lengths, as already fully explained in connection with the adjustments, all depend upon the Page, Shelton, Salina, and El Paso Bases, the last mentioned having but little effect upon the lengths.

The positions—that is, the latitudes, longitudes, and the azimuths—need a special explanation.

All of the positions and azimuths have been computed upon the Clark spheroid of 1866, which has been in use in the Coast and Geodetic Survey for many years.

After a spheroid has been adopted and all the angles and lengths in a triangulation have been fully fixed, it is still necessary, before the computation of latitudes, longitudes, and azimuths can be made, to adopt a standard latitude and longitude for a specified station and a standard azimuth of a line from that station. For convenience let the adopted standard position (latitude and longitude) of a given station, together with the adopted standard azimuth of a line from that station, be called the *geodetic datum.*

The primary triangulation in the United States was commenced at various points, and existed at first as a number of detached portions in each of which the geodetic datum was necessarily dependent only upon the astronomic stations connected with that particular portion. As examples of such detached portions of triangulation there may be mentioned the early triangulation in New England and along the Atlantic coast, a detached portion of the transcontinental triangulation centering on St. Louis and another portion of the same triangulation in the Rocky Mountain region, and three separate portions of triangulation in California in the latitude of San Francisco, in the vicinity of Santa Barbara Channel, and in the vicinity of San Diego. With the lapse of time these separate pieces have expanded until they have touched or overlapped.

The transcontinental triangulation, of which the office computation was completed in 1899, joins all of the detached portions mentioned and makes them one continuous triangulation. As soon as this took place the logical necessity existed of discarding the old geodetic data used in these various pieces and substituting one datum for the whole country, or at least for as much of the country as is covered by continuous triangulation. To do this is a very heavy piece of work, and involved much preliminary study to determine the best datum to be adopted. On March 13, 1901, the Superintendent adopted what is now known as the United States Standard Datum, and it was decided to reduce the positions to that datum as rapidly as possible. The datum adopted was that formerly in use in New England, and therefore its adoption will not affect the positions which have been used for geographic purposes in New England* and along the Atlantic coast to North Carolina, or those in the States of

*Many such positions are published in Appendix No. 8, Report for 1885, Appendix No. 8, for 1888, and Appendix No. 10, for 1894.

New York, Pennsylvania, New Jersey, and Delaware. The adopted datum does not agree, however, with that used in "The Transcontinental Triangulation" and in "The Eastern Oblique Arc of the United States," publications which deal primarily with the purely scientific problem of the determination of the figure of the earth.

As the adoption of such a standard datum is a matter of considerable importance, it is in order here to explain the desirability of this step more fully.

The main objects to be attained by the geodetic operations of the Coast and Geodetic Survey are, first, the control of the charts published by the Survey; second, the furnishing of geographic positions (latitudes and longitudes), of accurately determined elevations, and of distances and azimuths to engineers connected with the Coast and Geodetic Survey and to other organizations; third, the determination of the figure of the earth. The first two of these objects are purely practical; the third is purely scientific. For the first and second objects it is not necessary that the reference spheroid should be accurately that which most closely fits the geoid within the area covered, nor that the adopted geodetic datum should be absolutely the best that can be derived from the astronomic observations at hand. It is desirable simply that the reference spheroid and the geodetic datum adopted shall be, if possible, such a close approximation to the truth that any correction which may hereafter be derived from the observatians which are now or may become available shall not greatly exceed the probable errors of such corrections. It is, however, very desirable that one spheroid and one geodetic datum be used for the whole country. In fact, this is absolutely necessary if a geodetic survey is to perform fully the function of accurately coordinating all surveys within the area which it covers. This is the most important function of a geodetic survey. To perform this function it is also highly desirable that when a certain spheriod and geodetic datum have been adopted for a country they should be rigidly adhered to without change for all time, unless shown to be largely in error.

In striving to attain the third object, the determination of the figure of the earth, the conditions are decidedly different. This problem concerns itself primarily with astronomic observations of latitude, longitude, and azimuth, and with the geodetic positions of the points at which the astronomic observations were made, but is not concerned with the geodetic positions of other points fixed by the triangulations. The geodetic positions (latitudes and longitudes) of comparatively few points are therefore concerned in this problem. It is, however, in marked contrast to the statements made in preceding paragraphs, desirable in dealing with this problem, that with each new important accession of data, a new spheroid fitting the geoid with the greatest possible accuracy, and new values of the geodetic latitudes, longitudes, and azimuths of the highest degree of accuracy, should be derived.

The United States Standard Datum was adopted with reference to positions furnished for geographic purposes, but has no reference to the problem of the determination of the figure of the earth. It is adopted with reference to the engineer's problem of furnishing standard positions, and does not affect the scientist's problem of the determination of the figure of the earth.

The principles which guided in the selection of the datum to be adopted were: First, the adopted datum should not differ widely from the ideal datum in which the sum of the station errors in latitude, longitude, and azimuth should each be zero; second, it was desirable that the adopted datum should produce minimum changes in the publications of the Survey, including its charts; and third, it was desirable, other things being equal, to adopt that datum which allowed the maximum number of positions already in the office registers to remain unchanged, and therefore necessitated a miminum amount of new computation. These considerations led to the adoption as the United States Standard of the datum which had been in use for many years in the northeastern group of States and along the Atlantic coast as far as North Carolina.

An examination of the approximate station errors available on the United States Standard Datum at 204 latitude stations, 68 longitude stations, and 126 azimuth stations, scattered widely over the United States from Maine to Louisiana and to California, indicated that this datum approaches closely to the ideal with which the algebraic sum of the station errors of each class would be zero. How closely it approaches to that ideal will be set forth in a later publication.

The adopted United States Standard Datum, upon which the positions and azimuths given in this publication depend, may be defined in terms of the position of the station Meades Ranch, as follows:

$$\begin{array}{ll} & \quad {}^{\circ} \quad {}' \quad {}'' \\ \varphi & = 39 \; 13 \; 26.686 \\ \lambda & = 98 \; 32 \; 30.506 \\ \alpha \text{ to Waldo} & = 75 \; 28 \; 14.52 \end{array}$$

The positions here published on the United States Standard Datum therefore differ considerably from those given in the "Transcontinental Triangulation" (pp. 854–865), which depend upon a special geodetic datum which was adopted for the special purpose of that publication, and which was based upon the astronomic observations connected with that triangulation alone.

The position given for the station Meades Ranch, in the "Transcontinental Triangulation" (p. 862), is—

$$\begin{array}{ll} & \quad {}^{\circ} \quad {}' \quad {}'' \\ \varphi & = 39 \; 13 \; 25.006 \\ \lambda & = 98 \; 32 \; 30.469 \\ \alpha \text{ to Waldo} & = 75 \; 28 \; 16.52 \end{array}$$

The corrections to reduce this position to the United States Standard Datum are—

$$\begin{array}{l} \qquad\quad {}'' \\ \Delta\varphi = +1.680 \\ \Delta\lambda = +0.037 \\ \Delta\alpha = -2.00 \end{array}$$

Such corrections to reduce from a position on one datum to one on another are not constant, but vary slightly from station to station.

Index to positions, descriptions, and elevations.

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STATIONS IN KANSAS—Continued.

STATIONS IN NEBRASKA.

Index to positions, descriptions, and elevations—Continued.

STATIONS IN NEBRASKA—Continued.

TABLE OF POSITIONS, AZIMUTHS, AND LENGTHS.

The following tables give the positions of all points, and the azimuths and lengths of all lines, fixed by the triangulation here treated.

These tables may be conveniently consulted by using as finders the four sketches at the end of this appendix and the preceding index. In the second column of the index will be found for each point, first a reference to the page on which its position is given, and following this a reference to each page on which the azimuth and length of any line radiating from this point may be found.

The positions of all points for which the latitudes and longitudes are given to thousandths of seconds have been fixed by a complete adjustment of the triangulation concerned, so as to make all the triangles close and remove all discrepancies between lengths, azimuths, and positions. Such adjustments are of a very high degree of accuracy, as indicated in the preceding pages, for points on the primary scheme, of a less degree of accuracy for secondary points, and of a still more approximate character for tertiary points determined by intersections only. In each class all discrepancies are removed to the limit given by the decimal place shown. The statements in regard to the various degrees of accuracy refer to the manner in which the discrepancies were removed.

If less than three decimal places are given in the latitudes and longitudes the point in question has not been fixed by fully adjusted triangulation, or is fixed in such a way as to furnish no check on its position, and the accuracy with which its position is known is indicated in part by the number of decimal places given.

The seconds in meters are given for the convenience of draftsmen.

In the columns giving azimuths, distances, and logarithms of distances various numbers of decimal places are given, the intention being to indicate the accuracy to a certain extent, it being understood that in each quantity two doubtful figures are given. In some cases there is very little doubt of the correctness of the second figure from the right, and in a few cases some doubt may be cast upon the third figure.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Vine Creek	39 06 06.360	196.1					
	97 23 21.914	526.6					
Iron Mound	38 48 29.935	923.0	197 57 47.76	18 02 24.16	Vine Creek	34253.50	4.5347049
	97 30 41.549	1002.5					
Thompson	39 04 14.794	456.3	264 41 30.14	84 58 07.67	Vine Creek	38181.14	4.5818489
	97 49 44.067	1059.3	316 32 17.01	136 44 15.08	Iron Mound	40075.82	4.6028824
North Pole Mound	38 57 09.869	304.3	228 51 50.08	49 00 07.11	Vine Creek	25183.03	4.4011081
	97 36 31.235	752.1	332 14 15.85	152 17 55.35	Iron Mound	18113.49	4.2580021
			124 33 21.07	304 25 02.01	Thompson	23142.19	4.3644044
Salina East Base	38 52 25.110	774.2	345 46 19.74	165 47 07.53	Iron Mound	7481.14	3.8739678
	97 31 57.754	1392.2	143 08 26.59	323 05 34.80	North Pole Mound	10978.18	4.0405304
Salina West Base	38 51 07.674	236.6	177 28 56.39	357 28 43.58	North Pole Mound	11179.66	4.0484285
	97 36 10.840	261.4	248 36 22.26	68 39 01.06	Salina E. Base	6552.446	3.8164035
			301 27 14.28	121 30 40.75	Iron Mound	9313.81	3.9691274
Heath	38 50 40.442	1247.0	217 13 08.57	37 21 27.91	Thompson	31563.71	4.4991880
	98 02 58.247	1404.7	243 16 03.32	63 40 57.94	Vine Creek	63934.06	4.8057323
			252 25 45.16	72 42 21.71	North Pole Mound	40084.51	4.6029766
			274 45 16.98	95 05 31.22	Iron Mound	46890.33	4.6710833

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Lincoln	39 05 29.183	900.0	275 31 24.62	95 41 37.30	Thompson	23471.89	4.3705480
	98 05 55.923	1344.0	351 06 48.79	171 08 40.53	Heath	27737.76	4.4430713
Golden Belt	38 58 42.872	1321.9	235 05 58.82	55 13 50.26	Lincoln	21934.92	4.3411360
	98 18 24.488	589.4	255 57 27.70	76 15 30.98	Thompson	42631.89	4.6297346
			303 36 26.15	123 46 07.94	Heath	26820.24	4.4284626
Wilson	38 51 50.913	1569.9	230 56 08.33	51 02 57.34	Golden Belt	20182.61	4.3049773
	98 29 15.508	373.8	233 02 42.57	53 17 22.94	Lincoln	42091.26	4.6241919
			273 07 57.76	93 24 27.25	Heath	38094.10	4.5808577
Meades Ranch	39 13 26.686	823.0	290 53 50.41	111 10 37.33	Lincoln	41019.97	4.6129954
	98 32 30.506	731.7	314 30 36.47	134 49 12.64	Heath	59933.30	4.7776682
			323 12 24.56	143 21 18.14	Golden Belt	34001.33	4.5314959
			353 17 21.81	173 19 24.64	Wilson	40232.35	4.6045754
Bunker Hill	38 52 16.436	506.8	199 51 29.13	19 57 40.79	Meades Ranch	41661.11	4.6197308
	98 42 20.476	493.6	272 18 47.22	92 26 59.81	Wilson	18940.56	4.2773929
Waldo	39 09 55.645	1716.1	255 17 17.52	75 28 14.52	Meades Ranch	25783.11	4.4113352
	98 49 50.128	1203.4	318 17 14.47	138 30 11.69	Wilson	44734.45	4.6506421
			341 38 12.02	161 42 55.11	Bunker Hill	34407.64	4.5366549
Blue Hill	38 58 57.310	1767.1	228 48 22.76	48 58 32.79	Waldo	30876.87	4.4896332
	99 05 57.933	1394.4	240 45 31.84	61 06 37.98	Meades Ranch	55185.00	4.7418210
			289 46 43.15	110 01 33.78	Bunker Hill	36312.86	4.5600604
Allen	38 49 35.689	1100.5	131 19 58.31	311 11 23.81	Blue Hill	26260.11	4.4192965
	98 52 18.705	451.2	185 24 58.50	5 26 32.00	Waldo	37789.35	4.5773694
			250 59 06.05	71 05 21.30	Bunker Hill	15253.90	4.1833810
Ellsworth Water Tower, pole*	38 44 10.40	320.7	122 40 45.3	302 31 08.7	Wilson	26357.5	4.420904
	98 13 55.32	1336.2	232 45 52.8	52 52 44.5	Heath	19903.0	4.298919
Ellsworth Astronomic Station*	38 43 48.76	1503.5	159 29 28.4	339 29 21.9	Ellsworth W. Tower	712.5	2.85280
	98 13 44.98	1086.5					
Ellsworth North Base*	38 43 57.51	1773.3	29 09 59	209 09 55	Ellsworth Astr. Sta.	309.2	2.49018
	98 13 38.74	935.7	134 47 34	314 47 24	Ellsworth W. Tower	564.0	2.75132
Ellsworth South Base*	39 43 52.21	1609.9	9 06 17	189 06 16	Ellsworth Astr. Sta.	107.7	2.03232
	98 13 44.28	1069.5	219 14 25	39 14 29	Ellsworth N. Base	211.23	2.32475
			154 34 30	334 34 23	Ellsworth W. Tower	621.2	2.79320
Ellsworth Schoolhouse, cupola*	38 43 50.06	1543.6	27 16 26	207 16 25	Ellsworth Astr. Sta.	45.0	1.65358
	98 13 44.13	1065.8	176 54 02	356 54 02	Ellsworth S. Base	66.4	1.82239
			209 29 16	29 29 19	Ellsworth N. Base	264.1	2.42185
Salina, Phillips' House, dome	38 50 20.26	624.7	140 15 11	320 05 51	Thompson	33508.0	4.525148
	97 34 52.83	1274.2	299 16 49	119 19 26	Iron Mound	6951.0	3.842046
			91 01 27	270 43 50	Heath	40652.0	4.609082
Salina, St. John's Military College, vane on tower	38 51 45.51	1403.3	140 29 58	320 21 39	Thompson	29974.0	4.476745
	97 36 30.95	746.2	305 33 30	125 37 09	Iron Mound	10362.8	4.015479
			87 08 15	266 51 39	Heath	38327.1	4.583506
Soldier Cap Mound*	38 42 58.46	1802.6	176 04 43	356 03 32	Thompson	39450.5	4.596052
	97 47 51.84	1252.5	247 34 20	67 45 05	Iron Mound	26893.2	4.429643
Sugar Loaf Mound, rock pile	38 49 28.37	874.8	102 10 52	282 06 23	Heath	10564.5	4.023851
	97 55 50.04	1207.1	153 50 19	333 43 57	Lincoln	33025.4	4.518848
			197 50 17	17 54 07	Thompson	28720.0	4.458185
			272 42 11	92 57 57	Iron Mound	36437.5	4.561549
Lincoln College, cupola	39 01 59.80	1844.1	337 54 14	157 57 55	Heath	22604.8	4.354201
	98 08 50.84	1222.8	66 18 09	246 12 08	Golden Belt	15079.6	4.178391
			121 58 19	301 43 23	Meades Ranch	40143.6	4.603616
Turkey Point	38 56 17.33	534.4	112 09 00	292 04 11	Golden Belt	11923.9	4.076417
	98 10 45.68	1100.2	202 15 04	22 18 06	Lincoln	18390.1	4.264583
			244 00 57	64 14 11	Thompson	33739.1	4.528134
			312 38 26	132 43 19	Heath	15324.1	4.185374
Small Peak	39 15 22.39	690.5	300 44 08	120 57 35	Lincoln	35677.0	4.552388
	98 27 11.91	285.6	337 36 24	157 41 57	Golden Belt	33325.4	4.522776
			3 55 00	183 53 42	Wilson	33627.4	4.639759
			64 59 46	244 56 24	Meades Ranch	8432.6	3.925961

* No check on this position.

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Lone Tree (cotton-	39 03 36.31	1119.8	71 27 54	251 16 11	Golden Belt	28321.5	4.452116
wood)*	97 59 48.92	1176.2	111 33 53	291 30 01	Lincoln	9483.7	3.976979
Bunker Hill Water	38 52 15.48	477.3	50 13 06	230 01 51	Fairmount	33923.6	4.530502
Tower	98 42 18.17	438.0	71 15 37	251 09 20	Allen	15296.8	4.184600
			110 02 26	289 47 34	Blue Hill	36374.2	4.560794
			161 38 32	341 33 48	Waldo	34453.2	4.537229
			272 13 51	92 22 02	Wilson	18883.7	4.276088
Bunker Hill Method-	38 52 34.29	1057.3	69 32 01	249 25 38	Allen	15712.1	4.196234
ist Church, spire	98 42 08.46	203.9	160 57 45	340 52 54	Waldo	33978.7	4.531207
			274 02 17	94 10 22	Wilson	18681.8	4.271418
Bunker Hill School-	38 52 34.81	1073.4	69 41 51	249 35 24	Allen	15878.8	4.200817
house, cupola	98 42 01.34	32.3	160 40 52	340 35 57	Waldo	34020.0	4.531734
			199 31 27	19 37 27	Meades Ranch	40878.1	4.612491
			274 07 34	94 15 35	Wilson	18511.9	4.267450
Bunker Hill Flouring	38 52 30.80	949.7	49 27 24	229 16 13	Fairmount	34119.8	4.533007
Mill, iron chimney	98 42 24.02	579.0	69 25 06	249 18 53	Allen	15322.8	4.185338
			161 37 02	341 32 21	Waldo	33960.4	4.530973
Russell Tripod	38 54 39.51	1218.3	294 51 35	114 55 43	Bunker Hill	10481.0	4.020404
	98 48 54.96	1324.2	27 41 08	207 39 00	Allen	10578.2	4.024410
			177 19 01	357 18 26	Waldo	28282.3	4.451514
Russell High School,	38 53 19.51	601.6	116 50 25	296 41 26	Blue Hill	23131.2	4.364199
cupola, pole	98 51 40.44	974.6	184 55 44	4 56 53	Waldo	30832.4	4.489008
			216 30 10	36 42 15	Meades Ranch	46371.3	4.666249
			278 09 03	98 14 54	Bunker Hill	13636.2	4.134714
			7 37 04	187 36 40	Allen	6963.1	3.842802
			27 45 17	207 39 54	Fairmount	26796.6	4.428079
Russell Northwest	38 53 36.93	1138.7	283 28 32	103 33 01	Bunker Hill	10623.1	4.026250
Base	98 49 29.00	698.9	28 49 37	208 47 50	Allen	8490.0	3.928910
			112 36 52	292 26 30	Blue Hill	25785.5	4.411376
			179 02 16	359 02 03	Waldo	30185.0	4.479791
Russell Southeast Base	38 51 22.30	687.6	66 20 03	246 16 48	Allen	8181.2	3.912819
	98 47 08.07	194.6	117 22 07	297 10 17	Blue Hill	30622.8	4.486045
			140 43 05	320 41 36	Russell NW. Base	5364.4	3.729521
			173 32 05	353 30 24	Waldo	34553.0	4.538486
			256 26 19	76 29 20	Bunker Hill	7132.0	3.853213
Russell North School,	38 53 53.99	1664.7	280 02 45	100 04 02	Russell NW. Base	3012.9	3.478980
tall cupola	98 51 32.10	773.5	282 42 03	102 47 49	Bunker Hill	13631.5	4.134543
			306 17 30	126 20 15	Russell SE. Base	7898.5	3.897543
			184 43 12	4 44 18	Waldo	29755.7	4.473570
Blue Hill, U. S. Geolog-	39 20 29.64	914.0	325 49 25	145 57 41	Lincoln	33537.2	4.525527
ical Survey	98 18 59.83	1432.8	358 47 26	178 47 49	Golden Belt	40306.9	4.605379
Russell SE. Base Astr.	38 51 22.30	687.6	90	270	Russell SE. Base	6.16	0.78958
Sta.	98 47 07.81	188.3					
Salina Paper Mill, tall	38 50 54.29	1674.1	138 41 38	318 41 28	Salina West Base	549.4	2.739881
brick chimney	97 35 55.80	1345.6	175 47 13	355 46 51	North Pole Mound	11612.9	4.064941
			300 23 43	120 27 00	Iron Mound	8790.7	3.944022
New Cambria Stone	38 52 44.04	1358.0	2 57 18	182 57 07	Iron Mound	7846.2	3.894658
Church, white spire*	97 30 24.78	597.3	132 54 30	312 50 40	North Pole Mound	12047.2	4.080887
Section 31, T. 13, R. 12,	38 52 15.02	463.2	232 53 37	52 53 39	Bunker Hill	72.6	1.86096
SW. cor., stone	98 42 22.88	551.6					
Section 13, T. 11, R. 1,	39 06 52.08	1606.0	352 19 48	172 19 48	Vine Creek	142.2	2.15305
NW. cor., stone	97 23 22.70	545.4					
Section 22, T. 14, R. 14,	38 49 38.06	1173.6	302 27 11	122 27 14	Allen	136.2	2.13413
NW. cor., stone	98 52 23.47	566.1					
Dial	39 15 03.832	118.2	278 37 23.35	98 46 00.02	Meades Ranch	19817.10	4.2970402
	98 46 07.314	175.4	29 22 38.29	209 20 17.44	Waldo	10904.29	4.0375973
Kill Creek	39 16 51.330	1583.0	286 31 07.37	106 36 01.72	Dial	11631.36	4.0656305
	98 53 52.373	1255.2	335 35 37.51	155 38 10.69	Waldo	14074.56	4.1484348
Lawrence 2	39 31 13.088	403.6	345 35 22.00	165 38 45.23	Dial	30858.07	4.4893688
	98 51 27.586	659.0	7 26 23.19	187 24 51.29	Kill Creek	26800.75	4.4281469

* No check on this position.

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Old Well 2	39 36 42.774	1319.1	357 12 09.17	177 13 04.86	Meades Ranch	43105.42	4.6345318
	98 33 58.209	1388.6	23 35 17.61	203 27 34.51	Dial	43689.32	4.6403753
			68 00 02.01	247 48 53.58	Lawrence 2	27034.11	4.4319121
Brown	39 46 37.160	1146.0	327 00 59.85	147 06 18.22	Old Well 2	21842.53	4.3393029
	98 42 16.680	397.0	24 47 36.18	204 41 44.66	Lawrence 2	31380.06	4.4966538
Lipps	39 59 40.677	1254.5	331 25 06.55	151 31 01.13	Brown	27505.66	4.4394220
	98 51 29.619	702.6	359 56 49.80	179 56 51.10	Lawrence 2	52663.94	4.7215133
Lebanon	39 49 41.533	1280.9	7 58 23 47	187 56 53.36	Old Well 2	24251.31	4.3847352
	98 31 37.195	884.5	69 33 43.46	249 26 54.10	Brown	16240.88	4.2106096
Cooper	39 58 41.987	1294.9	342 04 23.34	162 06 48.79	Lebanon	17517.19	4.2434644
	98 35 23.929	567.7	23 43 35.68	203 39 11.05	Brown	24412.03	4.3876039
			94 36 12.19	274 25 51.63	Lipps	22983.18	4.3614101
Herrick	40 14 55.800	1721.2	335 19 24.94	155 25 30.19	Cooper	33040.00	4.5190400
	98 45 05.248	124.0	17 54 24.71	197 50 17.02	Lipps	29656.35	4.4721177
Blue Hill (Nebr.)	40 17 33.261	1025.9	11 05 42.51	191 02 36.64	Cooper	35553.50	4.5508824
	98 30 35.592	840.7	42 00 50.97	221 47 22.49	Lipps	44447.50	4.6478473
			76 46 45.95	256 37 23.80	Herrick	21113.72	4.3245648
Sand Creek	40 26 33.232	1025.0	313 39 07.92	133 47 06.06	Blue Hill	24098.72	4.3819940
	98 42 53.812	1268.2	8 13 02.65	188 11 37.56	Herrick	21734.30	4.3371456
Lars	40 27 06.162	190.1	273 13 31.04	93 21 37.04	Sand Creek	17683.28	4.2475627
	98 55 22.955	540.9	327 02 14.81	147 08 54.75	Herrick	26832.69	4.4286641
Lowell	40 36 22.800	703.3	331 55 02.54	151 59 29.96	Sand Creek	20604.89	4.3139702
	98 49 45.383	1067.0	24 51 48.09	204 48 08.72	Lars	18918.97	4.2768974
Wanda	40 35 01.377	42.5	341 19 22.84	161 24 22.87	Blue Hill	34117.60	4.5329785
	98 38 18.154	427.0	22 31 00.45	202 28 01.38	Sand Creek	16964.23	4.2295343
			98 53 46.93	278 46 19.74	Lowell	16353.50	4.2136107
Mason	40 35 06.889	212.5	6 01 37.14	186 00 02.91	Blue Hill	32678.76	4.5142656
	98 28 10.325	242.8	52 46 53.57	232 37 19.62	Sand Creek	26146.53	4.4174141
			89 22 24.44	269 15 49.00	Wanda	14295.73	4.1552063
Prosser	40 42 07.838	241.8	322 04 56.21	142 09 36.20	Mason	16450.46	4.2161780
	98 35 20.189	473.9	17 39 03.37	197 37 07.45	Wanda	13803.22	4.1399804
			62 26 28.43	242 17 04.76	Lowell	22944.02	4.3606695
Shelton East Base	40 46 38.396	1184.4	302 24 41.18	122 30 46.09	Prosser	15548.87	4.1916988
	98 44 39.333	922.4	20 45 22.57	200 42 03 03	Lowell	20303.04	4.3075610
Shelton West Base	40 45 11.763	362.8	250 09 34.96	70 13 01.48	Shelton East Base	7884.72	3.8967864
	98 49 55.610	1304.6	285 21 30.99	105 31 02.18	Prosser	21312.86	4.3286418
			359 09 20.72	179 09 27.39	Lowell	16318.19	4.2126719
Valley	40 50 57.044	1759.6	302 41 19 63	122 53 05.43	Prosser	30145.34	4.4792202
	98 53 20.885	489.2	303 05 06.31	123 10 47.19	Shelton East Base	14597.16	4.1642682
			335 40 05.82	155 42 19.96	Shelton West Base	11687.38	4.0677171
			349 21 32.25	169 23 52.86	Lowell	27437.34	4.4383420
Cameron	40 56 45.479	1402.9	345 22 09.41	165 25 26.19	Prosser	27976.24	4.4467893
	98 40 21.191	495.7	17 54 56.49	197 52 07.60	Shelton East Base	19678.44	4.2939907
			59 34 34.56	239 26 04.09	Valley	21180.56	4.3259375
Deer	41 13 00.766	23.6	338 18 24.80	158 24 00.93	Cameron	32368.59	4.5101238
	98 48 52.701	1227.6	8 44 48.14	188 41 52.08	Valley	41311.92	4.6160754
Divide	41 11 21.112	651.3	261 08 07.63	81 17 29.94	Deer	20125.46	4.3037458
	99 03 06.332	147.6	310 09 21.90	130 24 18.73	Cameron	41779.19	4.6209600
			340 01 59.97	160 08 24.21	Valley	40161.20	4.6038067
Pompey	41 06 25.530	787.5	14 10 49.76	194 05 32.93	Prosser	46370.04	4.6662375
	98 27 16.319	380.8	45 46 19.21	225 37 44.01	Cameron	25620.15	4.4085817
			112 05 15.98	291 51 02.71	Deer	32590.68	4.5130935
Yale	41 30 33.296	1027.2	329 04 28.24	149 13 39.63	Deer	37821.13	4.5777345
	99 02 47.100	1092.3	0 43 20.74	180 43 08.03	Divide	35547.37	4.5508075
Brayton	41 27 58.053	1791.0	347 31 31.89	167 35 41.29	Pompey	40832.16	4.6110024
	98 33 34.309	796.2	37 43 50.87	217 33 44.23	Deer	34959.83	4.5435693
			96 52 43.62	276 33 22.47	Yale	40942.95	4.6121791

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Custer	41 38 11.330	349.5	3 27 23.03	183 26 50.37	Brayton	18954.46	4.2777115
	98 32 45.067	1043.2	71 28 01.21	251 08 05.43	Yale	44075.97	4.6442019
Daily	41 35 45.236	1395.6	242 14 37.63	62 18 43.66	Custer	9688.99	3.9862783
	98 38 55.516	1285.7	332 38 49.42	152 42 22.39	Brayton	16222.91	4.2101288
			73 57 22.61	253 41 33.04	Yale	34544.82	4.5383829
Elm	41 44 00.909	28.0	292 27 44.53	112 40 10.79	Custer	28104.43	4.4487748
	98 51 27.207	628.8	311 15 25.66	131 23 45.34	Daily	23157.70	4.3646953
			32 20 39.90	212 13 08.31	Yale	29471.05	4.4693956
Ono	41 49 28.411	876.5	23 38 55.27	203 34 32.28	Custer	22797.84	4.3578937
	98 26 09.961	229.9	74 03 17.45	253 46 26.57	Elm	36467.23	4.5619027
Buffalo	41 55 47.859	1476.6	295 51 33.28	116 03 09.50	Ono	26747.68	4.4272861
	98 43 32.927	758.6	335 17 09.64	155 24 21.33	Custer	35865.46	4.5546764
			26 41 24.10	206 46 07.78	Elm	24402.79	4.3874394
Deloit	42 08 41.579	1282.9	9 22 17.69	189 19 27.50	Ono	36057.72	4.5569983
	98 21 55.540	1275.3	51 27 44.90	231 13 16.15	Buffalo	38214.93	4.5822331
McClure	42 12 04.636	143.0	291 47 14.74	111 54 51.75	Deloit	16833.15	4.2261653
	98 33 16.247	372.7	346 46 03.16	166 50 48.48	Ono	42978.35	4.6332497
			25 15 08.14	205 08 14.97	Buffalo	33305.61	4.5225174
Hall	42 18 03.421	105.6	30 10 18.17	210 05 23.35	Deloit	20043.58	4.3019752
	98 14 36.834	843.7	66 46 10.57	246 33 37.90	McClure	27947.41	4.4463415
Page Southwest Base	42 25 25.518	787.4	311 03 11.69	131 10 51.85	Hall	20743.59	4.3168839
	98 25 59.745	1365.8	349 44 17.87	169 47 02.18	Deloit	31477.62	4.4980019
			22 03 58.32	201 59 04.48	McClure	26656.61	4.4258050
Old	42 27 47.430	1463.5	344 36 15.64	164 38 41.65	Hall	18688.67	4.2715785
	98 18 13.438	307.0	67 42 25.02	247 37 10.33	Page SW. Base	11521.60	4.0615129
Page Northeast Base	42 28 53.601	1653.9	290 26 27.20	110 29 08.93	Old	5840.12	3.7664217
	98 22 12.960	296.0	38 55 46.01	218 53 12.94	Page SW. Base	8250.99	3.9165060
Walnut	42 35 10.185	314.3	359 38 02.40	179 38 08.36	Hall	31682.15	4.5008147
	98 14 45.669	1041.3	19 09 44.77	199 07 24.34	Old	14461.37	4.1602095
			40 31 51.28	220 24 15.84	Page SW. Base	23713.36	4.3749931
			41 20 25.31	221 15 22.93	Page NE. Base	15466.81	4.1894007
Prairie	42 32 29.669	915.5	304 12 48.15	124 19 06.39	Old	15467.56	4.1894218
	98 27 33.286	759.5	312 19 29.45	132 23 05.91	Page NE. Base	9895.82	3.9954517
			350 43 11.18	170 44 14.35	Page SW. Base	13260.80	4.1225696
			254 08 00.14	74 16 39.37	Walnut	18196.70	4.2599926
Lawrence, U. S. G. S.	39 31 13.081	403.4	93 27	273 27	Lawrence 2	3.377	0.52853
	98 51 27.445	655.6					
Old Well, U. S. G. S.	39 36 42.824	1320.7	67 58 10.7	247 47 03.2	Lawrence, U. S. G. S	27003.1	4.431413
	98 33 59.502	1419.4	272 52 31	92 52 32	Old Well 2	30.875	1.48961
Tipton, U. S. G. S.	39 21 33.77	1041.4	3 07 33	183 07 12	Meades Ranch	15043.1	4.177338
	98 31 56.31	1348.1	59 32 42	239 23 43	Dial	23671.8	4.374231
			122 38 05	302 25 41	Lawrence 2	33222.6	4.521433
			174 04 40	354 03 22	Old Well 2	28184.4	4.450009
Medicine Peak	39 21 37.40	1153.4	47 51 36	227 45 42	Dial	18072	4.25701
	98 36 48.44	1159.7	70 18 29	250 07 40	Kill Creek	26066	4.41607
Covert	39 21 40.58	1251.4	23 17 00	203 14 41	Dial	13318.0	4.124439
	98 42 27.77	664.8	61 31 02	241 23 48	Kill Creek	18668.3	4.271104
			143 52 31	323 46 48	Lawrence 2	21871.7	4.339882
			203 35 32	23 40 56	Old Well 2	30371.5	4.482466
Section 16, T. 5, R. 11, SE. corner	39 36 39.57	1220.3	102 14 44	282 14 32	Old Well 2	466.0	2.66839
	98 33 39.12	933.3					
Hardilee, U. S. G. S.	39 50 52.82	1629.1	205 48 53	25 52 26	Lipps	18089.5	4.257426
	98 57 01.67	39.7	290 27 21	110 36 48	Brown	22478.6	4.351769
			347 37 40	167 41 13	Lawrence 2	37244.5	4.571063
Smith Center Standpipe	39 46 39.90	1230.6	163 46 41	343 43 33	Lipps	25082.2	4.399366
	98 46 34.26	815.3	270 46 05	90 48 50	Brown	6130.4	3.787487
			13 46 29	193 43 22	Lawrence 2	29426.6	4.468740

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Smith Center Court-House, cupola, Kans.*	39 46 33.57 98 46 53.49	1035.3 1273.0	164 54 01 269 00 48	344 51 04 89 03 45	Lipps Brown	25146.7 6588.5	4.400481 3.818786
Lebanon Methodist Church, spire	39 48 36.36 98 33 16.66	1121.3 396.3	2 34 44 74 04 50 229 38 22	182 34 17 253 59 04 49 39 26	Old Well 2 Brown Lebanon	22030.1 13364.1 3104.2	4.343017 4.125940 3.491949
Lebanon Schoolhouse, cupola*	39 48 38.39 98 33 21.35	1183.9 507.9	73 41 18 231 48 59	253 35 35 51 50 05	Brown Lebanon	13274.3 3151.0	4.123012 3.498443
Kansas-Nebraska State Line A	40 00 08.37 98 51 28.78	258.2 682.7	198 19 13 276 33 08 1 20 05	18 23 20 96 43 28 181 20 05	Herrick Cooper Lipps	28838.4 23045.1 854.21	4.459971 4.362579 2.931566
Kansas-Nebraska State Line B	40 00 08.42 98 50 25.93	259.7 615.1	195 28 36 277 01 14 60 28 54	15 32 03 97 10 54 240 28 12	Herrick Cooper Lipps	28403.2 21564.8 1736.4	4.453367 4.333746 3.239661
Kansas-Nebraska State Line 1*	40 00 08.38 98 50 20.86	258.5 494.8	277 03 27 90 33 17	97 13 04 270 33 14	Cooper K.-N. State Line B	21445.2 120.4	4.331331 2.08061
Kansas-Nebraska State Line 2*	40 00 08.37 98 50 29.88	258.2 708.8	276 59 08 269 07 12	97 08 51 89 07 14	Cooper K.-N. State Line B	21657.8 93.8	4.335614 1.97218
Kansas-Nebraska State Line C*	40 00 08.67 98 34 30.28	267.4 718.2	25 27 51 151 16 10	205 27 17 331 09 21	Cooper Herrick	2960.9 31220.4	3.471423 4.494438
Red Cloud Standpipe*	40 05 46.75 98 31 20.94	1442.0 496.0	23 45 30 68 36 03	203 42 54 248 23 05	Cooper Lipps	14311.4 30796.5	4.155683 4.488502
Upland Elevator	40 19 08.51 98 54 00.00	262.5 0.0	172 26 31 301 37 41 354 20 37	352 25 38 121 43 27 174 22 14	Lars Herrick Lipps	14862.4 14843.4 36195.0	4.172090 4.171532 4.558649
Campbell Smoke-stack*	40 18 03.02 98 43 44.81	93.2 1058.3	272 44 51 18 13 27	92 53 21 198 12 35	Blue Hill Herrick	18662.5 6079.0	4.270969 3.783833
Campbell School-house, cupola*	40 17 47.23 98 43 59.54	1456.8 1406.3	271 13 38 16 22 07	91 22 18 196 21 25	Blue Hill Herrick	18993.3 5510.7	4.278600 3.741204
Madden	40 21 07.46 98 43 52.57	230.1 1240.7	8 31 21 124 15 43 187 50 48	188 30 34 304 08 15 7 51 26	Herrick Lars Sand Creek	11591.3 19684.0 10143.4	4.064132 4.294114 4.006183
Danish Lutheran Church, spire*	40 25 14.28 98 55 51.80	440.5 1221.2	191 08 27 321 16 51	11 08 46 141 23 50	Lars Herrick	3517.4 24430.1	3.546223 4.387925
Bladen Congregational Church, spire*	40 19 26.19 98 35 35.66	807.8 841.9	296 09 05 58 15 30	116 12 19 238 09 22	Blue Hill Herrick	7895.6 15830.0	3.897385 4.199480
Blue Hill Standpipe	40 19 58.90 98 26 59.98	1816.7 1415.8	48 35 41 70 03 36 118 28 59 150 12 13 176 37 09	228 33 21 249 51 54 298 18 41 330 04 53 356 36 24	Blue Hill Herrick Sand Creek Wanda Mason	6789.6 27285.6 25575.0 32097.4 28055.9	3.831844 4.435934 4.407816 4.506470 4.448024
Blue Hill Schoolhouse, cupola	40 19 43.75 98 26 59.29	1349.5 1399.7	51 47 01 119 22 40 150 35 19 176 38 34	231 44 41 299 12 21 330 27 59 356 37 48	Blue Hill Sand Creek Wanda Mason	6502.9 25815.3 32511.4 28523.3	3.813110 4.411877 4.512035 4.455200
Carter	40 28 04.17 98 32 05.12	128.6 120.6	353 47 55 79 39 38 145 43 36 202 57 02	173 48 53 259 32 38 325 39 34 22 59 35	Blue Hill Sand Creek Wanda Mason	19574.1 15540.3 15578.9 14161.9	4.291681 4.191460 4.192536 4.151120
White Spire	40 31 58.559 98 37 42.609	1806.2 1002.8	339 17 37.6 36 10 19.9 115 40 41.8 171 34 04.5 246 36 36.4	159 22 14.3 216 06 57.8 295 32 51.6 351 33 41.4 66 42 48.5	Blue Hill Sand Creek Lowell Wanda Mason	28525.7 12426.4 18854.5 5700.8 14663.6	4.455236 4.094344 4.275414 3.755933 4.166242
Methodist Church, spire*	40 30 35.82 98 38 49.69	1104.9 1169.9	37 33 56 185 10 21	217 31 17 5 10 42	Sand Creek Wanda	9437.0 8224.8	3.974836 3.915127
Juniata Schoolhouse, cupola	40 35 18.81 98 30 04.58	580.2 107.7	277 46 57 1 16 37 87 23 32 149 34 59	97 48 11 181 16 17 267 18 11 329 31 34	Mason Blue Hill Wanda Prosser	2711.9 32874.8 11620.0 14634.8	3.433273 4.516863 4.065205 4.165386

* No check on this position.

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Insane Asylum Stand-	40 35 02.69	83.0	10 18 41	190 15 59	Blue Hill	32898.5	4.517176
pipe	98 26 26.28	618.1	56 02 00	235 51 19	Sand Creek	28061.6	4.448112
			89 55 33	269 47 50	Wanda	16741.7	4.223800
			93 02 20	273 01 13	Mason	2450.3	3.389226
			136 19 05	316 13 17	Prosser	18148.3	4.258837
Hastings Standpipe	40 35 54.20	1671.8	16 53 14	196 48 31	Blue Hill	35481.2	4.549998
	98 23 19.21	451.6	58 04 06	237 51 23	Sand Creek	32618.0	4.513458
			77 59 30	257 56 21	Mason	6999.2	3.845050
			85 40 23	265 30 38	Wanda	21201.8	4.326373
			124 17 46	304 09 56	Prosser	20488.0	4.311499
Hastings Court-House,	40 35 11.65	359.3	17 29 19	197 24 37	Blue Hill	34220.6	4.534288
cupola	98 23 20.21	475.3	88 47 32	268 44 24	Mason	6824.2	3.834054
			89 13 17	269 03 33	Wanda	21119.8	4.324690
			127 15 30	307 07 41	Prosser	21236.5	4.327083
Insane Asylum, apex	40 35 01.50	46.3	90 03 05	269 55 20	Wanda	16824.8	4.225951
new building	98 26 22.75	535.1	93 46 03	273 44 53	Mason	2535.5	3.404056
			136 12 34	316 06 44	Prosser	18232.3	4.260841
Hastings Presbyterian	40 35 22.84	704.5	17 01 54	196 57 17	Blue Hill	34496.9	4.537780
Church, spire	98 23 27.80	653.7	85 47 26	265 44 22	Mason	6662.3	3.823624
			88 16 12	268 06 32	Wanda	20948.8	4.321160
			126 48 00	306 40 16	Prosser	20886.4	4.319864
Hastings Schoolhouse,	40 35 34.80	1073.4	82 49 46	262 46 38	Mason	6871.9	3.837077
dome, pole	98 23 20.41	479.9	87 17 06	267 07 22	Wanda	21136.6	4.325036
			125 42 04	305 34 15	Prosser	20808.2	4.318234
Kenesaw Schoolhouse,	40 37 20.74	639.7	338 55 02	158 55 47	Wanda	4606.8	3.663401
cupola*	98 39 28.62	672.7	13 36 43	193 34 30	Sand Creek	20548.1	4.312771
Kearney	40 37 29.006	894.7	296 54 23.8	116 58 31.8	Wanda	10050.7	4.002197
	98 44 39.253	922.6	352 59 46.2	173 00 54.7	Sand Creek	20379.1	4.309186
			74 11 03.1	254 07 43.8	Lowell	7480.3	3.873920
			236 43 38.4	56 49 42.7	Prosser	15698.3	4.195852
Minden West School-	40 29 52.64	1623.7	286 43 13	106 52 35	Sand Creek	21282.6	4.328024
house, cupola*	98 57 18.69	440.0	332 01 33	152 02 48	Lars	5813.9	3.764464
Minden Schoolhouse,	40 29 46.320	1428.8	249 35 19.3	69 47 24.4	Wanda	27997.0	4.447111
cupola	98 56 53.862	1268.4	286 40 24.6	106 49 29.8	Sand Creek	20666.6	4.315270
			336 33 22.4	156 34 21.4	Lars	5384.2	3.731124
Minden Standpipe	40 29 50.261	1550.3	187 17 38.3	7 19 57.3	Valley	39395.7	4.595449
	98 56 54.404	1281.1	219 46 45.9	39 51 24.8	Lowell	15764.0	4.197665
			249 49 52.1	70 01 57.6	Wanda	27966.9	4.446644
			286 59 07.5	107 [illegible] 13.0	Sand Creek	20714.0	4.316265
			336 56 14.9	156 57 14.3	Lars	5501.0	3.740441
Minden Presbyterian	40 29 45.242	1395.5	219 32 35.5	39 37 15.6	Lowell	15911.0	4.201698
Church, spire	98 56 56.260	1324.9	249 33 53.2	69 45 59.9	Wanda	28061.4	4.448110
			286 32 24.3	106 41 31.1	Sand Creek	20711.2	4.316205
			335 51 44.9	155 52 45.5	Lars	5376.6	3.730507
Minden Catholic	40 30 01.924	59.3	218 58 47.4	39 03 10.4	Lowell	15120.7	4.179571
Church, spire	98 56 19.960	470.0	288 26 14.8	108 35 0[illegible].6	Sand Creek	20275.1	4.306964
			343 45 43.3	163 46 26.8	Lars	5646.5	3.751778
Hartwell Elevator	40 34 09.155	282.4	336 32 02.2	156 34 50.4	Sand Creek	15328.2	4.185492
	98 47 12.806	301.2	41 32 08.9	221 26 50.5	Lars	17418.4	4.241008
			138 58 38.3	318 56 59.0	Lowell	5465.2	3.737602
Norman Church, spire*	40 28 39.606	1221.7	300 58 45.9	121 01 44.5	Sand Creek	7567.5	3.878950
	98 47 29.107	685.6	75 33 57.2	255 28 49.7	Lars	11529.8	4.061820
Belfry and Spire	40 32 12.458	384.3	347 24 50.7	167 25 55.1	Sand Creek	10720.7	4.030223
	98 44 32.936	775.2	58 22 33.2	238 15 31.1	Lars	17988.3	4.254990
			136 26 37.6	316 23 14.4	Lowell	10660.3	4.027770
Norman Elevator	40 28 47.258	1457.7	302 15 21.0	122 18 21.2	Sand Creek	7740.6	3.888773
	98 47 31.570	743.6	74 21 29.8	254 16 23.9	Lars	11535.0	4.062016
			167 22 50.6	347 21 23.6	Lowell	14399.9	4.158358
Kearney Reform	40 42 20.596	635.3	231 06 47.2	51 15 58.8	Valley	25418.2	4.405144
School Standpipe	99 07 25.512	599.0	270 19 28.0	90 40 23.6	Prosser	45200.2	4.655140
			293 48 15.3	113 59 46.0	Lowell	27241.0	4.435223

* No check on this position.

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Kenesaw Elevator	40 37 12.243	377.6	337 59 53.7	158 00 38.8	Wanda	4353.5	3.638840
	98 39 27.504	646.5	13 51 28.8	193 49 14.8	Sand Creek	20299.7	4.307490
			84 03 42.3	263 57 00.1	Lowell	14604.7	4.164493
Shelton Presbyterian	40 46 36.318	1120.2	195 21 10.9	15 23 35.2	Cameron	19488.0	4.289768
Church, spire	98 44 01.783	41.8	304 02 19.9	124 08 00.3	Prosser	14777.1	4.169588
			23 07 12.6	203 03 28.5	Lowell	20572.6	4.313290
			72 35 03.8	252 31 12.8	Shelton West Base	8699.0	3.939469
			121 35 25.0	301 29 19.6	Valley	15375.1	4.186819
Shelton Elevator	40 46 47.912	1477.8	22 52 35.5	202 48 49.8	Lowell	20923.6	4.320637
	98 43 59.404	1393.0	70 29 13.1	250 25 20.5	Shelton West Base	8865.2	3.947688
			120 20 07.8	300 14 00.8	Valley	15239.0	4.182956
Meisner's House,	40 47 50.110	1545.6	9 51 33.9	189 51 23.2	Shelton East Base	2245.3	3.351272
cupola	98 44 22.938	537.7	114 37 44.9	294 31 53.2	Valley	13862.4	4.141838
			198 53 56.4	18 56 34.6	Cameron	17457.9	4.241991
Gibbon Elevator	40 44 57.900	1785.9	248 06 30.8	68 07 00.4	Shelton West Base	1147.1	3.059595
	98 50 40.982	961.4	249 53 31.6	69 57 27.8	Shelton East Base	9031.2	3.955744
			355 17 48.9	175 18 25.1	Lowell	15942.4	4.202553
Gibbon Rwy. Windmill	40 44 58.575	1806.8	249 34 15.7	69 34 46.1	Shelton West Base	1165.7	3.066599
	98 50 42.178	989.5	250 04 35.5	70 08 32.5	Shelton East Base	9050.4	3.956668
			355 12 09.0	175 12 46.0	Lowell	15965.4	4.203180
Doniphan Chimney	40 46 37.661	1161.7	21 57 32.2	201 53 34.1	Mason	22969.0	4.361142
	98 22 05.105	119.7	66 01 40.9	245 53 02.0	Prosser	20427.7	4.310220
			100 29 05.4	280 08 39.5	Valley	44685.4	4.650166
			126 14 35.3	306 02 38.2	Cameron	31788.8	4.502274
			168 47 29.4	348 44 05.5	Pompey	37358.9	4.572394
Chadwick*	41 21 48.37	1491.9	197 54 23	17 56 08	Brayton	11986.4	4.078690
	98 36 13.12	304.9	336 14 37	156 20 31	Pompey	31092.5	4.492655
Wood River Church,	40 49 21.682	668.8	353 49 29.7	173 50 10.0	Prosser	13460.5	4.129060
spire	98 36 21.863	512.4	97 06 59.8	276 55 53.5	Valley	24055.5	4.381215
			157 45 46.0	337 43 09.4	Ca eron	14792.2	4.170033
Grand Island Presby-	40 55 54.58	1683.5	93 20 34	273 07 36	Cameron	27824.6	4.444429
terian Church, spire*	98 20 33.65	787.2	154 14 18	334 09 54	Pompey	21618.0	4.334816
Oak Canyon	41 38 54.582	1683.9	320 02 37.6	140 10 42.2	Brayton	26397.4	4.421561
	98 45 44.827	1037.3	56 56 53.4	236 45 35.0	Yale	28284.3	4.451545
			140 04 30.1	320 00 42.2	Elm	12329.1	4.090930
Grand Island Stand-	40 55 40.139	1238.1	39 51 33.0	219 41 51.3	Prosser	32603.7	4.513267
pipe	98 20 30.110	704.5	79 27 41.0	259 06 11.0	Valley	46956.5	4.671696
			94 14 44.6	274 01 44.2	Cameron	27936.7	4.446175
			154 32 54.2	334 28 27.6	Pompey	22055.6	4.343519
Cherry	41 00 54.630	1685.2	245 59 22.2	66 10 09.6	Pompey	25174.8	4.400966
	98 43 41.870	978.3	328 34 51.1	148 37 02.7	Cameron	9004.5	3.954460
			36 21 47.5	216 15 28.2	Valley	22876.0	4.359381
			125 31 38.1	305 18 52.6	Divide	33344.7	4.523027
			162 05 22.2	342 01 57.8	Deer	23544.8	4.371894
Oak	41 21 01.481	45.7	240 36 31.7	60 47 23.8	Brayton	26259.6	4.419289
	98 50 00.247	5.7	353 56 36.4	173 57 20.9	Deer	14912.8	4.173560
			45 41 38.0	225 32 59.5	Divide	25599.3	4.408229
			134 48 13.6	314 39 46.1	Yale	25064.5	4.399059
Greeley Center Catho-	41 33 03.591	110.8	13 00 42.3	192 59 40.1	Brayton	9674.1	3.985609
lic Church, spire	98 32 00.449	10.4	117 26 58.2	297 22 22.8	Daily	10832.4	4.034723
			173 47 32.9	353 47 03.2	Custer	9550.2	3.980010
Ericson	41 48 48.785	1505.1	265 41 35.9	85 49 32.1	Ono	16533.9	4.218375
	98 38 04.377	101.0	339 24 02.1	159 27 34.5	Custer	21005.8	4.322340
			2 48 17.8	182 47 43.5	Daily	24202.6	4.383862
			64 28 49.5	244 19 54.6	Elm	20559.6	4.313014
			149 39 37.2	329 35 57.9	Buffalo	14985.9	4.175684
Bartlett Windmill	41 52 56.157	1732.5	207 52 42.2	28 00 12.3	Deloit	33018.2	4.518754
(Bishop's)	98 33 07.906	182.3	303 34 40.8	123 39 19.7	Ono	11577.1	4.063600
			110 14 52.6	290 07 55.1	Buffalo	15349.0	4.186079

* No check on this position.

Table of positions, azimuths, and lengths—Continued.

Station.	Latitude and longitude.	Seconds in meters.	Azimuth.	Back azimuth.	To station.	Distance.	Logarithms.
	° ′ ″		° ′ ″	° ′ ″		*Meters.*	
Clark	41 58 31.422	969.4	36 30 21.5	216 24 22.9	Ono	20829.4	4.318677
	98 17 13.015	299.7	82 15 04.2	261 57 28.0	Buffalo	36736.4	4.565097
			138 40 02.0	318 29 16.4	McClure	33460.8	4.524536
			160 59 17.9	340 56 08.6	Deloit	19914.8	4.299176
			185 38 59.6	5 40 44.4	Hall	36338.3	4.560365
Schoolhouse, belfry	42 20 08.277	255.4	318 45 15.1	138 46 54.4	Hall	5122.6	3.709489
	98 17 04.274	97.9	128 40 37.2	308 34 36.4	Page SW. Base	15680.7	4.195366
			156 29 48.8	336 26 20.8	Page NE. Base	17679.4	4.247468
			173 38 08.8	353 37 22.2	Old	14255.4	4.153980
Orchard Schoolhouse, belfry	42 20 14.038	433.2	6 22 24.5	186 22 11.3	Hall	4055.2	3.608015
	98 14 17.181	393.3	120 56 36.9	300 48 43.5	Page SW. Base	18727.0	4.272467
			145 52 56.4	325 47 35.6	Page NE. Base	19374.4	4.287229
			158 54 15.0	338 51 35.7	Old	14996.8	4.175999
Page Schoolhouse, belfry	42 23 51.607	1592.4	351 06 52.4	171 09 00.9	Deloit	28418.3	4.453598
	98 25 06.698	153.2	27 15 09.3	207 09 39.8	McClure	24527.1	4.389646
			157 17 28.0	337 16 52.2	Page SW. Base	3141.3	3.497116
Venus Windmill*	42 26 37.24	1149.0	80 48 12	260 41 31	Page SW. Base	13763.4	4.138726
	98 16 05.45	124.5	126 32 01	306 30 34	Old	3639.3	3.561018
O'Neill Catholic Church, spire	42 27 36.985	1 141.2	239 43 55.6	59 51 34.6	Prairie	17951.4	4.254099
	98 38 52.745	1 205.2	282 51 33.2	103 00 14.9	Page SW. Base	18126.5	4.258313
			297 50 50.4	118 07 11.7	Hall	37716.7	4.576533
			344 58 34.5	165 02 21.0	McClure	29781.3	4.473944
O'Neill Standpipe	42 27 38.448	1 186.4	239 48 16.4	59 55 54.5	Prairie	17900.5	4.252864
	98 38 51.314	1 172.4	283 01 18.9	103 09 59.6	Page SW. Base	18104.7	4.257792
			297 55 53.5	118 12 14.0	Hall	37709.0	4.576445
			345 04 34.6	165 07 20.3	McClure	29816.6	4.474458
O'Neill Court-House, cupola*	42 27 35.12	1 083.8	239 27 32.0	59 35 08.9	Prairie	17918.9	4.253311
	98 38 49.62	1 133.7	282 48 56.9	102 52 36.4	Page SW. Base	18044.0	4.256334
Evan's House, chimney*	42 34 06.50	200.7	317 33 57.1	137 35 18.0	Prairie	4047.8	3.607215
	98 29 32.98	752.2	343 07 43.6	163 10 07.6	Page SW. Base	16796.8	4.225227
Section 24, T. 4, R. 11, S. center stone, Neb.	40 17 30.82	950.7	190 10	10 10	Blue Hill	76.53	1.88384
	98 30 36.16	854.2					
Section 32, T. 6, R. 14, N. center stone	40 27 07.53	232.3	38 31	218 31	Lars	54.13	1.73346
	98 55 21.52	507.1					
Section 4, T. 11, R. 12, S. center	40 56 44.85	1 383.4	263 58	83 58	Cameron	185.9	2.26934
	98 40 29.09	680.4					
Section 16, T. 14, R. 15, NW. corner	41 11 31.76	979.8	358 10	178 10	Divide	328.6	2.51663
	99 03 06.78	158.0					
Section 6, T. 13, R. 20, center	41 44 01.5	46.3					
	98 51 27.0	624.0					
Section 3, T. 17, R. 11, SE. corner	41 27 57.5	1 773.9					
	98 33 33.1	768.1					
Section 21, T. 27, R. 8, NE. corner	42 18 22.42	691.8	9 25	189 25	Hall	594	2.77405
	98 14 32.59	746.4					
Section 11, T. 7, R. 12, S. center, mound	40 34 55.95	1 725.8	177 20	357 20	Wanda	167.5	2.22401
	98 38 17.82	419.1					

* No check on this position.

DESCRIPTIONS OF STATIONS.

This list may be conveniently consulted by reference to the illustrations at the end of this appendix and the index on pages 391–393.

In each description the tense used is appropriate to the date at which the description was written.

All directions in the descriptions are given in the form of azimuths reckoned continuously from south around by west to 360°, west being 90°, north 180°, and east 270°. The azimuths are true, not magnetic.

In general, the surface and underground marks described are not in contact, so that a disturbance of the surface mark will not, in general, affect the underground mark. The underground mark should be resorted to only when there is evidence that the surface mark has been disturbed.

GENERAL NOTES IN REGARD TO STATION MARKS.

Note 1.—For each station referred to this note the underground mark is a bottle filled with ashes and buried from 2.5 to 3 feet below the surface. The surface mark is a marble post 6 inches square and 2¼ feet long, placed with its top flush with the ground and having two V-shaped grooves at right angles and the letters U. S. C. S. cut in its top. The witness marks are two hard limestone posts 6 inches square on top and 2¼ feet long, marked by a diagonal groove terminating in an arrowhead pointing to the station, and both placed in the meridian of the station, one to the northward and one to the southward of it.

Note 2.—Around each station referred to this note a circular trench 5 or 6 feet in diameter, 9 to 12 inches deep, and 6 to 10 inches wide, was dug and partly filled with soft coal.

Note 3.—For each station referred to this note the marking is the same as that indicated in Note 1, except that the buried bottle is stated to be a stone bottle.

Note 4.—For each station referred to this note the underground mark is a stone jug buried from 2 to 3 feet below the surface and marked with a cross and small drill hole in its bottom.

Note 5.—For each station referred to this note the underground mark is a stone milk crock buried bottom upward from 2 to 3.6 feet below the surface and marked with small drill hole and sometimes also with a cross.

Note 6.—For each station referred to this note the surface mark is a marble post 8 inches square and 2.3 to 2.6 feet long, placed with its top flush with the ground, and having two V-shaped grooves at right angles and the letters U. S. C. S. cut in its top.

Note 7.—For each station referred to this note the surface mark is as indicated in Note 6, except that the material is a hard sandstone.

Note 8.—For each station referred to this note the underground mark is an earthenware crock, buried from 2.7 to 3.5 feet below the surface, with bottom upward and with a small drill hole in the bottom.

Note 9.—For each station referred to this note the surface mark is a marble post 6 inches square and 2.5 feet long, having V-shaped grooves at right angles and the letters U. S. C. S. cut in its top.

DESCRIPTIONS OF PRIMARY TRIANGULATION STATIONS, SALINA BASE TO MEADES RANCH–WALDO, ON THE THIRTY-NINTH PARALLEL TRIANGULATION.

Vine Creek (Ottawa County, Kans., F. D. Granger, 1886).—This station is situated in NW. ¼ sec. 13, T. 11 S., R. 1 W. The nearest railroad stations are Vine Creek, 2½ miles to the northwest, and Manchester, 4 miles east, both on the Santa Fe Railroad. The geodetic point is marked by a bottle filled with ashes, buried 2.6 feet below the surface of the ground. Over this was placed a marble post, 6 inches square and 2.3 feet long, having two cross lines and the letters U. S. C. S. cut on its top surface, which was flush with the ground. As reference marks, two limestone posts, each 5 inches square and 2.5 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one north and one south, each distant 10.01 feet from the central marble post. The azimuths and distances to additional reference marks are as follows: The northeast corner of McDade's house, 53° 30′, 270.5 feet; stone at northwest corner of section 13, 172° 19′, 466.7 feet; southwest corner of old stone stable 263° 08′, 218.6 feet; stone on the sixth principal meridian at the southeast corner of the northeast quarter of section 13, 292° 48′, 5680 feet, and the northwest corner of stone "dugout," 294° 29′, 124.6 feet.

Iron Mound (Saline County, Kans., F. D. Granger, 1886).—This station is situated on a prominent and well-known butte in the NW. ¼ sec. 26, T. 14 S., R. 2 W., about 7 miles southeast of Salina. The geodetic point is marked by a stone ink bottle, filled with ashes and buried 2.7 feet below the surface of the ground. Over this was placed a marble post 6 inches square and 2.3 feet long, with cross lines and the letters U. S. C. S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 5 inches square and 2.3 feet long and having a single diagonal groove and arrowhead cut on the top, were placed in the meridian of the station, one north and one south of the central marble post.

Salina West Base (Saline County, Kans., F. D. Granger, 1895).—This station is situated in the northeast part of Salina, east of the tanks of the Standard Oil Company. The geodetic point is marked by the intersection of cross lines on a copper bolt set in a limestone post, 6 inches square and 2 feet long, sunk 2.5 feet below the surface of the ground. About 5 inches of earth covers the top of the post. Above this, except for a space of 8 inches square over the post, is a layer of concrete 4 inches thick and 36 inches square, on which rests a limestone block 30 inches square and 10 inches high, supporting another limestone 30 inches square and 15 inches high, with beveled top and having a copper bolt with cross lines and a small drill hole sunk into its top as a surface mark. The two blocks are cemented together and are surrounded by a body of concrete several inches thick. The exposed top of the block bears the inscription U. S. C. & G. Survey, 1896. The following distances are given as reference marks: The geodetic point is 42.75 feet northwest of the line of telegraph poles which follow on the north side of and parallel to the track of the Union Pacific Railroad, and 10 feet east of a north and south fence which marks the eastern limit of ground owned by the Standard Oil Company, 79 feet northwest of the north rail of the main track of the Union Pacific Railroad. It is also 79.7 feet west of a telegraph pole and 35.2 feet a little east of north of the fence corner of the Standard Oil Company's property.

Salina East Base (Saline County, Kans., F. D. Granger, 1895).—This station is situated about 1 mile west of the village of New Cambria, on land owned by Mrs. Mary Marlin, Salina. The geodetic point is marked, both under ground and at the surface, in practically the same manner as at West Base station, the only points of difference being that the under-ground post is 2.7 feet below the surface, with 8 inches of earth and 5 inches of concrete over it. The geodetic point is 78.8 feet a little south of west from a wire fence on the Marlin farm; 22.43 feet a little west of north of a wire fence alongside the railroad; 35.05 feet from the second telegraph pole, marked with a triangle, west of the gate entrance to the Marlin farm, and 70.3 feet in the same direction from the north rail of the Union Pacific Railroad track.

North Pole Mound (Saline County, Kans., F. D. Granger, 1890).—This station is situated on a prominent and well-known hill in the NW. ¼ sec. 1, T. 14 S., R. 3 W., and about 8.5 miles north of Salina. The geodetic point is marked by a bottle filled with ashes, buried 1 foot below the surface of the ground. Over this was placed a limestone block, 1 foot square by 5 inches thick, with two cross lines and the letters U.S.C.S. cut on its top surface, which was covered with several inches of earth.

Heath (Ellsworth County, Kans., F. D. Granger, 1890).—This station is situated in the SW. ¼ sec. 12, T. 14 S., R. 7 W., on land owned by William Heath, who lives in a stone house about one-third of a mile to the southwest. The nearest towns are Brookville, 14 miles to the southeast, and Ellsworth, 18 miles to the southwest, both on the Union Pacific Railroad. The geodetic point is marked by a glass bottle filled with ashes, the top being three feet below the surface of the ground. Over this was placed a marble post 6 inches square and 2.25 feet long, having two cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 6 inches square and 2.25 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one 7.51 feet south and one 7.16 feet north of the central marble post.

Thompson (Ottawa County, Kans., F. D. Granger, 1890).—This station is situated about 12 miles southwest of the town of Minneapolis, in the NW. ¼ sec. 25, T. 11 S., R. 5 W., on a prominent round-topped hill, belonging to Judge R. F. Thompson, of Minneapolis, Kans. The geodetic point is marked by a bottle filled with ashes, buried 3 feet below the surface of the ground. Over this was placed a marble post, 6 inches square and 2.25 feet long, having two cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 6 inches square and 2.25 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one 13.18 feet north and one 14.10 feet south of the central marble post.

Lincoln (Lincoln County, Kans., F. D. Granger, 1891).—This station is located on the high prairie 3½ miles north and 3½ miles east of the town of Lincoln, and about 300 yards west and 40 yards north of the southeast corner of sec. 16, T. 11 S., R. 7 W., on land held by a mortgage and investment company of Lincoln. It is about 15 yards south of the main road from Lincoln to Barnard, and the nearest house, which is about one-half mile to the northeast on the Barnard road, is owned and occupied by Mr. Parks. The reference stones are 10.09 feet north and 11.41 feet south of the station. (See notes 1 and 2, p. 403.)

Golden Belt (Lincoln County, Kans., F. D. Granger, 1891).—This station is near the south end of the northernmost of two prominent hills situated in the SE. ¼ sec. 27, T. 12 S., R. 9 W., on land owned by Mr. Marshall, of Lincoln Center, and used as a cattle range. The station is 110 yards from the north end and 20 yards from the south end of the hill on which it stands. There is an old stone quarry on the west face of the hill about 50 meters southwest of the station, and another about 200 yards to the southeast of the station on the northwest face of the southernmost hill. The two reference marks are placed 9.55 feet north and 9.01 feet south of the station. (See note 1, p. 403.)

Wilson (Russell County, Kans., F. D. Granger, 1891).—This station is situated in the SE. ¼ sec. 1, T. 14 S., R. 11 W., about one-half mile west and 2½ miles north of the town of Wilson, Ellsworth County, Kans. A road running north along the line, separating Ellsworth and Russell counties, passes over the ridge within 100 yards to the west of the station. The two reference marks are placed one 8.03 feet north and the other 15.08 feet south of the station. (See note 1, p. 403.) Recovered 1899, W. Eimbeck.

Bunker Hill (Russell County, Kans., F. D. Granger, 1891).—This station is situated in the SW. ¼ sec. 31, T. 13 S., R. 12 W., in the southwest part of the town of Bunker Hill, in an open lot west of the town water tower. The nearest corner of the water tower is 187.4 feet from the station and the stone marking the southwest corner of sec. 31, T. 13 S., R. 12 W., is 238.2 feet from the station. The two reference marks are 8 feet north and 8 feet south of the station. (See notes 2 and 3, p. 403.)

Allen (Russell County, Kans., F. D. Granger, 1892).—This station is situated in the NW. ¼ sec. 22, T. 14 S., R. 14 W., and about one mile west and 4 miles south of Russell, Russell County, Kans., on land owned by Mr. Montgomery, of Ohio, and under the management of Mr. Clements, who lives one mile south of the station. The azimuths and distances to certain points are: To stone marking the northwest corner of section 22 is 122° 27′ 14″, 446.8 feet; to the north chimney of the house of Mr. H. A. Allen, who rents the land on which the station stands, 99° 36′, about 150 yards; to the north chimmey of an old house is 158° 18′, and the southeast chimney of the house is 90 feet from the station. The station is 237 feet south of the center of the road. The reference marks are 9 feet north and 9 feet south of the station. (See notes 2 and 3, p. 403.)

Blue Hill (Ellis County, Kans., F. D. Granger, 1892).—This station is situated on a prominent ridge forming a part of the Blue Hills and in the south half of sec. 21, T. 12 S., R. 16 W. To reach the station from Walker, travel due north to the foot of the hills, thence to the northwest, passing to the eastward of a stone house and grove of small trees. Follow this road about 2 miles, and when well up on the ridge take the first trail bearing off to the west. This trail passes near the head of two deep canyons, which make up from the valley of the Saline River. After passing the head of the second canyon leave the trail and pass to the top of the ridge, which is narrow at the point and almost surrounded by ravines. There is a ravine in azimuth 63° 46′ and distant 112 feet; the head of a ravine in azimuth 133° 34′, distant 154 feet; the head of a ravine in azimuth 254° 25′, distant 213 feet; the head of a ravine in azimuth 288° 34′, distant 342 feet; and an old sod house in azimuth 340° 59′ from the station . The two reference marks are 8 feet north and 8 feet south of the station. (See notes 2 and 3, page 403.)

Waldo (Osborne County, Kans., F. D. Granger, 1892).—This station is situated on the highest ground in the SE. ¼ sec. 24, T. 10 S., R. 14 W., and about 4.5 miles northwest of Waldo, Russell County, Kans., on land said to belong to the Union Pacific Railroad Company. A well-traveled road from Waldo ascends the hill from the southwest, and turning north passes some 20 yards to the east of the station. The two reference marks are 9 feet north and 9 feet south of the station. (See note 1, page 403.) Note 2, page 403, also applies, except that the circular trench is 11 feet in diameter and 1½ feet deep. Recovered 1897, F. D. Granger.

Meades Ranch (Osborne County, Kans., F. D. Granger, 1891).—This station is on the highest part of a prominent ridge in sec. 34, T. 9 S., R. 11 W., and about one-half mile northeast of Meade's ranch house. A good road passes up from the house and crosses the hill within 100 feet west of the station. The nearest town is Lucas, or Elbon, 12 miles to the south on the Union Pacific Railroad, Lincoln Branch. The azimuths and distances to certain points are: To the chimney of Meade's Ranch house, 8° 36′, about one-half mile; to stone marking southwest corner of sec. 34, T. 9. S., R. 11 W., 34° 33′, 625 yards. The two reference marks are 8.70 feet north and 8.62 feet south of the station. (See notes 1 and 2, page 403.) Recovered 1897, F. D. Granger.

DESCRIPTIONS OF PRIMARY TRIANGULATION STATIONS, THIRTY-NINTH PARALLEL TRIANGULATION TO THE SHELTON BASE NET ON THE NINETY-EIGHTH MERIDIAN TRIANGULATION.

Dial (Osborne County, Kans., F. D. Granger, 1897).—This station is situated on a prominent hill locally known as Sand Mound, and is near the west center of the SW. ¼ sec. 22, T. 9 S., R. 13 W. A north and south section line road crosses Sand Mound at a short distance west of the station. The surface mark is a limestone post 6 inches square and 2 feet long, placed with its top flush with the surface, marked by the letters U. S. C. S. and with a drill hole marking the exact point, 6 inches deep, 0.7 inch in diameter, plugged with pine. The underground mark is a copper bolt 6 inches long and 0.6 inch diameter, set in a drill hole in a flat ledge of rock in its original position and firmly wedged in with wire nails. A cross is cut in top of the bolt to mark the exact point. The bolt is 2.03 feet below the top of the surface mark.

Kill Creek (Osborne County, Kans., F. D. Granger, 1897).—This station is situated about 880 feet north and 300 feet east of the southwest corner sec. 9, T. 9 S., R. 14 W., on a prominent swell of ground. The land belongs to a loan company. The nearest house is distant about 0.2 mile west, and is owned and occupied by J. E. Harris. The station is on line between the center of an old well and the southwest corner of an old sod house, 19.8 feet from the former and 16.35 from the latter. The line from the old well to the house is approximately northwest. The azimuth of the stone marking the southwest corner of section 9 is 17° 42′ 27″, and of the stone marking the northwest corner of section 9 is 174° 37′ 47″. The surface mark is a copper bolt with cross lines set in a limestone post 6 inches square and 2 feet long, marked with the letters U. S. C. S. on its top surface. (See note 4, p. 403.)

Lawrence (U S. Geological Survey, Osborne County, Kans.).—This station is described in Bulletin No. 122, Results of Primary Triangulation, U. S. Geological Survey, as follows: "In Osborne County, Kans., on a swell of ground near the center of the west side of sec. 23, T. 6 S., R. 14 W., and about on the highest point. Permanent mark: Cross and U. S. G. S. cut on top on large flat stone Jug with cross cut on it is underneath the flat stone."

Recovered in 1897, F. D. Granger. The flat stone referred to had been broken up, but the jug with cross cut on it remained undisturbed.

Lawrence 2 (Osborne County, Kans., F. D. Granger, 1897).—The station is 3.377 meters in azimuth 93° 27′ from the station Lawrence (U. S. G. S.) described above. The surface mark is a limestone post 1.6 feet long and 6 inches square, with two rectangular curves and the letters U. S. C. S. cut on its top. (See note 5, p. 403).

Old Well (U. S. Geological Survey, Smith County, Kans.).—This station is described in Bulletin No. 122, Results of Primary Triangulation, U. S. Geological Survey, as follows: "In Smith County, Kans., in the SW. ¼ of the SE. ¼ sec. 16, T. 5 S., R. 11 W., and is 42 feet north and 138.75 feet west of the northwest corner of a stone foundation for a building. The permanent mark: Cross and U. S. G. S. cut in large rock, and a bottle top set underneath the rock." Recovered 1897, F. D. Granger.

Old Well 2 (Smith County, Kans., F. D. Granger, 1897).—The azimuths and distances to certain points are: From this station to Old Well (United States Geological Survey) described above, 92° 52′ 32″, 30.875 meters; to the stone marking the southwest corner of sec. 16, 282° 14′ 32″, 466.0 meters; to the center of Mr. Okke Bohlen's house, 317° 16′, 21.94 meters. The surface mark is a rough stone post 9.5 inches square and 2.2 feet long, with two V-shaped crosses at right angles and the letters U. S. C. S. cut on its top. (See note 4, p. 403.)

Lebanon (Smith County, Kans., F. D. Granger, 1897).—This station is near the northwest corner of the NE. ¼ of the NE. ¼ sec. 2, T. 2 S., R. 11 W., and about 1¼ miles north and 1¾ miles east of Lebanon. It is in the line of an east and west wire fence on the south side of the section line road, about 200 feet east of the head of a small ravine which runs to the south, and about 1300 feet west of the northeast corner of the section. The highest ground in the vicinity lies about one-third mile to the north. The azimuths to certain points are: To Anderson's house, 211° 35′; to the Church of the United Brethren, 268° 59′ 42″; to Mr. J. Housel's house, 314° 02′. The surface mark is a Georgia marble post 6 inches square and 2 feet long, with two V-shaped grooves at right angles, and the letters U. S. C. S. cut on its top. (See note 4, p. 403.) To the north, in the exact projection of the line from Old Well 2, at a distance of 2.832 meters, is a pine stub with a nail in it and underneath the stub at a depth of 30 inches a stone jug with the top upward.

Brown (Smith County, Kans., F. D. Granger, 1898).—This station is about 4 miles east of Smith Center, on high ground near the northwest corner of the SE. ¼ sec. 20, T. 3 S., R. 12 W., on land owned by Mrs. M. A. Brown, 264 feet south of the hedge row on the south side of the east and west half-section line road. (See notes 5 and 6, p. 403.)

Lipps (Smith County, Kans., F. D. Granger, 1898).—This station is in the SW. ¼ sec. 1, T. 1 S., R. 14 W., on land owned by Joseph Lipps, whose house stands near the center of the west side of the southwest quarter of the section. It is 600 feet east of the north and south road passing Mr. Lipps's house. (See notes 6 and 8, p. 403.)

Cooper (Smith County, Kans., F. D. Granger, 1898).—This station is near the center of the NE. ¼ of SW. ¼ sec. 8, T. 1 S., R. 14 W., in a cultivated field belonging to Mr. E. M. Cooper, about 700 feet south and 325 feet west of the center of section 8. Red Cloud, the nearest town, is about 7.5 miles east and 7 miles north of the station. (See notes 4 and 6, p. 403.)

Blue Hill (Webster County, Nebr., F. D. Granger, 1898).—This station is near the south center of sec. 24, T. 4 N., R. 11 W., on land owned by Peter Paugh. It is about 2½ miles south and 3 miles west of the town of Blue Hill. The azimuths and distances to certain points are: To the standpipe at Blue Hill, 228° 33′ 21″; to W. W. Hogate's windmill, 339° 24′; to Hogate's house, 348° 19′; to the stone marking the south center of section 24, 350° 10′, 251.085 feet; to stone marking northwest corner of section 24, 152° 09′; to the wire fence, 90°, 43.7 feet. (See notes 5 and 6, p. 403.)

Herrick (Franklin County, Nebr., F. D. Granger, 1898).—This station is in the SW. ¼ of SE. ¼ sec. 2, T. 3 N., R. 13 W., about 3½ miles south and 1¼ miles west of the town of Campbell, on land owned by Lyman Herrick. The azimuths and distances to certain points are: To the stone marking the southeast corner of section 2, 271° 13′.4; to Lyman Herrick's windmill, 274° 38′.4, 149.8 feet; to the stone marking the south center of section 2, 84° 27′.4; to the stone marking the southwest corner of section 2, 88° 21′.4; to the belfry of the schoolhouse at Campbell, 196° 21′ 25″; to the southwest corner of Mr. Herrick's house, 274°.6, 118.6 feet; to the wire fence to the southward of the station, 89.3 feet. (See notes 5 and 7, p. 403.)

Lars (Kearney County, Nebr., F. D. Granger, 1898).—This station is near the northeast corner of the NW. ¼ sec. 32, T. 6 N., R. 14 W., on land owned by Lars Christianson, who lives in a small frame house about 200 yards to the southeast. Minden, the nearest town, is 3 miles north and ½ miles west. The azimuths and distances to certain points are: To the center of the road to the northward, 140 feet; to the stone marking the north center of section 32, 218° 31′, 177.6 feet; to the half-section line to the eastward, 116 feet; to the fence to the northward on the south side of the road, 64.3 feet; to the east line of trees, 68 feet; to a cottonwood tree with triangle cut in the east side, 90°, 10.86 feet; to the chimney of Mr. Christianson's house, 296° 21′; to Mr. Christianson's windmill, 299° 34′; to the standpipe at Minden, 156° 57′ 14″. (See notes 5 and 7, p. 403.)

Sand Creek (Adams county, Nebr., F. D. Granger, 1898).—This station is near the northeast corner of the SW. ¼ sec. 36, T. 6 N., R. 12 W., on the summit of a prominent range of sand hills situated about 1.5 miles south and 3 miles west of the town of Holstein. The azimuth to Burkholder's windmill is 26° 42′; to the cupola of the schoolhouse at Holstein is 245° 36′ 44″. (See notes 5 and 7, p. 403.)

Wanda (Adams County, Nebr., F. D. Granger, 1898).—This station is in the SE. ¼ of the SW. ¼ sec. 11, T. 7 N., R. 12 W., about 3 miles south and 1 mile east of the town of Kenesaw, on land recently acquired by Henry Pohlke (or Bohlke), who lives about 1 mile to the southwest. It is on the highest ground in the section, and is 549 feet north and 24 feet west of the south center of section 11. A north and south wire fence, following very nearly the half-section line, is 16.2 feet east of the station. The azimuths to certain points are: To the chimney of John Wycks's house, 72° 18′; to the elevator in Kenesaw, 158° 00′ 39″; to the schoolhouse in Juniata, 267° 18′ 10″; to the chimney of Fred Neinheuser's house, 338° 06′, and to the earth mound of south center of section 11, 357° 20′. (See notes 8 and 9, p. 403.)

Mason (Adams County, Nebr., F. D. Granger, 1898).—This station is in the SE. ¼ of the SW. ¼ sec. 8, T. 7 N., R. 10 W., 2 miles east of Juniata, on land owned by Stephen Mason, of Hastings. The azimuths and distances to certain points are: To schoolhouse in Juniata, 97° 48′ 11″; to the standpipe at the asylum, near Hastings, 273° 01′ 13″; to the chimney at the east end of Mr. Mason's house, 359° 30′; to the windmill near the house, 2° 13′; to the fence corner, 495 feet; to the north side of Mr. Mason's house, 750 feet, and to the center of the road, 935 feet. A stone jug, with the center of its top serving as a reference point, was buried 1 foot below the surface of the ground 1.45 feet due south from the station; 2 feet north of the station a 4 by 6 pine stub projecting 2 feet above the ground was set to protect the station mark against injury. (See notes 6 and 8, p. 403.)

DESCRIPTIONS OF PRIMARY TRIANGULATION STATIONS, SHELTON BASE NET, ON THE NINETY-EIGHTH MERIDIAN TRIANGULATION.

Prosser (Hall County, Nebr., F. D. Granger, 1898).—This station is on the summit of a prominent sand hill, locally known as Bean Hill, in sec. 31, T. 9 N., R. 11 W., about 1 mile northwest of the town of Prosser, Adams County, Nebr., on land used as a cattle range. It is under the charge of Mr. A. W. Bradley, of Juniata. (See notes 6 and 8, p. 403.) A stone jug, with a tack in the center of the cork, was placed 0.9 foot below the first underground mark. Recovered 1899, F. D. Granger.

Shelton West Base (Buffalo County, Nebr., F. D. Granger, 1899).—This station is about one-half mile east of the town of Gibbon and 56.3 feet north of the north rail of the main track of the Union Pacific Railroad. The azimuths and distances to certain points are: To East Base (parallel to the Union Pacific track), 250° 09′ 35″; to a switch stand on the Union Pacific Railroad, 7° 15′, 75.8 feet; to the railroad windmill in Gibbon, 69° 34′ 46″; to a telephone pole blazed with a triangle on the side facing the station, 110° 05′, 64.1 feet; to telephone pole No. 2, blazed with triangle on side facing station, 223° 35′, 95.1 feet. The surface mark is a copper bolt with cross lines set in a limestone post 8 inches square and 2.5 feet long. The top of the post is flush with the ground and is marked U.S.C.S. The underground mark is a copper bolt with cross lines set in a limestone block 15 inches square and 8 inches thick, 3 feet below the surface. Recovered 1900, A. L. Baldwin.

Shelton East Base (Buffalo County, Nebr., F. D. Granger, 1899).—This station is about one-half mile west of the town of Shelton and 56.3 feet north of the north rail of the main track of the Union Pacific Railroad and about 74 yards west of railroad trestle 115. Azimuths and distances to certain points are: To a telegraph pole marked with a triangle on side facing the station, 0° 00′; to West Base (parallel to railroad tracks), 70° 13′ 01″; to telephone pole No. 1, blazed with triangle on side facing station, 140° 53′, 42.7 feet; to telephone pole No. 2, blazed with triangle on side facing station, 230° 30′, 120.5 feet. The surface mark is a copper bolt with cross lines set in a limestone post 8 inches square and 2.5 feet long. The top of the post is flush with the ground and 2.93 feet above the underground mark. The underground mark is a copper bolt with cross lines set in a limestone block 15 inches square and 8 inches thick. Recovered 1900, A. L. Baldwin.

Lowell (Kearney County, Nebr., F. D. Granger, 1899).—Is in sec. 6, T. 8 N., R. 13 W., about 2.5 miles south and 1 mile east of Lowell, and about 2.5 miles north and 2 miles west of Hartwell, on the highest point of the most prominent sand hill of the range south of Lowell. The hill on which the station stands has a second summit to the westward of the station which is nearly as high as the station. (See notes 5 and 6, p. 403).

Valley (Buffalo County, Nebr., F. D. Granger, 1899).—This station is in sec. 10, T. 10 N., R. 14 W., near the center of the SW. ¼, about 7 miles north and 2.7 miles west of Gibbon, on the crest of a prominent ridge in Valley Township. The land is owned by Mrs. D. Riordin, of Illinois, and is at present occupied by Mr. Nicola Ellias Yanney, and is under cultivation. The station is nearly due west of the house occupied by Mr. Yanney. There are no roads leading to the point, which is difficult to reach on account of the rough and uneven character of the ground. The location of the station is known to Mr. Ashburn, of Gibbon, agent for the land. (See notes 6 and 8, p. 403.) The top of the surface mark was set 6 inches below the surface of the ground, and a 4 by 4 pine stub 2½ feet long was set 2 feet to the north, with its top projecting several inches above the ground.

Cameron (Hall County, Nebr., F. D. Granger, 1899).—This station is near the south center of the SW. ¼ of the SE. ¼ sec. 4, T. 11 N., R. 12 W., about 2 miles north and 2 miles west of Cameron, on the farm of Mr. Harry Chase, 138.2 feet east of the southeast corner of Mr. Chase's house and 1 foot north of the line of the south face of the house. The azimuths and distances to certain points are: To the south center of sec. 4, 83° 58′, 610 feet; to the southeast corner of Mr. Chase's house, 100° 24′, 138.2 feet; to the well and windmill, 133° 16′, 121.7 feet; to the southeast corner of the stable, 177° 36′; to a fence to the eastward, 268° 45′, 30.4 feet; to the southeast corner of sec. 4, 272° 13′; to the wire fence of the south side of the road, 358° 45′, 102.0 feet. (See notes 6 and 8, p. 403).

DESCRIPTIONS OF PRIMARY TRIANGULATION STATIONS, SHELTON BASE NET TO PAGE BASE.

Pompey (Howard County, Nebr., F. D. Granger, 1899).—This station is on the highest and most prominent sand hill of the range in the valley of the Loup River, between Grand Island and St. Paul, which is locally known as Mount Pompey (or Pompeii). It is near the center of the top of the hill, but not on its highest point. It is near the southwest corner of sec. 10, T. 13 N., R. 10 W., about 7 miles due south of St. Paul, and one-half mile south and 4½ miles east of Dannebrog. (See notes 6 and 8, p. 403).

Deer (Sherman County, Nebr., F. D. Granger, 1899).—Is near the center of sec. 4, T. 13 N., R. 13 W., about 1¼ miles west and 2 miles south of Ashton, near the north end of a cultivated field owned by Henry Heines, 1 030 feet north of the northwest corner of the German Lutheran parsonage and 34 feet west of the line of its west face. The azimuths and distances to certain points are: To the chimney of Peter Glinsmann's house, 255° 32′; to the chimney on the northeast corner of the German Lutheran church, 348° 25′; to the chimney of the parsonage, 358° 25′; to the northwest corner of the parsonage, 359° 10′, 1 030 feet; to the east end of a row of small cottonwood trees, 26° 39′, 545 feet; to the chimney on the north L of Claus Stulley's house, 32° 25′. (See notes 6 and 8, p. 403.) After the station was occupied some young trees were set around it.

Divide (Sherman County, Nebr., F. D. Granger, 1899).—This station is the NW. ¼ sec. 16, T. 14 N., R. 15 W., 24 feet east and 1 078 feet south of the northwest corner of the section, on the crest of the highest hill in the section and 0.7 mile east and 1.0 mile south of the town Divide, and about 10 miles southwest of Loup City. The azimuths to certain poins are: To the post-office at Divide, 140° 14′ 03″; to the northwest corner of sec. 16, 178° 10′; to the chimney of the yellow house on a hill north of Loup City, 217° 38′ 47″. (See notes 6 and 8, p. 403.)

Yale (Valley County, Nebr., F. D. Granger, 1899).—This station is on the crest of a prominent hill in the NE. ¼ sec. 28, T. 18 N., R. 15. W., about 600 feet east and 200 feet south of the north center of the section, and about 12 miles southwest of Ord, on land owned by the Burlington Railroad, and at present occupied by D. M. Ross, who lives about 2 miles to the northwest. The azimuths to certain points are: To A. L. Jewett's windmill, 36° 36′ 34″; to Charles Mason's windmill, 49° 27′ 28″; to windmill of post-office at Yale, 124° 12′ 22″; to the northeast corner of section 28, 264° 49′ 15″. (See notes 6 and 8, p. 403.)

Elm (Valley County, Nebr., F. D. Granger, 1899).—This station is on the summit of the highest hill in the section, and is about 16 feet west and 60 feet south of the center of sec. 6, T. 13 N., R. 20 W., on land owned by Mr. Clinton Upham, who lives in a sod house about 200 yards to the eastward at the foot of the hill. The country in the vicinity is very rough and broken, but there is a good trail from Upham's house to the Ord road. The distance to Ord is about 12 miles. The azimuths and distances to certain points are: To the church spire at Ord, 22° 57′ 47″; to a windmill at Bartlett, 236° 50′ 37″; to Mr. Upham's windmill, 265° 33′ 08″, about 200 yards. (See notes 6 and 8, p. 403.)

Brayton (Greeley County, Nebr., F. D. Granger, 1899).—This station is in the SE. ¼ sec. 3, T. 17 N., R. 11 W., about 60 feet north and 90 feet west of the southeast corner of the section, on a hill which is quite prominent as viewed from the northeast and east. It is 4 miles west and ¼ mile north of Brayton, and 5½ miles south and 1 mile west of Greeley Center, and is on land owned by the Burlington and Missouri River Railroad. The azimuths to certain points are: To a church spire at Greeley Center, 192° 59′ 40″; to chimney of Michael Gray's house, 243° 25′ 46″; to cupola of schoolhouse at Brayton, 272° 02′ 44″; to Cleary's windmill, 273° 46′ 11″. (See notes 6 and 8, p. 403.)

Daily (Greeley County, Nebr., F. D. Granger, 1900).—This station is on the crest of a prominent hill in the NW. ¼ sec. 25, T. 19 N., R. 12 W., 6 miles west and 3.5 miles north of Greeley Center, ⅓ mile to the southwest of the house owned and occupied by John Anderson, and on clay land owned by Mr. Daily. An old trail passes the southward of the station within 100 yards. The azimuths and distances to certain points are: To the head of a ravine, 280° 35′, about 103 yards; to the spire of the Catholic Church in Greeley Center, 297° 22′ 23″; to the schoolhouse at Horace, 18° 21′; to Everett's windmill, 168° 22′, ¾ mile; to John Anderson's windmill 221° 31′, ⅓ mile. (See notes 6 and 8, p. 403.)

Custer (Greeley County, Nebr., F. D. Granger, 1900).—This station is on the summit of a prominent hill in the NE. ¼ sec. 11, T. 19 N., R. 11 W., 3 miles east and 1 mile north of Belfast, and 0.5 mile west and 7 miles north of Greeley Center, on sandy land owned by McKinley & Laning Loan and Trust Company, of Hastings, Nebr. The azimuths and distances to certain points are: To George Van Arsdell's windmill, 71° 45′, 4/5 mile; to the chimney of Mrs. Judge's house, 266° 25′; to Mrs. Judge's windmill, 268° 59′, 3/5 mile; to the chimney at the east end of schoolhouse, 306° 13′, ⅓ mile; to the spire of the Catholic Church in Greeley Center, 353° 47′ 02″. There are two underground marks, a jug top 3 feet below the top of the surface mark and a milk crock with cross lines and a small drill hole in the bottom 2.72 feet below the top of the surface mark. (See note 6, p. 403.)

Ono (Wheeler County, Nebr., F. D. Granger, 1900).—This station is 15 feet northwest of the highest point of a prominent sand hill situated in the NE. ¼ sec. 2, T. 21 N., R. 10 W., about 3.5 miles south and 6.5 miles east of Bartlett, about 1.5 miles west of Ono, and about 200 yards south of the mail route from Ono to Bartlett. The azimuths and distances to certain points are: To Leonard Caswell's house, 97° 31′, ¾ mile; to the remains of a sod house, 145° 44′, 600 yards; to the remains of a sod house, 201° 59′, 325 yards; to W. Fabian's windmill, 281° 23′; to Henry Huff's grove, 345° 09′, 2.5 miles; to J. W. Huff's windmill, 10° 05′, 2.0 miles. (See notes 6 and 8, p. 403.)

Buffalo (Wheeler County, Nebr., F. D. Granger, 1900).—This station is on the highest sand hill of a prominent range distant about 9 miles west and 3 miles north of Bartlett, near SW. corner sec. 28, T. 23, R. 12 W., and 2 miles east of the Garfield

County line. There are no residences within 4 or 5 miles of the station. One of the nearest houses, distant about 7 miles to the northeast, is surrounded by a conspicuous grove of cottonwood trees plainly visible from the station and is owned and occupied by Mr. S. B. French, who knows the location of the station. The land in the vicinity of the station is the property of the United States and about 25 square miles of it is fenced in and used as a cattle ranch. The azimuths and distances to certain points are: To a windmill, 311° 16′, ½ mile; to a windmill, 351° 00′, 2 miles; to a cottonwood grove at Mr. French's house, 238° 42′, 7 miles; to a windmill at Bartlett, 290° 07′ 55″, 9.6 miles. There is a "blowout" 15 feet deep on the slope of the hill to the eastward of the station. (See notes 6 and 8, p. 403.)

McClure (Holt County, Nebr., F. D. Granger, 1900).—This station is near the south end of a short range of sand hills in the NE. ¼ sec. 26, T. 26 N., R. 11 W., about 15 feet southeast of and about 1 foot lower than the highest point of the hill on which it stands. It is 4 miles south and 11 miles west of Ewing, and about 1.7 miles northeast of the present site of the Little post-office. Azimuths to certain points are: To the southeast corner of section 26, 357° 43′; to the chimney of J. H. Wilson's house, now the Little post-office, 69° 11′; to the standpipe at O'Neill, which is visible only when the refraction is abnormally large, 165° 07′ 21″. (See notes 6 and 8, p. 403.)

Deloit (Holt County, Nebr., F. D. Granger, 1900).—This station is on the crest of the highest and most prominent hill in Deloit Township, in the NE. ¼ sec. 16, T. 25 N., R. 9 W., about 0.5 mile east and 3.7 miles north of Deloit, and about 1 mile west and 8 miles south of Ewing, on school land now rented and occupied by John Daniels. The azimuths and distances to certain points are: To W. W. Bethea's windmill, 221° 12′; to the northeast corner of section 16, 247° 14′; to the creamery at Deloit, 7° 57′; to John Daniels's windmill, 89° 44′; to the wire fence to the northward, 660 feet. (See note 6, p. 403.) The underground mark is a stone jug with a tack in the center of the cork, 2.9 feet below the top of the surface mark.

Hall (Antelope County, Nebr., F. D. Granger, 1900).—This station is in the NE. ¼ sec. 21, T. 27 N., R. 8 W., on land owned by an Eastern loan and trust company. The station is on the highest point in the vicinity, and from it the land slopes more rapidly to the north than in any other direction. It is 403 feet due west of the north-and-south fence line on the east side of the section-line road leading to Orchard. The azimuths and distances to certain points are: To cupola of the schoolhouse at Orchard, 186° 22′ 11″, about 2 miles; to the northeast corner of section 21, 189° 25′, 1 950 feet. (See notes 5 and 6, p. 403.)

Page Southwest Base (Holt County, Nebr., F. D. Granger, A. L. Baldwin, 1900).—This station is in the SW. ¼ sec. 1, T. 28 N., R. 10 W., about 2 miles north and 0.7 mile west of the town of Page, and about 2 miles south and 12 miles east of O'Neill, on land owned by Mr. William Lord and near his dwelling. The azimuths and distances to certain points are: To the northwest corner of a granary, 288° 23′, 143 feet; to the windmill, 305° 08′; to the northwest corner of Mr. Lord's house, 188 feet; to the center of the section-line road to the southward, 393 feet; to precise level bench mark, M_2 320° 07′, 80.93 meters. The bench mark is an Indiana Bedford stone post 4½ feet by 6 by 6 inches, the top 6 inches dressed to 6 by 6 inches. A square cut 1¼ by 1¼ by 1¼ inches is made in the top and lettered U. S. B. M. The surface mark of the station is a stone 24 by 24 by 14 inches set in cement and with a copper bolt, marked with cross lines, set in its upper surface to mark the exact point. The underground mark is a stone 6 by 6 by 8 inches, set in cement and carrying a copper bolt with cross lines to mark the exact point.

Page Northeast Base (Holt County, Nebr., F. D. Granger and A. L. Baldwin, 1900).—This station is in the SE. ¼ sec. 16, T. 29 N., R. 9 W., on the open prairie, on school land now rented by T. S. Roche, of Page. The land is nearly flat, and the only prominent object in the vicinity to which it can be referred is the northern end of a large "blowout" in azimuth 219° and 600 meters distant. The station marks are exact duplicates of those at Page Southwest Base.

Prairie (Holt County, Nebr., F. D. Granger, 1900).—This station is in the SW. ¼ sec. 26, T. 30 N., R. 10 W., 10 miles north and 2 miles west of Page, and about 12 miles northeast of O'Neill, on the open prairie, on the summit of a small elevation which rises about 15 feet above the general level. There is another similar summit to the southeastward of the station and within about 1 000 feet. The azimuths and distances to certain points are: To the southwest corner of section 26, 27° 04′, about 1 530 feet; to the standpipe at O'Neill, 59° 55′ 55″; to Stanton's house, 100° 54′, 1 mile; to the chimney of Evan's house, 137° 35′ 18″, 2 miles; to the cupola of barn on sheep ranch, 275° 21′, 2.2 miles. (See notes 6 and 8, p. 403.)

Old (Knox County, Nebr., F. D. Granger, 1900).—This station is on the crest of a small elevation in the NW. ¼ of the NW. ¼ sec. 30, T. 29 N., R. 8 W., 2 miles west and 0.6 mile north of Venus, on land which is under cultivation and owned by John Old. The nearest house, distant about 800 feet to the northwest, is owned and occupied by W. W. Carey. The azimuths and distances to certain points are: To W. W. Carey's windmill, 145° 49′, about 785 feet; to the northwest corner of section 30, 160° 32′; to Venus post-office, 281° 01′, 2 miles; to the center of the county-line road to the westward of the station, 376 feet. (See note 6, p. 403.) The underground mark is a stone jug, at a depth of 3.57 feet below the surface mark, with a tack in the center of the cork.

Walnut (Knox County, Nebr., F. D. Granger, 1901).—This station is in the west center of SW. ¼ sec. 10, T. 30 N., R. 8 W., on land owned by a land company of Norfolk, Nebr., on the highest point of a prominent range of hills in Washington Precinct, about 1.5 miles west and 4.5 miles north of Walnut post-office. The nearest house, situated in a ravine about ½ mile to the southwest, is owned and occupied by Frank Vonasek. A trail branches at a point to the southwestward of the station, and the north-and-south branch passes about 270 feet to the westward of the station. The stone marking the southwest corner of sec. 10, T. 30 N., R. 8 W. is about 0.3 mile a little south of west from the station, and is in the second ravine from the station and surrounded by bushes. (See note 6, p. 403.) The underground mark is a stone jug with a tack in the center of the cork, 3.34 feet below the top of the surface mark.

DESCRIPTIONS OF SECONDARY AND TERTIARY STATIONS BETWEEN MEADES RANCH-WALDO AND PAGE BASE.

Blue Hill (Mitchell County, Kans., United States Geological Survey).—This station is described in Bulletin 122 of the United States Geological Survey, page 192, as follows: "Permanent marks: Rock with cross and U. S. G. S. cut in the top." Recovered 1891, F. D. Granger.

Tipton (Osborne County, Kans., United States Geological Survey).—This station is described in Bulletin 122 of the United States Geological Survey, page 192, as follows: "In Osborne County, Kans., on the east side of sec. 15, T. 8, R. 11, on high hill 2 miles west of the town. Permanent mark: Large limestone rock with cross cut and U. S. G. S. on top. Bottom of bottle placed 2 inches below the rock." Recovered 1897, F. D. Granger.

Hardilee (Smith County, Kans., United States Geological Survey).—This station is described on page 193 of Bulletin 122 as follows: "In Smith County, Kans., on highest point of ground in sec. 20, T. 2, R. 14, near the center of the SE. ¼. Permanent mark: White sandstone rock marked with a cross and U. S. G. S." Recovered 1897, F. D. Granger.

Covert (Osborne County Kans., F. D. Granger, 1897).—This station is in the NW. ¼ sec. 18, T. 8 N., R. 12 W., near the south end of a prominent range of hills about 5 miles south and 0.7 mile west of Osborne. The surface mark is a rough stone post marked with a cross and the letters U. S. C. S. The underground mark is a jug top.

Kansas-Nebraska State Line C (F. D. Granger, 1898).—This station is an earth mound at the southeast corner of sec. 32, T. 1 N., R. 11 W., Webster County, Nebr. The underground mark is a stone jug buried 2 feet beneath the surface.

Kansas-Nebraska State Line A (F. D. Granger, 1898).—This station is a stone at the southwest corner of sec. 36, T. 1 N., R. 14 W., Franklin County, Nebr.

Kansas-Nebraska State Line B (F. D. Granger, 1898).—This station is a flag near the Kansas and Nebraska State line.

Kansas-Nebraska State Line 1 (F. D. Granger, (1898).—This station is a stone at the southeast corner of sec. 36, T. 1 N., R. 14 W., Franklin County, Nebr.

Kansas-Nebraska State Line 2 (F. D. Granger, 1898).—This station is a stone at the northeast corner of sec. 1, T. 1 S., R. 14 W., Smith County, Kans.

Madden (Kearney County, Nebr., F. D. Granger, 1898).—This station is in the SE ¼ sec. 36, T. 5 N., R. 13 W., on the line of an east and west wire fence, and is about 500 feet north and 500 feet east of the south center of sec. 36, on land owned and occupied by Robert Madden. The surface mark is a pine stub 4 inches square and 20 inches long, with a nail in its top marking the exact center. The underground mark is a stone jug top buried 2 feet below the surface.

Kearney (Kearney County, Nebr., F. D. Granger, 1898–99).—This station is in the NE. ¼ sec. 35, T. 8 N., R. 13 W., about 5 miles nearly due west of Kenesaw, on the highest point of a sand hill. There is an east and west wire fence 93 yards north of the station, which intersects with a north and south fence 145 yards to the northeast of the station. The surface mark is a pine stub 3.0 feet long projecting a few inches above the ground, with a nail in its center. The underground mark is a bottle top 3.5 feet below the surface.

Carter (Adams County, Nebr., F. D. Granger, 1899).—This station is 1 mile due east of Roseland, in the SE. ¼ sec. 22, T. 6 N., R. 11 W., on land owned by T. W. Carter, of Roseland. The surface mark is a nail in a triangle on the north side of a cottonwood tree. The underground mark is a jug 0.9 foot below the surface. The station point is 0.2 foot south and 0.5 foot east of the nail in the triangle on the cottonwood tree, and 0.6 foot south and 0.5 foot east of the center of the jug. An old frame house stands to the southward of the cottonwood tree.

Cherry (Buffalo County, Nebr., F. D. Granger, 1899).—This station is on a prominent round-topped sand hill with a deep "blow-out" on its west face, and is in the NW.

¼ sec. 13, T. 12 N., R. 13 W., about 1.75 miles southeast of St. Michael railroad station and 11 miles east of Ravenna. Station is marked by bottle top buried 2.0 feet below the surface of the ground.

Methodist Church Spire (Adams County, Nebr., F. D. Granger, 1899).—This station is in sec. 2, T. 6 N., R. 12 W.

Danish Lutheran Church Spire (Kearney County, Nebr., F. D. Granger, 1899).—This station is in sec. 8, T. 5 N., R. 14 W.

White Spire (Adams County, Nebr., F. D. Granger, 1899).—This station is in sec. 36, T. 7 N., R. 12 W.

Oak (Sherman County, Nebr., F. D. Granger, 1899).—This station is in sec. 18, T. 16 N., R. 13 W., on a round-shaped hill, about 6 miles east and 5.5 miles north of Loup City, and 4 miles west and 7.5 miles north of Ashton. The surface mark is a pine stub 4 by 6 inches and 2 feet long, having two diagonal grooves cut in its top. The underground mark is a jug with a tack in the center of the cork, set 2.5 feet below the surface.

Ericson (Wheeler County, Nebr., F. D. Granger, 1899–1900).—This station is on the highest sand hill in the vicinity of Ericson railroad station, about 3.5 miles to the northeast of that place, in sec. 5, T. 21 N., R. 11 W. The underground mark is a stone jug with a tack in the center of the cork, 2 feet below the surface.

Clark (Antelope County, Nebr., F. D. Granger, 1900).—This station is in the SE. ¼ sec. 7, T. 23 N., R. 8 W., on land owned by Lewis Clark, whose house stands on the southwest face of the hill, 250 yards from the station. Elgin is 10 miles nearly due east from the station. The distance east to a tree with a triangle cut on its west face is 28.2 feet, south to a wire fence is 180 feet, and south to the center of a road is about 900 feet. The underground mark is a stone jug with a tack in the center of the cork, 3.05 feet below the top of the surface mark. (See note 6, p. 403). The top of the surface mark projects about 4 inches above the ground.

GENERAL STATEMENT IN REGARD TO THE DETERMINATION OF ELEVATIONS ALONG THE NINETY-EIGHTH MERIDIAN.

While the measurement of horizontal angles was in progress at each station the vertical angles to each station of the primary scheme were also measured on as many days as possible. Vertical measures were also made to many secondary and tertiary stations. The observations in the primary scheme were reciprocal, but not simultaneous; that is, each line was observed in both directions, but at different times. The vertical measures were all made during the middle part of the day, when the refraction is near its minimum value and when its diurnal change is slow. The zenith distances of two or more of the stations visible from a given station were observed directly with a vertical circle. The vertical angles to the other visible stations were determined by measuring the differences of the zenith distance between these stations and the two or more of which the absolute measures had been made. For this purpose an eye-piece micrometer on the telescope of the theodolite used in measuring the horizontal angles was employed.

It is useless to aim at a high degree of accuracy in such vertical measures over lines from 10 to 30 miles long or longer, since the irregular variation of the refraction from hour to hour and day to day produces changes in vertical angles which affect the tens of seconds, and sometimes even the minutes. All differences of elevation computed from such observations are subject to large errors, due to these atmospheric changes, regardless of the degree of refinement of the instrumental measures. The accuracy of the elevations determined along the ninety-eighth meridian would probably have been increased somewhat by extending the observations at each station over many days, but such slight increase in accuracy would not have justified the extra expenditure of time and money.

The accuracy of the elevations has been kept within such limits as to make them valuable for topographic and cartographic purposes by frequent connection of the measures with bench marks of which the elevations have been accurately determined by precise leveling forming a part of the level net covering the eastern half of the United States.

COMPUTATION, ADJUSTMENT, AND ACCURACY OF THE ELEVATIONS.

The zenith distances and the differences of the zenith distances directly observed at each station were first computed. At each station at which the zenith distances of two or more stations were observed, and differences of zenith distances were also measured, involving these stations as well as the remaining stations, certain rigid conditions existed between the observed quantities. An approximate adjustment was made to satisfy these conditions, and the resulting zenith distances for all stations derived. These zenith distances were corrected for height of object observed and of instrument so as to refer them all to the ground at each station, or to the station marks.

The difference of elevation of each pair of stations in the main scheme was then computed from the observations over the line adjoining them by the formula

$$h_2 - h_1 = s \tan \tfrac{1}{2} (\zeta_2 - \zeta_1) \left[1 + \frac{h_2 + h_1}{2\rho} + \frac{s^2}{12\rho^2} \right]$$

in which h_2 and h_1 are the elevations of the stations, ζ_2 and ζ_1 are the measured zenith distances, s is the horizontal distance between the stations, and ρ is the radius of curvature.

As there are always two or more lines to each new station, many rigid conditions existed between the observed differences of elevation, even if the connections with the precise leveling were ignored, and the least square adjustment furnishes the readiest accurate means of deriving the required elevations.

The least square adjustment was made in two sections. The first adjustment involved all stations in the primary scheme from the Salina Base to and including the Shelton base net as shown in Illustrations Nos. 1, 2, and 3, and including also the secondary station Russell Southeast Base and Russell Northwest Base. The second adjustment involved all the remaining stations of the primary scheme to and including those in the Page base net.

In the following table the observed differences of elevations treated in the first adjustment are shown together with their adjusted values. The weight, p, assigned to each observed difference of elevation was made inversely proportional to the length s of the line between stations and was conveniently computed by the formula $\log p = 9 - 2 \log s$. The observed difference of elevation is given the sign of the elevation of the second station named minus the elevation of the first. The quantity v in the last column but one is the correction to be applied to observations to obtain the difference of adjusted elevations.

Station 1.	Station 2.	Weight p.	Observed diff. of eleva. h_2-h_1	Adjusted diff. of eleva. h_2-h_1	Adj.-Obs. v.	pv^2
			m	m	m	m
North Pole Mound	Salina West Base	8.02	−74.47	−74.66	−0.19	0.289
Iron Mound	Salina West Base	11.53	−84.26	−84.35	−0.09	0.093
North Pole Mound	Salina East Base	8.25	−81.02	−80.74	+0.28	0.646
Iron Mound	Salina East Base	17.86	−90.44	−90.43	+0.01	0.002
Thompson	North Pole Mound	1.87	−39.93	−39.68	+0.25	0.117
Vine Creek	North Pole Mound	1.58	−13.19	−13.08	+0.11	0.019
Iron Mound	North Pole Mound	3.05	− 9.74	− 9.69	+0.05	0.008
Vine Creek	Iron Mound	0.85	− 3.37	− 3.39	−0.02	0.000
Iron Mound	Heath	0.45	+96.52	+97.22	+0.70	0.220
Iron Mound	Thompson	0.62	+29.51	+29.99	+0.48	0.143
Vine Creek	Heath	0.24	+91.10	+93.83	+2.73	1.789
Vine Creek	Thompson	0.69	+27.76	+26.60	−1.16	0.929
Heath	Thompson	1.00	−67.50	−67.23	+0.27	0.073
Heath	Lincoln	1.30	−40.97	−40.57	+0.40	0.208
Heath	Meades Ranch	0.28	+43.86	+45.56	+1.70	0.809
Heath	Golden Belt	1.39	−25.85	−26.06	−0.21	0.061
Thompson	Golden Belt	0.55	+42.02	+41.17	−0.85	0.397
Thompson	Lincoln	1.81	+26.79	+26.66	−0.13	0.031
Lincoln	Golden Belt	2.08	+14.32	+14.51	+0.19	0.075
Lincoln	Meades Ranch	0.59	+86.27	+86.13	−0.14	0.012
Golden Belt	Wilson	2.45	+40.17	+39.83	−0.34	0.284
Golden Belt	Meades Ranch	0.86	+71.08	+71.62	+0.54	0.251
Meades Ranch	Wilson	0.62	−32.70	−31.79	+0.91	0.513
Meades Ranch	Bunker Hill	0.58	−27.45	−28.98	−1.53	1.358
Meades Ranch	Blue Hill (Kans.)	0.33	+54.24	+53.31	−0.93	0.285
Meades Ranch	Waldo	1.51	+19.56	+19.63	+0.07	0.007
Wilson	Bunker Hill	2.79	+ 2.65	+ 2.81	+0.16	0.073
Wilson	Waldo	0.50	+52.90	+51.42	−1.48	1.095
Bunker Hill	Blue Hill (Kans.)	0.76	+81.85	+82.29	+0.44	0.147
Bunker Hill	Waldo	0.84	+49.64	+48.61	−1.03	0.891
Bunker Hill	Allen	4.30	+ 9.93	+ 9.27	−0.66	0.015
Waldo	Russell NW. Base	1.10	−57.06	−57.89	−0.83	0.758
Waldo	Allen	0.70	−39.51	−39.34	+0.17	0.020
Waldo	Blue Hill (Kans.)	1.05	+33.89	+33.68	−0.21	0.046
Allen	Blue Hill (Kans.)	1.45	+73.49	+73.02	−0.47	0.320
Allen	Russell NW. Base	13.87	−18.54	−18.55	−0.01	0.001
Russell SE. Base	Waldo	0.84	+44.80	+45.55	+0.75	0.478
Russell SE. Base	Allen	14.93	+ 6.25	+ 6.21	−0.04	0.024
Russell SE. Base	Blue Hill (Kans.)	1.07	+78.42	+79.23	+0.81	0.702
Waldo	Kill Creek	5.06	+ 3.68	+ 4.12	+0.44	0.982
Waldo	Dial	8.40	+ 5.19	+ 4.95	−0.24	0.484
Meades Ranch	Dial	2.55	+24.22	+24.58	+0.36	0.331
Meades Ranch	Old Well 2	0.54	−50.65	−49.77	+0.88	0.418
Dial	Old Well 2	0.52	−74.51	−74.35	+0.16	0.014
Dial	Lawrence 2	1.05	−55.01	−54.55	+0.46	0.223
Dial	Kill Creek	7.38	− 0.60	− 0.83	−0.23	0.390
Kill Creek	Lawrence 2	1.39	−54.11	−53.72	+0.39	0.211
Lawrence 2	Old Well 2	1.37	−19.86	−19.80	+0.06	0.005
Old Well 2	Brown	2.10	+39.59	+40.15	+0.56	0.659
Old Well 2	Lebanon	1.70	+38.31	+37.99	−0.32	0.174
Lawrence 2	Lipps	0.36	+78.76	+82.33	+3.57	4.588
Lawrence 2	Brown	1.01	+20.68	+20.35	−0.33	0.110
Brown	Lipps	1.32	+61.87	+61.98	+0.11	0.016
Brown	Cooper	1.68	+22.70	+22.93	+0.23	0.089
Brown	Lebanon	3.78	− 2.24	− 2.16	+0.08	0.024
Cooper	Lebanon	3.27	−25.17	−25.09	+0.08	0.021
Cooper	Lipps	1.90	+39.32	+39.05	−0.27	0.139
Cooper	Herrick	0.92	+26.22	+26.66	+0.44	0.178
Cooper	Blue Hill (Nebr.)	0.79	+ 9.39	+ 9.72	+0.33	0.086
Lipps	Herrick	1.14	−13.19	−12.39	+0.80	0.730

Station 1.	Station 2.	Weight p.	Observed diff. of eleva. h_2-h_1.	Adjusted diff. of eleva. h_2-h_1.	Adj.−Obs. v.	pv^2.
			m.	m.	m.	m.
Blue Hill (Nebr.)	Herrick	2.24	+17.37	+16.94	−0.43	0.414
Blue Hill (Nebr.)	Sand Creek	1.72	+ 9.76	+ 9.91	+0.15	0.039
Blue Hill (Nebr.)	Wanda	0.86	+11.99	+11.76	−0.23	0.046
Blue Hill (Nebr.)	Mason	0.94	−15.48	−15.37	+0.11	0.011
Herrick	Lars	1.39	+38.42	+38.52	+0.10	0.014
Herrick	Sand Creek	2.12	− 7.12	− 7.03	+0.09	0.017
Sand Creek	Lars	3.19	+45.53	+45.55	+0.02	0.001
Sand Creek	Wanda	3.47	+ 1.92	+ 1.85	−0.07	0.017
Sand Creek	Mason	1.47	−25.26	−25.28	−0.02	0.001
Wanda	Prosser	5.25	+ 5.96	+ 6.17	+0.21	0.232
Wanda	Mason	4.90	−27.07	−27.13	−0.06	0.018
Mason	Prosser	3.70	+33.36	+33.30	−0.06	0.013
Lars	Lowell	2.79	−19.35	−19.27	+0.08	0.018
Sand Creek	Lowell	2.36	+25.98	+26.28	+0.30	0.212
Wanda	Lowell	3.73	+24.76	+24.43	−0.33	0.407
Prosser	Lowell	1.90	+18.35	+18.26	−0.09	0.015
Lowell	Shelton West Base	3.75	−30.97	−31.38	−0.41	0.630
Prosser	Shelton West Base	2.20	−12.70	−13.12	−0.42	0.387
Lowell	Shelton East Base	2.42	−43.03	−42.58	+0.45	0.490
Prosser	Shelton East Base	4.13	−24.80	−24.32	+0.48	0.950
Lowell	Valley	1.33	+37.56	+37.58	+0.02	0.001
Shelton West Base	Valley	7.31	+68.72	+68.96	+0.24	0.421
Shelton East Base	Valley	4.70	+80.51	+80.16	−0.35	0.576
Prosser	Valley	1.10	+55.64	+55.84	+0.20	0.044
Prosser	Cameron	1.28	− 1.04	− 1.16	−0.12	0.018
Shelton East Base	Cameron	2.58	+23.19	+23.16	−0.03	0.002
Valley	Cameron	2.23	−57.10	−57.00	+0.10	0.022

In the adjustment, of which the direct results are indicated above, the elevations of eight station marks were fixed by precise leveling as follows:

Stations.	Elevation above mean sea level.
	Meters.
Salina East Base,	366.18
Salina West Base,	372.26
Bunker Hill,	570.41
Russell Southeast Base,	573.47
Russell Northwest Base,	561.13
Blue Hill (Nebr.),	622.42
Shelton East Base,	616.03
Shelton West Base,	627.23

The elevations of 29 remaining stations indicated by the observations are the 29 unknowns determined by least squares from the 87 differences of elevations indicated above.

The probable error of an observation of weight unity as derived from the adjustment is ± 0.47 meter. In other words, the reciprocal observations over a line 19⅔ miles ($=31^{km}.7$) long (this being the length of the line corresponding to unit weight) determined the difference of elevation of two points with such a degree of accuracy that it is an even chance whether the error is greater or less than 0.47 meter. The probable errors for lines of other lengths were assumed to be proportional to their lengths.

The probable errors of the elevations of the eight stations fixed by precise leveling are about $\pm$ 0.11 meter. The probable error approaches this value for stations adjacent to those fixed by precise leveling and is greatest for the most remote stations. Station Brown was estimated to be the one least accurately determined and its probable error was therefore computed as a limiting value and found to be $\pm$ 0.28 meter from the vertical angle measures alone, or when combined with the probable error of the elevation furnished by precise leveling it was $\pm$ 0.30 meter.

In other words, for the least accurately determined station in the main scheme between the Salina and Shelton Bases there is about an even chance that the elevation is correct within 0.3 meter, or about 1 foot, and for most stations the accuracy is much greater than this.

The results of the second adjustment in which the stations concerned are those from Valley, Cameron, and Prosser on the edge of the Shelton base net to the Page Base, are shown below in the form used for the first adjustment.

Station 1.	Station 2.	Weight p.	Observed diff. of eleva. h_2-h_1.	Adjusted diff. of eleva. h_2-h_1.	Adj.—Obs. v.	pv^2.
			m.	*m.*	*m*	*m.*
Valley	Divide	0.62	+26.40	+26.29	−0.11	.007
Valley	Deer	0.59	−24.72	−25.25	−0.53	.166
Cameron	Deer	0.96	+30.96	+31.75	+0.79	.599
Cameron	Pompey	1.52	−29.08	−29.27	−0.19	.055
Pompey	Deer	0.94	+60.91	+61.02	+0.11	.011
Pompey	Brayton	0.60	+61.92	+61.28	−0.64	.246
Deer	Divide	2.47	+51.55	+51.54	−0.01	.000
Deer	Brayton	0.82	− 0.44	+ 0.26	+0.70	.402
Divide	Yale	0.79	+28.03	+27.89	−0.14	.016
Yale	Brayton	0.60	−79.80	−79.17	+0.63	.238
Yale	Elm	1.15	−12.13	−12.27	−0.14	.023
Yale	Custer	0.52	−48.77	−49.16	−0.39	.079
Yale	Daily	0.84	−58.49	−58.66	−0.17	.024
Brayton	Daily	3.80	+20.36	+20.51	+0.15	.084
Brayton	Custer	2.78	+30.00	+30.01	+0.01	.000
Daily	Elm	1.86	+46.31	+46.39	+0.08	.011
Daily	Custer	10.67	+ 9.47	+ 9.50	+0.03	.011
Custer,	Elm	1.26	+36.96	+36.89	−0.07	.006
Custer	Buffalo	0.78	− 0.35	− 0.03	+0.32	.080
Elm	Buffalo	1.68	−36.86	−36.92	−0.06	.007
Elm	Ono	0.75	−43.63	−43.62	+0.01	.000
Custer	Ono	1.92	− 6.70	− 6.73	−0.03	.002
Ono	Buffalo	1.40	+ 6.82	+ 6.70	−0.12	.020
Ono	Deloit	0.77	−51.48	−51.31	+0.17	.022
Buffalo	McClure	0.90	−56.59	−56.60	−0.01	.000
Buffalo	Deloit	0.69	−57.95	−58.01	−0.06	.003
Deloit	McClure	3.53	+ 1.37	+ 1.41	+0.04	.007
Deloit	Page SW. Base	1.01	−16.63	−16.54	+0.09	.008
Deloit	Hall	2.49	−18.44	−18.50	−0.06	.010
McClure	Page SW. Base	1.41	−17.97	−17.95	+0.02	.000
McClure	Hall	1.28	−20.00	−19.91	+0.09	.010
Hall	Page SW. Base	2.32	+ 2.02	+ 1.96	−0.06	.009
Hall	Old	2.86	−46.65	−46.61	+0.04	.005
Page SW. Base	Old	7.55	−48.53	−48.57	−0.04	.015
Page NE. Base	Old	29.38	− 2.97	− 2.92	+0.05	.073
Page NE. Base	Prairie	10.19	+15.85	+15.71	−0.14	.204
Page SW. Base	Prairie	5.65	−29.93	−29.94	−0.01	.000
Prairie	Old	4.19	−18.28	−18.63	−0.35	.059
Page SW. Base	Page NE. Base	14.69	−45.54	−45.65	−0.11	.176

In this second adjustment the elevations of four stations were taken as fixed, namely: Valley and Cameron fixed by the previous adjustment, their elevations being 696.19 and 639.19 meters respectively, and the stations Page Southwest Base and Page Northeast Base fixed by precise leveling, their elevations being 626.63 and 580.98 meters, respectively. The elevations of the fifteen remaining stations indicated by the observations are the fifteen unknowns determined by the least squares from the thirty-nine observed differences of elevations given in the above table.

The probable error of an observation of weight unity as derived from the adjustment is ± 0.23 meter. The length of line corresponding to unity weight was again 31.7 kilometers ($19\frac{2}{3}$ miles). The probable error for the elevation of stations fixed by precise leveling is about ± 0.10 meter. The station Elm was estimated to be the one least accurately determined. Its probable error, computed from the vertical measures line, is ± 0.32 meter, or combined with the uncertainty of the elevations fixed by precise leveling it is ± 0.34 meter. In this section, therefore, for the least accurately determined station in the main scheme there is about an even chance that the elevation is correct within 0.3 meter, or within 1 foot, and for most stations the accuracy is much greater than this.

It is interesting to note that in spite of the fact that the observations were made on a smaller number of days at each station, that the probable error corresponding to unit weight is much smaller than in the southern group of observations, being ± 0.23 meter as compared with ± 0.47 meter.

The elevations of various tertiary stations outside the primary scheme which were determined by observations of vertical angles from the primary stations were computed by using the following formula, which is applicable to the observations made in one direction only over each line,

$$h_2 - h_1 = s \cot \zeta + \frac{1-2m}{2\rho} s^2 + \frac{1-m}{\rho} s^2 \cot^2 \zeta$$

in which m is the coefficient of refraction.

The value of the coefficient of refraction used on each line was a mean value derived from a group of lines in the primary scheme in the general locality in question, it being assumed that the most important conditions affecting the coefficient which can be effectively taken into account are the influence of the region and of the climatic conditions of the particular year and months during which the observations were taken.

The computed differences of elevations being combined with the adjusted elevations at the primary stations, there were obtained for each tertiary station as many determinations of its elevations as there were lines to it. The weighted mean of these was adopted and is given in the following table of elevations. The weights assigned to the different lines were inversely proportional to the squares of the lengths of the lines. These tertiary elevations are of course of a much lower grade of accuracy than the elevations of the primary stations. Occasionally the separate determinations of the elevation of one of these points differ by as much as a meter.

TABLE OF ELEVATIONS.

The datum for all the elevations is mean sea level. The stations are in three classes.

First. Those fixed directly by the precise leveling and of which the elevation is subject to probable error of ± 0.11 meter.

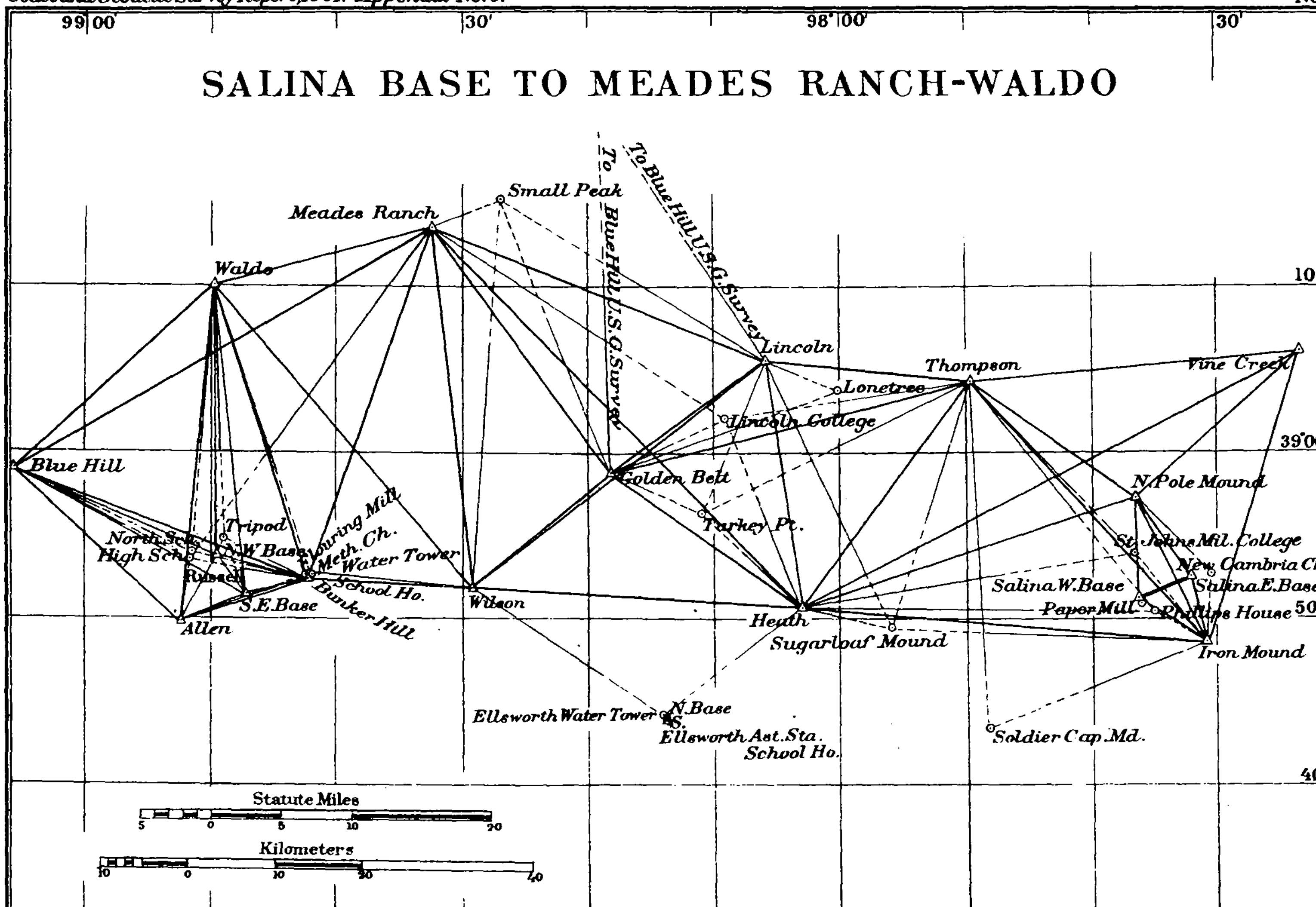
Second. The primary stations fixed by reciprocal measures of vertical angles and which are subject to probable errors varying from ±0.30 to ±0.34 meter.

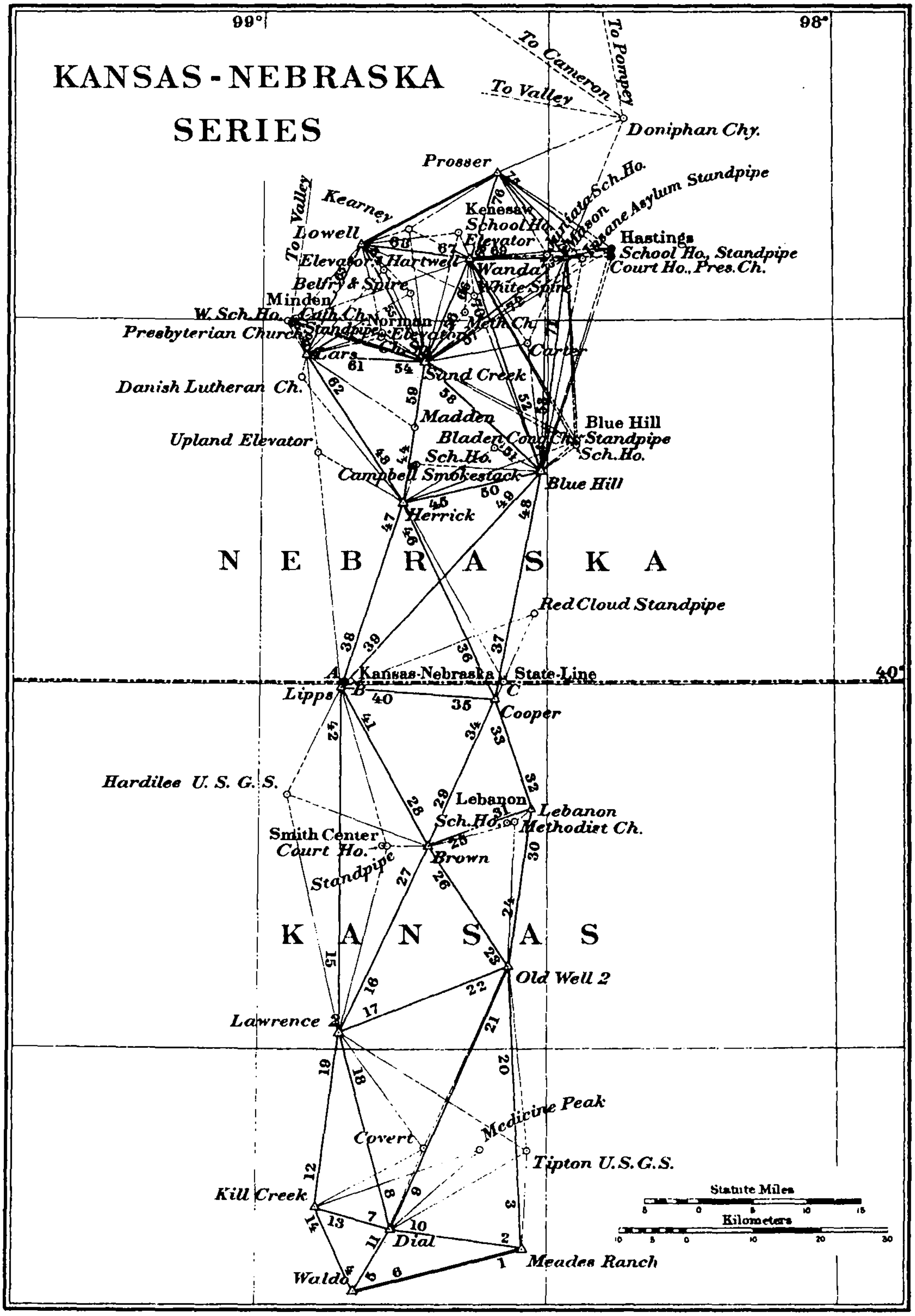
Third. The tertiary stations of which the elevations are fixed by measures of vertical angles which are not reciprocal, the tertiary stations not being occupied. These elevations are subject to probable errors which may be as great as ±0.5 meter in some cases.

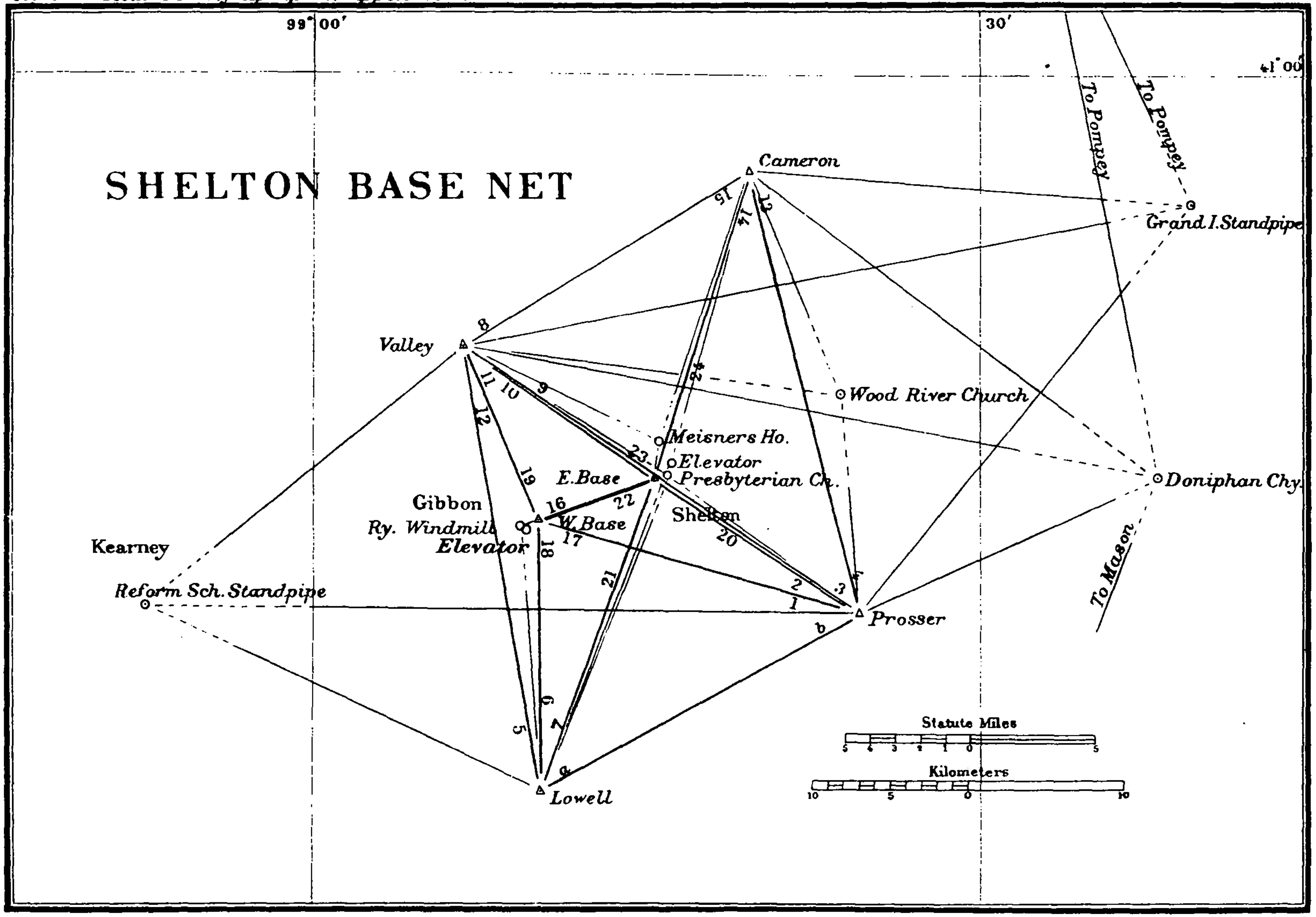
For more exact elevations of the stations fixed by precise leveling and for an exact statement of the points on each station mark to which such elevations are referred, the published results of precise leveling should be consulted.

Table of elevations.

Station.	Point to which elevation refers.	Elevation.
		Meters.
Salina East Base	Bolt	366.18
Salina West Base	Bolt	372.26
Bunker Hill (or B. M. S.)	Stone	570.41
Russell SE. Base (or B. M. T.)	Stone	573.47
Russell NW. Base	Stone	561.13
Blue Hill, Nebraska	Stone	622.42
Shelton East Base	Bolt	616.03
Shelton West Base	Bolt	627.23
Page SW. Base	Bolt	626.63
Page NE. Base	Bolt	580.98
North Pole Mound	Stone	446.9
Iron Mound	Stone	456.6
Vine Creek	Stone	460.0
Thompson	Stone	486.6
Heath	Stone	553.8
Lincoln	Stone	513.3
Golden Belt	Stone	527.8
Wilson	Stone	567.6
Meades Ranch	Stone	599.4
Allen	Stone	579.7
Blue Hill, Kansas	Stone	652.7
Waldo	Stone	619.0
Dial	Stone	624.0
Kill Creek	Stone	623.1
Lawrence 2	Stone	569.4
Old Well 2	Stone	549.6
Brown	Stone	589.8
Lebanon	Stone	587.6
Cooper	Stone	612.7
Lipps	Stone	651.8
Herrick	Stone	639.4
Sand Creek	Stone	632.3
Lars	Stone	677.9
Lowell	Stone	658.6
Wanda	Stone	634.2
Mason	Stone	607.0
Prosser	Stone	640.4
Valley	Stone	696.2
Cameron	Stone	639.2
Deer	Stone	670.9
Pompey	Stone	609.9
Divide	Stone	722.5
Brayton	Stone	671.2
Yale	Stone	750.4
Daily	Stone	691.7


99 00'
30'
98 00'
30'
SALINA BASE TO MEADES RANCH-WALDO
To Blue Hill U.S.G. Survey
To Blue Hill U.S.G. Survey
Small Peak
Meades Ranch
Waldo
10'
Lincoln
Thompson
Vine Creek
Lonetree
Lincoln College
39 00'
Blue Hill
Golden Belt
N. Pole Mound
Turkey Pt.
Tripod
North Sch.
High Sch.
N.W. Base
Flouring Mill
Meth. Ch.
Water Tower
Russell
School Ho.
S.E. Base
Bunker Hill
Allen
Wilson
St. Johns Mil. College
New Cambria Ch.
Salina W. Base
Salina E. Base
Paper Mill
Phillips House
50'
Heath
Sugarloaf Mound
Iron Mound
Ellsworth Water Tower
N. Base
S.
Ellsworth Ast. Sta.
School Ho.
Soldier Cap Md.
40'
Statute Miles
5 0 5 10 20
Kilometers
10 0 10 20 40


KANSAS - NEBRASKA
SERIES
99°
98°
40°
To Cameron
To Pompey
To Valley
Doniphan Chy.
Prosser
Kearney
To Valley
Lowell
Kenesaw School Ho.
Elevator
Hastings
School Ho. Standpipe
Court Ho., Pres. Ch.
Insane Asylum Standpipe
Elevator
Hartwell
Wanda
White Spire
Belfry & Spire
Minden
W. Sch. Ho.
Cath. Ch.
Norman
Standpipe
Elevator
Meth. Ch.
Presbyterian Church
Carter
Sand Creek
Danish Lutheran Ch.
Madden
Blue Hill
Bladen Cong. Ch.
Standpipe
Sch. Ho.
Upland Elevator
Sch. Ho.
Campbell Smokestack
Blue Hill
Herrick
N E B R A S K A
Red Cloud Standpipe
Kansas-Nebraska State Line
Lipps
Cooper
Hardilee U. S. G. S.
Lebanon Sch. Ho.
Lebanon Methodist Ch.
Smith Center Court Ho.
Standpipe
Brown
K A N S A S
Old Well 2
Lawrence 2
Medicine Peak
Covert
Tipton U.S.G.S.
Kill Creek
Dial
Meades Ranch
Waldo
Statute Miles
Kilometers



SHELTON BASE NET
99° 00′
30′
41° 00′
Cameron
Grand I. Standpipe
To Pompey
To Pompey
Valley
Wood River Church
Meisners Ho.
Elevator
E. Base
Presbyterian Ch.
Doniphan Chy.
Gibbon
Ry. Windmill
Elevator
W. Base
Shelton
Kearney
Reform Sch. Standpipe
Prosser
To Mason
Lowell
Statute Miles
Kilometers

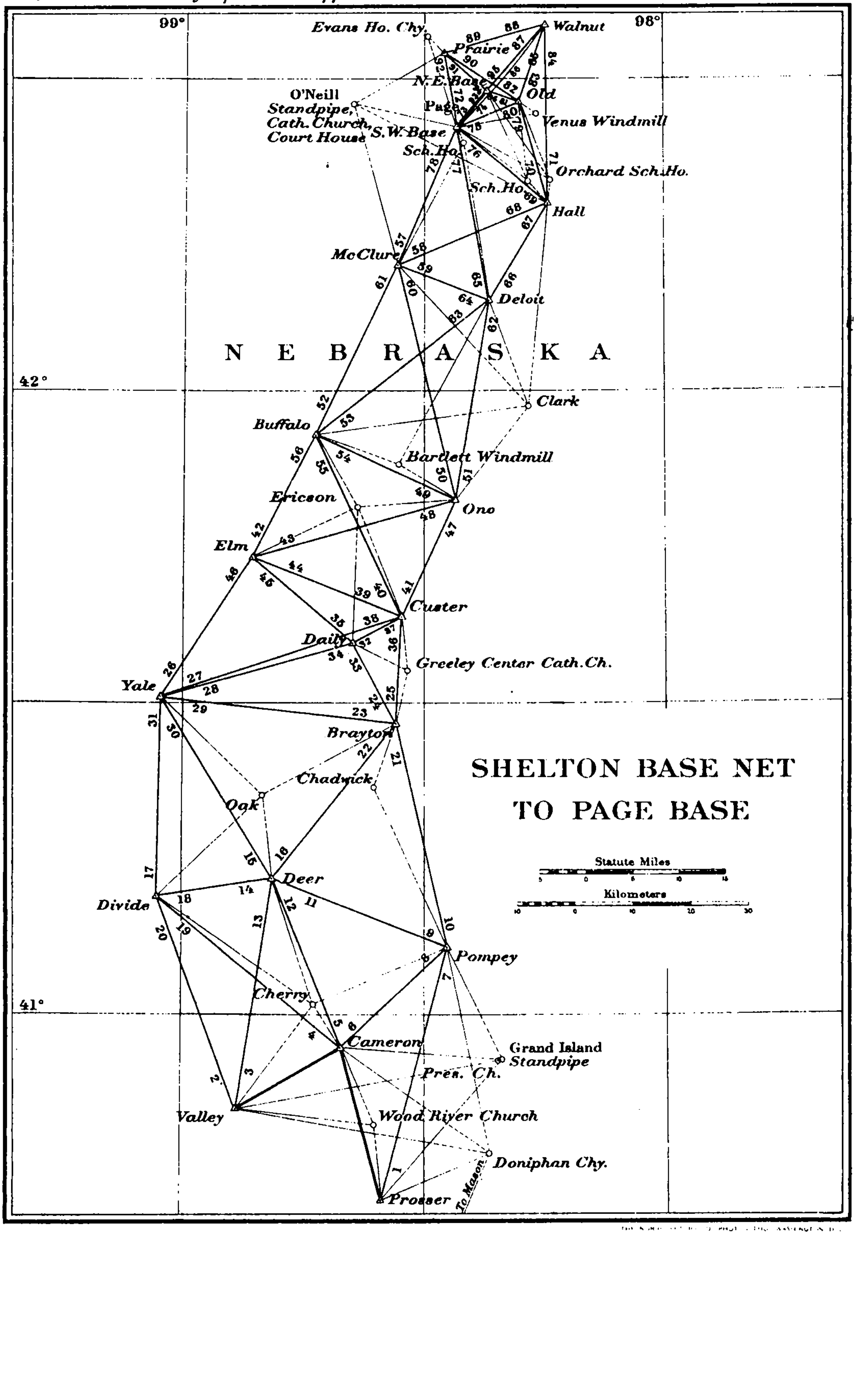

SHELTON BASE NET
TO PAGE BASE
Statute Miles
Kilometers
N E B R A S K A
99°
98°
42°
41°
Evans Ho. Chy.
Walnut
Prairie
N.E. Base
Old
O'Neill
Standpipe,
Cath. Church,
Court House
Page
S.W. Base
Venus Windmill
Sch. Ho.
Orchard Sch. Ho.
Sch. Ho.
Hall
McClure
Deloit
Clark
Buffalo
Bartlett Windmill
Ericson
Ono
Elm
Custer
Daily
Greeley Center Cath. Ch.
Yale
Brayton
Chadwick
Oak
Deer
Divide
Pompey
Cherry
Cameron
Grand Island
Standpipe
Pres. Ch.
Valley
Wood River Church
Doniphan Chy.
Prosser
To Mason

Table of elevations—Continued.

Station.	Point to which elevation refers.	Elevation.
		Meters.
Custer	Stone	701.2
Elm	Stone	738.1
Buffalo	Stone	701.2
Ono	Stone	694.5
Deloit	Stone	643.2
McClure	Stone	644.6
Hall	Stone	624.7
Old	Stone	578.1
Prairie	Stone	596.7
Soldier Cap Mound	Ground	480.4
Sugar Loaf Mound	Ground	512.5
Salina, St. John's Military College	Top of cupola	403.7
Salina, Phillips' House	Top of dome	411.6
Ellsworth Water Tower	Top	512.6
Turkey Point	Ground	532.6
Small Peak	Ground	564.1
Lincoln College	Top of cupola	452.6
Blue Hill, U. S. G. S.	Ground	535.3
Lone Tree	Ground	497.2
Bunker Hill Water Tower	Tank	581.9
Russell High School	Top of cupola	585.4
Russell North School	Top of cupola	577.8
Russell Tripod	Ground	565.6
Bunker Hill Methodist Church	Spire	583.8
Bunker Hill Schoolhouse	Top of cupola	581.2
Tipton, U. S. G. S.	Ground	553.1
Covert	Ground	561.9
Medicine Peak	Ground	541.6
Smith Center Standpipe	Top	589.7
Hardilee	Ground	615.6
Red Cloud Standpipe	Top	562.9
Kansas-Nebraska State Line 1	Stone	641.5
Kansas-Nebraska State Line B	Ground	632.1
Kansas-Nebraska State Line 2	Stone	627.6
Kansas-Nebraska State Line C	Mound	590.6
Carter	Ground	598.0
Blue Hill Standpipe	Top	635.2
Madden	Ground	649.3
Kearney	Ground	656.4
Hastings Standpipe	Top	626.7
Insane Asylum Standpipe	Top	627.0
Minden Standpipe	Top	695.9
Kearney Reform School Standpipe	Top	731.6
Doniphan Chimney	Top	638.6
Grand Island Standpipe	Top	601.3
Cherry	Ground	641.1
Chadwick	Ground	637.7
Oak	Ground	692.0
Ericson	Ground	702.9
Clark	Ground	662.1
O'Neill Standpipe	Top	642.2

ALPHABETICAL INDEX.

(Exclusive of Appendices 3 to 6.)

[For Table of Contents see page 7. Tabular Index of Field Work on page 61.]

A.

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N.

O.

P.

Q.

R.

S.

T.

U.

V.

W.

Y.

Z.

COAST AND GEODETIC SURVEY REPORT, 1900.

ERRATA.

Page 564, line 5, for t read x; to line 6 add "for the flood stream;" line 12, for $+$, read $\pm$; line 13, for $+$ read $-$; line 14, for κ^2 read $-\kappa^2$; line 18, for $\sin\alpha$ read $-\sin\alpha$; lines 20, 22, for α read $-\alpha$.

Page 659, line 19, for "line" read "little."

Page 677, No. 925, for "3, 302, 0, 332.5, 22.17, 21.77," read "186, 120, 178, 153, 10.20, 9.80."

Page 684, ninth line from bottom, and page 685, eleventh line from bottom, delete "amplitude of tide outside".

O