REPORT OF THE SUPERINTENDENT

U. S. COAST AND GEODETIC SURVEY

SHOWING

THE PROGRESS OF THE WORK

DURING THE

FISCAL YEAR ENDING WITH

JUNE, 1879.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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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,

COMMUNICATING,

In obedience to law, a report of the Superintendent of the Coast and Geodetic Survey, showing the progress made in the survey of the Atlantic, Gulf, and Pacific coasts, for the year ending June 30, 1879.

DECEMBER 15, 1879.—Ordered to lie on the table and be printed.

TREASURY DEPARTMENT, *December* 12, 1879.

SIR: In compliance with section 4690, United States Revised Statutes, I have the honor to transmit herewith, for the information of the Senate, a report addressed to this department by Carlile P. Patterson, Superintendent of the Coast and Geodetic Survey, showing the progress made in the survey of the Atlantic, Gulf, and Pacific coasts during the year ended June 30, 1879, and accompanied with a map illustrating the general progress made in that work.

Very respectfully,

JOHN SHERMAN,
Secretary.

Hon. WILLIAM A. WHEELER,
Vice-President of the United States, President of the Senate.

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ABSTRACT OF CONTENTS OF REPORT.

CONTENTS OF APPENDICES.

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ALPHABETICAL INDEX.

A.

B.

D.

E.

F.

G.

H.

I.

J.

M.

N.

Q.

R.

S.

W.

Y.

Z.

REPORT.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
Washington, December 12, 1879.

SIR: I have the honor to transmit herewith a detailed report of the operations prosecuted in the course of the fiscal year ending June 30, 1879, in continuation of the Coast and Geodetic Survey of the United States. It will be seen by the table given as Appendix No. 1, which shows the distribution of the field and hydrographic parties, that the work has been advanced in thirty of the States of the Union and in four of the Territories. In general, the weather was favorable, and the regular work has been extended as far beyond the limits reached in the preceding year as could be expected with the means available for the parties severally.

During the earlier years of the survey, neither the urgent demand for the important preliminary results, nor the general state of the survey permitted every class of work for which the survey was instituted to be taken in hand and advanced simultaneously. But I am glad to record the fact that during the past year all branches of the work were finally organized and in progress, so far as the reduced appropriations would permit, along the Atlantic, Gulf, and Pacific coasts, and in many of the interior States.

These classes of work include the measurement of base lines; primary, secondary, and tertiary triangulation; astronomical determinations of azimuths and latitudes; determinations of telegraphic differences of longitude; pendulum observations in the field; verification of standards of length; lines of level of precision to extend across the continent; systematic magnetic observations, both on land and at sea; investigations in relation to the best signals for use at night in geodetic work; topographical work of several classes; simultaneous meteorological and magnetic observations on mountains eleven thousand feet high, and in valleys at their bases only two hundred feet above the sea level; inshore, offshore, and deep-sea hydrography, including serial temperatures, current observations and dredgings, in the study of the Gulf Stream; tidal observations at both permanent and temporary tidal stations; observations of sea currents, other than the Gulf Stream; full tidal discussion by harmonic analysis; observations relating to possible tidal or other periodic action of the earth's surface; observations relating to possible change in the surface affecting primary points of triangulation; publication of the Coast Pilot and charts, hand-books and manuals of the several classes of work; meteorological researches in reference to practical uses for the Coast Pilot; physical hydrography of rivers and harbors; discussion of eighteen hundred miles of primary geodetic arcs in relation to the figure of the earth; the substitution of glass for metal in theodolite limbs; and the planning of a general map of the United States founded on the most accurate geodetic, astronomical, hypsometric, and geographical data available.

At first only the most necessary classes of work were taken in hand; as the work progressed others were added; some carried on continuously, others from time to time as opportunities offered; but at no one time have all these classes of work been carried on simultaneously until the past year. The appropriations that were sufficient when only a certain number of branches of work were in progress, are certainly not adequate to keep them all in hand at the same time and have the survey carried on with an even front, every part bearing its due proportion to the whole. It is manifest that economy and the best interests of the survey require that no one part, or any one class, be permitted to lag behind; for, of necessity, when any branch of the work has been permitted to fall behind, some other classes of work must periodically be neglected, so as to bring the class that had been suspended for want of funds into proper relation to the rest of the survey. The Coast and Geodetic Survey in all its branches is one consistent whole, and no one branch can be neglected without detriment to the whole.

It is especially satisfactory that the aggregate length (eighteen hundred miles) of our continuous geodetic arcs has enabled us to contribute additional data for the determination of the figure of the earth, tending to a form more nearly in accord with that found by Colonel Clarke than with that of Bessel, for which the first-named figure has already been substituted. As our data accumulate, that will in its turn, doubtless, be modified. The great arc along the thirty-ninth parallel from the Atlantic to the Pacific, about three thousand miles in length, will lead to the solution of many difficult points of discussion. But in all this work, no arc is being, or has been, measured merely as an arc. Each arc in the survey is the result of work necessary for the other purposes of the survey. The thirty-ninth parallel arc is for the purpose of connecting the Atlantic system of triangulation with that of the Pacific, and for forming a base from which accurate surveys can be carried north and south. The line of levels of precision being carried across the continent is for the purpose of providing an accurate base for the determination of all heights in the interior, and is necessary for the accurate reduction of the geodetic work.

A systematic magnetic survey of the whole country is a work of immense utility, the necessity for which is too manifest for discussion.

The great length of the period (nineteen years) required for a full series of tidal observations at each locality, has only within the past three or four years admitted of their discussion, although partial discussions have been made for shorter periods at certain localities.

The deep-sea sounding throughout the Gulf of Mexico, parts of the Caribbean Sea, and channels around Cuba, with serial temperature observations from surface to bottom, and observations of currents, are beginning to yield valuable results in the direction of a more definite conception of the flow, mass, and direction of the Gulf Stream. The "problem of the Gulf Stream" has been one of the principal studies of this survey; but, for several years before the war, during the war, and for several years after, the want of means and suitable vessels suspended its investigation. After the data previously secured, those to be obtained were: (1st) Depths throughout the Gulf of Mexico and Gulf of Florida. (2d) Temperatures from surface to bottom over the same area. (3d) Character of bottom throughout the same area, (4th) Specimens of water for analysis from surface to bottom throughout the same area. (5th) Currents. (6th) Animal life from surface to bottom, especially the latter. After all the data have been obtained in reference to the waters forming the Gulf Stream, including those of the Gulf of Mexico and of the Atlantic east of the Caribbean islands, the Stream is to be followed to its conclusions. Its oscillations of position, differences of velocity monthly and annually, and increase of volume north of Cape Canaveral from the open sea, if any, are also to be determined.

Congress having partially provided means, the work of obtaining data under the first five heads was begun in 1872 in the Gulf of Mexico, by Lieut. Commander J. A. Howell, U. S. N., Assistant Coast Survey, commanding successively the steamers Bache and Blake. Howell successfully ran seven hundred and forty miles of sounding lines from shore out to depths of twelve hundred fathoms, by the old methods, obtaining the collateral data.

Sir William Thomson's wire sounding apparatus having been successfully used in the Pacific in depths of forty-six hundred and fifty-five fathoms by Commander George E. Belknap, U. S. N., commanding steamer Tuscarora, with improvements devised by that officer, one set was obtained for use in researches to be made by officers attached to the Coast Survey. At this time Lieut. Commander Howell was transferred to other duty. He was succeeded in the command of the Blake by Lieut. Commander C. D. Sigsbee, U. S. N., Assistant Coast Survey, and by that officer the deep-sea soundings (generally beyond one hundred fathoms and to depths of twenty-one hundred and fifty fathoms) of the whole Gulf of Mexico were completed. He obtained at the same time full data under the first five headings named. When Sigsbee saw the Thomson wire sounding apparatus he at once suggested important improvements, and devised additional apparatus to relieve the strain on the wire during violent and rapid movements of the vessel. He also made other improvements so greatly facilitating the work that in two thousand fathoms depth the Blake (of three hundred and twenty tons, new measurement), was enabled in nearly all weathers to sound and obtain serial temperatures continuously day and night, with a probable error in sounding not exceeding one-quarter of one per cent. of the depth, even during moderately severe gales. The number of nautical miles of sounding lines run by Sigsbee in the Gulf, with serial temperatures, was thirteen thousand seven hundred and fifty. This great work was, by the energy and unremitting labor of Lieut. Commander Sigsbee, earnestly supported by the officers and crew of the Blake, completed in the early summer of 1877. The remaining part of the work, viz, the collection of specimens of animal life from surface to bottom was yet to be done. As naval officers are professionally neither naturalists nor geologists, I sought the services of Prof. Alexander Agassiz, who consented to take charge of this special part of the work, requiring only the outlay needful for his daily expenses. From his great experience with wire rope in mining operations, Professor Agassiz proposed its use for dredging purposes. Lieut. Commander Sigsbee, after conference with Professor Agassiz and myself, and to meet the requirements of the work in every way, thoroughly fitted the Blake for dredging and other purposes.

Professor Agassiz joined the Blake at Havana in December, 1877, when Lieut. Commander Sigsbee at once began a series of dredgings in the Gulf of Mexico over ground indicated by Professor Agassiz, who "viewed" as they came from the water, took charge of, and preserved the "finds" of each haul of the dredge and tangles. The nets, dredges, &c., had been made from the best models formerly used in researches abroad, but some not proving entirely successful were, at the first failure of each, made completely successful by suggestions from Lieut. Commander Sigsbee, Professor Agassiz, Master Jacoby, and other officers of the vessel.

Professor Agassiz was obliged to return home at the end of March, 1878. A number of successful hauls of the dredge were made after his departure. With his usual energy, Lieut. Commander Sigsbee, in the Blake, continued until June other work of sounding, serial temperatures, &c., under special instructions.

The experience of that season suggested to Lieut. Commander Sigsbee many new improvements of the machinery and facilities for dredging, and also an improved sounding accumulator of his own design for relieving the strain on the wire. Under his special direction, and in accordance with his plans, the Blake was completely refitted with new reeling engine, dredging engine, sounding apparatus, &c., for all the varied classes of work of deep-sea sounding, dredging, &c.

Lieut. Commander Sigsbee's term of service on the survey having expired, he was relieved in the command of the Blake by Commander J. R. Bartlett, U. S. N., Assistant Coast and Geodetic Survey, in November, 1878.

The discovery, by the Challenger, of submarine lakes, whose temperatures are constant to the greatest depths with that of the ocean at the depths of their rims, rendered it more than ever imperative to determine the depths of the rims separating the waters of the Gulf of Mexico from the Caribbean, and *its* waters from those of the Atlantic, both at the eastward and northward. I assigned the Blake for this development, and Professor Agassiz again accompanied the vessel to care for his own class of the work. As he was obliged to return home in March, 1879 (the Blake having left Washington November 28, 1878), the first work done was of course the dredgings. Commander Bartlett effected these with many successful hauls, at localities indicated by Professor Agassiz, in depths of from ten to twenty-four hundred and fifty fathoms, everything, ship, officers, men, naturalists, all working in harmony, with the necessary result—complete success. Of course the dredging operations of the vessel were conducted by the officers and crew under the direction of Commander Bartlett. After the departure of Professor Agassiz, Commander Bartlett, under my instructions, completed all the required soundings and serial temperatures, &c., between all the islands in the series from Grenada to Cuba and Jamaica, making no soundings in the Gulf of Mexico. The Blake arrived at New York on May 28, 1878. Under the head of Section IX a detailed statement of the operations conducted in that vessel will be given in this report.

All the deep-sea soundings taken by Lieut. Commanders Howell and Sigsbee and Commander Bartlett have been or are being engraved on the charts. All other physical data are under discussion, and, at Professor Agassiz's suggestion, entirely approved by me, the discussions and descriptions of the several natural-history specimens (reserving duplicates for the National and other museums) have been assigned by him to scientists most eminent in the study of each particular branch without regard to nationality, the scientific world being a cosmopolitan republic in which the ablest govern. By referring specimens to the men who can handle them best, we obtain full descriptions, assignment to place, and engraved drawings from the most eminent authorities known, and results are given to the world with the least delay. By his own rapidity in work and the influence of his energy on others, many of these memoirs have already been completed, with illustrations of all new specimens, and have been published and distributed to this office, to scientists and others, as publications of the Museum of Comparative Zoology at Cambridge, Mass., of which Professor Agassiz is the director, all without cost to the government. Through this office that institution of course receives full credit for its work.

Without specifying the great results obtained from this continuous research, I may be pardoned in referring with some gratification to the fact that in the small steamer Blake, of only three hundred and twenty tons burden, new measurement, under the energetic and skillful command of Lieut. Commander Sigsbee and Commander Bartlett, with a complement of forty-five, including officers and crew, four soundings were taken in the depth of two thousand fathoms during the same length of time which the Challenger, of twenty-three hundred tons burden, with a complement of twenty-nine naval and civilian officers and a correspondingly large crew, occupied in taking one; and five hauls of the dredge at the same depth were made by the Blake in the time occupied by the Challenger in making one.

Professor Agassiz and his scientific friends express themselves as being more than gratified at the results of the dredging operations, and with the number of newly discovered as well as before known "beasts" brought from the depths of the sea. The Professor has also engaged to make an independent discussion of the "Gulf Stream," with its relations to the present and former zoological continents and islands, when the accumulation of facts shall sufficiently justify him.

In regard to the "Gulf Stream" and the general circulation of the waters of the ocean there are many theories, but this office relies on observations and rests on conclusions demonstrated by facts.

In meteorological researches, with a view to practical uses in navigation, Mr. William Ferrel, having previously discussed the general motions and laws of the atmosphere, has within the year extended investigation to include the effect of local and abnormal disturbances such as irregular distribution of temperature over the globe, cyclones, tornadoes, and waterspouts. His theoretical results, after comparison with observation, have furnished numerous examples showing the applicability of certain derived laws to the practical purposes of the navigator. The aim has been to develop the principles upon which the general laws, as well as the abnormal and local motions of the atmosphere, are based, so that the navigator, with knowledge of the principles, need not be subject to mere rules that must vary under different circumstances. With due knowledge he will be able to modify the rules so as to suit various circumstances under which they must be applied in navigation along our extended coasts, where the hydrography, contour of shores, ocean currents, &c., must be taken into consideration.

In a notice by M. Thiesen in the "*Zeitschrift der Österreichischen Gesellschaft für Meteorologie,*" it is signified by that able investigator that, however the course of research may be widened in future, Mr. Ferrel has the merit of being among the few who have treated apparently inexplicable mazes in meteorological phenomena from a higher standpoint by applying accurate means of analysis.

An aggregate of forty stations were occupied in the course of the year for determinations of magnetic declination or variation of the compass at points in the region between Wyoming Territory and Yucatan, and including also points on the shores of some of the West India Islands. The stations will be mentioned in the several sections to which they belong, between Sections VI and XVII, inclusive. All previous results in regard to magnetic declination were embodied in the map issued with my annual report for the year 1876. The data since collected verify the courses then drawn to represent lines of equal magnetic variation, and with the observations now in progress means will be afforded for extending the lines from north to south across the Gulf of Mexico.

Within the year a third edition was issued of the paper by Assistant Charles A. Schott on the secular change to which the variation of the compass needle is subject. This will meet a demand which is constantly increasing. Of late years many applications in regard to the rate of variation, and magnetic variation in former years, have been made by surveyors and by members of the legal profession.

The paper here referred to explains the principal periodic change in the direction of the magnetic needle, but the law of secular change is treated in detail and illustrated by two engraved plates. The discussion was based on upwards of five hundred observed declinations recorded at fifty-two localities. These include points in the United States, Brazil, the West India Islands, Canada, the Sandwich Islands, and the northeast coast of Asia.

A synopsis showing the localities of work done in the year ending June 30, 1879, is here appended. Prospective work to be mentioned in detailed estimates for the fiscal year ending June 30, 1881, will be stated in the usual order, corresponding with the geographical arrangement observed in stating the progress made in the survey.

The operations of the year ending June 30, 1879, include hydrography of the coast of Maine from Petit Manan Light southward and westward to completed limits, and soundings in the eastern approaches to Mount Desert Island; drawings of prominent features of that island; soundings in Frenchman's Bay near the Porcupine Islands; topography of those islands and of the shores of Skilling River, and of the shores of Union River Bay near Ellsworth, Me.; topographical surveys of Long Island and Bartlett's Island; soundings in the approaches to Deer Isle, including parts of Jericho Bay and Placentia Bay, and in the approaches to Isle au Haut, developing there numerous ledges, and also a ledge in Muscongus Bay; tidal observations at North Haven, in Penobscot Bay; geodetic observations at Gunstock Mountain, Starr King Mountain, and Mount Monadnock, in New Hampshire; light-house at Portsmouth, N. H., and at Newburyport and Cape Ann, Mass., determined in position; reconnaissance for geodetic stations in Vermont; hydrography of the entrance and bar of Merrimac River, Mass.; inspection and verification of the harbor commissioners' survey of the upper harbor of Boston; sea currents observed and recorded at stations in the Gulf of Maine; examination for positions of aids to navigation along the coast of Massachusetts and Rhode Island; tidal observations in Buzzard's Bay and at Providence, R. I.; geodetic observations at Mount Prospect, N. Y.; hydrography of the vicinity of Block Island, including development of South-West Ledge; positions examined of the aids to navigation along the coast of Connecticut, and in Long Island Sound and Hudson River; the eastern part of Jamaica Bay surveyed and sounded; tidal observations at Sandy Hook, N. J., and at Governor's Island, New York Harbor; topography of the shores of the Hudson near Peekskill; examination of the ground marks at triangulation points on the coast of New Jersey; geodetic observations at Pickles Mountain and at Mount Horeb, in New Jersey; triangulation, topography, and hydrography, with special observations on the tides and currents of Delaware River, at Philadelphia, for the Board of Trade; hydrographic survey of the Delaware, from Marcus Hook to New Castle, for the Light-House Board; geodetic observations connecting stations in Eastern Pennsylvania with points in Maryland; pendulum observations at stations in Pennsylvania; astronomical observations at Washington for determining the longitude of southern stations; magnetic declination, dip, and intensity determined as usual at Washington, D. C.; investigation of the oyster reefs in Tangier Sound, Pocomoke Sound, and James River, Va.; tidal observations at Old Point Comfort; detailed survey of the shores of James River continued in the vicinity of Richmond, Va.; geodetic observations at stations in West Virginia; geodetic level determined at points between Hagerstown, Md., and Athens, Ohio; positions determined of life-saving stations on the coast of Virginia and North Carolina for entry on engraved charts; in Albemarle and Pamplico Sounds; compilation of notes for the Coast Pilot; development of a harbor of refuge inside of Cape Lookout; coast of North Carolina sounded from Barren Inlet southward and westward to Cape Fear; topography of Smith's Island in the vicinity of that cape; longitude determined at a station in Statesville, N. C.; hydrography of the coast of South Carolina from Murrell's Inlet southward to the approaches of Winyah Bay, and soundings of the Sampit River, above Georgetown, S. C.; topography of the shores of parts of Stono River and Wappoo Creek, near Charleston, S. C.; longitude determined at a station in Atlanta, Ga.; tidal observations at Fernandina, Fla.; triangulation and topography of Indian River, Fla. extended southward to Malabar Point, including the adjacent beach of the Atlantic; triangulation of the Gulf coast between Charlotte Harbor and Sarasota Bay; inshore hydrography of that vicinity; magnetic elements determined at Fernandina and Key West, Fla.; at Nassau (New Providence), at South Bemini, Salt Key Bank, Matanzas, Bahia Honda, Havana and Cape San Antonio (Cuba); at Belize, in British Honduras, and at Cozumel and Mujeres, off Yucatan; geodetic observations at stations in Northern Alabama; currents observed and recorded at stations in the Gulf of Mexico off the mouths of the Mississippi; at New Orleans, records of the water level; triangulation of the Mississippi between Donaldsonville and Iberville, between Natchez and Grand Gulf, between Vicksburg and Milliken's Bend, and from Bennett's Landing to Memphis; hydrography of the Mississippi River between Grand View Reach and Point Houmas; soundings in the mouths of the Red River and the Atchafalaya, and also of the Bonnet Carre, Morganzia, Glascock and Diamond Island Crevasse; inshore hydrography of the coast of Texas abreast of Matagorda Peninsula; triangulation of Laguna Madre, near the Rio Grande boundary; deep-sea soundings, serial temperature observations, and dredgings in the waters of the Caribbean Sea and in passages between the Windward Islands; magnetic declination, dip, and intensity determined at San Antonio, Fort Worth, and Sherman, in Texas; and at Atoka and Eufaula, in Indian Territory.

On the Pacific coast of the United States the work of the year includes the geodetic connection, giving true positions of the Santa Barbara Islands off the coast of California, and the detailed survey of Santa Catalina Island and San Clemente Island; also the hydrography of the approaches to those islands; inshore hydrography of the coast from Newport Bay to Point Vincente, and soundings in the southern approach to Santa Barbara channel; coast triangulation from Point Arguello northward to Point Sal, and topography of the coast of California in the vicinity of Point Purissima; hydrography of part of Suisun Bay and part of San Pablo Bay; soundings at the mouths of the Sacramento and San Joaquin Rivers; tidal observations at Saucelito, in San Francisco Bay; geodetic observations at Mount Lola, Cal.; detailed survey of the coast from Fisherman's Bay northward and westward to Haven's Anchorage; extension northward of the main triangulation of the coast of California to the vicinity of Point Cabrillo; tidal records from the self-registering gauge at Honolulu, Sandwich Islands; triangulation of Columbia River, Oreg., extended upward to Willamette Slough; triangulation across the waters of Washington Sound, in the vicinity of Point Partridge, W. T.; hydrography of the southern part of Puget Sound from Battery Point to Henderson's Inlet; survey of the shores of Hood's Canal between Port Gamble and Hazel Point; triangulation of Case's Inlet, Pickering Passage, Peale's Passage, Eld Inlet, and Totten's Inlet, connecting with Puget Sound; and topography of the shores of Carr's Inlet, W. T.

Further material has been compiled for the Coast Pilot of Alaska, and illustrative of the meteorology of that Territory.

In localities between the Atlantic coast and the Pacific coast, geodetic work has been advanced by marking a base line near Louisville, Ky., and selecting adjacent points for triangulation; by geodetic observations near Lebanon, in Tennessee; selection of geodetic points between Athens and Columbus, Ohio, and in Indiana between Indianapolis and New Albany; in Illinois, points have been selected to connect with the base line on American Bottom, and observations were recorded at Springfield for the magnetic declination, dip, and intensity; further westward the operations of the year include magnetic observations at Madison, Wis., and geodetic work between that city and the Mississippi River, also in Missouri, beyond completed stations near the Gasconade River; magnetic observations at Great Bend, Sargent, Humboldt, Emporia, and Dodge City, in Kansas; geodetic observations in Nevada and Colorado; magnetic observations at Denver, North Pueblo, Fort Lyon, Colorado Springs, and Greeley in Colorado, and at Salt Lake City, Castle Rock, and Ogden, in Utah; at Laramie City, Rock Creek, Creston, Point of Rocks, Cheyenne, Fort Steele, Green River, and Carter Station in Wyoming Territory.

Office operations of the year include reduction and discussion of all the field observations, preparation for issue of the records and results; the drawing of hydrographic charts from the original note books, and of topographical and hydrographic maps on the several scales of reduction from originals, for publication; engraving, electrotyping, and printing of the same; and repairs of instruments used in the survey. Tide tables of the principal ports of the United States for the year 1880 have been published; drawings for fifty-nine charts have been in progress, and of these twenty-eight were completed within the year, nine of which were photolithographed.

In engraving, one hundred and forty-five plates have received additions, twelve chart plates have been completed, and engraving is in progress on ten others begun within the year.

An aggregate of twenty-three thousand two hundred and thirteen copies of charts has been issued, and returns show, by threefold increase in sales, a large demand for them; nine hundred and sixty-three copies of the annual reports have been distributed; calls have been met, as heretofore, for information relating to local topography and hydrography, tides, magnetic variation, geographical positions, heights, distances, directions, and other particulars contained in the office records. The second volume of the Atlantic Coast Pilot, for navigation between Boston and New York, has been published, and also a second edition of part of the Coast Pilot for the Gulf of Maine.

The third volume, nearly ready for the printer, will complete descriptions of the coast, and sailing directions for navigating between Passamaquoddy Bay and Chesapeake entrance; and notes are now in hand for a fourth volume, to include the coast south of Cape Henry.

ESTIMATES.

For continuing the work of the Survey during the fiscal year ending June 30, 1881, detailed estimates were transmitted to the Department in October last. The following explanatory remarks were appended:

"The aggregate of estimates now submitted is greater than the appropriation for the present fiscal year, as continued experience verifies the statement made in submitting estimates for the present year in regard to the cost of separate results. To secure economy the yearly aggregation of results should be larger than the reduced appropriations of the present and past years will permit. The work of the Coast and Geodetic Survey depends on the aggregation of certain varieties of fact, formulated to obtain unity of results. It is plain that in such work the cost of obtaining a single fact by itself will greatly exceed the average cost of a similar class if provision is made for obtaining a considerable number of facts in the same period of time. It is also plain that there is a limit beyond which an enlarged scale for such work will not lessen the average cost of separate facts. As between the extremes here adverted to, and with close reference to the most productive scale of operations, the estimates for continuing the work are presented.

"The appropriations of the present and recent years are below the amount necessary to secure individual results at the least cost; hence estimates are submitted larger in amount, but, in respect of the results to be obtained, less in proportion than the more costly but reduced appropriation for the current fiscal year. Public interests, as to time and means, could not be fully realized without an appropriation twenty per cent. larger than the estimates now submitted, to permit the early completion of the coastwise work, and the prosecution of geodetic measurements in immediate demand.

"In addition to the appropriation for the regular progress of the work along the coast, and for determining geographical points in the interior, an amount is greatly needed for resurveys of important localities, as parts of Nantucket and Long Island Sounds, New York Bay and approaches, Delaware Bay, San Francisco Bay, Columbia River entrance, &c.; in which, from natural causes, serious changes have taken place since the original surveys were made.

"I earnestly hope that the estimates now presented may be approved, as mature consideration of the interests concerned have constrained me to regard them requisite for the due and economical progress of the Coast and Geodetic Survey."

The synopsis, already given, of work done in the course of the fiscal year ending June 30, 1879, accompanied the estimates.

Estimates in detail.

The estimates for continuing work in the Eastern Division of the Coast and Geodetic Survey during the year ending June 30, 1881, are intended to provide for the following progress:

FIELD WORK.—To continue the topography of the western shore and islands of Passamaquoddy Bay and its estuaries; to complete the topography between Penobscot Bay and Narraguagus Bay, and that of the shores of the Penobscot near Bangor; to determine heights at geodetic points between Boston and the Saint Croix, and coefficient of refraction; to complete the hydrography between

Penobscot Bay and Narraguagus Bay, and continue soundings in the coast approaches eastward of Petit Manan Island; to continue a topographical and hydrographic survey of Portsmouth Harbor, and make such additional triangulation as may be requisite for that and other surveys on the eastern coast; to continue the triangulation of New Hampshire; determine the position of new light-houses between Eastport, Me., and New York; to continue the triangulation of Vermont; to continue soundings along the coast of Maine, and other offshore hydrography between Cape Cod and Manan, and make special examination for the sailing lines for charts; to continue the observations of sea and tidal currents in the Gulf of Maine; to continue tidal observations, and to make such astronomical and magnetic observations as may be required; to continue such topographical and hydrographic resurveys of the coast between Cape Cod and New York as may be found necessary; to continue the survey of the Connecticut River from its mouth to Hartford; to make such examinations as may be required in New York Harbor, and such surveys in its vicinity as may be necessary, including the continuation of the topographical and hydrographic resurvey of the south coast of Long Island; to make, along this part of the coast, observations on tides and currents; to extend the plane-table survey of the west shore of Hudson River above Haverstraw; to continue triangulation between Hudson River and Lake Champlain, and between Lake Champlain and Lake Ontario; to make the requisite astronomical observations, to continue the topographical and hydrographic resurveys of the coast of New Jersey and of Delaware Bay and river; to continue the triangulation of New Jersey and Pennsylvania; to connect the Atlantic coast triangulation with that of the Chesapeake Bay near the boundary line between Maryland and Virginia; to complete the detailed survey of James River, Va., including the hydrography, and continue the plane-table survey of the Potomac River; to continue westward the main triangulation from the Atlanta base to the Mississippi River at or near Memphis, including astronomical and magnetic observations; to continue the supplementary hydrography between Cape Henlopen and Cape Henry, and the tidal observations, including also such as may be required in Chesapeake Bay; to continue westward the triangulation in West Virginia along the thirty ninth parallel; to measure base lines of verification and determine azimuths for the coast triangulation south of Cape Lookout, and make the astronomical and magnetic observations requisite; to continue the offshore hydrography between Cape Henry and Cape Fear; to complete the hydrography of Pamplico Sound and its rivers; to sound the entrance to Cape Fear River; to continue the topographical and hydrographic survey of rivers near the coast of South Carolina and Georgia; to determine azimuths for the triangulation of the coast of South Carolina and Georgia; to continue the detailed survey of sea islands and water passages north and south of Savannah River entrance, and make tidal observations; to continue offshore hydrography between Cape Fear and the Saint John's River, Fla.; to continue southward from Cape Malabar, near latitude 28° north, the triangulation, topography, and hydrography of the eastern coast of Florida, including Indian River; to continue the triangulation, topography, and hydrography of Saint John's River; to make the requisite astronomical observations; to continue hydrography off the eastern coast of Florida from Cape Cañaveral to the southward; to continue soundings and observations for deep-sea temperatures, currents, and dredgings in such parts of the Gulf Stream, northward of the latitude and eastward of the meridian of Cape Florida, as may be deemed advisable, and also in the Caribbean Sea, and, within the same limits, such as may be considered advantageous in conjunction with the United States Commission on Fish and Fisheries; to continue the astronomical and magnetic observations requisite throughout the Gulf of Mexico; to complete the hydrography of Charlotte Harbor, Fla., and continue the triangulation, topography, and hydrography of the western coast of Florida between Cedar Keys and Tampa Bay, and between Tampa Bay and Charlotte Harbor; to continue the same classes of work to the southward of Charlotte Harbor; to run lines of soundings and dredging and make observations of sea temperatures in the Gulf of Mexico, and develop the hydrography of the Gulf coast included in field operations; to connect the trigonometrical survey of the Mississippi River at New Orleans with that of Lake Borgne, Lake Pontchartrain, and Maurepas; to continue the triangulation of the Mississippi River above New Orleans to the head of ship navigation; to determine geographical positions, and make the astronomical and magnetic observations requisite; to extend the triangulation, topography, and hydrography of the coast of Louisiana westward of the Mississippi Delta, and continue the hydrography of the Gulf of Mexico between the mouths of the Mississippi and Galveston, Tex.; to continue the triangulation, topography and hydrography of the coast of Texas westward between Sabine Pass and Galveston, and between Corpus Christi and the Rio Grande; and to measure a base line of verification and make the astronomical and magnetic observations requisite between Sabine Pass and the Rio Grande; to continue the hydrography of the approaches to the coast of Texas; and triangulation across the States of Ohio, Indiana, Illinois, Missouri, and Kansas; to connect the surveys of the Atlantic and Pacific coasts, and continue triangulation in Kentucky, Tennessee, and Wisconsin; to furnish points for State surveys; to continue the determination of the positions of new light houses and life-saving stations along the coast between New York and the Rio Grande; to continue field work for the verification of data for the Coast Pilot; to continue the organized system of magnetic observations required for a complete magnetic survey, and to run lines of levels connecting points in the main triangulation with the sea level.

OFFICE WORK.—*To continue the deduction of results by computation from the field operations* along the Atlantic and Gulf coasts, and in connection with interior geodetic surveys, including astronomical, geographical, magnetic, hypsometric, and tidal work; to advance the publication of the Coast Pilot for the Atlantic and Gulf coasts, and compute tidal predictions for the year 1881 for those coasts; to continue the publication of original topographical maps, and reductions thereof, and to plot the hydrographic surveys; to make additions to the drawings of sailing charts A, from Cape Sable to Cape Hatteras, and of No. 1 and No. 2, Cape Sable to Sandy Hook, and Nantucket to Cape Hatteras; to continue the drawing and engraving of the general chart of the Atlantic coast from Quoddy Head to Cape Cod, and of coast chart No. 3, Frenchman's Bay, and Blue Hill Bay; to begin the engraving of coast charts, Passamaquoddy Bay to Seal Island Light, and from thence to Petit Manan, and of harbor charts of parts of Passamaquoddy Bay, Machias Bay, and approaches, Englishman's Bay, Moose-a-bec Reach and Pleasant Bay; to begin the drawings of harbor charts of Deer Island Thoroughfare and complete those of Frenchman's Bay, Somes' Sound, Blue Hill Bay, and Union River Bay; to begin the engraving of a new edition of the chart of Newburyport Harbor, also of Lynn Harbor; to complete drawings of the charts of Thames River, and of the harbors of New London and Norwich, of Great South Bay and the adjacent coast of Long Island, and of a new edition of the chart of New York Harbor and Hudson River; to continue the drawing of a chart of the coast of New Jersey, and of the harbor of Philadelphia; to continue the drawing of a chart of Delaware River in the vicinity of Philadelphia, complete engraving of the chart of James River, Va., continue drawings of sailing charts from Cape Hatteras to Key West, and drawing and engraving of local charts between the same limits; to begin drawings of charts of the Inside Passage from Charleston to North Edisto River, S. C., and of Saint John's River south of Jacksonville; to finish the engraving of the chart of Halifax River to Mosquito Inlet, Fla., begin drawing of the general coast chart, Cape Cañaveral to Cape Florida, complete the chart of the coast of Florida between Chassahowitzka River and Cedar Keys, and begin engraving of that from Cedar Keys to Steinhatchee River; to begin engraving for charts of Saint Joseph's Bay, and Saint Andrew's Bay, Fla.; to begin the engraving of a chart of the Gulf coast from Mobile Bay to Atchafalaya Bay; to continue drawing and begin engraving charts of Chandeleur Sound, Breton Sound, and the approaches to the Mississippi Delta; to finish the engraving of Gulf Coast chart from Point au Fer to Côté Blanche, including Atchafalaya Bay; to continue the engraving of charts of the coast of Texas between Galveston and the Rio Grande; for material for drawing, engraving, map-printing, for electrotyping and photographing, and for instruments and apparatus.

Total for the Atlantic and Gulf coasts, and involving work in thirty-four States and two Territories, will require $371,000.

The estimates for continuing work in the Western Division of the Coast and Geodetic Survey of the United States are intended to provide for the following progress:

FIELD WORK.—To make the requisite observations for latitude, longitude, azimuth, and the magnetic elements at stations along the Pacific coast of the United States; to continue offshore soundings along the coast of California, Oregon, and Washington Territory, and tidal observations at San Francisco, and such other localities as may be necessary; to continue the main coast triangulation from Monterey Bay to the southward, and from Point Concepcion to the northward, and from San Pedro toward San Diego; to continue reconnaissance for the main triangulation of the coast from San Pedro to Point Concepcion, from Russian River to the northward, from Columbia

River north to Puget Sound, and south up the Willamette Valley; to continue the primary triangulation through the Sacramento and San Joaquin Valleys and measure base lines in the Western Division of the Survey; to continue the coast triangulation and topography from Newport, Los Angeles County, Cal., toward San Diego; to continue the tertiary triangulation and topography from Point Buchon toward San Simeon, and hydrography between San Diego and Monterey Bay; to develop hydrographic changes in San Francisco Bay and its approaches; to continue triangulation across the States of California, Nevada, Colorado, and the Territory of Utah along the thirty-ninth parallel, to connect the survey of the Pacific coast with that of the Atlantic, and furnish points for the survey of the States named; to complete the secondary and tertiary triangulation and topography of the coast between Bodega Bay and Point Arena; to continue soundings between Cape Mendocino and the Klamath River, and between Cape Sebastian and Point Orford; to observe currents along the coast, and take soundings and temperature observations in the California branch of the Kuro-Siwo current, and execute such other hydrographic work as local demands may require; to continue tidal and current observations at the Golden Gate, and observations on ocean currents along the coast of California; to continue the triangulation, topography, and hydrography of the Columbia River; to complete the detailed survey between Cape Sebastian and Crescent City, and offshore hydrography at Crescent City Reef; to measure a base line and continue the triangulation of the Strait of Fuca, and the topography and hydrography of Puget Sound and the adjacent waters; to continue reconnaissance of the coast and islands of Alaska with observations of the tides and currents, and the requisite astronomical and magnetic observations; to continue field work for description of the coast and verification of the Coast Pilot of the coasts of California, Oregon, Washington Territory, and Alaska Territory; to continue the organized system of magnetic observations required for a complete magnetic survey; and to run lines of levels connecting points in the main triangulation with the sea level.

OFFICE WORK.—To make computations of the field observations, including astronomical, geodetic, magnetic, and tidal work; to continue the compilation of the Coast Pilot of the coasts of California, Oregon, Washington Territory, and Alaska Territory; to prepare tidal predictions for the year 1881; to continue the publication of the original topographical maps and reductions of them, and to plot the hydrographic surveys; to continue drawing and begin engraving of a chart of the coast of California between San Diego and Santa Monica, and complete the drawing of that between Santa Monica and Point Concepcion; to begin the drawing of a new edition of the chart of San Diego Bay, and of coast charts between Point Concepcion and Cape Mendocino; to begin engraving for a chart of the vicinity of Shoal-water Bay, and of sheet No. 4, of Columbia River; to execute local harbor charts for the waters of Puget Sound, and complete engraving for the general coast chart of that sound, including Admiralty Inlet; for materials for drawing, engraving, and map printing, for electrotyping and photographing, and for instruments and apparatus.

Total for the Pacific coast, and involving work in four States and seven Territories, will require $246,000.

For repairs and maintenance of the complement of vessels used in the Coast and Geodetic Survey will require $44,000.

For continuing the publication of observations made in the progress of the Coast and Geodetic Survey will require $8,000.

For general expenses of all the work, rent, fuel, for transportation of instruments, maps, and charts, miscellaneous office expenses, and for the purchase of books, maps, and charts, will require $36,000.

OBITUARY.

HENRY WOOD BACHE died at Bristol, R. I., on Thursday the 7th of November, 1878, in the thirty-ninth year of his age.

Though not related by birth, Henry Wood was adopted in childhood by Prof. A. D. Bache, late Superintendent of the work now under my direction, and hence the name by which the deceased was known through life. His physical constitution was apparently sufficient for any active service, but was conjoined with a temperament peculiarly sensitive to changes, and especially so to the effect, on his system, of labor in the field. During the preceding year he was retained on easy, quiet duty, but the transfer induced no change in the tendency to loss of vitality in the vascular system, and under that condition he steadily declined until he died.

By associates who are yet living, Mr. Bache will be remembered as an amiable and genial friend. In feeling he was strongly attached to the service, the leading operations of which he had witnessed in boyhood.

PART II.

The abstracts which follow will include under separate heads, and arranged in geographical order, general notices of the work done in each locality, proceeding from north to south on the Atlantic coast to the Rio Grande boundary, and from south to north on the Pacific coast. In accordance with that arrangement, the sites occupied by field and hydrographic parties in the course of the fiscal year ending June 30, 1879, will be given in tabular form as heretofore, in Appendix No. 1.

The work done in the office will be briefly mentioned in the concluding chapter of the report. Of the several office branches, the hydrographic division bears near relation to arrangements for work done in the field or afloat. Commander Edward P. Lull, U. S. N., in charge of the division as hydrographic inspector, confers with the chiefs of parties when vessels are needed, and by his intimate acquaintance with details pertaining to hydrographic work, the operations of the year have been greatly facilitated. As heretofore, the original hydrographic sheets are carefully inspected in this division, in advance of their reference to others for drawing and engraving.

Last year the authorities of Hobart College at Geneva, N. Y., applied for advice in regard to methods proper for a topographical, hydrographic, and physical survey of the Seneca Lake basin, in which work it was proposed to engage members of the sophomore or junior class for a short period in each year, as a school of practice. A matter of such public utility being worthy of encouragement, Assistant Richard D. Cutts was requested to confer personally with President Hinsdale, and for that purpose sojourned two days in the spring of 1878 in the vicinity of the lake. A rapid reconnaissance was made, and the proper location of a base line was indicated. Suggestions were also given in regard to stations for the needful triangulation. In the course of the year, arrangements were completed at the college, students were selected and assigned, field work was begun, and, when sufficiently advanced, preparations were made for undertaking work needful for constructing a chart of the lake.

In May last Commander Lull passed four days with the sophomore class, attended by Hamilton C. Smith, LL. D., and Prof. J. Towler, in practice with instruments for locating positions, sounding, dredging, obtaining water and bottom specimens at all depths, and for plotting the results. The great depth of the lake; its unusual sources of supply; the temperature of the water at different seasons; and the specialties of its fauna, will doubtless afford useful exercise under the direction of the professors who will be in immediate connection with this interesting survey.

In the course of the year Commander Lull was associated with hydrographic parties working at the entrance of Merrimac River, and near Mount Desert Island, and also with special work in Mississippi River.

The channels from sea at some of the barred harbors of our Atlantic coast, are so often changed in direction by great storms, as to lessen the usefulness of the charts, but more especially in crossing the bars. This fact is well known to navigators, and in such cases they depend upon the local pilots entirely for crossing the bars. Of course the utility of the charts holds for all other purposes of commerce and navigation at any one of the ports, the entrances of which are so affected. Sometimes, but not always, the depth is maintained notwithstanding the change in position of the bar and channel. In regard to such entrances it is therefore of much interest that record should be made at least of the variations of depth at stated periods throughout the year, if practicable, and this, it was judged, might be effected by engaging a single person residing at each of the localities to report the condition of the bar once in each month, such conditions to be published in certain daily commercial and local papers. Under that view, Lieut. Commander Philip H. Cooper, U. S. N., while attached to the survey, under my instructions visited all the harbors of which the bars were known to be subject to change, along the Atlantic seaboard. Full inquiry at each made it certain that persons of sufficient intelligence could be engaged, but the allotment of means for the ordinary work of the year did not admit of completing the proposed arrangement. The subject is reserved for consideration when means are available, and in order to be of immediate use to navigators the results will be published without delay.

On the 8th of November, 1878, Lieutenant-Commander Cooper was detached from the survey, and then entered on special duty required by the Navy Department.

Lieut. H. E. Nichols, U. S. N., who had previously rendered acceptable service in the hydrographic division of the survey, was again assigned from the Navy Department, at my request, for duty after his return from the Mediterranean, and rejoined the office on the 1st of February. His readiness in details pertaining to charts, and to arrangements for the outfit and repair of vessels, has greatly assisted in the dispatch of business connected with the division.

After a very active period extending beyond the term usually allowed to officers for naval service in the Coast and Geodetic Survey, Lieut. Commander Charles D. Sigsbee, U. S. N., was relieved on the 13th of November, 1878, from the command of the steamer Blake, and then entered upon duty in the hydrographic office of the Navy Department.

It is gratifying to record of this accomplished officer that his ingenuity and aptitude in professional details were enforced by energy and constant devotion to the interests of the survey. Intelligent earnestness in securing accurate results, and steady determination equal to the greatest emergencies that have yet arisen in hydrographic operations, have added special value to the charts which bear his name.

In my preceding annual reports full mention has been made of the difficulties encountered in the hydrographic development of the Gulf of Mexico, and of the successful completion of that work. The records were intrusted to Lieutenant-Commander Sigsbee, after his detachment, and the observations will be discussed by him under permission of the honorable Secretary of the Navy, for the publication of results from this office.

For extending hydrographic research southward, into the waters immediately connected with the Gulf of Mexico, the command of the steamer Blake was transferred to Commander J. R. Bartlett, U. S. N. An abstract of the operations of his party will be given in Section IX of this report,

Mr. William H. Mapes, long connected with the hydrographic division, and of great usefulness as inspecting engineer, died suddenly on the 15th of April, 1879, in his forty-fourth year. He entered the service in 1857, and was employed ten years as engineer on sea-going steamers engaged in hydrography. At intervals he supervised the repairs of engines and vessels, and the construction of all the vessels assigned for the work of the survey, in the course of the last ten years. For these duties Mr. Mapes was especially qualified by intelligence, good judgment, native industry and unvarying kindness towards all. This record is due to his memory; his devotion to the interests of the service was entire, and his business intercourse was marked by scrupulous integrity.

SECTION I.

MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, AND RHODE ISLAND.—(SKETCHES Nos. 3, 4, and 5.)

Hydrography, coast of Maine.—The hydrography of the approaches to the coast of Maine has been advanced from Nash Island in a direction southward and westward to Schoodic Head, by Lieut. Commander Theodore F. Jewell, U. S. N., Assistant in the Coast and Geodetic Survey, with his party in the steamer Gedney. Soundings were commenced on the 1st of August, 1878, and closed for the season on the 29th of October, after which the party was transferred for service which will be stated under the head of Section IX in this report.

On the coast of Maine the work of the party in the steamer Gedney extends fifteen miles seaward, and is continuous with that of several others by which the hydrography has been advanced from Portland northward and eastward as far as the entrance to Pleasant Bay. The sea-approaches of three-fourths of the coast of that State, including within the limits named the most intricate hydrography, have been fully developed. Within the same limits most of the bays and other indentations have been sounded. The statistics of the work done by the party in the steamer Gedney are:

Miles run in sounding	741
Angles measured	3,196
Number of soundings	2,343

Lieutenant-Commander Jewell was assisted in this work by Lieut. John Garvin, U. S. N., by Masters Charles E. Fox and Milton K. Schwenk, U. S. N., and by Ensign Charles H. Amsden.

Hydrography, eastern approach to Mount Desert Island.—After the completion of work in several sections between the coast of Maine and the Mississippi River, of which separate mention will be made under other heads, Lieut. Commander C. M. Chester, U. S. N., Assistant in the Coast and Geodetic Survey, with his party in the steamer Bache, took up soundings in the eastern approach to Mount Desert Island. This work was begun on the 28th of May, 1879, and was completed a few days after the close of the fiscal year. The sheet containing the soundings joins on the eastward with a survey made by Lieutenant-Commander Jewell; on the south with the hydrography done by Lieutenant Moser in 1877, and on the north with soundings recorded by the party of Lieutenant Ackley. The statistics of the work done by the party in the steamer Bache are:

Miles run in sounding	315
Angles measured	4,068
Number of soundings	7,569

While soundings were in progress the tides were observed at Clark's Wharf, South West Harbor, Mount Desert Island. A bench-mark was established, and a description of its position has been filed with the hydrographic records.

Lieutenant-Commander Chester was assisted in this survey by Lieut. A. V. Wadhams, U. S. N.; Master T. G. C. Salter, U. S. N., and Ensigns H. F. Reich and M. L. Wood, U. S. N. The party worked early in the fiscal year at another locality in this section, and also in Sections II, VI, VIII.

Mount Desert Island.—The surface of this island is diversified by almost every variety of topographical details, and affords scenery which attracts many visitors to the place as a resort in summer. Its harbors are convenient, and the outline, the approaches and views from the sea, are such as to invite all who have leisure for excursions afloat. During the summer of each year the island will doubtless be as heretofore a point second in importance only to the interests which cluster around a commercial center. This is true in reference to the whole area. Parties from the mainland pass along the eastern and western sides in steamers, enter Somes Sound, land at points in the interior, traverse the island in carriages, and finally reach landings from which the steamers take them to the mainland. The same facilities avail for the inmates of many summer residences that are steadily increasing in number, and thus all who resort to the place may in the course of a few hours enjoy the impressions due to association with lakes and forests, mountains and ravines, the broad ocean being in view of the spectator while passing over ground, picturesque by nature, and now more enticing to the eye by successful cultivation. Six separate mountains, averaging upwards of twelve hundred feet in height, and in proximity as many lakes, all considerably above the ocean level, are distinguishing features east and west of Somes Sound. The remainder of the insular area, which in all is about one hundred square miles, presents topographical gradations that contrast agreeably with the bold features of the middle zone of the island. On our engraved charts, Mount Desert Island is shown in detail, with the adjacent hydrography.

For the selection of types of representation to be embodied in the Topographical Manual, Mr. Edwin Hergesheimer was directed to make special examination of parts of the topographical survey, and to take views of the characteristic features, and that service was successfully performed in the course of the summer of 1878. The eight sheets returned to the office contain drawings of Eagle Cliff, Brown's Mountain, Echo Mountain, and Robinson's Mountain. At the end of the fiscal year he made arrangements for adding to the material already gathered for the Manual, specimens characteristic of the topography of the Pacific Coast.

Hydrography of Frenchman's Bay, Me.—In September and October, 1878, the hydrography of Frenchman's Bay was advanced by a party in charge of Lieut. S. M. Ackley, U. S. N., Assistant in the Coast and Geodetic Survey, working with the schooner Eagre. The projection made to receive the soundings included the space westward of Stave Island and Jordan's Island.

At Bar Harbor (Mount Desert Island), Commander E. P. Lull, U. S. N., hydrographic inspector, joined the party, and advised in regard to methods for prosecuting the work. After identifying points of the triangulation, signals were set up on the island, and soundings were commenced. The hydrography from Bar Harbor includes the waters around the Porcupine Islands, and also the harbor between Stave Island and the eastern side of Frenchman's Bay. During September the weather was generally favorable, but in the month following winds, rain, and cold greatly impeded the progress of the work. The statistics are:

Signals erected	39
Angles to locate signals	232
Angles to locate soundings	1,113
Number of soundings	5,874

While soundings were in progress the tides were observed at three stations within the limits of the completed hydrography.

In November the schooner Eagre sailed to the south, and was employed in service, of which notice will be taken in Section VIII. On the coast of Maine, Lieutenant Ackley was assisted by Lieut. H. T. Monahon and Master F. E. Sawyer.

Topography of Frenchman's Bay, Me.—The party of Assistant Charles Hosmer took the field on the 8th of July, 1878, to resume the plane-table survey of the shores of Skilling River, at the head of Frenchman's Bay, that work having been suspended in consequence of the illness of the chief of the party, as mentioned in my report of last year. In the course of the season preceding the 6th of October the detailed survey was completed. On a second projection, Mr. Hosmer mapped the Porcupine Islands, in Frenchman's Bay. Both sheets have been deposited in the office. The statistics of the work are:

Shore line surveyed, miles	26
Roads, miles	26
Area of topography, square miles	22¼

In Section VIII of this report reference will be made to the subsequent work of Assistant Hosmer.

Topography of Union River Bay, Me.—In continuation of the plane-table survey of the coast of Maine, Assistant A. W. Longfellow resumed field work in May, 1878, and in the course of the season extended work eastward from previous limits. The details include topographical features adjacent to the shores of Morgan's Bay, Patten's Bay, and the east and west sides of Union River Bay, with numerous coves, and the river at the head of the bay as far up as The Narrows, below Ellsworth. All roads near the water line were traced and mapped with other surface features. The projection taken to the field was nearly filled with details, but several miles of the east bank of the river below Ellsworth remain to be mapped. Plane-table work was continued for a week after the setting in of cold weather with snow, but it was found impracticable to finish the sheet in the field. Mr. Longfellow therefore closed operations on the 12th of November, 1878. The statistics are:

Shore line surveyed, miles	45
Creeks, miles	16½
Roads, miles	27½
Area of topography, square miles	12½

Assistant Longfellow is now engaged in extending the detailed survey in the vicinity of Union River Bay.

Topography of Bartlett's Island and Long Island, near Blue Hill Bay, Me.—For completing the detailed survey of islands west of Mount Desert, Assistant H. G. Ogden took the field on the 3d of August, 1878, with projections to include the topography of Long Island and Bartlett's Island.

Of these the first named forms the eastern side of Blue Hill Bay. Finding no accommodations for his party on that island, Mr. Ogden was constrained to prosecute the work from a station on the mainland. Long Island, as represented on the resulting sheet, is very hilly, and covered for the most part with a dense growth of small trees and bushes. The southern end is under partial cultivation. Only the general outlines of the hills are represented, as greater minuteness in detail would have involved great expense and labor in opening lines for the movement of the party from point to point.

Less difficulty was found in the survey of Bartlett's Island, which lies between Long Island and Mount Desert. All available parts of the surface of Bartlett's are under cultivation, and the details were mapped readily. Quarters were obtained in farm-houses, and the party being favored by good weather completed the survey of the two islands by the 28th of September.

On a third sheet Assistant Ogden traced the shore lines of Goose Cove and Jordan's River, two indentations of the mainland eastward of Union River Bay. Of necessity this sheet remained unfinished, but will be completed in the course of the ensuing season. The party was disbanded on the 12th of October, 1878. A synopsis of statistics of the work is appended:

Shore line surveyed, miles	37
Roads, miles	14
Creeks and ponds, miles	13
Area of topography, square miles	11

Assistant Ogden passed the winter and spring in duty at the office in Washington, and at the end of the fiscal year made preparation to resume field work in this section.

Hydrography of Placentia Bay and Jericho Bay, Me.—The party of Lieut. J. M. Hawley, U. S. N., Assistant Coast and Geodetic Survey, reached Belfast, Me., in the schooner Silliman on the 26th of July, 1878. A few days were passed there in fitting the steam-launch Sagadahock for service and in providing lumber for signals, but when ready to start for the working ground, calms and foggy weather delayed the movement of the vessel, and in consequence the party was unable to reach Deer Isle until the 5th of August. In that vicinity the space to be sounded was the south-eastern approach to the island, including the waters around Whitmore's Island, and as far southward as Saddleback Island.

A party in the launch set up signals, and soundings were begun on the 13th of August. Many signals were requisite, as the outlines of the islands include numerous small bays and inlets: hence, throughout the season, while one party was employed in sounding, another was engaged in setting marks for continuing the work. The tides were observed day and night at Oceanville, for determining a plane of reference in reducing the soundings.

Three dangerous shoals were developed in Deer Isle Thoroughfare. Of these, two were previously known, namely, Door Rock, which rises to a small knob with only five feet of water on it, half a mile north of Bold Island, and Grindstone Ledge to the northward of Dumpling Island. One hundred and thirty yards to the southward and westward of Grindstone Ledge, the sounding party found a small and dangerous ledge, having on it seven and a half feet at mean low water. The channel is deep between this ledge and the Grindstone, which last only, at the time of the survey, was marked by a buoy. Bearings and distances for finding the danger were communicated to the Light-House Board early in October, 1878. Sunken ledges, known locally, but as yet not marked by a buoy, were developed about two hundred yards to the eastward of the Bold Island ledges. These sunken ledges have from four to six feet of water, and vessels frequently strike on them in beating through the Thoroughfare. The hydrography of the vicinity of Deer Isle was completed on the 25th of September. Lieutenant Hawley then transferred the party to Mackerel Cove, and commenced work for completing the soundings in Placentia Bay. The triangulation points were readily found, and thus the erection of signals was much facilitated. As October opened with favorable weather, the work advanced under unusual advantages. Tidal observations were recorded at Mackerel Cove, and soundings were steadily prosecuted by two parties. As a check for the results of the work done in the two separate localities, simultaneous observations were recorded, to connect the tide gauges at Oceanville, Green's Landing, Mackerel Cove, and Naskeag Point.

Having advanced the hydrography some distance northward and westward of Swan Island, the vessels were moved to Naskeag Harbor, on the 18th of October, 1878, and soundings were prosecuted around Pond Island, to fill the upper part of the projection for work in this quarter. As opportunity offered, one of the sounding parties was sent to run lines over shoal spots previously developed by the party of Lieutenant Hawley in Eggemoggin Reach, Jericho Bay, and Isle au Haut Bay. In several instances the last soundings showed that the shoals had increased. Three ledges were developed in the course of these subsidiary operations: one, which has been named Thurlow's Rock, with eight feet on it at mean low water, between Green's Head and Thurlow's Island; the second lies about a third of a mile northwest of Swan Island and has been marked on the chart as Hanus' Ledge. The third, named Hawley's Ledge, like the one last named, was found by the party while engaged in sounding.

After the 20th of October, the weather became very stormy and cold, and but little advance could be made in the survey. The party was consequently recalled and returned to Belfast at the end of that month. After securing the launch, and before passing southward with the schooner, Lieutenant Hawley went to Castine Harbor, and there determined the position of a rock on which he found only four feet at mean low water. Leaving Castine on the 10th of November, the Silliman was kept on her course as far as White Head, but was constrained by stormy weather to remain four days in Seal Harbor. When the weather cleared the run to New York was made in three days. The statistics of the work are:

Miles run in sounding	417
Angles measured	3, 719
Number of soundings	33, 806

Two hundred and nineteen signals were erected by the party in the course of the season. Having rendered effective and very acceptable service in hydrographic surveys throughout the period allowed by the regulations of the Navy Department, Lieutenant Hawley was detached early in April. Masters G. C. Hanus and A. H. Cobb, U. S. N., who assisted in the work during several seasons, were detached on the 31st of December; and Master Albert Mertz, who was also attached to the party in the Silliman, was transferred to another vessel for service in Section VIII.

Hydrography of Isle au Haut Bay, Me.—For completing the hydrography of the eastern part of Isle au Haut Bay, and of the unsurveyed space south of Deer Isle, and including the approaches to Isle au Haut, two projections were made at the office and taken to the working ground by Lieut. Jeff. F. Moser, U. S. N., Assistant in the Coast and Geodetic Survey. This party reached Rockland in the steamer Endeavor on the 15th of June, 1878, and after prosecuting a detached survey, of which mention will be made under a separate head, took up the work requisite for filling the projections. On Isle au Haut and Deer Isle signals were erected without delay, and soundings commenced before the end of the month. At all favorable intervals the hydrography was continued until the 22d of October, the work being then successfully joined with soundings to the eastward and westward made in preceding seasons. The space between the two hydrographic sheets of Lieutenant Moser was filled with soundings by the party of Lieutenant Hawley, whose work has been referred to under the preceding head.

In the course of the season many ledges were developed by the party in the Endeavor. These were taken separately, and subsequently lines of soundings were run between the numerous islands included within the working limits.

Lieutenant Moser was assisted in this section by Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N. The statistics of the work are:

Miles run in sounding	755
Angles measured	12, 156
Number of soundings	23,685

In November, 1878, the vessel proceeded to Norfolk, and was there refitted for service, of which notice will be taken under the head of Section IV.

Ledge in Muscongus Bay, Me.—Before taking up the work mentioned under the last head, Lieutenant Moser developed by soundings the vicinity of a ledge between Monhegan Island and Pemaquid Point. The least water found was seventeen feet, on what proved to be a pinnacle of rock. The position of the ledge was carefully determined, and tidal observations were recorded during eighteen hours for the adjustment of soundings. This survey was begun on the 19th of June, 1878, and completed on the day following.

Hydrographic surveys conducted by Lieutenant Moser in other localities will be mentioned under Sections IV and V in this report.

Tidal observations.—At North Haven, on one of the islands in Penobscot Bay, coast of Maine, the series of observations commenced in January, 1870, has been maintained during the year by Mr. J. G. Spaulding. The self-registering gauge used at the station is provided with heating apparatus to protect the float from ice in the winter. So far the record of observations is one of the most perfect yet made. From the outset great care has been taken to guard against interruptions. When short stoppages become necessary for repairs the series is kept up by frequent staff readings. Mr. Spaulding, in connection with the tidal record, continues the record of meteorological observations.

Geodetic operations in New Hampshire.—At the opening of the fiscal year Prof. E. T. Quimby, having previously occupied Gunstock Mountain, was still engaged in the measurement of horizontal angles, and was detained at that station, by unfavorable weather, until the 4th of August, 1878. Soon after the party and instruments were transferred to Starr King Mountain, and the requisite measurements at that station were completed early in October. Field work was then suspended, and the camp fixtures and instruments stored as usual. The statistics of the work are:

Stations occupied	2
Directions determined	92
Number of pointings	2,207
Vertical angles measured	42

From the angular measurements recorded at the two primary stations the positions of ninety outlying secondary and tertiary stations were determined.

As the process involved very little expense additional to the outlay for triangulation, Professor Quimby had complete profiles taken at each station, showing the appearance and relative position of the hills and mountains around. This was done by Mr. J. R. Edmands, a member of the party, with a camera of his own invention. The instrument was so constructed that in focusing for near and distant objects, no distortion of the image is produced, and the accuracy of the profile represents truly the relative position of objects.

At the close of the fiscal year, June 30, 1879, Professor Quimby made arrangements for resuming field work.

Geodetic operations.—Observations in the primary triangulation were prosecuted on Mount Monadnock in this section, in September, 1878, by Assistant Richard D. Cutts, but as that station is the eastern limit of lines passing to stations in New York, the details of the work will be included in a subsequent notice in this report, under the head of Section II.

Light-house positions, coasts of New Hampshire and Massachusetts.—The angular measurements needful for determining the positions of lights on the coast of New England were conducted by Assistant S. C. McCorkle, in September and October, 1878.

At Portsmouth, N. H., the triangulation stations Pulpit Rock and New Castle were found and occupied with the theodolite, as was also Portsmouth light-house. From these the position of the new light-house on Whale's Back was determined, and in relation to it that of the old structure now used for a fog-bell.

At Newburyport, Mass., the positions of the light-house and of the inner and outer beacons were determined by angular measurements from Indian Hill, a triangulation point west of the harbor, and from an additional station on the east side, both being in connection with the well determined stations at Old Town and Powow Hill.

Near the close of October, Mr. McCorkle identified on Cape Ann the marks at Poole's Hill and Beacon Hill, two stations formerly occupied in the coast triangulation, and from them determined the positions of the light-houses on Thatcher's Island. The field statistics are:

Signals erected	7
Stations occupied	12
Angles measured	50
Number of observations	480

Assistant McCorkle returned to Philadelphia on the 11th of November, 1878. His work in that vicinity will be mentioned under a separate head in Section II of this report.

Reconnaissance in Vermont.—Between the work mentioned under the preceding head, and the triangulation which includes Lake Champlain and the valley of the Hudson, an interval remained in which no points had been determined previous to the opening of the present fiscal year. This interval embraces nearly all that part of the area of Vermont lying between the Connecticut River and the Green Mountains. In due time as the work of triangulation advanced westward in New Hampshire, the governor of Vermont requested that the benefit of the law of Congress in regard to geographical points might be extended to that State, and provision was made accordingly. This application was filed on the 20th of July, 1878.

Prof. V. G. Barbour, of the University of Vermont, was recommended by the governor, and also by the State geologist and faculty of the university, as qualified for the field operations, and was accordingly placed in charge of the work. He conferred personally with Assistant Richard D. Cutts, who was engaged at a primary station in the vicinity, and commenced reconnaissance from the line Killington-Hawkes, early in September. After thoroughly examining the country to the southward of Rutland, Professor Barbour presented a practicable scheme of triangulation. This, as most desirable, consists principally of quadrilaterals, and extends southward from Herrick Mountain opposite to the south end of Lake Champlain. The southern limits of the scheme are at Brattleboro, on the Connecticut, and Greylock, a primary station in the western part of Massachusetts.

The mountain features of Vermont are well known. In prosecuting the reconnaissance the difficulty was, to avoid high mountains, as they are generally wooded and comparatively inaccessible; and in lieu of such to select stations sufficiently elevated to secure not only a good scheme of work but economy in its execution. The sketch forwarded to the office in October, with the report of Professor Barbour, shows that he has successfully accomplished the preliminary work.

Hydrography of Merrimac River entrance, Mass.—In order to develop changes known to have taken place near the bar of Merrimac River, a party was detailed under the charge of Lieut. Commander C. M. Chester, U. S. N., Assistant in the Coast and Geodetic Survey, to make the needful examination. The steamer Bache with the party on board reached the entrance of the river on the 8th day of August, 1878. At the outset, the hydrographic inspector, Commander E. P. Lull, U. S. N., personally examined the place and advised in regard to the method proper for conducting the hydrography.

Ranges were erected on shore sixty yards apart, on an east and west bearing, and lines of soundings were run from the beach outward to depths of six or seven fathoms. This work was done by two parties, one conducted by Lieutenant-Commander Chester and Lieut. A. V. Wadhams; the other by Lieut. Uriel Sebree and Master T. G. C. Salter. The bar was found to be of coarse sand, shifting with gales, freshets, and strong tides, and marked by a succession of ridges and gullies.

While soundings were in progress, the Outer Badger Rock was determined in position, having only seven feet of water on it, and also a ledge known as "Breaking Rock," about three miles to the northward of the bar, and half a mile from shore.

For the adjustment of soundings, tidal observations were recorded at Black Rock Spindle, and also at a station on the north end of Plum Island, as near to the bar as the sea would permit.

The frequent changes at the bar of the Merrimac make it unsafe to enter at any time without a pilot. For the information of the light-house inspector of the district, Lieutenant-Commander Chester marked the best position for the outer range light and gave suggestions for moving the outer and inner buoys. The statistics of the hydrographic survey are:

Miles run in sounding	106
Angles measured	2,068
Number of soundings	9,290

The survey of the Merrimac bar was completed at the end of August. Subsequently the hydrographic party in the steamer Bache was engaged in service which will be referred to under separate headings in Sections II, VI, and VIII of this report. At the close of the fiscal year, Lieutenant-Commander Chester was conducting hydrographic work in the approaches to Mount Desert Island, as already mentioned under a preceding head.

Topography of Boston Harbor.—In my last annual report mention was made of the determination of points by triangulation, at the request of the board of harbor commissioners for the survey of the upper harbor of Boston. Means for the topographical survey having been provided by the city authorities, Assistant H. L. Whiting, at the request of the commissioners, was authorized to supervise the work. As the result of subsequent inspection, Mr. Whiting remarks:

"The accuracy and style of this survey are of the first order, and the details minutely represented. These include the marginal ground between the outer faces of the wharves, and the first street bordering the general wharf line. Within this space the outlines of all structures were determined, and the character of each is expressed by a conventional sign, in wharves distinguishing between pile work and solid filling, and in buildings distinguishing between wood and brick or stone. This marginal work embraces a large amount of detail, valuable in the study and treatment of change and improvement in the harbor frontage."

The results of this resurvey are on twelve full-sized plane-table sheets. Eleven of them are on a scale of $\frac{1}{1000}$, and include Fort Point Channel from Dover street bridge to its mouth; the South Boston sea walls and dock; the frontage of the city proper; Charles River from the navy-yard to West Boston bridge; Chelsea Creek from the navy-yard to Meridian street and Chelsea bridges, with all intermediate improvements; the south channel of Mystic River; and the frontage of East Boston. The twelfth sheet, on a scale of $\frac{1}{2000}$, includes Charles River or Cambridge Basin, from West Boston to Brookline bridge. This survey is based on sixty-seven points carefully determined by triangulation. The work was completed early in January.

Assistant Whiting conducted in person a plane-table party on the shores of Hudson River, of which mention will be made in the next section of this report.

Sea currents, Gulf of Maine.—As detailed in my last annual report, a number of positions were occupied for the observation of sea currents along a line curving southward and eastward between Cape Sable and Nantucket Island. Four additional stations, indicated as heretofore by Assistant Henry Mitchell, were occupied in the course of the fiscal year by the same party, in charge of Master Robert Platt, U. S. N., Assistant in the Coast and Geodetic Survey, with the schooner Drift. Other stations were attempted, but the vessel was forced away from her anchorage by bad weather. In the operations of this year the first position successfully occupied was in the open sea about twenty-five miles southeast of Mount Desert Island. Midway between the first station and Cape Sable, another position was occupied, and a third to the southward of Brown's Bank, where similar observations were made last year. To the westward of that bank, and in the vicinity of very heavy tide rips, a fourth station was occupied. In each case the schooner was brought to anchor, and held while the currents were recorded. The schooner remained twenty-six hours at anchor in 100 fathoms at the fourth position. For some days the weather had been good, and the wind very moderate, but the sharp, irregular, and confused sea at the Rip, was much like that found last year when Master Platt was near the same station. Excepting on slack water, the vessel rolled and pitched very badly. "On the flood tide it seems to be made up of numerous small broken rips with toppling sea, but on the ebb it is continuous. With great noise and confusion the sea runs up and sometimes combs over against the current as a breaker does before reaching shore in moderate weather."

Even in favorable weather the rip was extremely rough. Master Platt suggests that it must be dangerous to small vessels during storms. Coasters and fishermen aware of their roughness avoid the vicinity of the rips, and some European traders make the land as high up as Monhegan Island, and from thence pass to the westward of the rough water.

Master Platt was assisted in work in the Gulf of Maine, by Mates John Odendhal and Harold Neilson.

As bad weather was frequent after the completion of observations at the four stations, the party was recalled on the 8th of October. From Boston southward the passage was stormy. Off Barnegat Master Platt was constrained to turn back and anchor inside of Sandy Hook, and again at the Delaware Breakwater in consequence of a hurricane on the 22d of October, 1878. Fortunately no damage was sustained by the Drift, although eight wrecks were then in the harbor. The

American schooner Aldine had lost sails, spars, and boats, and her crew had been on short allowance during twenty-eight days. Provisions were supplied from the Drift, to enable the master of the Aldine to reach Philadelphia.

After detention of two days at the Breakwater, Master Platt sailed for Norfolk, and there the schooner was refitted for service which will be the subject of mention in Section VIII of this report.

The party on board the Drift while that vessel was becalmed off Race Point, Cape Cod, saw within a few hundred yards of them what seemed to be a very large round spar projecting twelve to fifteen feet out of the sea. In the course of three minutes the object curved and disappeared, but in half an hour again appeared, at some distance on the opposite side of the vessel, projecting as much as thirty-five feet above the water, and near it an object having the form of an enormous dorsal fin. As before, the object soon curved and went out of sight. While in view it was observed with good glasses, and although it could not be identified as a creature, all on board the schooner agreed that no fragment of floating wreck was anywhere in sight.

Aids to navigation—In April last, Assistant J. S. Bradford made a comprehensive report in regard to changes desirable in the positions of the buoys then in place along the coast westward of Boston. His recommendations were communicated for the information of the Light-House Board. The report specifies in each case the precise position to which the buoy should be moved. In this section the recommendations include the aids to navigation in the approaches to Chatham Bay and at Kill Pond Bar, in Nantucket Sound. Other suggestions in regard to changes of position will be mentioned in Section II of this report.

Atlantic Coast Pilot.—While the second edition of the Coast Pilot for the Gulf of Maine was in progress, means were taken to embody in it descriptive notes of the more important changes which have occurred along the coast of New England since the issue of the first edition. As heretofore, the work connected with the publication remains in charge of Assistant J. S. Bradford, and under his direction several localities were visited in October, 1878, by Mr. John W. Parsons, for the purpose of noting the alterations proper for mention in the new edition. At Newburyport, Mass., record was made of prominent features now presented in the approaches to that port by the recent erection of large hotels and other structures. It was noticed that the main channel had shifted in position, but without any change in average depth. Mr. Parsons consulted with the best pilots, and carefully drew up sailing directions to suit the present conditions for entering the harbor.

A few changes were observed at Gloucester, but the chart of that harbor in respect of accuracy is regarded by the pilots as sufficient for all requirements.

At Salem changes in the appearance of the shores have taken place since the first issue of the Coast Pilot, due mainly to the erection of numerous buildings, and in particular to the erection of the reform school, a large structure on Winter Island. Here, as at the places already noticed, the sailing lines were tested, and the ranges for entering were found correct.

At Lynn considerable changes were found in the channels, increased depth having been gained by frequent dredging. Alterations thus occasioned by private parties, include the cutting of a second channel from the vicinity of Sand Point to what is locally known as the Gas house wharf. As these operations have been prosecuted since the completion of the hydrographic survey, the chart merely represents the condition of the harbor as it formerly existed.

Before leaving the section a shoal with twelve feet at low water, and known as Cliff Ledge, was marked in approximate position on a copy of the engraved chart. The ledge is about two miles south by east from Bass Point.

The notes recorded by Mr. Parsons have been used by Assistant Bradford in the revision of the volume, the issue of which may be expected soon after the close of the fiscal year to which this report corresponds.

Tidal observations.—In the autumn of 1878 a systematic examination was begun of the tides of Buzzard's Bay. Assistant Henry Mitchell selected positions at which records were desirable, and Mr. C. H. Van Orden was assigned to make arrangements for the observations. By himself and others ten stations were occupied. At the two outside stations (Block Island and Clarke's Point) self-registering gauges were used for periods of about three months. The other stations were selected at suitable distances along the shores of Buzzard's Bay. At these glass tubes were used, and the height of the water was recorded at intervals of fifteen minutes.

At Back River Harbor the observations were continued nearly a month, and at the other stations simultaneous observations were recorded during six days. As shown by the records, the time of high or low water seems to be very nearly the same at all the stations on the shores of Buzzard's Bay.

Tidal records from the self-registering gauge lent to the city authorities of Providence, R. I., have been received up to January, 1878. The instrument is still kept in operation under the direction of the city engineer, and the records already show that the series will be of special value. Discussion of the observations will be deferred until the series can be conjoined with observations made at Boston and New York.

SECTION II.

CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE.—(SKETCHES Nos. 4, 5, 6, and 7.)

Geodetic operations.—In pursuance of the scheme of triangulation for connecting the survey of Lake Champlain with that of the Atlantic coast, Assistant Richard D. Cutts completed arrangements for field work late in June, 1878, and occupied Prospect Mountain, a station about twenty miles to the southward and westward of the south end of the lake. Instruments were promptly set in place and adjusted for determinations of time, azimuth, and latitude, as well as for the measurement of horizontal and vertical angles, but during an entire month the region north and south of the station was enveloped in smoke from the burning forests in Northern New York. The outlying signals of the triangulation were in view only once preceding the 20th of July. After that date the drawback lessened, and the requisite observations were completed by the 29th of August.

To provide for the ready occupation of Killington Station to the eastward of the south end of Lake Champlain, Assistant Cutts stored his camp fixtures and instruments at Rutland, reserving only the theodolite and observing tent for occupying Mount Monadnock, in New Hampshire. The season proved to be unfavorable, and for days in succession that summit was enveloped in fog, but the chief of the party and his aid, Mr. C. H. Sinclair, watched patiently until the close of September, and finally completed the record of horizontal angles.

The length of the lines observed in the course of the season varied from thirty-seven to sixty-three miles. On Prospect Mountain horizontal angles were measured by means of heliotropes stationed at Helderberg, Greylock, Killington, and Potato Hill. While at Monadnock heliotropes were observed on at Mount Tom, Greylock, and Mount Equinox. The horizontal angles were determined by seven hundred and eighty-four pointings, and the vertical by one hundred and eighty-five double-zenith distances.

Besides the usual observations for determining local time, and the value of scale divisions of the level and micrometer, the latitude at Prospect was deduced from one hundred and twenty-eight observations on twenty-six pairs of stars. For azimuth, two hundred and seventy-two observations were made on Polaris at and near its eastern elongation.

The records of the field work in eleven volumes have been duplicated and placed in the office.

Before leaving the section an examination was made of the region along the west side of Lake Champlain for selecting a station near Plattsburg to perfect the geodetic connection between the primary triangulation and that of the lake. After his return to the office, Assistant Cutts computed and turned in the results of his field observations for triangulation, latitude, azimuth, and local time.

Hydrography, vicinity of Block Island.—With a suitable projection, Lieut. Commander C. M. Chester, U. S. N., Assistant in the Coast and Geodetic Survey, proceeded with his party in the steamer Bache to the vicinity of Block Island, and commenced soundings in the middle of September, 1878. In the course of the following three weeks all the approaches to the island were carefully sounded to the distance of one mile off shore, and the results are given on two hydrographic sheets. On a third sheet, Lieutenant-Commander Chester plotted the soundings made in the course of a close survey of Southwest Ledge. The following remarks are taken from the concluding report of that officer:

"The southern and southwestern shores particularly are studded with large bowlders, many of them entirely below the surface, making it extremely hazardous to approach nearer than half a mile from the land. By inquiry it appeared that most of the accidents have occurred on the southwest coast and in foggy weather, the strong tide from the sound forcing vessels on the island. Owing to the rocky nature of the bottom only a small proportion of the wrecks get off again even in smooth weather.

"With a chart, careful leadsmen can know when they are nearing this part of Block Island, as Southwest Ledge is joined to the island by a ridge with eight or nine fathoms of water. This ridge is steep-to on its northern side, and shoals gradually on its southern side.

"The breakwater now in course of construction on the east coast of Block Island makes a snug little harbor for small vessels during a southeast gale of wind, but with wind to northward of east-northeast heavy sea sets in, making it dangerous to remain near for any vessel that cannot enter the basin.

"The basin, about one hundred yards square, is dredged out to seven feet at mean low water, and in it small vessels can lie in almost any weather.

"To the northward of the breakwater vessels may anchor, protected from westerly winds in five and six fathoms of water; hard, sandy bottom. The best anchorage, however, is on the west side of the island, abreast of low land adjoining the salt ponds, where in eight or nine fathoms a soft clay mixed with sand makes very good holding ground."

For the adjustment of soundings the tides were observed at a station on the west side of the basin, east coast of Block Island. The ordinary statistics of the work are:

Miles run in sounding	352
Angles measured	3,109
Number of soundings	10,350

Lieutenant-Commander Chester was assisted in this section by Lieuts. Uriel Sebree and A. V. Wadhams, U. S. N., and by Master T. G. C. Salter, U. S. N. The party was subsequently engaged in Sections I, VI, and VIII.

Aids to navigation.—After personal examination, Assistant J. S. Bradford reported in April last the changes desirable in the positions of buoys that heretofore have served as aids in coast navigation between Boston and New York. Thirty-four separate localities were examined. The recommendations indicate in each instance the exact position to which the buoys should be moved so as to be most effective in aiding the navigator. In this section the entire sailing course was carefully followed through Long Island Sound, and continuously by the way of New York up the Hudson River to Troy. The changes deemed expedient have been made known to the Light-House Board.

Survey of Jamaica Bay, N. Y.—Field operations for this survey were resumed early in July, 1878, by Assistant J. W. Donn, who extended eastward his triangulation work of the preceding year. Additional points were determined to the eastward to include Far Rockaway, and also the head of the bay. The shore lines were traced as rapidly as possible, and results were furnished for the use of the hydrographic party. In its progress the survey by Mr. Donn was made so as to show the changes that have taken place, especially in front of Far Rockaway. At Rockaway Inlet the shore was resurveyed, proving that a retrograde movement had occurred in the course of the year. This, however, is regarded as temporary. Assistant Donn reports that the inlet is surely moving westward, and at a considerable rate. "The small sandy island called Duck Bar, by recent accretions is now above the mean high-water level, and lies nearly due south of the east end of Manhattan Beach. During the summer of 1877 no part of it was visible at mean high water. The point of the beach has receded about three hundred meters, but very shoal water extends as far into the inlet as the high-water line of last year.

"The shore line of the beach from the point at which the survey was begun in the present year, and on as far as the site of the hotels, has suffered little by abrasion or scour, notwithstanding the fact that the sea swept over it in many places during the storm of January, 1879.

"There is no evidence of weakness at any point between the inlet and Far Rockaway, and it seems probable that the westward advance of the inlet will continue for some years."

The statistics of the plane-table survey are:

Shore line surveyed, miles	193
Roads, miles	15
Area of topography, square miles	25

Assistant Donn was subsequently employed in field work in Section III, and at the close of the fiscal year resumed work on the coast of Long Island.

Hydrography of Jamaica Bay, N. Y.—Soundings were commenced in the eastern part of Jamaica Bay on the 14th of August, 1878, by Lieut. W. I. Moore, U. S. N., Assistant in the Coast and Geodetic Survey, with a party on board the schooner Ready. The requisite shore line was furnished by Assistant Donn, of whose work mention was made under the preceding head. Lieutenant Moore at the outset of work established a tide-gauge on the wharf in front of the Holland House, on the south side of the bay, at a point nearly midway of the space to be included in soundings. After joining properly with the hydrography done by Lieutenant Maynard in the summer of 1877, the soundings were extended to include the eastern part of the bay. The lines were run generally at high water, and were crossed by others for developing the channels.

"In the channels of the eastern part of Jamaica Bay the bottom was found to be uniformly hard sand. In the small passages, or in deep water cut off by bars, the bottom is soft, black mud, probably washings of the peat formation of the marsh islands."

From the observations recorded at the tide-gauge the mean rise and fall was found to be 4.5 feet. The statistics of the hydrography are:

Miles run in sounding	151
Angles measured	1,732
Number of casts of the lead	13,068

Immediately after the completion of the hydrography the chart of Jamaica Bay was issued by photolithography. Lieutenant Moore was assisted in the work afloat by Lieuts. W. F. Low and S. H. May, U. S. N.

Tidal observations.—Observations with the self-registering tide-gauge at Governor's Island, in New York Harbor, were kept up by Mr. R. T. Bassett until the 1st of May, 1879, when the series was brought to a close, fair observations having been recorded continuously for a period of nineteen years. The occasional breaks in the record were caused by ice in extremely cold weather, but that inconvenience in late years was generally overcome by the free use of hot water.

The self-registering gauge was first started at Governor's Island in 1852. Owing to the difficulty of keeping it in operation during cold winters, the series of continuous observations was not begun until the year 1860, but since that date the series has been well maintained. The records are of great value, and will be subject to further discussion.

At Sandy Hook a well-furnished self-registering tide-gauge was put up in October, 1875, on one of the wharves of the New Jersey Southern Railroad. Since that date the record has been kept up by Mr. J. W. Banford with success. The best position was selected for the gauge, yet the water is sometimes very rough, and causes rapid wear in the working parts of the apparatus. As might be expected, the tides at this place when great storms are raging are much affected by the wind.

Topography of Hudson River, N. Y.—In continuation of the detailed survey of the shores of the Hudson, Assistant H. L. Whiting took the field early in the fiscal year, and prosecuted the work northward from the limits reached in the previous season near Peekskill. Two sheets were filled in the course of the season preceding the 1st of December, 1878, representing the topographical details of the east bank of the river. The survey was carried inland to the best practicable boundary, and includes the characteristic features of the valley of the Hudson between the working limits. The headlands known as Sugar Loaf and Anthony's Nose are shown on the map of the present year.

The locality included in this survey is of peculiar interest; many difficulties offer in its advance, but it is nevertheless desirable that the work should be done with precision. In alluding to the topographical features, Mr. Whiting remarks:

"Most of the hill-sides and summits are thickly wooded with trees common to the latitude and soil—oaks, chestnut, hickory, maple, birch, &c., with some pines and cedars, the deciduous trees being the characteristic growth. Movement with instruments was much impeded and observations rendered difficult, the summits being as inaccessible as the valleys and ravines. Changes in contour are abrupt, and the features of such magnitude that no system for generalization can be assumed. It became necessary, therefore, not only to go over all the ground, but to record observations and measurements under difficulties which made the progress of the survey laborious and slow."

As the historical interest and general importance of this particular section of topography call for the utmost that can be done in the way of delineation, Mr. Whiting spared no effort. The results of his work will meet all possible requirements. Expedients suggested by his experience in the field, but not commonly employed, were brought into requisition when it became apparent that ordinary methods, carried of necessity in this case beyond controlling points, would involve errors in position and in detail. The plane-table sheets represent all surface features with such precision that beyond their limits the survey of the State in the vicinity of the Hudson will be greatly facilitated. The statistics are:

Shore line surveyed, miles	19
Streams and ponds, miles	21
Roads, miles	68½
Area of topography, square miles	12

Mr. W. C. Hodgkins served as aid in the survey on the Hudson, and subsequently with a party in Section VI.

Station marks.—In July and August, 1878, Assistant F. H. Gerdes examined the vicinity of eight stations of the secondary triangulation of the coast of New Jersey. These were occupied many years ago, and ground marks had been set sufficient for the time, the advance of improvement being slow. But here and elsewhere along the coast the surface of the ground has been materially changed in recent years. Knolls and elevations on which signals once stood have been levelled, the ground thus converted has been planted in corn, and in some cases no trace remains of points formerly marked and occupied by the theodolite. Such changes were to be expected; hence, at the outset, range marks were set at some distance from the triangulation point, and so described in the record as to admit of use in identifying the position, even after the removal of the original ground surface.

Five of the stations visited were identified by Mr. Gerdes, three in the upper part of New Jersey, at Bound Brook, Bloomfield, and Throckmorton, and two in the vicinity of Cape May, at Baird and Leaming's Point. At the former station, Chew, it was made evident by outlying range marks that the hill on which the theodolite stood has been levelled, and a turnpike now passes over the site.

Field work subsequently prosecuted by Assistant Gerdes will be described in Section IV.

Geodetic operations in New Jersey.—At the beginning of the fiscal year, Prof. Edward A. Bowser was engaged in the measurement of horizontal angles at Pickles Mountain, a station connecting with an important geodetic point in Pennsylvania, and with five others in New Jersey.

Early in August, 1878, angular measurements were completed at Pickles, and the theodolite was transferred and placed in position on Mount Horeb, where observations were continued until the 30th of October. The signals observed on from the first-named station vary in distance from fifteen to twenty miles, and from the last-named eighteen to thirty miles.

At the close of the fiscal year, Professor Bowser made arrangements to resume work at Mount Horeb. The statistics of the field work include:

Angles measured	18
Number of observations	498

This work has been kept in close geodetic connection with adjacent primary stations of the triangulation of the Atlantic coast.

Hydrography of Delaware River.—For the uses of the Light-House Board, the Delaware River was sounded between Marcus Hook and the New Castle Flats in August and September, 1878, by a party in charge of Mr. Charles Junken, of the Coast Survey Office. The steamer Arago was assigned for the service. Col. W. F. Raynolds, United States Engineers, in charge as engineer of the Fourth Light-House District, indicated the limits and scale of the work, and in conjunction with Commander G. B. White, U. S. N., inspector of the district, selected three range lines which were marked by Mr. Junken in the course of his operations.

Signals were set up early in August for the needful triangulation, and soundings were begun in the middle of that month. The weather was favorable, and in general the plotting of the soundings was kept well up with the progress of work afloat. As soon as practicable the chart was completed, representing about ten miles of the course of the river, and was delivered to Colonel Raynolds. The statistics of the hydrographic work are:

Miles run in sounding	284
Angles measured	2,862
Number of soundings	17,506

As usual the records of the work have been filed in the office. The working expenses of the party were paid from the funds of the Light-House service.

Mr. W. C. Willenbucher aided Mr. Junken in this hydrographic survey, and after its completion both returned to duty in the office.

Special survey at Philadelphia.—For the general purposes of the survey of the Delaware River begun last year at Philadelphia, additional points were determined along the shores in the vicinity of League Island by Assistant S. C. McCorkle in the summer of 1878. On several lines of the original triangulation it was found that structures erected since the stations were first occupied hid from view the points needful for the survey near the mouth of the Schuylkill. New stations were therefore established, and additional points determined on both sides of the river between Fort Mifflin and Philadephia. On the Jersey side a new station was substituted for the one previously occupied at Eagle Point, the station there being lost by the caving in of about one hundred feet of the river embankment.

Above Philadelphia additional stations were occupied in November and December, 1878, by Assistant C. M. Bache. The angular measurements then made determined the positions of four points exclusive of a station in connection with them on Petty's Island. The aggregate statistics are:

Signals erected	11
Stations occupied	13
Angles measured	65
Number of observations	1,326

During the winter of 1878–'79 the movement of ice in the Delaware was closely examined by Assistant McCorkle along the stretch of river from Bridesburg, above Philadelphia, to Fort Mifflin, below the city. After completing his observations, the courses taken by the floating ice both on the flood and on the ebb tide were traced on charts. It was noticed that between Greenwich Point and the Horse Shoe, and also immediately opposite to the Horse Shoe, the tendency of the ice was to pack on both tides, but below the old navy yard the ice packed mostly on the flood tide. The ebb deposited ice opposite Gloucester, N. J., and the flood above and below on the same side of the river. During the winter the channel was generally free of ice abreast of League Island, but floating ice packed on the flood at Fort Mifflin. Opposite to Philadelphia the ice when moving with the flood tide kept a course along the city wharves, but on the ebb the ice left the main channel near the upper end of Smith's Island, and passed down in the eastern channel midway between the island and the Camden wharves.

The observations recorded at Philadelphia by Mr. McCorkle, having close relation to studies in which the effects of tides and currents must be carefully considered, were placed in the hands of Assistant Mitchell, under whose direction the special survey for the city of Philadelphia has been conducted.

Field work prosecuted by Assistant McCorkle in the autumn of 1878 has been mentioned in Section I of this report.

The city councils of Philadelphia having made an additional appropriation, the topographical survey begun in August, 1878, was continued by four plane-table parties working under the direction of Assistant R. M. Bache. Three of the projections were filled with details by the close of November, and the sheets were inked in the course of the following spring. The fourth sheet, including the city front opposite to Camden, N. J., and the wharf lines of that city, was mapped in April of the present year. All the work is on a scale of four hundred feet to the inch, and was executed with extreme care. The statistics are:

High-water outline traced, miles	85
Low-water outline, miles	43
Marsh outlines, miles	23
Ditches, miles	97
Streets and roads, miles	57

The sheets represent also an aggregate of seventy-seven miles of railroad within an area of twenty-one square miles. More than half of that area is actually covered by the wharves, houses, and other details given on the topographical sheets.

After completing his field work and inking the drawings, Assistant Bache made duplicates and traced on them, for comparison with his own as given by this last survey, the shore lines found on the oldest maps of the vicinity of Philadelphia. These were compiled from documents representing at various dates parts of the river outline between Bridesburg and Fort Mifflin. On the comparative map the dates were attached to outlines, which in earlier years were regarded as representing the condition of the river when the outlines were traced.

This special survey, as mentioned in my last annual report, was made at the request of the board of trade committee on coastwise and foreign commerce. The members of the board being largely interested in foreign trade, have given earnest attention to all steps in the work, the aim ot which is to add, if possible, to the facilities for commerce at the port of Philadelphia.

Current observations in the Delaware.—In continuation of the operations in physical hydrography, directed by Assistant Henry Mitchell, and of which an abstract was given in my last annual report, Assistant H. L. Marindin resumed work early in May, 1878, with a party in the steamer Fathomer. Base lines were measured for current observations on cross-sections, additional to those run last year, and these were joined with the work of the previous season off Petty's Island.

Until the middle of August current observations were recorded for transverse curves of velocities at fifty-three cross-sections of the bed of the Delaware, the object being to obtain records at the moment of maximum velocity of both ebb and flood, and these were made in connection with soundings to develop the perimeter of the sections. The currents were observed by means of loaded poles drawing six feet of water, left to float free, and started in the stream above ranges two hundred feet apart. At each range the time of the passage of the float was noted by observers with theodolites at each end of the base line. The position of the float while crossing each range was noted by another observer with a theodolite stationed at a position suitable for determining the point on the range at which the float crossed. The positions of the bases and stations of the observers were determined in the usual way from the triangulation points of the survey. Statistics of the current observations are:

Cross-sections observed	53
Float observations	1,239
Angles measured on floats	2,312
Soundings on cross-sections	8,520
Angles for soundings	3,324
Angles measured with theodolites	878

While current observations were in progress the hydrographic survey was begun and prosecuted at intervals until the middle of August, 1878, when the entire party was enlisted for sounding the bed of the Delaware, between Bridesburg and Fort Mifflin light-house. The soundings made are represented by four sheets on a scale of four hundred feet to the inch, corresponding to the scale of the topographical sheets, the completion of which has been already mentioned. The hydrographic statistics are:

Miles run in sounding	323
Angles measured for position	10, 350
Number of soundings	30, 716

Permanent bench-marks were established at Five Mile Point, at Kensington water-works, at the old navy-yard, and at League Island. Each of these was referred to the others by simultaneous tidal observations. As usual, careful descriptions of the bench-marks were sent to the office.

While Assistant Marindin was at work in the Delaware, operations for improvement were in progress under the charge of Gen. J. N. Macomb, United States Engineers. At the request of that officer, Mr. Marindin was authorized to furnish the results of his survey of the bulkhead at Five Mile Point.

In prosecuting the general hydrography of the Delaware, abreast of the city of Philadelphia, a shoal was developed in the vicinity of the wharves of the American Transatlantic Steamship Company. Full particulars in regard to the obstruction were communicated in September, 1878, to the mayor of Philadelphia, in order that measures might be taken for its removal.

Assistant Marindin was aided at Philadelphia by Mr. J. B. Weir. When the operations of the party afloat were closed in November, the hydrographic sheets were completed and results of the current observations were put in form. Assistant Mitchell in due time presented an elaborate report, in which all the results of observations are embodied.

Geodetic operations in Pennsylvania.—When my last annual report was closed, the party of Prof. L. M. Haupt was engaged at Big Rock, a station near the Lehigh River, and at the eastern extremity of the scheme of triangulation in Pennsylvania. Angular measurements at that point were made by Prof. C. L. Doolittle, of Lehigh University. In July, 1878, the party was transferred to Maryland, and there two stations, Meeting House Hill and Principio, and, in Pennsylvania, Londonderry and Rawlinsville, were occupied in succession in the interval preceding the middle of October when the field work was closed. At these stations the geodetic operations were conducted alternately by Professors Doolittle and Haupt. The statistics are:

Observing tripods and scaffolds erected	4
Stations occupied	5
Angular measurements	2, 150

When the fiscal year closed, Professor Haupt was in readiness to resume field operations. Of these further mention will be made in my next annual report.

Pendulum observations.—Experimental and mathematical studies for the determination of gravity have been continued by Assistant C. S. Peirce. Flexure, as a source of error in the ordinary support used for pendulum experiments, and the possibility of allowing for the error, as suggested by him in 1875, are now admitted by European observers to be essentials for success in the investigation. Mr. Peirce says:

"There still remains a question in regard to the difference between the flexure under a force applied continuously and under one intermittent like that caused by a swinging pendulum. Experiments at Hoboken, N. J., show that this difference is large upon a wooden support, but insignificant upon a metallic support."

In a mathematical analysis published in the "Proceedings of the American Academy of Arts and Sciences," Assistant Peirce has shown that any difference between the statical and dynamical flexure which could possibly have an appreciable effect on the time of oscillation of the pendulum, would largely increase the rate of decrement of the amplitude of oscillation. He remarks further:

"No considerable effect of this sort exists, the rate of decrement being almost exactly the same upon the Repsold tripod that it is upon another support of much greater stiffness. But, although the difference between the statical and dynamical flexure will be very small when good judgment has been used in mounting the pendulum, the correction for flexure remains a source of anxiety and trouble in making the experiments. For this reason a careful mathematical study has been made of the method of avoiding the difficulty, as proposed by M. Faye, which consists in swinging two similar pendulums simultaneously on the same support, with equal amplitudes of oscillation, but opposite phases."

The views of Assistant Peirce in this connection are fully set forth in his paper on Faye's method, communicated to the American Journal of Science.

The concluding report of the season mentions, as a special difficulty in determining gravity, the uncertain effect of the wearing and blunting of the knife edge upon which the pendulum rests, and of its motion upon the plane which supports it. Experimental investigations of these subjects have already been undertaken, and will be further prosecuted in the course of the coming year.

The acceleration of gravity has been accurately measured by Assistant Peirce, at the Allegbany Observatory in Pennsylvania. Stations on the mountains in that State will be occupied in succession, as means for estimating the disturbing effect of the mass of the Appalachians on results for latitude, longitude, and azimuth.

In general reference to researches for completing the spectrum meter, Assistant Peirce thus remarks:

"One of the difficulties in the measurement of gravity is the circumstance that metallic bars, hitherto our ultimate standards of length, probably change in length in the course of years. The confusion into which such spontaneous changes in standards of length may throw all precise measurements referred to them, is too obvious to be insisted upon. Hence search has been made for a length in nature which should be more strictly invariable than that of a metallic bar."

The idea that a wave length of light would be more invariable than any substantial measure has been entertained by several distinguished physicists, such as Arago and Clarke Maxwell, but their suggestions are to be regarded as purely speculative. The means of comparing with great precision a wave length of light with a tangible object were not known when the suggestions were recorded. In reference to the basis for his subsequent development of the idea, Assistant Peirce thus observes:

"It was not until our ingenious countryman Lewis M. Rutherfurd, by various mechanical achievements, and especially by his manufacture of diffraction plates of extreme accuracy, had made the attempt practicable, that any one could seriously propose to measure a wave length to one-millionth part of its own length.

"The length of the wave depends, first, on the internal constitution of the chemical atoms of the substance which gives rise to the spectral line, and this we have reason to believe the most unalterable thing known in nature; secondly, on the density and elasticity of the luminiferous ether as it exists in vacuo; and though we have as yet no positive information in regard to the inalterability of these qualities, we have reason to suppose that they are free from influences which cause the spontaneous alterations of metallic bars."

The matter must necessarily remain tentative, but the end sought is well brought out in the results. After many essays Mr. Peirce succeeded in manufacturing in Mr. Rutherfurd's laboratory, with the aid of his trained assistant, Mr. D. C. Chapman, a comparator by which a diffraction plate of one centimeter width has been compared with each one of a decimeter scale of centimeters accurately to the one-millionth part of a centimeter. The further comparison of the decimeter with each one of a meter scale of decimeters has been commenced but not concluded.

The other part of the investigation, to compare the wave length of light with the breadth of the diffraction plate, has been successfully accomplished by means of a spectrometer of original construction, provided with a circle divided upon glass, after Mr. Rutherfurd's design.

In studying the various sources of error in measurements of the deviation of a line in the diffraction spectrum, Assistant Peirce observed the supplementary images, commonly called "ghosts," due to irregularities in ruling the lines. These he found to be an entirely new species of diffraction phenomena, and that instead of their position depending on the amount of irregularity in the ruling, as had been commonly supposed, only their brightness depends upon this, while their position depends solely on the period of the inequality. After confirming his mathematical analysis of the subject by careful angular and photometric measurements, Mr. Peirce presented the results in a memoir which was read at the last meeting of the National Academy of Sciences.

Among several forms of projection devised by Assistant Peirce, there is one by which the whole sphere is represented upon repeating squares. This projection, as showing the connection of all parts of the surface, is convenient for meteorological, magnetological, and other purposes. The angular relation of meridians and parallels is exactly preserved; and the distortion of areas is much short of the distortion incident to any other projection for the entire sphere.

SECTION III.

MARYLAND, VIRGINIA, AND WEST VIRGINIA. (SKETCHES NOS. 8, 10, AND 11.)

Longitude determinations.—For determining the longitude of a point in Statesville, N. C., of which further mention will be made under Section IV; and also of a point in Atlanta, Ga., to be referred to under the head of Section V, the usual arrangements were made at Washington, D. C., in November, 1878. The work was under the general charge of Assistant G. W. Dean, and Assistant Edwin Smith was directed to co-operate in the service. By permission of Rear-Admiral John Rodgers, U. S. N., Superintendent of the Naval Observatory, the station occupied by the observers in Washington for telegraphic longitude exchanges with the southern stations, was located in the Observatory grounds, and due arrangements were made for erecting a temporary structure. Meanwhile, Messrs. Dean and Smith were accommodated in the Transit of Venus building, and there, with Transit No. 8, each observer recorded one hundred and twenty-two observations on fifty-four stars for personal equation during five nights of November and December, 1878.

Assistant Smith proceeded to Statesville, N. C., on the 13th of December accompanied by Mr. C. H. Sinclair. Between the station there selected, and the station at Washington, telegraphic exchanges were recorded by Mr. Dean during four nights in December. As usual, the observers then changed places, Assistant Dean receiving at Statesville the signals sent by Mr. Smith during three nights from Washington.

Mr. Dean transferred the instruments from Statesville, to Atlanta, Ga., and from that station exchanged signals during five nights with Assistant Smith, who remained at the Naval Observatory in Washington. Changing places as before, Mr. Smith sent from Atlanta, during six nights, signals which were recorded by Assistant Dean, at Washington.

Exclusive of details immediately connected with longitude determinations, the two observers recorded at the Naval Observatory three hundred and ninety-two observations in January and February on ninety-three stars for chronometer corrections. In the next section reference will be made to the determination of longitude at Statesville, N. C. For the operations of the longitude party the usual facilities were afforded free of charge by the officers and operators of the Western Union Telegraph Company.

In March, when Assistants Dean and Smith again met in Washington, one hundred and fourteen observations were recorded by each on thirty-six stars during four nights with Transit No. 8.

During January and February, Mr. F. H. Parsons aided in the work at the Naval Observatory in recording and also in computations.

Magnetic observations.—At the station established some years ago on Capitol Hill, in Washington, D. C., the magnetic declination, dip, and intensity have been observed annually by Assistant Charles A. Schott. In June, 1878, the series was continued by observing on the 9th, 10th, and 11th of that month.

Assistant Schott reports that his last observations show the law in regard to secular change of the magnetic declination at Washington to be as it was found by the observations of preceding years.

A third discussion of the secular change of declination (variation of the compass) in the United States and adjacent countries has been completed by Mr. Schott, and will be ready for issue at an early day.

Special hydrographic investigation.—Inquiry has frequently been made for such information as could be incidentally gathered by parties working afloat in regard to the growth of oysters, which, in the mass, are commonly termed *reefs*, and sometimes *rocks*. In order to meet the interest manifested, some general remarks by L. F. Pourtales, Esq., formerly Assistant in the Coast Survey, were given to the public in 1873, relating chiefly to oyster supply and to the manifest waste in the method employed in taking them in the waters near New York.

Recently, inquiries on the subject were renewed by the United States Fish Commissioner, Prof. S. F. Baird, with reference to the adoption of such means as might be practicable for preserving the supply of food-producing mollusks in Chesapeake Bay, and as all needful appliances were at hand the investigation desired by the Commissioner was promptly undertaken. The work was committed to Master Francis Winslow, U. S. N., Assistant in the Coast and Geodetic Survey, with a party in the schooner Palinurus.

Early in August, 1878, Master Winslow examined the oyster beds in the James River from Sewall's Point upwards, and closed investigation in that river on the 17th after traversing forty miles of existing beds. During the strength of the tide, current observations were recorded at the separate beds, and specimens of water were taken at different depths for analysis. The temperature of the water was carefully noted.

The latter part of August was employed by the party in Tangier Sound. Many specimens were taken of different ages, some from each bed or "rock," as the mass is termed by the local oystermen, and with the living mollusks specimens of the bottom on which they were found. Over each "rock" the current was measured as nearly as possible at half flood and ebb. All the beds were marked on copies of the engraved chart, and traverse lines of soundings were run to develop the locality, the proceeding at each being like that conducted in reconnaissance about a shoal.

Subsequently the oyster reefs in Pocomoke Sound were examined and mapped as in the localities already referred to. By the schooner, and her boats, upwards of nine hundred stations were occupied for determining positions, and eight hundred and fourteen miles were run in sounding. The records show five hundred and seventy-five observations for temperature, and four hundred and twelve specimens of bottom were preserved. The dredge was used in depths varying from twelve fathoms to as little as eight feet.

Master H. H. Barroll, U. S. N., was attached to the Palinurus, and effectively assisted in the investigations. In his concluding report, Master Winslow cordially mentions his obligations to Mr. T. S. Hodson, collector, and Mr. J. E. Sterling, postmaster at Crisfield, for their kindness, and for suggestions that facilitated the work in many ways. Mr. T. B. Ferguson, of the Maryland Fish Commission, furthered the investigations, and Mr. H. J. Rice gave direct assistance in the details and valuable suggestions for prosecuting the work. The information gathered by Master Winslow will be placed at the disposal of the United States Commissioner on Fish and Fisheries.

Masters Winslow and Barroll were subsequently engaged in hydrographic work, notice of which will be taken in the next section in this report.

Tidal observations.—The series of tidal observations continued for many years at Fort Monroe, Va., with a self-registering gauge, was closed in July, 1878. The observations will in time be thoroughly discussed by the method most suitable for a continuous record of many years.

Survey of James River, Va.—Field work for the detailed survey of the river between City Point and Dutch Gap was resumed by Assistant J. W. Donn early in November, 1878, his party using, as heretofore, the schooner Scoresby. Above the Gap, signals were set up for extending the survey to Richmond and Manchester, and computations were made of the points requisite for the plane-table work. As opportunity offered, the stations were occupied with the theodolite, and angular measurements were made on spires and objects in Richmond for connecting with points used in the early survey of the river. The markings of the base line of that survey were sought for, but have not yet been identified. Thorough examination will be made in the course of the ensuing season when the party will again be at Manchester, and it is deemed probable that the ground-marks may yet be recovered.

The topographical survey was advanced to a point about five miles below Richmond, and includes in detail the jettees and other works of the James River Improvement Company. Owing to restriction in the means for work and the necessity of maintaining parties on stretches of the coast not previously developed, it was found inexpedient to continue the survey in the vicinity of Richmond. The detailed survey, including the hydrography, will, however, be extended up to that city in the course of the ensuing season.

Geodetic connection in Virginia.—After completing the chain of quadrilaterals along the Blue Ridge between Harper's Ferry and the base line at Atlanta, reconnaissance was made for stations by which a similar chain might be extended from the headwaters of the Rappahannock westward to the Ohio River. Some of the stations having been selected and marked by signals in the usual way, Assistant A. T. Mosman took the field on the 20th of April, 1878, and occupied Humpback Mountain, and in succession, in the course of the present fiscal year, four other primary stations in connection with it to the westward. Three of the points occupied are upwards of forty-three hundred feet above the sea level. In addition to angular measurements requisite for the geodetic connection, twenty-four mountains of the Blue Ridge, Great North Mountains, and the main Alleghany range were determined in approximate position and elevation. Twelve of these peaks, mostly at the headwaters of the Potomac, James, and Kanawha Rivers, are more than four thousand feet above the sea. Mr. Mosman also included, by proper measurements, the astronomical station occupied at Staunton, Va., in 1866; and incidentally traced a meridian line two miles in length near that city. As usual, the ends of the line were marked by stone posts.

After completing work at Humpback, the twenty-inch theodolite was used in succession at Elliott's Knob, Bald Knob, Paddy's Knob, and State Springs, the last-named station being some miles to the northward and westward of Harrisonburg.

Three secondary stations were occupied in the vicinity of Staunton. At Elliott's Knob, azimuth was determined by two hundred and forty-five observations on Polaris. For time, forty-two stars were observed on ten nights; and for latitude one hundred and eighty-nine observations were recorded with twenty-three pairs of stars on eighteen nights. All the points observed on from the four primary positions occupied within the fiscal year were determined in height by the measurement of vertical angles. Observations were completed at Elliott's Knob on the 6th of August. Bald Knob was occupied a few days after, but of necessity the camp of the party was sixteen hundred feet below the summit, as no water could be found near the station.

Paddy's Knob was occupied early in October, and State Springs later in the same month. Both are difficult of access and distant from any road. The party put up log cabins for shelter, and occupied them while the observations were in progress. Up to the middle of October the weather was such as to admit of rapid progress, but observations were interrupted by a violent storm of wind, hail, and snow, continuing four days after the 17th of that month. During two days the temperature was below freezing. Observations at Paddy's Knob were finally completed on the 24th of October, and the measurements at State Springs on the 1st of November, 1878, the temperature for some days previous being as low as 13° Fah., with a strong wind.

The secondary work at Staunton was completed early in November and gave data for determining the position of the court-house, and other public buildings, as well as for connecting the astronomical station with the primary triangulation. The statistics are:

Stations occupied	7
Signals erected	13
Horizontal angles measured	213
Vertical angles	63
Number of observations, primary	2,102
Number of observations, secondary	567

The records of the work have been filed in the office. Assistant Mosman, at the end of the fiscal year, made arrangements for occupying stations near the headwaters of the Kanawha River for extending the geodetic connection westward towards the Ohio.

Geodetic levels.—Mention was made in my report of last year that a line of levels of precision had been started westward from Hagerstown, Md., and run towards the Ohio River, and that work on the line was resumed by Subassistant Andrew Braid in May, 1878. After testing the work previously done, the line was extended westward with the geodesic micrometer level, No. 1. At the office the constants of the instrument were carefully determined, and in the course of operations in the field have been verified.

Instead of working in opposite directions, two lines were run simultaneously, and generally the rods were at different distances from the instrument. The record of each rod is a complete line, so that it is unnecessary to apply any correction for difference of zero points of their scales.

As the work advanced, two orders of permanent bench-marks were used, the primary being specially distinguished from the secondary. The first primary was marked on the court-house in

Hagerstown, and the last of the working season on the pier of the bridge across the Hockhocking River, at Athens, Ohio, where Mr. Braid closed operations in December, after including an aggregate length of three hundred and thirty-five miles in operations with the levelling instrument. Sixteen primary bench-marks were inscribed for future identification, and fifty secondary ones. Temporary bench-marks were set at three hundred and seventy positions on the line. In the main the weather was favorable, but during November and December the work was carried on under many disadvantages. In the middle of the last-named month the party was disbanded. Mr. Braid then returned to Washington and entered upon the computation incident to his field operations. These involve great labor, due to the processes, and checks found needful for securing accuracy in the observations.

At the close of the fiscal year, Subassistant Braid again took the field, to advance the geodetic leveling westward of Athens. In my next annual report, this work will be referred to under the head of Section XIV.

Life-saving stations.—In the course of the fiscal year the positions of a number of stations of the Life-Saving Service were determined by Assistant F. H. Gerdes. On the coast of North Carolina he took the field in June, 1878, and again in October, and proceeded northward towards Cape Henry. Most of the stations being in Section IV, the work done in that service will be described in the next chapter of this report. The occupation of Mr. Gerdes in the summer of 1878 has been mentioned in Section II.

SECTION IV.

NORTH CAROLINA. (SKETCHES NOS. 9 AND 11.)

Life-saving stations.—In preceding seasons the stations of the Life-Saving Service have been determined in position, and marked on the original plane-table sheets of the survey of the Atlantic coast from the northeastern boundary as far south as Cape Henry, on the coast of Virginia. Some of the engraved chart plates have been already marked with the positions, and all others will be when charts are issued in future. Of the ten stations between Cape Henry and Cape Hatteras, eight were marked in position last year by Assistant F. H. Gerdes. The service was resumed early in June of the present year, and the two remaining stations, Chicomicomico and Little Kinnakeet, were determined and recorded for office use in marking the charts. For the same district Congress appropriated means for thirteen additional life-saving stations, but Mr. Gerdes found that very few of the localities were selected, and that the construction of station-houses had not been commenced Pending the action towards that end, he therefore returned to Washington, and after due preparation took the field for other duty, of which mention has been made in Section II of this report.

Early in October Assistant Gerdes again proceeded to North Carolina. In Albemarle Sound the use of the United States Revenue Marine sloop Saville was courteously offered by Lieut. Walter Walton, and with the co-operation of that officer the work of determining positions was resumed.

Finding that the Oregon Inlet station had been moved southward on account of sea washings, Mr. Gerdes carefully determined the new position, and two others, which had been in his temporary absence from the section decided upon near Bodie's Island light-house. The buildings were then in progress at Pea Island and Tommy's Hammock, and for chart purposes were located by angular measurements from adjacent trigonometrical stations.

At the new stations, Hatteras and Creed's Hill, four posts were set by officers of the Life-Saving Service to mark the intended locations, but the erection of the buildings had not been begun. The positions of the post were determined by reference to known points. While engaged in this service the Saville weathered in Pamplico Sound a hurricane of seven hours' duration. At Cape Hatteras the velocity of the wind was eighty miles per hour, and by its force a vessel was cast ashore and totally wrecked at a position only a few miles from that of the little revenue sloop. When the weather moderated, Lieutenant Walton sailed outside and Mr. Gerdes took angles and bearings for marking the position at Big Kinnakeet, where the foundation of a life-saving station had been laid out. At Cedar Hammock the house was finished, though not then occupied, and fixed in position by reference to trigonometrical points. The passage to Currituck Sound was boisterous, but the party safely anchored in Kittyhawk Bay, and in that vicinity two new stations, known as Kill Devil Hill and Gamel's Hill, were located in position by reliable observations.

At Caffrey's Inlet Assistant Gerdes left the vessel and travelled northward sixty miles along the beach, accompanied by Lieutenant Walton, who had official business at several stations in the direction towards Norfolk. On reaching the new station, Poynes Hill, Mr. Gerdes made needful measurements for marking its position on the chart. At Currituck light-house he was detained several days by stormy weather, but as soon as practicable visited the stations at Old Currituck Inlet and Deal Island and ascertained their positions by good observations. Severe weather delayed operations two days, during which the party remained at the old station house, False Cape, but then passed on without further delay. Little Island station had been marked by four posts for the site of the building, but after diligent search, in which Lieutenant Walton personally assisted, the posts could not be found. As a dense fog prevailed at the time, a sketch was left with Lieutenant Walton, who subsequently measured the necessary angles and forwarded the data to Mr. Gerdes.

The last of the new life-saving stations determined in position was Seatack, about five miles below Cape Henry. From the site of the intended building (marked as in other cases merely by four posts) no permanent object was visible, and of necessity the location was approximately fixed by reference to the topographical sheet.

In connection with the work here described Assistant Gerdes examined the ground marks of six of the principal triangulation points in this section, and also the marks at the ends of the base line on Bodie's Island. Additional marks were set where they seemed to be required for ready identification in future.

Before taking the field for service on the coast of Virginia and North Carolina, Mr. Gerdes was furnished at the office of the Life-Saving Service with notes and references to aid in his movements from station to station along the coast. The Superintendent of that service, S. I. Kimball, afforded all the facilities in his power to further the work. Assistant Gerdes closed operations on the coast of Virginia on the 29th of November, 1878. After his return to the office the results of his observations were adjusted and applied to the original sheets. The life-saving stations thus determined in position will be marked on the engraved charts without delay.

Atlantic Coast Pilot.—In continuation of his work of last year, which was confined to descriptions of the outer coast of the Southern States, Lieut. Frederick Collins, U. S. N., Assistant in the Coast and Geodetic Survey, with a party in the schooner Palinurus, sailed from Baltimore on the 21st of October, and in the course of the following six weeks examined all points of interest to navigators in Albemarle and Pamplico Sounds, including the tributaries. As heretofore, notes for the compilation of the Coast Pilot were recorded at all points likely to be resorted to by trading vessels.

Mr. J. R. Barker accompanied the party as draughtsman and sketched views of Hatteras Inlet, Ocracoke Inlet; of the entrances to Core Sound and Neuse River; of the vicinity of New Berne and Washington, N. C.; of Pamplico River entrance; four views of Roanoke Sound and Croatan Sound; views of Kittyhawk Bay, Currituck Sound, Alligator River, Plymouth, and Edenton; of the entrances to Chowan River, Roanoke River, Scuppernong River, Perquimons, Pasquotank, Little River, and North River; and views of Hertford and Elizabeth City.

Lieutenant Collins was assisted in this service by Masters Francis Winslow and H. H. Barroll, U. S. N. After the return of the Palinurus to Norfolk on the 1st of December, 1878, the officers proceeded to Washington, and there completed the descriptive notes pertaining to the work done in Albemarle and Pamplico Sounds.

Cape Lookout Cove.—It has been noticed for some years that the small bight inside of Cape Lookout so increased as to promise the advantages of a harbor of refuge. In order to develop the improved condition of the place, a careful survey of the cove was included in the plan of work for the party in the schooner Palinurus, the prosecution of which was mentioned under the last head. At a favorable interval in the general work Lieutenant Collins, assisted by Masters Winslow and Barroll, traced the shore line of the cove and carefully sounded out the harbor. The statistics of the work are:

Miles run in sounding	12
Angles measured	211
Number of soundings	1,920

This survey was made on the 2d and 3d of November, 1878. The soundings were plotted without delay, and a chart of the harbor was issued.

Hydrography, coast of North Carolina.—With his party in the steamer Endeavor, Lieut. Jeff. F. Moser, U. S. N., Assistant in the Coast and Geodetic Survey, left Norfolk on the 16th of December, 1878, and by way of the interior sounds and water passages reached Hatteras Inlet a few days after. Some delay was incurred on account of bad weather, but the vessel arrived at Wilmington, N. C., on the 26th and there completed arrangements for prosecuting hydrographic work, of which notice will be taken in its proper place under Section V. Lieutenant Moser returned to Section IV, and commenced inshore soundings above Cape Fear on the 3d of March, 1879. As heretofore, the erection of signals along the beach proved to be the greatest difficulty in the work. The coast line being inaccessible, lumber for signals was of necessity brought into place by transportation on land. Only a few of the triangulation points could be found. New Inlet was deemed unsafe as a harbor for the vessel, and the party was constrained to double Frying Pan Shoals in going to and from work. After setting up signals along the beach as far to northward as Barren Inlet, lines of soundings were run off shore to a distance of about ten miles. At the southern limit the hydrography was joined with soundings previously made in the approaches to Cape Fear. The weather during the time employed by the party in this section was unusually severe. Lieutenant Moser closed work near Cape Fear on the 19th of April, and a few days after, his party reached New York with the steamer. The statistics of the work are:

Miles run in sounding	271
Angles measured	662
Number of soundings	4,029

Hydrographic work previously done by the party in the Endeavor has been mentioned under the head of Section I. Under a subsequent head in this report the hydrography done by the party before taking up the survey above Cape Fear will be described.

Lieutenant Moser was efficiently assisted throughout the season by Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N.

Topography of Cape Fear, N. C.—For completing the survey of Smith's Island a party was sent in the schooner Caswell early in January of the present year, to work under the direction of Assistant C. T. Iardella. In consequence of very low tides and head winds the vessel was compelled to remain some time at anchor opposite Smithville, the party meanwhile going daily to work on the island, five miles distant from the anchorage. Soon after the middle of the month, weather and tide proving favorable, the schooner was taken into the Slue, near the working ground, and the detailed survey without further hindrance was completed at the end of January. During much of the time employed near the cape, the cold was extreme and high winds prevailed. The temperature was frequently below the freezing point.

As represented by the plane-table sheet, the interior of Smith's Island is traversed by numerous water-courses, and marked by many hammocks surrounded with marsh. During high water of spring tides the marsh is entirely submerged. Among the details are the courses of Cape Creek and Light-House Creek. Points requisite for the plane-table survey were obtained by erecting thirty-six signals, and determining the positions by observations with a theodolite. The topographical statistics are:

Shore lines of water-courses, miles	36
Area of topography, square miles	5

On the 9th of February the schooner Caswell sailed for Charleston, S. C., near which city Mr. Iardella prosecuted field work, as will be mentioned in the next section.

Longitude of Statesville, N. C.—As mentioned in the last section, arrangements were completed in November, 1878, at Washington, D. C., for determining the longitude of a point in Statesville, N. C. Assistant Edwin Smith reached the last-named place in the middle of December, and selected a station in the grounds of Simonton College. The resulting determination for longitude was, however, referred by proper measurements to the cupola of the college building.

Assistant G. W. Dean, in general charge of the work, aided by Mr. F. H. Parsons, remained at Washington, where, at the outset, Assistants Dean and Smith recorded observations for determining the difference in their personal equation.

After conducting a telegraph loop of half a mile to the station at Statesville, Mr. Smith set in place transit No. 6, and during four nights in December sent by telegraph to Washington, D. C., signals, for which returns were made by Assistant Dean. At Statesville, Assistant Smith was aided by Mr. C. H. Sinclair.

In January Mr. Dean repaired to the station in Simonton College grounds, and was replaced at the Naval Observatory in Washington by Mr. Smith. Telegraphic signals were again successfully exchanged between the observers during three nights. The chronometer corrections at Statesville were derived from one hundred and forty-two observations on forty-two stars on clear nights in December and January. The geodetic connection of Simonton College with the primary triangulation along the Blue Ridge was effected by measuring horizontal angles to include the cupola of the college as a station additional to the adjacent stations occupied on Young's Mountain and Anderson's Mountain when the triangulation was in progress. Four days were occupied by Mr. Sinclair with the theodolite at the college; three days were passed in angular measurements at Young's Mountain, and two days at Anderson's.

After closing observations at Statesville, Assistant Dean, accompanied by Mr. Sinclair, moved the instruments to Atlanta, Ga. The operations there will be described under a proper head in the next section.

SECTION V.

SOUTH CAROLINA AND GEORGIA.—(SKETCHES NOS. 11 AND 12.)

Hydrography, coast of South Carolina.—As stated under a preceding head this work was taken up by Lieut. J. F. Moser, U. S. N., Assistant Coast and Geodetic Survey, at the end of December, 1878. The space sounded includes the sea approaches to Winyah Bay, S. C., and inshore soundings along the coast of South Carolina as far northward as Murrell's Inlet. This work was closed at the end of February. The steamer Endeavor was then moved to the vicinity of Cape Fear, and the party engaged in work, of which mention has already been made. In reference to the eastern approach of Winyah Bay, Lieutenant Moser remarks:

"There appear to be several ridges running parallel to the coast. These show about one fathom less water than on either side. They are said to be coral. We failed in attempts to bring up specimens, but saw pieces of coral along the beach.

"At Murrell's Inlet numerous specimens of phosphate rock were found, apparently as pieces broken from a mass in the vicinity and thrown up by the action of the sea.

"Along the beach ledges of limestone were noticed, cropping out at different points between Eight Mile Swash and North Inlet.

"The soundings in approaching the bar at Winyah Bay are not regular, and the discolored water that extends more than ten miles to the northeast is deceptive, the discoloration being due to a mere film of muddy river water sustained on the surface by the greater density of the clear water of the sea."

The following synopsis of statistics appears on the hydrographic sheet of the vicinity of Winyah Bay:

Miles run in sounding	346
Angles measured	936
Number of soundings	8,129

Another detached survey prosecuted by Lieutenant Moser in this section will be referred to under the next head.

Hydrography of Sampit River, S. C.—In March last the party of Lieutenant Moser, in the steamer Endeavor, surveyed about five miles of the course of the Sampit River, above its entrance into Winyah Bay. The sheet of soundings includes the river front at Georgetown, S. C., and it junction with the hydrography of Winyah Bay. Previous and subsequent surveys by this part have been mentioned under other heads. Of the work on the Sampit, the following is a synopsi of statistics:

Miles in sounding lines	24
Angles measured	524
Number of soundings	1,631

Lieutenant Moser was assisted in this section by Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N.

Topography of Stono River, S. C.—For this work, Assistant C. T. Iardella proceeded to Charleston with the schooner Caswell, after completing a survey in the vicinity of Cape Fear, as stated in the preceding section. Signals were put up for defining the courses of Wappoo Creek and its connections with the Stono. The shore lines were traced, and the ground was mapped north and south of the creek, to include the roads and other adjacent topographical details, to the eastward below Fort Pemberton.

From the Stono River, large tug-boats drawing seven feet of water take through Wappoo Creek scows laden with phosphate for delivery at Charleston, but on reaching Ashley River, as on starting from the Stono, the tugs wait for high water in order to cross the sand banks that obstruct both ends of the Wappoo.

Twenty-seven signals were erected and determined in position. The general statistics of the work are:

River and creek shore line surveyed, miles	18
Streams, miles	9
Roads, miles	25
Area of topography, square miles	3

Field work was closed at the end of February, when the Caswell was dispatched for Baltimore and laid up.

Longitude of Atlanta, Ga.—After the completion of operations, which have been described under separate heads in Section III and Section IV of this report, Assistant G. W. Dean proceeded to Atlanta, Ga., for determining the difference of longitude between the Naval Observatory in Washington, D. C., and the station which had been occupied by Assistant Edwin Smith in 1874, when the difference was determined between a point in the city hall square of Atlanta and the astronomical station in Savannah, Ga.

Assistant Dean, aided by Mr. C. H. Sinclair, mounted transit No. 8 at the station point in Atlanta, and successfully exchanged signals on five nights with Mr. Smith, who remained in Washington. The observers then changed places, and during six nights in February and March Assistant Smith sent signals from Atlanta to be recorded by Mr. Dean at the Naval Observatory in Washington. The chronometer corrections were ascertained in Atlanta from two hundred and nineteen observations on fifty-five stars during favorable nights in January, February, and March.

As before mentioned, observations for personal equation were recorded at Washington in advance of taking up the longitude work, and again after the close of operations. The records of the observations for longitude have been duplicated as usual and deposited in the office.

The observations at Atlanta were facilitated by the courtesies and friendly assistance of the mayor, Col. W. L. Calhoun, and his associates in the city government. As usual, the operators of the Western Union Telegraph Company cordially assisted in the work, under the sanction of the officers of the company, who at all times have manifested great interest in the longitude determinations.

SECTION VI.

EAST FLORIDA, SAINT MARY'S RIVER TO ANCLOTE KEYS ON WEST COAST.—(SKETCHES NOS. 13, 14 15, AND 16.)

Tidal observations.—At Fernandina, Fla., the continuity of the record of tidal and meteorological observations was interrupted by the illness of the observer, Mr. H. W. Bache, who died at Bristol, R. I., on the 7th of November, 1878, as mentioned elsewhere in this report. So far, the endeavor to maintain the gauge in operation with untrained observers has been unsuccessful, but arrangements will be made for resuming the record at an early day. Mr. M. O'D. White, a native of the climate, is now preparing to take charge of the apparatus. A series of observations at this station is very desirable, and in due time will be secured.

Triangulation and topography of Indian River, Fla.—For continuing this work Subassistant W. I. Vinal completed preparations in the early part of November, 1878, and reached Georgiana on the 22d of that month. The sloop Steadfast served in previous seasons for transportation, and was relied on for continuing the survey. But the vessel had been blown from her moorings at Titusville by a hurricane on the 11th of September, and was thereby considerably injured. As soon as possible the sloop was refitted, and was afloat when Mr. Vinal arrived, yet much labor was required for replacing on board the articles taken on shore of necessity at the time of the accident. All arrangements were complete early in December, and the party moved to the working ground, and resumed the triangulation at Malabar station, where the operations of the preceding season had been closed by Assistant R. M. Bache. After setting signals to extend the triangulation southward, observations with the theodolite were prosecuted as steadily as the varying conditions of the weather allowed. On the 22d of March the work was closed for the season at stations about ten miles below Malabar. "Observations on signals along the ocean beach were rendered difficult, and often impossible, by almost constant beach fog; and the work was frequently interrupted in consequence of fires started by settlers in clearing land, or by sportsmen in driving game. The air over extensive tracts was thus filled with dense smoke for days at a time." At such intervals the party was employed in cutting trails to the beach through the thick scrub and heavy undergrowth, and lines were opened to make signals intervisible. Most of the natural difficulties of the ground were overcome by erecting scaffold signals, with platforms elevated from eighteen to twenty-five feet above the general surface.

When a sufficient number of signals had been determined, the topography was begun, and was carried forward with the triangulation. The weather greatly improved as the season advanced. Below Malabar the ocean beach and the western shore of Indian River were included in the plane-table survey. Ensign James P. Underwood, U. S. N., was attached to the party, but his health was such as to prevent his co-operating in the work. Finding no benefit in the climate, he was constrained to return to his home before the close of the season. In the middle of January Mr. W. C. Hodgkins joined the party as aid, and served efficiently in carrying on the topographical survey. The sheet represents ground consisting principally of low pine lands, swamp, mangrove, and palmetto. Some of the land on the west side of the river is more than twenty feet above the water level. At the close of the season the Steadfast was securely moored in Turkey Creek and all due precautions were taken for her safe keeping. The following are statistics of the field work:

Signals erected	46
Stations occupied	10
Positions determined	21
Horizontal angles measured	70
Number of observations	2,784
Shore-line surveyed, miles	46
Creeks, miles	7
Trails cut in reaching signals, miles	8¼
Area of topography (square miles)	8

After returning to the office, Subassistant Vinal turned in the topographical sheet, and engaged in computing the results of his triangulation. At the close of the fiscal year he was assigned to field duty in Section I.

Survey of the Gulf coast between Charlotte Harbor and Sarasota Inlet.—For defining the Gulf coast to the northward and westward of Charlotte Harbor entrance a party was sent in November, 1878, under the charge of Subassistant Joseph Hergesheimer. The schooner Quick was assigned for the needful transportation from point to point.

Much of the ground to be passed over is impracticable for ordinary processes in triangulation. All the station points would of necessity be elevated structures put up at great cost, and the return in accuracy would not be commensurate with such outlay for mapping a stretch of coast, the extremities of which connect with triangulation of the usual character. Hence the part here under notice was defined principally by beach measurement. Triangles were laid out at the upper and lower ends of the work, where the lagoons occur known as Little Sarasota Bay and Lemon Bay, and by the points thus determined the shores of the two bays were surveyed. While the party remained in this section, the anchorage of the schooner was in Lemon Bay, and was reached by Stump Pass, on the bar of which the depth was six feet at high water.

For extending the work southward from previous limits near Sarasota Pass, Mr. Hergesheimer erected nine signals, and occupied seven points with the theodolite. Iron screw piles were set as marks at the stations, and careful measurements from each of the points to permanent objects were recorded for reference hereafter. From the last station on the shore of Little Sarasota Bay, the beach was measured by courses in a direction southward and eastward, to an aggregate distance of about ten and a half miles, terminating at a station of the triangulation laid out for including Lemon Bay. Fourteen tripods were set up between that station and Gasparilla Pass, where the triangulation of Charlotte Harbor was closed in a former season. The work in charge of Subassistant Hergesheimer was well advanced towards completion when it was found that all the parties in the field could not be retained with the balance of the appropriation for the year. In consequence the operations on the shores of Lemon Bay were closed on the 10th of March. Previous to that date fifteen lines had been opened through the pines to admit of the use of the theodolite in measuring horizontal angles. The general statistics are:

Signals erected	35
Stations occupied	8
Angles measured	53
Number of observations	1,254

Ten points were determined in position. An early opportunity will be taken for completing the connection along the beach between the separate surveys of Charlotte Harbor and Sarasota Bay. Thirty-five miles of the coast of the Gulf of Mexico are included in the operations of this party.

Gulf hydrography near Charlotte Harbor, Fla.—The plan of work laid out for the party in the steamer Bache included the extension of the inshore hydrography of the Gulf of Mexico, above and below the entrance to Charlotte Harbor, and also in the vicinity of Tampa Bay.

Lieut. Commander C. M. Chester, U. S. N., Assistant in the Coast and Geodetic Survey, arrived at Charlotte Harbor with his party early in January, 1879, and made arrangements for prosecuting work afloat, to fill the projections sent from the office. In the course of a fortnight, however, an emergency arose, calling for the transfer of the steamer and party to Section VIII, under which head mention will be made of the work done in the spring of the present year. The party was engaged also in Sections I and II.

Magnetic observations.—In previous reports reference was made to determinations of the magnetic elements at points so selected that the results would yield the utmost in regard to present knowledge of the distribution of magnetism over the area, and also seaward of the coast lines of the United States. For the compasses which appear on our charts, the data have been so procured, and in the course of the fiscal year additional points were occupied for the same purpose in the interior, north of the coast of Texas, as will be mentioned elsewhere in this report under proper heads. In general the positions here referred to are on isogonic lines that in their extension southward cross the Gul of Mexico. It was, therefore, desirable to procure observations of the magnetic elements at points along the northern coast line of the islands which inclose the Gulf basin. This duty was intrusted to Lieut. S. M. Ackley, U. S. N., Assistant in the Coast and Geodetic Survey, and has been successfully accomplished as to the eastern series of stations marked for occupation. If practicable, the western stations will be occupied in the ensuing year. Before setting out with his party in the schooner Eagre, in January last, Lieutenant Ackley practiced at the magnetic station of the survey with instruments for determining the declination, dip, and intensity, and conferred fully with Assistant Charles A. Schott in regard to the requirements for precision in observing and for keeping the field record.

On the passage southward the Eagre touched at Fernandina, Fla., and was there swung, in order to ascertain the deviation of the compass due to the iron used in the construction of the vessel. Subsequently the Eagre was swung for the same purpose at Bahia Honda, on the north coast of Cuba, and again at Fernandina on the return of the party from the Gulf of Mexico. No perceptible change had taken place during the run of the vessel in the vicinity of the West India Islands.

Lieutenant Ackley was provided at the office with a good azimuth compass, a magnetometer (C. S. No. 8), and a Kew dip circle (Casella, C. S. No. 18), the latter provided with needles for deflections, and also to be used with fine weights.

The schooner Eagre being a wooden-built sailing vessel, was specially adapted for the work here under notice. After recording observations of the magnetic elements at Fernandina, Lieutenant Ackley occupied stations at Nassau (New Providence); at South Bemini and Water Cay; at Matanzas and Havana (Cuba); at Key West, Fla.; at Bahia Honda and Cape San Antonio (Cuba); at Belize on the coast of Honduras; at Cozumel Island, and at Mujeres Island, off the east coast of Yucatan.

"When the weather and other circumstances would admit, observations for the magnetic declination were taken at sea, with variable results. The amplitudes when the sun could be observed directly were very good, but the azimuths not so, on account of the vibration of the sun's image on the reflectors."

While at sea Lieutenant Ackley recorded observations for the declination at twenty positions. The interest manifested in the work by that intelligent and energetic officer enlisted the members of the party, and all familiarized themselves more or less with the use of the instruments.

At Belize, in British Honduras, Governor Barlee received the party with great cordiality, and afforded all facilities for conducting the magnetic observations in the grounds of the government house. A true meridian line was traced there and marked, at the governor's request, for the use of the colonial surveyors. At all the stations occupied, twelve in number, three complete sets of observations were recorded, except at Water Cay, on the northwest side of Salt Key Bank. The vessel remained there four days, but landing was impracticable on account of a northeast gale.

Lieutenant Ackley was assisted in these observations by Lieut. H. T. Monahon, U. S. N.; Master F. E. Sawyer, U. S. N.; and Ensign W. H. Nostrand, U. S. N. The schooner Eagre, after closing work in the Gulf of Mexico, returned north, and arrived at Washington, D. C., at the end of May. Under Section I, mention has been made of work previously conducted by Lieutenant Ackley.

SECTION VIII.

ALABAMA, MISSISSIPPI, LOUISIANA, AND ARKANSAS. (SKETCHES NOS. 18, 19, AND 21.)

Reconnaissance and geodetic work in Alabama and Mississippi.—In extending triangulation westward from the base line near Atlanta, Ga., special difficulties have been encountered in the selection of points. As stated in former reports, mountain ridges, that under other conditions would be favorable, are in this region hindrances to progress. Being of equal height, near together, and running in a direction transverse to that desirable for the chain of quadrilaterals, lines of requisite length have been obtained only by unusual labor.

Assistant C. O. Boutelle remained in the field during the first half of the fiscal year, and pushed the reconnaissance westward of stations in Alabama at which angular measurements were completed in the preceding season. After a thorough examination it was found that, in general, structures will be required to elevate the theodolite when the stations are occupied. Points were selected by Mr. Boutelle for extending the triangulation across the boundary line between Alabama and Mississippi, and at these the greater labor of opening lines of sight on wooded mountain ridges will be avoided by constructing high platforms when the angular measurements are made.

Assistant F. D. Granger was in the field when my last annual report was closed, and had traversed the region of northern Mississippi lying eastward of Holly Springs, finding difficulties, such as have been mentioned, in obtaining a plan for continuing field work towards the Mississippi River. Beyond the western limits reached by Assistant Boutelle, Mr. Granger selected two stations, and in succession others to extend the series of points beyond Ripley to stations in the vicinity of Holly Springs. On some of the ridges (all being heavily wooded) extreme labor was incurred in identifying adjacent points at which flags had been placed on high trees; at others it was found necessary to open avenues to bring into view the outlying stations of the scheme of triangulation. The lines vary in length from ten to thirty miles, but the surface of the region is such that tripods of fifty and sixty feet will be requisite, and, at some of the stations, structures of greater height for bearing the theodolite.

While on reconnaissance, Assistant Granger mounted trees from seventy to ninety feet high, and observed on flags attached to long poles, and nailed to the tops of trees of even greater height. The region traversed affords few facilities for comfort in travel, but the people are hospitable, and readily aided in furthering the purposes of the reconnaissance.

The descriptions of the stations adopted include mention of the height of the tripod required at each. Mr. Granger remained in the field until the 20th of January, 1879, and then returned to the office.

At Wilson station Assistant Boutelle put up a tripod, with a scaffold for supporting the twenty-inch theodolite at an elevation of seventy feet above the ground. June and July were passed in measuring horizontal angles from that point, the excessive heat and consequent exhalations and haze having much delayed the work. During twenty-two consecutive days in July, as shown by the field report, the temperature of the air ranged night and day between 85° and 98°.

Warnock Mountain was occupied in August, and early in September the party was transferred to Smither's Mountain. Here the operations were further delayed. Yellow fever, then raging at Memphis, had advanced along the Tennessee River to Tuscumbia, Florence, and Decatur, or within twenty miles of the geodetic station, and directly upon the lines of railroad used in posting and communicating with the heliotropers at outlying stations. By the 20th of October, however, all observations were completed at Smither's. The instruments were then removed to Tanyard Mountain, three miles west of Courtland, Alabama. Assistant Boutelle proceeded to occupy that station, retaining the aid, Mr. C. Terry. Mr. J. B. Boutelle was sent to observe at Summit station the angles upon Wilson, which point was not visible when Summit was occupied in 1877.

At Tanyard Mountain a tripod with scaffold elevated one hundred feet from the ground was requisite for bringing into view adjacent points of the scheme of triangulation. Arrangements were made for its construction, but while the work was in progress Assistant Boutelle, in consequence of a serious hurt early in November, was compelled to leave the field. The astronomical work was continued by Mr. J. B. Boutelle. After closing the angular measurements at Summit he recorded observations for latitude on twenty-nine pairs of stars during ten nights in December. Azimuth was determined in the latter part of November by observations on Polaris with the twenty-inch theodolite; local time was ascertained as usual, and the customary tests were made during five nights for the value of the micrometer of zenith telescope, No. 5.

Nineteen directions upon as many stations were determined in the course of the season by thirty-three series of observations; forty-three subsidiary objects were observed on from the primary stations, for position and elevation, and nineteen zenith distances were carefully recorded for ascertaining the heights of the primary stations. The ordinary statistics are:

Stations occupied	5
Angular measurements	1,254

In his field report Assistant Boutelle remarks as follows: "An inference of the late Assistant Webber from the discussion of his record of vertical angles, has been verified by the observations of this season. We find the observed coefficient of refraction to be less on the western than on the eastern slope of the Appalachian chain, for points of equal elevation. This may be due to a smaller amount of aqueous vapor in the air of the western slopes than in that upon the ocean side of the great dividing range of mountains."

Currents near the Mississippi Delta.—For observing and recording the currents of the Gulf of Mexico in the approaches to the Mississippi Delta, a party was assigned early in January for service in the schooner Drift, under the charge of Master Robert Platt, U. S. N., Assistant on the Coast and Geodetic Survey, but that officer being delayed on account of sickness, the vessel was taken south by Ensign J. W. Stewart, U. S. N. In the plan of work, thirteen stations were indicated by Assistant Henry Mitchell, and it was desirable that the currents should be observed while the schooner was at anchor. Master Platt joined the party at Port Eads on the 18th of February, and found the vessel in readiness for the intended work. Efforts made in March to occupy stations were much interrupted by fog and wind. Several of the stations were occupied twice, and one of them three times, in order to secure the observations desired. The month of April was favorable in respect of weather, but difficulty was experienced in consequence of the softness of the bottom on which the anchor was dropped. Slight breezes caused the vessel to drag away from the station; and the currents were such as to take the vessel off her course as much as three or four miles, in a run of only twelve miles. By the pilots this peculiar movement is termed the "*witch current.*" From the observations thus far recorded Master Platt could not identify, near the Delta, any regular current or tidal currents, to compare in any degree with what has been so well defined by the operations of the same party in the Gulf of Maine. Of the stations occupied, four were near the entrances to the four passes. Outside of these a second series was observed with stations at several points between the approaches to the passes. The currents were observed at the surface, and at depths of twelve feet, five fathoms, ten, twenty, thirty, forty-five, eighty, and ninety fathoms, according the depth of water at the stations occupied. The outer series was at an average distance of about eleven miles from the entrances to the passes. All the positions occupied were previously indicated by Assistant Mitchell.

Master Platt was assisted in this work by Ensigns J. W. Stewart and J. C. Colwell, U. S. N. The schooner Drift again reached New York near the end of May.

At the several current stations the temperature of the water was recorded at the surface and bottom, and also at each station, at a depth intermediate between the bottom and the surface. An aggregate of four hundred and ninety-seven observations was recorded with thermometers. The currents at varying depths for the thirteen stations were determined by twenty-one hundred and thirty-one observations.

As might be expected, Master Platt found the currents in the vicinity of the Delta extremely variable. Occasionally it was observed that while the surface current was in one direction, the water at a few feet below the surface was moving in a contrary direction.

Work done by the party in the schooner Drift earlier in the fiscal year has been mentioned under the head of Section I in this report.

Tidal observations.—The observations recorded regularly at intervals of six hours on a staff gauge at New Orleans, by Mr. G. Faust, begun January 1, 1872, were closed on the 1st of January, 1879. The daily fluctuation is of course nearly insensible, but the rise and fall in the course of the year amounting to eleven or twelve feet, due to floods and occasional dry seasons, are worthy of investigation because of their seeming periodicity, and it would appear that without question such periodicity must be related to meteorological conditions prevailing over large tracts of country in the region of the Mississippi.

Triangulation of the Mississippi River.—The scheme of triangulation laid out by Assistant F. W. Perkins in the summer of 1878, and of which the details were resumed in the present season and prosecuted until the close of the fiscal year, includes about twenty-four miles of the river course above the base line at Donaldsonville.

Owing to the topographical peculiarities of the region the selection of stations was difficult.

The highest land and principal obstructions lying along the middle of the tract to be triangulated, it was necessary to run out each line before deciding upon the location of a point for advancing the scheme. Many of the points were not intervisible because of the growth of corn and cane, but these came into view after the removal of the crops. In 1878, Assistant Perkins remained at work on the Mississippi until late in August. Yellow fever was then prevalent above and below the site of operations, but no case of sickness had occurred in the party. The air was unusually still, and there was rarely wind enough to admit of moving the schooner Research, on which the party relied for transportation. As a consequence the hands were constrained to travel unusual distances while employed in erecting signals. The field report for that summer shows that rain fell every afternoon, almost without exception, during the stay of the party, and that the heat was extreme.

As the summer of 1878 drew on, the alarm on account of yellow fever became general. Parties from an infected district were not admitted elsewhere, and finally it became uncertain whether supplies could be had for continuing work, or communications be maintained by mail with the office in Washington. The hands were willing to remain, but under the circumstances it was deemed inexpedient to prosecute further operations. Assistant Perkins was therefore directed to close for the season and disband his party. At the end of August, 1878, he returned to the office.

Capt. Henry T. Hutchinson, sailing master of the schooner Research, preferred to remain at Donaldsonville in charge of the vessel. He had passed several summers at and near New Orleans when fever prevailed, and had no fear in regard to the disease. A few weeks after the close of work on the river, when infection became general in the town, it was deemed advisable to moor the schooner at a convenient place about a mile and a half up stream, and for that purpose the sailing master was authorized to ship a seaman to assist in the transfer and future care of the vessel. The Research was taken to her anchorage, above Donaldsonville, on the 18th of September, 1878, and five weeks passed without incident. But, notwithstanding all precautions, and in a position which Captain Hutchinson regarded as exempt from infection, he was seized with yellow fever, and died on board the vessel on the 30th of October, after an illness of only five days.

In December the schooner was disinfected and refitted for service by the party. Field work was then resumed by Assistant Perkins, all the points of triangulation were finally selected, signals were erected, and lines of sight were opened. Up the river a careful reconnaissance was made for continuing the work as far as the bend below Baton Rouge. Throughout this stretch of the river close examination has been found necessary, in advance of locating the signals, to preserve the scale of the triangulation. The work was advancing favorably in the middle of May, when Mr. Perkins reported that it could well be continued through the summer unless there should be a recurrence of yellow fever. The statistics of the work then reported are as follows:

Signals erected	7
Points determined	6
Objects observed on	14
Angles measured	51
Number of observations	1,584

At the close of the fiscal year the party of Assistant Perkins was still actively engaged in field work. The results will be stated in my next annual report.

Hydrography of the Mississippi River.—The steamer Bache, with the party of Lieut. Commander C. M. Chester, U. S. N., Assistant in the Coast and Geodetic Survey, reached New Orleans on the 21st of January, 1879, provided with a projection for soundings between Grand View Reach and Point Houmas. Work was commenced without delay, and while the hydrography was in progress the tides were observed and recorded at Homestead Plantation and at New Hope Landing. Soundings were made also at the mouths of the Atchafalaya and Red River, and at several of the crevasses.

Commander E. P. Lull, U. S. N., hydrographic inspector of the Coast and Geodetic Survey, accompanied the party while engaged on the Mississippi, and collected important particulars in regard to changes which have affected that great highway to the Gulf within recent years. These include the history of the Atchafalaya as an outlet of the Mississippi during a period of fifty years, and remarks on the relation of both to Red River.

Of the several crevasses surveyed by the hydrographic party in the steamer Bache, Commander Lull obtained notes in regard to origin, and with these combined a comprehensive statement showing the present condition of each. At Cowpen Bend, about four miles above Natchez, sections were run across the river.

Morganzia Crevasse was sounded, as was also that at Diamond Island and Bonnet Carré. Glascock Crevasse was examined, but had so filled up as to overflow only at the highest stages of the river, and as no water had gone over it this season, a survey was not deemed necessary.

The statistics of hydrographic work done by the party of Lieutenant-Commander Chester in this section are:

Miles run in sounding	168
Angles measured	3,174
Number of soundings	5,151

Forty-six signals were erected by the party for prosecuting work in the several localities referred to in this abstract.

Lieutenant-Commander Chester was assisted by Lieuts. U. Sebree and A. V. Wadhams, U. S. N.; by Master T. G. C. Salter, U. S. N., and by Ensign M. L. Wood, U. S. N. The steamer Bache left New Orleans on the 14th of April, and, after touching at Key West and Baltimore, reached New York on the 1st of May. The party was subsequently engaged in duty, of which mention has been made in Section I of this report, and previously in Section II.

Triangulation of the Mississippi River from Natchez to Grand Gulf.—In my report for last year, mention was made of the measurement of a base line opposite to Natchez for the triangulation of the Mississippi. A few stations in the immediate vicinity of Natchez were occupied by Assistant W. H. Dennis in the latter part of that year. The work was resumed in December, 1878, with a party working in the steamer Barataria, but the movements of Mr. Dennis were much hindered for several weeks by the ice which made the use of boats impracticable in the Mississippi until the 20th of January. From that date until the 1st of June the weather was almost continuously good for field work. Sixty-nine miles of the course of the river are defined by the operations of this party during the season. In order to avoid heavy cutting, and the claims for damages incident thereto, the triangulation stations were in general located on the immediate banks of the river. But the disadvantage of the reduced scale for triangle sides was overcome, as far as possible, by the care of Mr. Dennis in arranging the scheme of work so as to obtain double, and often triple, determinations of the station points. Notwithstanding the lessened size of the triangles, an aggregate of twenty-five miles of cutting was necessary, mostly through the light growth of willows, and for this no outlay was incurred in damages. The proprietors of lands over which the party passed in the prosecution of work cordially aided in every way likely to further progress in field operations.

Mr. C. H. Van Orden served as aid in the party of Assistant Dennis. The statistics of the work are:

Signals erected	63
Stations occupied	66
Angular measurements	12,354

The work was closed for the season at Hard Times Landing, above Grand Gulf.

Triangulation of the Mississippi River above Vicksburg.—At the end of November, 1878, Assistant Charles Hosmer repaired to Vicksburg, Miss., to resume the triangulation previously conducted in that vicinity, but suspended in the preceding year. For the use of his party the steamer Hitchcock was transferred from the Atlantic coast, as mentioned in my last annual report, but in consequence of the prevalence of yellow fever was of necessity stopped on her voyage and laid up at Pensacola. The vessel reached Vicksburg on the 12th of January. Field work was resumed immediately, and was continued until the 10th of May. Master Albert Mertz, U. S. N., acted as sailing-master during the season, and at the end of May took the vessel to Saint Louis, where the crew was discharged.

In extending the triangulation above Vicksburg, about eighteen miles of the course of the Mississippi were included. Several stations were occupied above Milliken's Bend. The season generally was favorable, but observations were hindered in February and March by smoke from burning cotton-stalks. At such times, however, other parts of the work were steadily advanced.

Mr. John B. Weir aided in the field work. The statistics are:

Signals erected	20
Stations occupied	23
Angles measured	110
Number of observations	2,164

Twenty-six points were determined in position by the measurement of horizontal angles.

Assistant Hosmer had been previously engaged in plane-table work, of which mention has been made in Section I of this report.

Triangulation of the Mississippi River from Bennett's Landing to Memphis, Tenn.—For continuing the triangulation of the Mississippi, the party of Assistant C. H. Boyd was organized on the 20th of December, 1878, on board the steamer Baton Rouge, at Helena, Ark. As the yellow fever had not then entirely ceased in that locality, the repairs to the boiler of the vessel were hastened, and all arrangements were complete by the end of the month, but severe weather closed navigation for several weeks in January. When the ice gave way the party proceeded to Bennett's Landing, and resumed work at the limits of previous operations. For a fortnight progress was interrupted, and the vessel endangered by drift ice, but inconvenience from that cause proved to be temporary. Field work was continued up the river without interruption until the middle of March, when the engineer, Mr. W. H. Pleasants, was suddenly taken with the country fever, and died after being ill only three days. He was a faithful and energetic member of the party on the Baton Rouge, and was in high esteem among his associates.

The condition of the ground in the latter part of March being favorable for the measurement of a check base at the end of the triangulation, Mr. Boyd prepared and measured a line of twenty-five hundred and fifty meters at Hopefield, directly opposite the city of Memphis. The ends of the line are in proper geodetic connection with the astronomical station occupied in that city in the year 1877. Substantial monuments were set, as usual, to mark the Hopefield base line. Azimuth was determined at the southern end of the base, and equal altitude observations were recorded during a fortnight for rating chronometers.

After completing the azimuth observations, the triangulation was resumed, and extended down the river to a junction with the work done at the outset of the season. In general the stations occupied were in the immediate vicinity of the shore lines of the river. About thirty-one miles of the course of the Mississippi is included in the work of Assistant Boyd during this season.

Early in May the hands in the party became affected by the sickness incident to the region, and the further prosecution of field work was deemed inexpedient. After the discharge of the crew the steamer was laid up at Helena.

Master William Kilburn, U. S. N., was attached to this party, and rendered acceptable service in the management of the vessel, and care of the crew while field operations were in progress.

The character of the country covered by this work, is similar to that passed over last season—dense swamp forests, extensive sand shoals, and caving river banks. The swamp thickets entailed great labor in cutting lines of sight. Forty-three lines required opening, so as to admit of observing with the theodolite.

Mr. C. A. Ives was attached to the party as aid. The statistics of the work are:

Signals erected	38
Stations occupied	41
Angles measured	431
Number of observations	9,804

Fifty geographical positions were determined by the angular measurements.

SECTION IX.

TEXAS AND INDIAN TERRITORY.—(SKETCHES NOS. 20, 21, AND 31.)

Hydrography of the coast of Texas.—For extending the inshore hydrography of the coast of Texas, Lieut.-Commander Theo. F. Jewell, U. S. N., Assistant in the Coast and Geodetic Survey, arrived on the working ground on the 21st of January, 1879, with his party, in the steamer Gedney. Several days were employed in reconnaissance and in erecting and determining the positions of signals, but as very few of the station marks of the triangulation could be found, determinations were made by reference to Matagorda light, Half Moon Reef light, and the remains of houses, the chimneys of which, as points observed from other points of triangulation, were marked on the projection taken by Lieutenant-Commander Gedney. Soundings were begun on the 20th of March and closed on the 19th of June. Beginning at a point near the upper end of Matagorda peninsula, the hydrography of the coast of Texas was made continuous from its previous limit, and pushed southward and westward about fifty-five miles to a position twelve miles south of Pass Cavallo. At intervals of about a mile, lines were run normal to the coast, and into the Gulf to an average distance of eleven miles, and these were crossed for verification by two lines, one in three fathoms, and the other in seven fathoms of water. No shoals were found, the depth increasing evenly in going outward to twelve or thirteen fathoms at twelve miles from the shore. Inside of the six-fathom line the bottom is hard sand, and occasionally sand with broken shells; beyond that depth the bottom is mud with small shells occasionally intermixed.

Lieutenant-Commander Jewell noticed that the currents were mainly due to the direction and force of the wind, and that they followed the shore line, no set, on or off shore, being observable. The tides also were largely influenced by the winds. Tides were small with northerly, westerly, and southwesterly winds; and larger with southerly, southeasterly, and easterly winds. The statistics of the work are:

Miles run in soundings	765
Angles measured	2,107
Number of soundings	9,497

Lieutenant-Commander Jewell was assisted in this section by Lieut. John Garvin, U. S. N., Masters C. E. Fox and M. K. Schwenk, U. S. N., and by Ensign C. H. Amsden, U. S. N. The same party was previously engaged in Section I.

Triangulation of Laguna Madre, Tex.—At the opening of the fiscal year, this work was resumed by Assistant R. E. Halter, at the limits reached in the preceding season. In passing southward and eastward, stations were occupied at proper intervals on Padre Island, and signals were erected on the opposite shore of the lagoon. As thus laid out, the scheme of triangulation includes a stretch of sixty-five miles of Gulf coast and lagoon, above Point Isabel. The average width of this part of the lagoon is about eight miles. Previous to the 3d of March all the stations along the Gulf coast had been occupied, and two on the mainland. The remaining stations on the mainland above Point Isabel will be occupied in the course of the present year. Of the work done the statistics are:

Signals erected	23
Stations occupied	10
Angles measured	58
Number of observations	8,370

Assistant Halter is now in the field, and before the close of the season the triangulation will doubtless be extended to the mouth of the Rio Grande.

Within the limits of work done this year in the Laguna Madre, is an isolated bed on the western side, twenty-six miles in length and averaging more than a mile in width, in which bed the depth of water is nine feet. No definite channel leads into the pocket from any direction.

Hydrography of West Indian approaches to the Gulf of Mexico.—In order to complete the hydrographic development of the southern approaches to the Gulf of Mexico, the steamer Blake was refitted under the direction and supervision of Lieutenant-Commander Sigsbee, and passed southward early in December, 1878, with a party in charge of Commander J. R. Bartlett, U. S. N., Assistant in the Coast and Geodetic Survey. Provision was made, as in the cruise of last year, for procuring specimens of life to be found in the waters traversed by the hydrographic party, and, as before, Prof. Alexander Agassiz, with his assistant, S. W. Garman, accompanied the vessel.

The steamer Blake reached Key West on the 6th of December after a stormy passage. Coal was taken in, and the vessel proceeded to Port Royal (Jamaica), making, off Havana, several successful hauls with the dredge, and others in the bight to the eastward of the entrance to the harbor of Port Royal. A line of soundings was run across the old Bahama channel abreast of Lobos Cay light, showing in the deepest part only five hundred fathoms, although the ordinary charts are marked "nine hundred fathoms, no bottom." In the Windward Passage the trades were very strong, and the Blake rolled heavily, but the reeling engine and sounding machine worked well. On his course southward Commander Bartlett noted a number of errors in the charts hitherto relied on by navigators.

On the course from Kingston to St. Thomas work was impracticable in consequence of the heavy sea; the trades were almost a gale, and the steamer could make only about two knots per hour against wind and sea between Jamaica and Hayti. From Jamaica to St. Thomas a current was found setting to the eastward, at times with a rate of two knots per hour, making a very short, disagreeable sea. In reference to this current Commander Bartlett observes:

"The captain of the English telegraph steamer at St. Thomas says that at this time of the year he generally found the current setting to the eastward, south of St. Domingo and Porto Rico; and mention of it is also made in the Sailing Directions issued by the Hydrographic Office, in which it is said to be south of Jamaica. In my opinion the Caribbean Sea has a circulation of its own, independent of any source of supply or waterway for the Gulf Stream."

After leaving the anchorage under Ile de Vache, strong trade winds were met in going eastward until south of Porto Rico, and there soundings and dredgings were made in eight hundred and seventy-four fathoms of water.

At St. Thomas the Danish governor visited the steamer Blake, and manifested special interest in the apparatus and proposed investigations. The governor had examined the outfit of the Challenger when that vessel was at St. Thomas, and recognized that improvements had been made in the sounding apparatus used on board the Blake.

Early in January a week was passed in sounding and dredging between the island of St. Thomas and Santa Cruz. Twenty-seven hauls were made, and a variety of living specimens obtained, some from a depth of twenty-three hundred and seventy-six fathoms, the trawl bringing up at the same time from that depth a rock weighing three hundred pounds.

By the middle of January the operations of the party under Commander Bartlett had procured specimens sufficient to enable Professor Agassiz to describe the characteristic fauna of the sea in the vicinity of Cuba, Hayti, Jamaica, Porto Rico, and the Virgin group of islands. The latter part of the month was occupied in dredging along the islands from St. Christopher to Dominica, and in that neighborhood one hundred hauls were successfully made. In the passages from island to island the trade winds continued to be very strong. Dredging was carried on under the lee of each island and along the Grenadines to Grenada; also across the channel to the southward of the last-named island. Barbadoes was reached on the 4th of March, 1879, and a week was spent in dredging under its lee. Here many of the crew were affected by malarial fever, though all hands remained well until a few days previous to the arrival of the Blake. The fever appeared soon after touching at Grenada, but fortunately no case took a serious turn.

At Barbadoes, Professor Agassiz left the vessel and returned to resume professional duties at Cambridge. All the dredging apparatus was then unrigged in preparation for recording soundings during the remainder of the season. From Barbadoes and St. Vincent lines were run in passing from one to another of the Windward Islands, and the soundings show that in the passages between the islands the depth in each case is less than the depth of water inside or outside of the range. The channels thus developed seem to be merely depressions in a range of partly submerged mountains. Between St. Vincent and St. Lucia the greatest depth found was four hundred and eighty-eight fathoms; between St. Lucia and Martinique, five hundred and forty-eight; between Martinique and Dominica, five hundred and seventy-five; between Dominica and Guadaloupe, three hundred and forty-six; between Guadaloupe and Antigua, three hundred and forty, and between Antigua and Nevis, three hundred and eighty-six fathoms. In broad contrast with these results found by the sounding line is the fact that mountain peaks upwards of four thousand feet in height occur on St. Christopher, Dominica, and St. Vincent. The Virgin Islands, a separate group, pertain to Porto Rico, and between that group and the Windward Islands the depth of the passage is ten hundred and seventy-six fathoms. The Mona Passage, between Porto Rico and St. Domingo, has only two hundred and sixty fathoms, and the Windward Passage, between Hayti and Cuba, eight hundred and seventy-three fathoms. One of the mountain peaks of Cuba is upwards of eight thousand feet high, and one on Hayti is more than seven thousand feet in height. The Blue Mountain Ridge of Jamaica is eleven hundred feet high, and the depth found between that island and Hayti was eight hundred and five fathoms.

The work done proves moreover that in the passages between the islands the depths are irregular, the soundings indicating submerged peaks and ridges. In sounding between Guadaloupe and Antigua a peak was found having only forty fathoms on it. This was in midchannel, and yet the mean depth, as before stated, is three hundred and forty fathoms.

In general, serial temperatures of the water were well recorded at positions under the lee of the islands, but in the passages between them the pitching of the vessel made the record uncertain. The lowest temperature found by Commander Bartlett in the Caribbean Sea was in twenty-five hundred fathoms near St. Croix, the thermometer indicating 38°. In depths between twelve hundred and nineteen hundred fathoms the temperature was 38½°. Between Anegada and Sombrero the temperature was 38° at thirteen hundred and forty-six fathoms, 37½° at sixteen hundred and forty-three fathoms, and 36½° at twenty-five hundred and thirty-eight fathoms outside. To the westward of the islands at one thousand and fifteen hundred fathoms the temperature was about 39°.

The methods devised by Lieutenant-Commander Sigsbee, when in command of the steamer Blake, for obtaining soundings and temperature records in deep water, and adopted in practice this season by Commander Bartlett, are strongly commended by that able officer.

Observations on the currents were regarded as of special importance, but the investigation was attended with difficulties. In general reference to the subject, Commander Bartlett remarks:

"The water does not set into the Caribbean Sea through the channels between the islands to any great extent. The trade wind banks the water against the windward side of the islands, and near their ends the current sets strong to the westward; but near midchannel between the islands I have never found a westerly current. All the water to the east and west of the long chain of islands sets *northward*. South of Grenada we experienced a current of two to three knots setting to the westward.

"The Blake made the passage from St. Vincent to Barbadoes with a very light easterly breeze, and was set fifteen miles northwest. Returning to St. Lucia, I found a northerly set of nineteen miles in twelve hours, and when steering north from Barbadoes a current was found of a knot and a half setting north. H. B. M. ship Blanche reported at Barbadoes that on the course from Martinique she had a northerly current of forty miles in twenty-four hours.

"North of Guadaloupe the current was very strong to the northward. It was quite smooth after leaving Saba Island, and I found the current north-northwest, about a mile per hour. A current of one knot was also observed setting to the eastward on the course from Nevis Island to Santa Cruz."

The Blake sailed from St. Thomas on the 27th of April for the Mona Passage. There the current showed an ebb and flow, but after clearing the Passage, and to the northward of St. Domingo, a current was entered setting to the westward over one knot per hour. The depth of water found between St. Domingo and the Bahama Banks was two thousand fathoms.

While the steamer was at work in the vicinity of the Windward Islands large patches of seaweed were observed, during light winds and calms always tending in long lines to the northward.

Lines of soundings were run between Jamaica and the Pedro and Rosalind Banks, and a line also from the last-named bank to Cape St. Antonio, giving depths of over two thousand fathoms in the Gulf of Honduras.

Commander Bartlett, in his report accompanying the record of the season's work, deduces from his observations on the currents, that the equatorial current which sets directly against the Windward Islands is by them and their connecting ridges deflected northward, and so follows their outer edge, and passes around the Virgin Islands to the westward through the deep channel north of St. Domingo. He suggests also that on reaching Cuba the current divides, part flowing north through the old Bahama Channel, and part through the Windward Passage by the deep channel between Cuba and Jamaica, and thus by Cape St. Antonio into the Gulf of Mexico. His report states that the specimens of bottom taken in the Windward Passage give evidence that the current in that passage moves in depths greater than eight hundred fathoms, and that it reaches the bottom. The temperature found on the ridge at eight hundred fathoms was 39°, and this temperature was always found at and below that depth inside, as is also the case in the Gulf of Mexico. Outside of the ridge the temperature fell to 36½°, at two thousand fathoms.

Between Rosalind Bank and Cuba the currents were observed to be very feeble, and there was a total absence of Gulf weed in those waters. On the current found south of Grenada, and especially in reference to its origin, Commander Bartlett remarks as follows:

"The current always found flowing north along the eastern side of South America, on reaching the island of Tobago divides, part joining the equatorial current setting north along the chain of islands; the remainder following the coast line of Trinidad and the Spanish Main, and so around the entire circumference of the Caribbean Sea, finding at last an outlet at the Mona Passage and the Anegada Channel to join the equatorial current on its way to the Gulf of Mexico."

After closing operations for the season at the south, the steamer Blake reached New York at the end of May.

In the work here noticed, Commander Bartlett was assisted by Lieuts. W. O. Sharrer and J. P. Wallis, U. S. N.; Master H. M. Jacoby, U. S. N., and Ensigns G. N. Peters and E. L. Reynolds, U. S. N. The records of the various operations in service afloat were made by Assistant Surgeon Charles J. Nourse, U. S. N., and Mr. L. C. Sigsbee.

Commander Bartlett's suggestion in regard to the course of the currents in the Caribbean Sea is based on observations made during part of a single season. Similar observations repeated in other years would be requisite to substantiate the theory.

Professor Agassiz, in a very interesting communication (Appendix No. 6), remarks as follows:

"One of the most interesting results reached by this year's cruise is the light thrown upon the former extension of the South American continent by the soundings taken while dredging, and those subsequently made in the passages between the islands by Commander Bartlett. These, together with the soundings already known, enable us to trace the outline of the old continent with tolerable accuracy, and thus obtain some intelligible, and at the same time trustworthy, explanation of the peculiar geographical distribution of the fauna and flora of the West India Islands. As is well known, Cuba, the Bahamas, Hayti, and Porto Rico, instead of showing, as we might naturally assume from their present proximity to Florida, a decided affinity in their fauna and flora with that of the Southern United States, show, on the contrary, unmistakable association with that of Mexico, Honduras, and Central America. The Caribbean Islands show in part the same relationship, though the affinity to the Venezuelan and Brazilian fauna and flora is much more marked."

"In attempting to reconstruct, from the soundings, the state of things existing in a former period, we are at once struck by the fact that the Virgin Islands are the outcropping of an extensive bank. The greatest depth between these islands is less than forty fathoms, this same depth being found on the bank to the east of Porto Rico, the one-hundred-fathom line forming, in fact, the outline of a large island, which would include the whole of the Virgin Islands, the whole of Porto Rico, and extend some way into the Mona Passage. The one-hundred-fathom line similarly forms a large plateau, uniting Anguilla, St. Martin, and St. Bartholomew. It also unites Barbuda and Antigua, forms the Saba Bank, unites St. Eustatius, St. Christopher, Nevis, and Redonda. It forms an elongated plateau, extending from Bequia to the southwest of Grenada, and runs more or less parallel to the South American coast from the Margarita Islands, leaving a comparatively narrow channel between it and the one-hundred-fathom line south of Grenada, so as to inclose

Trinidad and Tobago within its limits, and runs off to the southeast in a direction also about parallel to the shore line. At the western end of the Caribbean Sea the one-hundred-fathom line forms a gigantic bank off the Mosquito coast, extending over one-third the distance from the mainland to the island of Jamaica. The Rosalind and Pedro Banks, formed by the same line and a few other smaller banks, denote the position of more or less important islands which must have once existed between the Mosquito coast and Jamaica. On examining the five-hundred-fathom line, we thus find that Jamaica is only the northern spit of a gigantic promontory, which once extended toward Hayti from the mainland, reaching from Costa Rica to the northern part of the Mosquito coast, and leaving but a comparatively narrow passage between it and the five-hundred-fathom line encircling Hayti, Porto Rico, and the Virgin Islands in one gigantic island. The passage between Cuba and Jamaica has a depth of three thousand fathoms, and that between Hayti and Cuba is not less than eight hundred and seventy-three fathoms, the latter being probably an arm of the Atlantic. The five-hundred-fathom line connects as a gigantic island, the banks uniting Anguilla to St. Bartholomew, Saba Bank, the one connecting St. Eustatius to Nevis, Barbuda to Antigua, and from thence extends south so as to include Guadeloupe, Marie-Galante, and Dominica. This five-hundred-fathom line thus forms one gigantic island of the northern islands, extending from Saba Bank to Santa Cruz, and leaving but a narrow channel between it and the eastern end of the five-hundred-fathom line running round Santa Cruz. As Santa Cruz is separated from St. Thomas by a channel of forty miles, with a maximum depth of over twenty-four hundred fathoms, this plainly shows its connection with the northern islands of the Caribbean group, rather than with St. Thomas, as is also well shown by the geographical relations of its Mollusca. The five-hundred-fathom line again unites, in one gigantic spit extending northerly from the mouth of the Orinoco, all the islands to the south of Martinique, leaving Barbadoes to the east, and a narrow passage between Martinique and the islands of Dominica and St. Lucia.

"At the time of this connection, therefore, the Caribbean Sea connected with the Atlantic only by a narrow passage of a few miles in width between St. Lucia and Martinique, and one somewhat wider and slightly deeper between Martinique and Dominica, another between Sombrero and the Virgin Islands, and a comparatively narrow passage between Jamaica and Hayti. The Caribbean Sea, therefore, must have been a gulf of the Pacific, or have connected with it through wide passages, of which we find the traces in the Tertiary and Cretaceous deposits of the Isthmus of Darien, of Panama, and of Nicaragua. Central America and Northern South America at that time must have been a series of large islands with passages between them from the Pacific into the Caribbean. It is further interesting to speculate what must have become of the great equatorial current, or rather of the current produced by the northeast trades. The water banking up against the two large islands, then forming the Caribbean Islands, must, of course, have been deflected north, have swept round the northern shores of the Virgin Islands, Porto Rico, and Hayti, and poured into the western basin of the Caribbean Sea, through the passage between Hayti and Cuba. This water being forced into a sort of funnel, by the five-hundred-fathom line forming the southern line of the Great Bahama Island, which connected nearly the whole of the Bahamas with Cuba and formed a barrier to the western flow of the equatorial current, must, therefore, for the greater part, have been deflected north, and either swept in a northeasterly direction, as the Gulf Stream now does, or round the north end of the Bahamas, across Florida, which did not then exist, across the Gulf of Mexico, and into the Pacific over the Isthmus of Tehuantepec.

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"The soundings made by Commander Bartlett, after I left the Blake, to determine the ridges uniting the various islands between Sombrero and Trinidad, show plainly that the cold water of the Caribbean can only come in through the passage between Sombrero and the Virgin Islands, which is about eleven hundred fathoms, with a bottom temperature of 38°, while the five-hundred-fathom line, as I have said, forms a gigantic island of all the islands to the south of Sombrero, including Dominica, with a narrow passage of one thousand fathoms between it and Martinique; the five-hundred-fathom line again uniting into one large spit, as a part of South America, all the islands to the south of it. Thus the bulk of the water forced into the Caribbean Sea has a comparatively high temperature—an average, probably, of the temperature of the three-hundred-fathom line. The cold water of the Atlantic is, however, again forced into the western basin of the Caribbean through the Windward Passage, and all this through the Yucatan Channel, between Cape San Antonio and the Yucatan Bank. It is, therefore, incredible that with this huge mass of water pouring into the Gulf of Mexico, there should be anything like a cold current forcing its way up hill into the Straits of Florida, as has been asserted on theoretical grounds. The channel at Gun Key can only discharge the surplus by having a great velocity."

Magnetic Observations.—When my last annual report closed Subassistant J. B. Baylor was in this section, determining the magnetic declination, dip, and intensity at points in Texas. He had completed observations at Dollar Point, Austin, Hempstead, and Groesbeck; and at the opening of the fiscal year, to which this report corresponds, a station was occupied at San Antonio. Passing on northward Mr. Baylor determined the magnetic elements at Fort Worth, and at Sherman in Texas, and subsequently at Atoka and Eufaula in Indian Territory. Thirty-four stations in all were occupied in the course of the season. Of these, not already referred to, mention will be made further on in this report. Late in July, 1878, Mr. Baylor proceeded to Humboldt, Kans., of which station, and others occupied in that region, notice will be taken under the head of Section XV. Subsequently he recorded observations in Colorado (Section XVI); in Wyoming Territory (Section XVII); and before closing for the year, also in Wisconsin and Illinois, as will be stated under the head of Section XIV.

Notwithstanding the disadvantage arising from its variations from the meridian, the compass needle is almost exclusively used to mark out the boundaries of adjoining properties. In his intercourse with the people, Subassistant Baylor found that every one of average intelligence recognized the practical importance of a work establishing means for the corrections of an instrument so universally used as the surveyor's compass.

Of many of this section, who tendered courtesies and aid in his operations, Mr. Baylor's report specially mentions the Hon. Guy M. Bryan, of Galveston; Capt. C. Comly, U. S. A., stationed at the San Antonio Arsenal; and Mr. Rhodes Fisher, chief clerk of the land office at Austin.

SECTION X.

CALIFORNIA.—(SKETCHES NOS. 22, 23, AND 24.)

Geodetic operations, Santa Barbara Channel, Cal.—As mentioned in my last annual report, Subassistant D. B. Wainwright was in the field at the opening of the fiscal year, July 1, 1878, and was then occupying the primary station on San Clemente Island, and observing on signals previously stationed on Catalina and Santa Barbara Islands. During the stay of the party on Clemente, dense fog generally hung around that island, but occasionally the heliotrope on Santa Barbara was seen for short periods. By watching closely, the measurement of horizontal angles was completed on the 21st of August. Before leaving the island, Mr. Wainwright recorded observations on Polaris for azimuth.

Early in September, observations with the theodolite were begun at the primary station on Catalina Island, signals having been previously set at San Pedro Hill, and Las Bolsas on the mainland abreast of Santa Catalina. The weather proving moderately good, observations for horizontal angles and for azimuth were finished by the 5th of October.

San Pedro Hill was next occupied, and the measurement of horizontal angles needful there was completed before the middle of November. The party was then transferred to Las Bolsas, but the work at that station was much hindered by thick smoke from burning stubble drifting from the interior down to the coast. The required measurements were, however, obtained by the 9th of December. The statistics of the work are:

Signals erected	4
Stations occupied	5
Angles measured	14
Number of observations	1,978

The work here reported completes the geodetic connection between the Santa Barbara Islands and the main coast of California. After storing the camp equipage at San Pedro and forwarding the instruments to San Francisco, Subassistant Wainwright reported in person at the office in Washington. He has again resumed field duty on the coast of California.

Topography of Catalina and San Clemente Islands, Cal.—The topographical survey of Catalina Island, in progress at the opening of the fiscal year, was completed on the 26th of August, 1878. On the day following, Assistant Stehman Forney went to San Clemente in a small sloop, and, after reconnaissance, found that his party could be supplied with fuel and water only by transporting what might be requisite from the mainland or from Catalina Island. An old tank at the landing on the northwest end of San Clemente was repaired, and used for storing water while the survey of the island was in progress.

After securing the property used on Catalina, and selecting essentials for use on San Clemente, Mr. Forney again reached that island on the 14th of September with his party and supplies of water and provisions. The month following was occupied in establishing hydrographic signals and identifying the triangulation points. All the station marks were recognized, and also the astronomical station which had been occupied by Assistant Davidson in 1852.

The detailed topographical survey of San Clemente Island was begun on the 22d of October, and was completed on the 22d of January, 1879. This island is high and bold at the southern end, the land gradually falling to the northward. Its length is nearly twenty-one and a half miles and the average width about two and a half miles. The southern part at one point rises to nineteen hundred and sixty-four feet above half tide, and from that height the land gradually slopes to the northwestern end of the island. The southwestern face is marked by a succession of well-defined terraces, or old sea-beaches, all of which were carefully delineated on the plane-table sheet by Assistant Forney. His concluding report mentions Wilson's Cove as a useful anchorage. This is an open roadstead on the eastern side of the island, and rather more than two miles from its northern extremity. All the wool raised in the island is shipped from Wilson's Cove. Thirteen and a half miles southward, and also on the eastern shore of the island, is a small cove called Mosquito Harbor, and that is reported as a good shelter for boats of ten tons during summer months.

Smuggler's Cove, at the southern end of the island, affords a good lee from northwest and northeast winds, but its shallow sand beach makes the landing uncomfortable.

Along the northeastern face of San Clemente, boats may land anywhere, but on the opposite or southwestern side there are only three practicable boat-landings; one of these, called Seal Harbor, is about midway between the northern and southern ends. This is a noted sealing-station. The other landings are near the north end of the island. During the stay of the party, the sea approach to the western shore was very rough, most of the time being marked by immense breakers rolling in upon the beach.

"The entire surface of the island is broken up with deep gulches, especially on the southern and southwestern slopes, where some of them are eight and ten hundred feet deep. But in general the surface shows extensive plains of rolling land, thickly covered with wild grasses, common along the coast of California."

"The geological formation is almost entirely of black volcanic rock, impervious to water, and covered with a shallow soil. In the deep gulches and other obscure parts of the island, clumps of scrub-oak and bushes are found, but not elsewhere. The entire southern and southwestern slope is covered with cactus, in many places so thick that it is impossible to ride a horse through it."

On the plane-table sheet Mr. Forney denoted the positions of ten tanks for maintaining a supply of water for the stock raised on the island. From eight to nine thousand head of sheep are supported annually. During summer and autumn the animals feed at night, while dew and moisture from fog are on the vegetation, and thus derive enough water to sustain themselves.

On the 22d of January Commander Coffin, by previous arrangement, transferred Assistant Forney and his party from San Clemente Island to San Diego, where preparation was made for the survey of San Nicolas, and the party was taken to that island in the Hassler on the 8th of February. Field work was begun immediately, and was prosecuted until the 15th of March, when the means available for this work were exhausted. Mr. Forney, in consequence, disbanded the party and returned to Santa Barbara to engage in office work. His plane-table sheets of San Clemente

Island, and two others, showing the completed survey of Santa Catalina, have been received at the office in Washington. The topographical statistics are:

Shore line surveyed, miles	76
Roads, miles	9¾
Area of topography, square miles	84¾

Hydrography near Santa Catalina and San Clemente Islands, Cal.—The party of Commander G. W. Coffin, U. S. N., Assistant in the Coast and Geodetic Survey, working with the steamer Hassler, was engaged during the summer and part of the autumn of 1878 in sounding the approaches to Santa Catalina Island. The results were returned to the office on three hydrographic sheets, showing the depth of water to an average distance of five miles from the shore line, and all the reefs found within the limits of the work.

After completing the survey about Santa Catalina, the Hassler sailed for San Clemente Island, taking a projection for the hydrography of its western and southern approaches. Points on the island had been determined in position by Assistant Forney, as also at Catalina, when soundings were in progress there. At San Clemente all favorable intervals were employed, and by the 17th of February the projected sheet was filled. As usual, all reefs in the vicinity of the shore line were carefully developed and marked on the chart. The statistics of work are:

Miles run in sounding	790
Angles measured	11,284
Number of soundings	10,330

Commander Coffin was assisted in hydrographic operations by Lieuts. C. W. Jarboe and W. H. Driggs, U. S. N., and by Ensign C. F. Putnam, U. S. N.

At the end of the fiscal year the party in the steamer Hassler resumed duty afloat off the coast north of San Francisco entrance.

Hydrography of Bahia de los Tremblores and adjacent coast of California.—In the prosecution of inshore hydrography of the coast of California north and west of Newport Bay, good progress has been made by Lieut. E. H. C. Leutzé, U. S. N., Assistant in the Coast and Geodetic Survey, with a party in the steamer McArthur. Between the 1st of July and the 16th of December, 1878, three sheets were filled with soundings. Of these, one represents the inshore hydrography from Newport Bay northward and westward to Point Fermin, developing the bight known as Bahia de los Tremblores. In connection with it the second sheet defines the character of the sea-approaches above and below San Pedro, or between Point Fermin and Point Vincente, and in the last-named vicinity joined with hydrography previously completed.

Farther up the coast Lieutenant Leutzé filled a third projection with soundings required to complete the survey of the southeastern approach to Santa Barbara Channel. The southern limit of this sheet is Point Dume, and seaward the lines of soundings were extended about twenty miles. Above Anacapa Island the work joins with hydrography done in the year 1869. The statistics are:

Miles run in sounding	1,136
Angles measured	2,753
Number of soundings	12,773

In the course of the season the party erected forty-four signals. The tides were observed at Wilmington while the party was at work above and below Point Fermin. For the hydrography south of the Santa Barbara Channel, tidal observations were recorded at Point Hueneme. The three hydrographic sheets have been received at the office in Washington.

Lieutenant Leutzé was assisted in the operations of the season by Lieut. E. K. Moore, U. S. N., and by Masters L. C. Heilner, W. P. Elliott, and R. H. Galt, U. S. N.

At the close of the fiscal year the party in the steamer McArthur was again organized to prosecute soundings in the vicinity of San Clemente Island. Further mention of the work done in that quarter will be made in my next annual report.

Triangulation and topography of the coast between Point Arguello and Point Sal.—The party of Assistant W. E. Greenwell took the field at Point Arguello, on the 11th of August, 1878, and resumed the triangulation at points to which the work had been brought from the southward in a previous season. In going northward, stations were selected along the coast line, and others at distances inland suitable for defining the shore line north and south of Point Purissima. In the vicinity of Point Sal, Mr. Greenwell connected his work with the primary station Lospe, and with points formerly determined in position.

After occupying the stations of his scheme with the theodolite, and completing the angular measurements, a plane-table sheet was filled with details representing the coast features north and south of Point Purissima, the work in general being carried about three miles back from the water line.

"The character of the topography is peculiar. Sand dunes with a trend to the eastward denote the prevailing winds of eight months of the year. Within a mile of the shore the dunes are nearly destitute of vegetation, but further inland they are covered with low bushes."

Twenty-two miles of coast line are defined by the triangulation. The statistics of the field work are:

Signals erected	34
Stations occupied	26
Angles measured	303
Number of observations	6,964
Shore line surveyed, miles	9
Creeks, miles	5¼
Roads, miles	12½
Area of topography, square miles	23½

Operations in the field were discontinued on the 8th of March, when Assistant Greenwell returned to Santa Barbara and engaged in office work. At the close of the fiscal year his party was reorganized for extending the topographical survey north and south of the limits of the sheet already completed.

Hydrography of Suisun Bay and San Pablo Bay, Cal.—For this work the schooner Yukon was placed in charge of Assistant Gershom Bradford, on the 27th of July, 1878. Arrangements were made immediately by setting up a self-registering tide-gauge at Magazine wharf, on Mare Island, and in the latter part of August the hydrography was in progress in the vicinity of Army Point in Suisun Bay. The wind very frequently interrupted soundings, but at such times the party was employed in erecting signals and determining the positions needful in the work. By taking all favorable intervals, the hydrography was extended to the lower end of Chipp's Island, and through the Suisun Cut-off, and between Roe Island and King's Island. Tides were recorded steadily at a station on the eastern end of King's Island, and also at Collinsville and Benicia Arsenal. The upper part of the bay, including the mouths of the Sacramento and San Joaquin Rivers was sounded, and all the work needful in Suisun Bay was completed by the 18th of December. Smoke from the farm refuse, which is ordinarily burnt at the approach of the rainy season, much delayed the operations of the party, the smoke being more dense when the wind was light, and on that account favorable for work afloat.

In the latter part of December, station marks were identified on the shores of San Pablo Bay. The signals needful were set up, and a tide-gauge was established at a position about three-quarters of a mile east of Penole Point. The space sounded was on the south side of the bay, abreast of Point Wilson, and extending about four miles northward. This work was completed by the 14th of March, 1879, when the party was disbanded. Permanent bench-marks were established near the positions occupied by the tide-gauges at Magazine wharf (Mare Island) and Arsenal wharf, Benicia.

The soundings were numerous, and the determinations of position made with great care. In reference to results Mr. Bradford observes:

"I found considerable change in parts of the shore line in Suisun Bay and near Collinsville, apparently the effect of the growth of tules, and the wasting and building of the banks by the action of the current. Lumps of tule turf were noticed *floating*, either torn away by the water or cut away by dike-builders, and these lumps if deposited in an eddy would tend to form new banks.

"The greatest changes have occurred at the mouth of the Sacramento, near Collinsville; at the mouth of the San Joaquin, near Bush Point, and opposite to that point, at the mouth of Montezuma Creek. The changes are also considerable at the western end of Suisun Cut-off."

In the prosecution of the hydrography, Assistant Bradford erected seventy-five signals, and from shore stations measured seventeen hundred angles with the theodolite. Thirty-seven natural objects were determined in position. The ordinary statistics of the soundings are:

Miles run in sounding	630
Angles measured	7,210
Number of soundings	44,372

After laying up the schooner Yukon at Mare Island, Mr. Bradford plotted the sheets of his work in Suisun and San Pablo Bays, and forwarded them to the office. The more important changes found by comparison with the previous survey are thus noticed in the concluding report:

1. "The closing to deep vessels of the passage south of the Seal Islands by the extension of the shoal eastward from the eastern part of those islands.

2. "The deepening of water on the bar northwest of the Seal Islands from fourteen and a half feet to fifteen and seven-tenths feet.

3. "The narrowing and shoaling of the channel passing close to the eastern end of Roe Island where sixteen and seven-tenths feet can now be carried only by careful steering, as against three and three-fourths fathoms, the last-mentioned depth being formerly found in a channel of considerable width.

4. "Increase of depth eastward of Beacon 4 to some seventeen to nineteen feet, giving a clear passage thence to Middle Point.

5. "The deepening of the bar southeastward of the Middle Ground, from fourteen feet to fifteen and a half feet."

On the completion of the charts of Suisun and San Pablo Bays, Mr. Bradford resumed the compilation of matter for the Coast Pilot of the Pacific, as heretofore under the direction of Assistant Davidson.

Tidal observations.—The self-registering tide-gauge established at Saucelito by Assistant George Davidson has been kept in successful operation during the year by Mr. E. Gray. The series has already been continued through two years, and promises to be one of the most complete in respect of continuity.

At Mare Island navy-yard a good series of observations extending through seven months, and closing in March, 1879, was recorded by Assistant Gershom Bradford. The record was kept while his party was engaged in sounding parts of San Pablo and Suisun Bays.

Geodetic operations in California.—At the outset of the fiscal year, as intimated in my last report, Assistant George Davidson was at Paris as a commissioner for examining and reporting upon geodetic and other instruments of precision, deposited for exhibit in the International Exposition of the year 1878. The specified duties were such that attention to other branches of the exhibit would severely tax his endurance, yet being urged to accept appointment as one of twenty-two jurors on machines, Mr. Davidson was with great unanimity at once chosen by his fellow-members as president of that jury, and throughout assisted in its deliberations. In the latter part of July, 1878, the presentation of his detailed report on machines left him free to pursue the special object of the sojourn abroad, and by arduous application through the month of August, Mr. Davidson was enabled to complete examinations of theodolites, transits, levels, and such telegraph apparatus as might be useful in longitude determinations. Subsequently some of the most noted workshops in Paris were visited, and in the course of the autumn the principal manufactories of Geneva, Neuchatel, Munich, Vienna, Dresden, Berlin, Hamburg, Cassel, London, and York. Professor Davidson gave special attention to such graduating engines as were not carefully excluded from view, but in Paris he was prohibited from even testing the graduation of theodolites, or from making any sketches or drawings. One of the principal cases of instruments at the Exposition was kept permanently closed, so as to preclude inspection of the details of construction. As Professor Davidson had with great patience made tests of graduations in America, it was judged to be part of his duty to inquire of manufacturers of repute in Europe, but no one of the number questioned had ever tested a theodolite after graduation. The concluding report states that the inspection of instruments revealed much of deep interest, but nothing to discourage observers and mechanicians in the United States from claiming equality of rank with any in skill and precision.

After his return from Europe, Mr. Davidson made a short stay at the office, and early in December, 1878, was again at San Francisco. The winter and spring were passed in the completion of office work, computations of former field work, and details connected with the service in Europe, and in arrangements for resuming geodetic operations in California.

In some previous years Assistant Davidson had annually repeated observations for the magnetic elements at San Francisco. The series was resumed under his direction, and the declination, dip, and intensity were observed by Assistant B. A. Colonna during four days near the middle of March. The records of this work will yield important data concerning the secular motion of the magnetic needle, which motion near the coast of California has gradually diminished to a small annual rate. In the course of the next twenty years it is inferred that the direction of the needle on that coast will have reached a stationary condition in which it will probably remain some years before reversing its movement.

In February temporary structures were put up on the summits of Lola and Round Top for the shelter of the party and instruments, in advance of occupying these, the most eastern stations of the Davidson quadrilateral. Arrangements were made also for stationing heliotropes at different stations of the geodetic scheme in connection with that quadrilateral, when the condition of the snow admitted of occupying high stations.

Subassistant E. F. Dickins joined Assistant Davidson in February, and was efficient in details requisite for the field operations, as was also Subassistant J. F. Pratt. Assistant J. J. Gilbert joined in the middle of May, and on the 20th of that month the party set out for Mount Lola. The course lay through deep snow, but by the 7th of June the large theodolite was placed in safety on the summit of the mountain. There the earth was found to be frozen to the depth of two feet and a half. Bad weather delayed arrangements for observing, but ceased on the 12th of June, after sixty consecutive hours of snow, sleet, rain, and wind. The nights were intensely cold, and ice formed frequently to the thickness of an inch, but, notwithstanding the incidental hardships, Messrs. Colonna and Gilbert set up piers for the instruments, and observations from the summit of Mount Lola were commenced on the 18th of June. All the heliotropes, even the most distant ones, were in view, and the prospect was fair for an early completion of the geodetic work at that station. On Mount Shasta, one hundred and sixty-nine miles distant, Assistant Colonna made arrangements for mounting a heliotrope in the course of the month, at the instance of Assistant Davidson, who confidently expected to include that station in the series of angular measurements to be recorded at Mount Lola. At the close of the fiscal year the work at that station was well advanced. The progress there and at Round Top will be stated in my next annual report.

During the stay of Assistant Davidson in Europe, the details of business at the suboffice in San Francisco were conducted by Assistant A. F. Rodgers. Office data and tracings required in the operations of the parties on the Pacific coast are supplied as usual, under the direction of Assistant Davidson, by Messrs. F. Westdahl and G. Farquhar.

Under the supervision of Mr. Davidson, additional notes have been collected for the Coast Pilot of California, Oregon, and Washington Territory by Assistant Gershom Bradford, and operations maintained as heretofore with the self-registering tide-gauge at Saucelito.

Triangulation and topography west of Fisherman's Bay, coast of California.—In the operations of previous years, the detailed survey of the coast of California was extended northward and westward from Point Reyes to Fisherman's Bay. The work was there resumed by Assistant L. A. Sengteller on the 15th of September, 1878, the plan including also the development of a scheme for the coast triangulation from Stewart's Point northward to Point Arena.

In the course of the season previous to the 25th of February, 1879, the detailed topographical survey was extended from Fisherman's Bay to a point north of the entrance to the Walalla River, and the tertiary triangulation (somewhat further in the same direction) was closed for the season at Haven's anchorage. In general the plane-table details include, in the stretch of coast referred to, all features within a mile of the Pacific sea-board. The ground along the inner margin of the plane-table is represented as having an average elevation of seven hundred feet. Near the northern limit of work the Walalla was traced, and is shown as a small stream not navigable. It has two or three feet of water at the mouth during winter, but the bed of the stream is dry during summer. The statistics of the work are:

Stations occupied	14
Points determined	19
Angles measured	197
Number of observations	4,177
Shore line surveyed, miles	20½
Road, trails, and telegraph line, miles	51
Area of topography, square miles	14

At the end of the fiscal year, and after completing the computations and other details pertaining to the work here under notice, Mr. Sengteller again took the field, and in the course of the coming year will probably close the interval in the detailed topographical survey below Point Arena. North of that point the survey is continuous as far as Rocky Point, north of Trinidad Head.

In the reconnaissance for triangulation, Assistant Sengteller kept in view the expedient of mounting the theodolite on high trees, cut off at such elevation as would bring into view the outlying points that should in turn be occupied in like manner. In his party this plan has been successful in practice in regions that, owing to the density of the timber growth, could not otherwise be covered by triangulation.

Geodetic operations north of San Francisco, Cal.—For perfecting the system of points to be occupied in the region north of San Francisco, Assistant B. A. Colonna took the field on the 5th of July, 1878, provided with instruments and means for determining the intervisibility of stations that had been indicated in a general way in the preliminary examination.

After making the requisite angular measurements on Sanel Mountain, Mr. Colonna proceeded to Walalla, and was there joined by Subassistant J. F. Pratt, who had previously gone northward under directions to select a station near the Pacific coast at Point Cabrillo. In order to pass the red-wood region, through which the opening of lines of sight was impossible, Mr. Colonna decided to erect a high signal and platform for sustaining the theodolite. The details of this work were subsequently committed to Mr. Pratt, who selected a suitable tree and built around it a secure structure, with easy access to a platform one hundred and thirty-five feet from the ground. Above the platform a pole projects twenty-two feet, making the height of the distinctive signal available for observing four adjacent stations one hundred and fifty-seven feet. Subassistant Pratt rejoined the party at Walalla in the middle of August, and Subassistant E. F. Dickins later in that month. Angular measurements were completed there, and at the adopted stations signals were erected, after the question of intervisibility had been settled by the use of heliotropes.

On the 6th of September, 1878, the party arrived at Cold Spring, a station northward of Walalla. While the measurement of horizontal angles was conducted there by Subassistant Dickins, outlying stations were selected and marked by Assistant Colonna. His course from station to station was extremely difficult, as the trails on which he mainly depended were crossed in all directions by others that terminated abruptly in places resorted to by hunters. In some instances Mr. Colonna passed the night on the mountain top in order to perfect the arrangements needful at the point then under consideration as one in the geodetic series. The requisite observations were completed at Cold Spring station on the 16th of October, and on the day following the triangulation party started for the Great Caspar station. There Mr. Pratt, who had been detailed for the purpose, was about completing the construction of the high signal already mentioned, and the theodolite was mounted on its platform on the 23d of October, but the weather was then unfavorable for observing. Mr. Colonna therefore passed on to Chimise Mountain by a trail along the coast, and there stationed a heliotroper. Subassistant Pratt meanwhile remained at Great Caspar and when practicable observed on the outlying signals including that at Chimise station, and four others to the southward. The good judgment manifested in selecting the Great Caspar as a station, and in erecting the high signal there, has been already illustrated by the results.

Assistant Colonna visited Lassac's Peak seventy miles to the northward and eastward of Great Caspar, and accompanied by Mr. Dickins, who acted as guide, passed the night of November 2, 1878, on the summit. The height was estimated to be about six thousand feet. Careful examination was made, and six stations to the eastward, southward, and westward, were identified, one of them at a distance of sixty-five miles, but the Great Caspar could not be seen.

In going northward, and in selecting the primary points, close attention was given to proper connections with the tertiary triangulation on which the topographical survey of the coast depends.

Angular measurements were completed at Great Caspar on the 29th of November. A few days after, the instruments were mounted at Paxton station. The horizontal and vertical angles required there were obtained by the 18th of December. After storing the property and instruments in the court house at Ukiah, which in the course of operations was connected with the triangulation, the party was disbanded.

The field notes show that on reconnaissance Assistant Colonna, and Subassistants Dickins and Pratt traversed an aggregate distance of more than twenty-six hundred miles, much of the way being on mountain trails dangerous for horses, and all of it difficult and laborious in travel. The ordinary statistics of the triangulation done by the party in the course of the year are:

Signals erected	15
Stations occupied	5
Horizontal angles measured	60
Vertical angles	33
Primary points determined	6
Number of observations with theodolite	12,876

At mountain stations the party was supplied with water brought in canvass pouches on a pack animal, and the packing-boxes into which the water was drawn off were, for the purpose of holding it in store, lined with tin.

The comprehensive report made by Assistant Colonna, after completing his office work and computations, contains a valuable review of the field of work, including its connection with the series of geodetic points now going eastward from the vicinity of San Francisco, and also the extension of the main work northward along the coast above Shelter Cove.

At the end of the fiscal year Mr. Colonna and Messrs. Dickins and Pratt were assigned to field duty connected with the geodetic operations in charge of Assistant George Davidson.

Tides at the Sandwich Islands.—As mentioned in previous annual reports, a tide-gauge of the best construction was sent from the office, at the request of Mr. W. D. Alexander, superintendent of the survey of the Sandwich Islands. The records of an entire year were received in return, in August, 1878, and the series of observations will doubtless be continued further, as recording paper was sent since that date at the request of Mr. Alexander. The records of this station will in time be of much interest, in connection with the final discussion of tidal observations recorded at stations on the Pacific coast of the United States.

SECTION XI.

OREGON AND WASHINGTON TERRITORY—(SKETCHES NOS. 24 AND 25).

Triangulation of Columbia River, Oreg.—In previous years the triangulation of the Columbia was advanced to the vicinity of Kalama. For extending the work in order to provide for the topographical survey, Assistant Cleveland Rockwell was assigned to field service on the 26th of April, 1878. At Astoria he took charge of the barge Kincheloe and immediately proceeded to the working-ground. In passing up the river, stations were selected on the banks, and when practicable the scheme of triangulation was enlarged by adopting points a few miles from the river. Through May and June, in heavy rains day after day, the party worked in clearing lines for sight. Soon after the air suddenly became very dry, and by the 1st of August the smoke was so dense that positions could not be even roughly determined in reconnaissance. Signals on lines only four or five miles long could not be seen. At that time the air was full of white ashes and scorched fern, and during September an observer on one bank of the river could not see the opposite banks, and sometimes was unable to recognize objects only one hundred yards distant. As before when rains prevented observations with the theodolite, the smoky season was employed in opening lines, and in establishing a chain of stations up the channel of the river to a point near Willow Bar, eight miles below the mouth of the Willamette River.

"The bar at the lower end of Sauvie's Island near Saint Helen's, and extending down to Columbia City, is one of the few very shoal places in the Columbia, and is of much importance. A channel is maintained across the bar by dredging, which is done yearly under the direction of the United States Engineer Department."

Under many difficulties, owing to causes already stated and to heavy timber obstructing the lines of his triangulation, Mr. Rockwell advanced the work up the Columbia seventeen miles. The following are the statistics:

Signals erected	33
Stations occupied	33
Points determined	43
Angles measured	247
Number of observations	6,883

Assistant Rockwell disbanded his party on the 13th of January, and then engaged in office work.

At the close of the fiscal year the party was reorganized for prosecuting the topographical survey and extending the triangulation.

Triangulation of Washington Sound, Wash. Ter.—Stations for this work were selected in a previous season by Assistant J. S. Lawson, and, as mentioned in my last annual report, preparations were made for occupying a station at Point Partridge with the theodolite. Much difficulty was experienced in the necessity for clearing parts of the lines leading from that station to the point on Smith's Island, and also to Mount Erie, a station on Fidalgo Island. In order to connect the larger triangulation of the sound with that of Admiralty Inlet, signals were erected at Admiralty Head, Marrowstone Point, Point Hudson, Point Wilson, and at Ross, a station occupied when the triangulation of the inlet was in progress.

At Point Partridge observations have been greatly retarded by unfavorable conditions of the atmosphere. On the 9th of December, 1878, the observing tent was totally destroyed by a furious storm, and four of the outlying signals were thrown down. The statistics of the triangulation at that date were:

Signals observed on	8
Angles measured	10
Number of observations	1,152

The smoky condition of the air during the year was caused by innumerable forest fires, and these as stated in the concluding field report prevail to an unusual extent in alternate summers. Safe navigation at such periods in the waters of Washington Sound is a matter of constant care and watchfulness.

Hydrography of Puget Sound, Wash. Ter.—Lieut. Richard M. Cutts, U. S. N., Assistant in the Coast and Geodetic Survey, was actively engaged at the opening of the fiscal year with a party in the schooner Earnest in the waters of Puget Sound. In the course of the season four hydrographic sheets were completed and returned to the office. These contain soundings made to the southward of Battery Point, developing the waters eastward of Vashon Island, and as low down as Point Brown, where the work joins with the previously completed survey of Commencement Bay. Quartermaster's Harbor, at the south end of Vashon Island, was carefully sounded, and the results were plotted on a separate sheet. On a third sheet, the passage known as The Narrows was developed, connecting the waters around Vashon Island with the lower part of Puget Sound, and the fourth sheet represents the hydrography east and west of Anderson's Island, including Balch's Passage, Drayton Passage, and Cormorant Pass, in the vicinity of Steilacoom. Beyond Moody Point, Henderson's Inlet was sounded, and there the operations were closed on the 1st of April, 1879. The statistics of the hydrography are:

Miles run in sounding	966
Angles measured	12,952
Number of soundings	24,232

Lieutenant Cutts was assisted in this work by Lieuts. A. B. Wyckoff and U. R. Harris, U. S. N. On the detachment of Lieutenant Cutts, the charge of the party devolved on Lieutenant Wyckoff.

Triangulation and topography of Hood's Canal, Wash. Ter.—At the outset of the fiscal year, Assistant J. J. Gilbert had advanced the triangulation, and commenced the plane-table survey of the shores of Hood's Canal. When the winter rains set in, the determination of points had been extended as far as Hood's Point, four miles above Seabeck. Dabop Bay and Quilcine Bay were included in the triangulation.

The topography was prosecuted as far as possible while the preliminary work was in progress. A sheet was completed representing the shores in detail between Point Gamble and Hazel Point, and on another the shore line of the canal was traced to its junction with Dabop Bay. Operations with the plane-table were made laborious by the necessity of cutting lines of sight through the brush in order to obtain points for contouring the ground surface.

In moving from station to station the party used the small steam-cutter Tarry-Not. Field work was continued until the middle of December, when the party was disbanded, and Mr. Gilbert returned to Olympia, where the steam-cutter was laid up for the winter. The office work was then taken in hand and completed, and, as usual, the original and duplicate records were forwarded to the office. Of field work the statistics are:

Signals erected	36
Stations occupied	42
Angular measurements	2,455
Miles of shore-line surveyed	30
Miles of roads	13
Area of topography, square miles	32¾

An aggregate of thirty-one miles was cut through brush in order to obtain lines for the use of the party while working with the plane-table.

Triangulation and topography of branches of Puget Sound, Wash. Ter.—At the opening of the fiscal year, Subassistant Eugene Ellicott was at work with his party in the vicinity of Anderson Island, on the eastern side of Puget Sound. The topography of Carr's Inlet, for which points had been determined in the preceding year, was prosecuted by moving with a small sloop from the station on Anderson Island.

Late in August, 1878, Mr. Ellicott moved to a small bay near the head of Case's Inlet, and from that as a working center pushed the triangulation of the inlet northward and westward of Heron Island. The branch known as Pickering Passage, on the northwestern side of Hartstein Island, was also defined by triangulation. This occupied the party until the middle of November. A station was then selected at Dofflemeyer Point, six miles north of Olympia, and from that position the party conducted the triangulation through Eld Inlet, Peale's Passage, and Totten Inlet, and properly joined with the work previously done in Pickering Passage.

But little inconvenience was experienced in carrying on the field work during the winter. Ice formed while the party was in Totten's Inlet, but its thickness did not exceed half an inch. In general the air was remarkably clear in January, 1879, and highly favorable for observing with the theodolite. In the preceding August and September, field operations were hindered by extremely thick smoke from burning forests.

Subassistant Ellicott closed work in the middle of February. The following are statistics for the season:

Signals erected	88
Stations occupied	78
Angles measured	482
Number of observations	5,706
Shore-line surveyed, miles	72
Roads, miles	3
Area of topography, square miles	48

Mr. Ellicott completed his office work without delay, and then made arrangements for extending the triangulation into Hammersley's Inlet. His work in that quarter will be the subject of mention in my next annual report.

SECTION XII.

ALASKA TERRITORY.

Coast of Alaska.—Since my last annual report was closed, the preparation of material for the Coast Pilot of Alaska has been continued by Assistant W. H. Dall, and the part descriptive of the Columbian and Alexander Archipelago is now ready for the printer. This comprises about one-half of the coast line. Of the remaining half of the work a considerable part is in hand. The coast line of the Territory, including that of the inner passage from the Gulf of Georgia to Fort Tongass, makes an aggregate about four times as great as that of the Atlantic coast from the northeastern boundary southward to Key West.

A monograph of the climatology of Alaska and adjacent region, together with a list of books and charts relating to that part of the western hemisphere, is in the hands of the printer. This will be appended to the Coast Pilot, and contains isothermal and isobaric charts for each month and for the year; illustrative diagrams of the winds; records of temperature, of rain fall, &c., at different stations, and a view of the magnetic and meteorological observatory at Sitka, where observations of high character were recorded for many years.

Papers on collateral subjects, especially on the anthropology and biology of the Alaskan region, were prepared by Mr. Dall at intervals in the course of the year, and have been accepted for publication by the Smithsonian Institution, the Philadelphia Academy of Sciences, the Zoological Society of London, and other scientific bodies. At the request of Mr. Dall, a paper treating of some of the Nudibranchiata obtained in his explorations while in charge of a Coast Survey party in Alaska was prepared by Dr. R. Bergh, of Copenhagen, and has been published by the Philadelphia Academy of Sciences. Other papers on different groups of similar material, treating of specimens procured by Mr. Dall, are in preparation by eminent naturalists.

In details pertaining to his work on the Coast Pilot of Alaska, Assistant Dall has been efficiently aided by Mr. Marcus Baker.

SECTION XIII.

KENTUCKY AND TENNESSEE.—(SKETCHES NOS. 26 AND 27.)

Geodetic operations in Kentucky.—The reconnaissance for the selection of geodetic points in Kentucky, was actively pushed by Prof. William Byrd Page from the opening of the fiscal year until the middle of October, 1878. As stated in my last annual report, his party took the field early in the preceding May. The difficulties and delay incident to the selection of intervisible points in a country so densely wooded and of such uniform elevation are fully described in the field report. In the course of the season Professor Page traversed an area of four thousand square miles, and examined one hundred and thirty points with more or less success for the progress of the work. As an expedient for identifying distant points when viewed from other stations, Professor Page devised a cheap form of heliotrope by joining small mirrors in pyramidal form so as to move on a vertical axis, and attaching four small tin hemispheres arranged like those of the anemometer. These signals revolved in the lightest breeze, and the flash of the mirrors could be seen on the longest lines.

Including the results of the present season, the scheme of triangulation in Kentucky now extends in a northwesterly direction from the Cumberland Mountains, on the Virginia and Tennessee boundary line, to Louisville, on the Ohio River, with some few connecting stations on the Indiana shore. The system is made up of triangles and quadrilaterals closing at a base site a few miles southwest of Louisville. In prosecuting the work Professor Page used the aneroid barometer, and determined the approximate altitude of each station and of many points on routes intervening between the stations. The results will be a valuable contribution, and will aid in the future topographical delineation of the State.

After closing the office work incident to his field operations, Professor Page, having previously made arrangements for taking residence in a distant State, to my regret, resigned the charge of the geodetic work in Kentucky.

Geodetic operations in Tennessee.—As stated in my last annual report, the party of Prof. A. H. Buchanan was in the field at the opening of the fiscal year. In July, 1878, the erection of signals, which work had been begun earlier in the season, was sufficiently advanced to admit of the measurement of horizontal angles. Eight signals in all were constructed, ranging in height from forty to fifty feet, and in the months of August, September, October, and part of November four stations were occupied. All the requisite angular measurements at the stations were made with a twelve-inch theodolite.

The field records, original and duplicate, and the computations connected with the work have been received at the office. The statistics of the triangulation are:

Signals erected	12
Stations occupied	4
Angles measured	20
Number of observations	6,284

Shortly before the close of the fiscal year Professor Buchanan resumed the geodetic operations. Details of the progress made will be stated in my next annual report.

SECTION XIV.

OHIO, INDIANA, ILLINOIS, WISCONSIN, AND MICHIGAN.—(SKETCHES NOS. 26, 28, 29, AND 31).

Reconnaissance in Ohio.—As stated in my last annual report, arrangements were made near the close of the last fiscal year for commencing geodetic work in Ohio. After full conference with Assistant Richard D. Cutts in regard to the scheme of triangulation, Prof. R. S. Devol took the field for reconnaissance at the end of June, 1878, and continued at work until the close of September. The country between Athens and Columbus, a distance of seventy miles by air line, was thoroughly examined, and a chain of quadrilaterals was marked out to connect at Columbus with a site selected for a base line, and also with the astronomical station previously occupied in that vicinity. The lines of the proposed triangulation vary in length from five to twenty-two miles. The topographical character of the country over which the scheme of geodetic work extends is described by Professor Devol to be, between the mouth of the Hocking River and Lancaster, a succession of hills of nearly uniform height—some densely wooded. Beyond Lancaster and to the north and west the hills become less abrupt until a rolling country is reached, and finally ground almost level in the vicinity of Columbus.

The general absence of prominent elevations required a very close examination before any two stations could be declared intervisible. At the close of the fiscal year Professor Devol was preparing to resume work in the field.

Reconnaissance in Indiana.—The arrangements in progress at the close of the previous fiscal year for beginning geodetic work in Indiana, were stated in my last annual report. After a full understanding in regard to preliminaries, Prof. J. L. Campbell took the field in the middle of June, 1878, and was occupied until the end of August in a careful reconnaissance of the country between Indianapolis and New Albany, a distance of one hundred miles. From this examination, frequently repeated, and comparison between the natural elevations in regard to their respective advantages, twenty-one points were gradually and finally selected as stations for the proposed geodetic work. Descriptions of all the stations are given in detail in the report sent in by Professor Campbell at the close of the season.

The ground passed over in the reconnaissance presented no insuperable obstacle to the triangulation, but stations in the section north of Columbus, which is generally level and bears a dense forest growth, will doubtless require high artificial structures for observing with the theodolite. By these, however, the greater labor and expense of opening lines of sight will be avoided. After a minute description of the surface features, Professor Campbell states that so far as observed the hills in Indiana resulted from denudation, the strata being for the most part horizontal. The barometric measurements show that even in the very hilly parts of Bartholomew and Brown Counties, the roughest in the State, the summits have a very nearly uniform elevation above the sea level. Absence of prominent heights increased the labor of reconnaissance, and rendered longer lines impossible, yet the scheme made up of lines varying from four to twenty-two miles in length, covers a wide and important section of the State. Near New Albany some further examination may be necessary to determine the intervisibility of a few of the stations.

In the vicinity of New Albany the scheme laid out by Professor Campbell will be connected with the geodetic work of Kentucky by a base line common to both chains of triangulation. The geodetic series, after the measurement of angles in Indiana, will be continuous from the Cumberland Mountains near the southwestern corner of Virginia, northward to Indianapolis. This connection will illustrate the process by which a groundwork of geodetic points may be increased in number from year to year until the entire country is covered, each and all of the points being determined by the same scientific and precise methods. The points, few or many, serve for correcting the State maps, and will be so applied long in advance of the time at which the State authorities may deem it expedient to provide for detailed topographical surveys.

Geodetic reconnaissance.—At the opening of the fiscal year, Assistant G. A. Fairfield was engaged in examining the ground eastward of the Mississippi, for a scheme of intervisible points in Illinois, to be in geodetic connection with work already extended westward from Saint Louis, Mo. In July, 1878, a signal was put up at a station eastward of the two selected in the preceding season, and its direction from each was ascertained by flying signals, the points not being intervisible from the ground. As heretofore, the lines were run out with the leveling instrument to determine the practicability of occupying the stations with the theodolite by erecting platforms for the instrument. Subsequently, three other points were selected for extending the work eastward, and the result is a practicable scheme of triangulation with lines from eight and a half to twenty-five miles long, leading from the base line measured in the autumn of 1872 on the American Bottom in Illinois for the series of triangles going westward.

After applying all requisite tests, Mr. Fairfield reports that five stations can be occupied for angular measurements when tripod and scaffold signals are erected at the selected points, no higher ground intervening on either of the lines. He states also that the difficulties met in the vicinity of the American Bottom, on account of unusually level ground, will not so greatly impede the work in going further eastward. Field work was closed for the season on the 19th of December.

Magnetic observations.—In July, 1878, after completing observations at stations in Texas and Indian Territory, of which mention has been made under the head of Section IX in this report, Subassistant J. B. Baylor passed into Kansas (Section XV), Colorado, and Utah Territory (Section XVI), and subsequently occupied stations in Wyoming Territory in Section XVII. The points occupied in each will be separately mentioned under those respective heads.

In November, 1878, Mr. Baylor reached Madison, in Wisconsin, and observed for declination, dip, and intensity at a point about one mile east of the University. The magnetic observatory established in the University grounds in the spring of 1877, has continued its records under the care of Mr. David Mason, in accordance with the plan of operations arranged by Assistant Charles A. Schott. Unfortunately the magnetic traces of one month were lost in the mail by accidental fire at the Chicago post-office, but, with that exception, the photographic register is complete for nearly two years, and has been submitted to discussion by Assistant Schott. Although every precaution was taken in selecting the site for this observatory, the instruments are at present affected by the recent erection near it of a large building covered with *iron shingles*, but as the action of the instruments is differential their proper adjustment can be again secured.

Absolute measures for the magnetic declination, dip, and intensity have been recorded at this station annually since its erection, and similar observations were made near the same place in 1876. In September, 1878, Mr. Werner Suess recorded a series, and in November the series was repeated by Subassistant Baylor. These are intended for the verification of earlier results which in discussion yielded an unusually large secular variation. The series of observations will be repeated annually. At present it seems probable that the secular change at Madison is much greater than has been found at any station along the coasts of the United States. The field report of Mr. Baylor states that his operations at the station in the grounds of the University of Wisconsin were furthered by the assistance of Prof. J. E. Davies.

In December, 1878, the magnetic elements were determined at Springfield, Ill.; but the intensity of the cold made it impracticable to include two other stations, as intended in the plan of operations for the year. After completing the records at Springfield, Subassistant Baylor returned to the office in Washington. His previous observations will be mentioned under the head of Section XV. At Springfield the work, while in progress, received the friendly encouragement of the Hon. John T. Stuart and J. C. Parsons, esq.

Geodetic work in Wisconsin.—The measurement of the base line in the valley of the Wisconsin River was remarked on in detail in my last annual report. The connection of the line with the astronomical station at Madison has been already accomplished. In the course of the present season the scheme starting from the measured base was extended in a southwesterly direction, and the terminal points are on the banks of the Mississippi River. The geodetic scheme of the fiscal year consists of four quadrilaterals, and one large octagon with several checks.

Prof. J. E. Davies prosecuted the work here under notice during the months of July, August, September, and October. New points were introduced for the gradual enlargement of the scheme in respect of length in the triangle sides. Progress made in the course of the season is shown by the following statistics:

Tripods erected	9
Ordinary signals set up	10
Horizontal angles measured	120
Angular measurements	6,876
Vertical angles	43
Separate vertical measurements	2,136

At the close of the fiscal year Professor Davies again took the field. The details of the work then resumed will be a subject of mention in my report of next year.

SECTION XV.

MISSOURI, KANSAS, NEBRASKA, MINNESOTA, AND DAKOTA.—(SKETCHES Nos. 29 AND 31.)

Geodetic operations in Missouri.—Triangulation begun in 1872, in the vicinity of Saint Louis, has been extended westward to stations on the Gasconade River. The work done in the present fiscal year was conducted by Assistant J. A. Sullivan. Subassistant H. W. Blair co-operated, and in the course of the season occupied six stations at the eastern end of the series of points selected in reconnaissance. While he was so engaged, Assistant Sullivan examined the country westward of Jefferson City, and marked out a scheme for extending the geodetic connection to stations in the vicinity of Sedalia. Near Versailles, on the prairie land, a base line five miles in length was located. The site is easy of measurement, and connects favorably with the scheme of triangles. This line is about one hundred and fifty miles westward of the base line referred to in the preceding section of this report, as having been measured in the autumn of 1872, on the American Bottom in Illinois.

Subassistant Blair completed the measurement of horizontal and vertical angles at Berger station before the close of September. After observing for azimuth, he occupied five other positions in succession, closing at Geyer Station on the 28th of November. Mr. Isaac Winston served as recorder. At four of the occupied stations the theodolite was mounted on scaffolds, some of the lines of sight not being clear at the distance of a few feet above the surface of the ground. Mr. Blair erected a scaffold thirty feet high, and another of sixty feet elevation for occupying stations in immediate connection with the points at which he closed his angular measurements in November. In passing westward Mr. Sullivan put up signals for facilitating the operations of the triangulation party which will again take the field at the close of the fiscal year.

After storing his instruments at Pilot Knob, Mr. Blair joined Assistant Sullivan early in December, 1878, at Jefferson City. The statistics of triangulation are:

Signals erected	10
Stations occupied	6
Points determined	7
Observations of horizontal angles	2,320
Observations of vertical angles	702

In conducting the reconnaissance in Missouri the aim has been to obtain lines as long as the nature of the ground would afford, but much difficulty is met in maintaining the scale of work desirable for geodetic purposes. The higher elevations only have been used, but in going westward the necessity of elevated structures for the theodolite will probably continue until the work is joined with the scheme of triangulation in Colorado. In a general way the region westward of Sedalia, Mo., has been examined beyond the boundary line between Missouri and Kansas. Early in December Assistant Sullivan discontinued field operations, and returned to the office. Subassistant Blair then took in hand and completed his computations.

Magnetic observations.—In July, 1878, Subassistant J. B. Baylor, after closing work at stations in Texas, and Indian Territory, as already mentioned under the head of Section IX, proceeded to Kansas, and in the course of that month and the following occupied five stations. At Great Bend and at Sargent the magnetic declination, dip, and intensity were determined. At three other places, namely, Humboldt, Emporia, and Dodge City, in Kansas, the observations were limited to the magnetic declination. Under the next succeeding heads mention will be made of observations at other points in the interior.

SECTION XVI.

NEVADA, UTAH, COLORADO, ARIZONA, AND NEW MEXICO.—(SKETCHES NOS. 30 AND 31.)

Geodetic operations in Nevada and Utah.—For extending eastward the geodetic work mentioned under the head of Section X in this report, careful reconnaissance has been made through Nevada and Utah, along the thirty-ninth parallel of latitude, by Assistant A. F. Rodgers. In the course of the examination, Assistant William Eimbeck was assigned to co-operate in the selection of stations and to occupy such as might be practicable within the fiscal year.

Eastward of Lake Tahoe intervisible stations were readily found, but not related so as to admit of laying out a scheme in quadrilaterals going eastward. Hence, after due examination, a pentagon was adopted, the angles meeting at Genoa Peak, and, in geodetic connection with it, two hexagons, the middle stations of which are within a few miles of the thirty-ninth parallel. By fourteen intervisible stations the work will be advanced due east to a distance of four hundred and fifty miles from the California boundary. Assistant Eimbeck passed the month of October in the measurement of horizontal angles at Pah-Rah, a station connecting with the Davidson quadrilateral.

The adjustment of the scheme of triangulation necessitated the ascent of many mountains exclusive of the positions finally adopted. At each of the peaks, Assistant Rodgers carefully measured the angles made by lines leading to others, and sketched the outlines of the horizon near the identified stations, and the mountain masses intervening between them and the point of observation. The summits visited for purposes of reconnaissance range in height from eight thousand to upwards of twelve thousand feet.

After traveling in the aggregate more than two thousand miles; Assistant Rodgers closed field operations on the 7th of November, 1878, and reported in person at the office in Washington. At the close of the fiscal year Assistant Eimbeck made preparation for occupying stations of the pentagon in Nevada. Assistant Rodgers at the same time arranged for extending the coast triangulation of Northern California. Until he took the field for reconnaissance in Nevada, Mr. Rodgers directed details in the sub-office at San Francisco, the charge devolving on him at the departure of Assistant Davidson for the International Exposition at Paris.

Reconnaissance for geodetic points in Colorado.—In the preceding section mention was made of the progress in triangulation along the thirty-ninth parallel across the State of Missouri, and of the selection of points for continuing the work westward. For perfecting in advance a scheme of geodetic connection, the region along that parallel in Colorado was examined in the course of the fiscal year by Assistant O. H. Tittmann. After visiting Pike's Peak, Platte Peak, and Mount Morrison, search was made for the site of a base line to connect properly with a scheme of triangulation running east and west. The line finally selected is near the thirty-ninth parallel, about fifteen miles northeast of Colorado Springs, and affords a length of seven miles, requiring for measurement only the removal of large tufts of grass along the line.

Eastward of the base site, Mr. Tittmann selected eleven stations for extending a series of triangles in that direction to points beyond the Kansas Pacific Railroad. In general the region does not offer the facilities desirable for geodetic operations in a given direction, the drainage being nearly parallel with the proposed scheme of triangulation. Of thirteen stations selected east and west of the base site, observing scaffolds will be required at four, varying in height from thirty to forty feet. Tripods were erected at eight stations, which in succession will be occupied by Assistant Tittmann, whose party was reorganized for that purpose at the close of the fiscal year. In field operations Mr. J. E. McGrath served as recorder. The party was disbanded on the 22d of November, 1878, when Mr. Tittmann resumed duty in the office.

In a favorable position at Bijou Basin, in Elbert County, Colorado, Assistant Tittmann observed the solar eclipse of July 29, 1878, confining himself principally to noting the duration of totality. At the moment of greatest obscuration Mount Evans was distinctly seen, though fifty-eight miles distant. The place of observation was approximately determined in position by reference to known points of the Hayden survey.

Mr. William Ferrel, of the office, being at the same time in the vicinity, observed the eclipse from the summit of Gray's Peak, at an elevation upwards of fourteen thousand feet above the sea level. The appearance of the corona, and the phenomena generally, were carefully observed and described in a report from Mr. Ferrel, but no special provision had been made in regard to instrumental outfit by himself or Mr. Tittmann. Several other qualified observers, not connected with the survey, noted the moon's passage across the disc of the sun, but no two of the Colorado observers agree in descriptions or drawings of the coronal features.

Magnetic observations.—As mentioned in the preceding section, Subassistant J. B. Baylor recorded magnetic observations, in August, at several stations in Kansas. Before the close of that month he passed into Colorado, and determined the magnetic declination, dip, and intensity at North Pueblo and at Denver. The declination of the magnetic needle was determined subsequently in the vicinity of Fort Lyon, and also at Colorado Springs and Greeley, in Colorado.

After completing his record of observations at other places, of which mention will be made under the head of Section XVII, Mr. Baylor occupied stations at Castle Rock, Ogden, and Salt Lake City, in Utah; at the first two determining the declination, and at Salt Lake City the magnetic declination, dip, and intensity.

Under preceding heads mention has been made of the earlier observations of Subassistant Baylor. The determinations in Utah were made in October, 1878.

SECTION XVII.

MONTANA, IDAHO, AND WYOMING.—(SKETCH No. 31.)

Magnetic observations.—Under preceding heads twenty-six stations have been mentioned at which the magnetic declination was determined in the course of the season by Subassistant J. B. Baylor. In September, 1878, he passed into Wyoming Territory, and before the close of that month determined the declination at Laramie City, Rock Creek, Creston, and Point of Rocks. All the magnetic elements were determined by observations at Cheyenne, Fort Steele, Green River, and Carter.

Mr. Baylor closed operations in Wyoming Territory late in October, and was subsequently engaged at other places, as already stated, until the 13th of December, 1878, when he reported at the office in Washington. He is now employed in similar duty in Section I.

At Fort Steele, in Wyoming Territory, Subassistant Baylor had the useful co-operation of Surgeon Calvin De Witt, U. S. A., who is stationed at that post.

COAST AND GEODETIC SURVEY OFFICE.

The charge of the Coast and Geodetic Survey Office, which had been temporarily assigned to Assistant Charles A. Schott, was resumed by Assistant J. E. Hilgard upon his return from Europe in November, 1878, after an absence of about five months.

Reports of the execution of the important public duties committed to Assistant Hilgard while abroad have been prepared by him, and will be in readiness for publication at an early date.

As a member of the International Committee on Weights and Measures, he was instructed to co-operate with that body in perfecting the organization and assist in initiating the practical working of its establishment near Paris. He visited London to make a recomparison of the Coast Survey standard yard (Bronze No. 11) with the British Imperial standard, and appeared as a representative of the Coast and Geodetic Survey at the annual session of the International Geodesic Association, held last year at Hamburg.

No essential change took place in the organization of the office throughout the year.

Assistant Edward Goodfellow remained on duty, aiding the Assistant in Charge in administrative details and in the office-correspondence.

Efficiency of administration is maintained by the active co-operation of the chiefs of the several divisions, by their immediate responsibility to the Assistant in Charge, and by monthly reports, stating in detail the occupation of each person employed.

All records and computations of the field work of the survey are sent to the office, with a view to their discussion and verification by such scientific methods as may be established with the approval of the Superintendent. These records or computations may relate to the preliminary work of reconnaissance; to astronomical and magnetic observations; to measurements of bases; to the primary, secondary, and tertiary triangulations and azimuth determinations connected therewith; to observations of tides, and to topography and hydrography in the forms of topographic and hydrographic field sheets.

Upon the receipt of these records, and after acknowledgment duly made to the officer transmitting them, they are referred for action by the Assistant in Charge to the chiefs of divisions in the office.

Some special scientific investigations were prosecuted by Mr. Hilgard, as opportunity offered, with the aid of field officers temporarily assigned to office duty. Under his direction, Assistant H. G. Ogden examined the graduation of the limb of twenty-four-inch theodolite U. S. C. and G. S. No. 2; made comparisons of twenty-four thermometers with a Kew standard; made a series of experiments with the prismatic salinometer, designed by Mr. Hilgard; determined the relative lengths and expansions of the Committee meter, iron meter No. 6, steel meter No. 19, and the Lenoir iron meter at temperatures ranging from 37° to 81° Fah.; took a series of observations for determination of the errors of reading the telemeter in field work, and for ascertaining the errors of incidental determination of a vertical plane.

He made also a series of micrometric readings for testing the graduation of the limb of theodolite No. 118, and supervised the preparations for marking the ends of the trial base line established at Arlington, with a view to its preliminary measurement, comparing for this purpose the new six-meter measuring rods with the standard six-meter bar. Mr. Ogden was detached for field duty towards the end of June.

Assistant William Eimbeck reported to the office early in January, and was directed to make a complete series of magnetic observations for the instruction and practice of one of the naval officers assigned to duty on the Coast and Geodetic Survey. He then made a special set of observations for testing vertical circle No. 100, and, upon the completion of the computations required for the adjustment of his triangulation in Nevada, made a design for and description of monuments for marking the terminal points of a base line; also, a design and description of two instruments for referring the ends of base bars to the groundmarks of primary base lines during measurement. After assisting in an examination of the Arlington trial base-line with a view to its extension, and in the comparisons of the six-meter standard bar, Mr. Eimbeck then begun a collection of maps and data needed for arranging the plan of a magnetic survey in California and Nevada, Oregon and Washington Territory, and was occupied in other preparations for field work till he left the office late in June.

Assistant O. H. Tittmann, upon reporting early in January for office duty, was directed to take up a revision of the list of latitude stars (two hundred and fifty-eight in number) included in the Coast Survey "Catalogue of Stars for Observations of Latitude," in regard to the places of which more accurate determinations were to be made at some of the leading observatories. This revision completed, he made comparisons of relative length between the standard British well-yards bronze No. 11 and iron No. 57; arranged and reduced the observations made by Mr. Hilgard in London for the comparison of standard yard bronze No. 11 with the Imperial standard No. 1 and the accessible standard No. 6; compared two six-meter subsidiary base rods with the six-meter comparing bar; made an examination of the newly-constructed geodesic level No. 3, and determined its constants; supervised arrangements for comparing the primary base apparatus at a high temperature, and commenced the compilation of that portion of the report of standard weights and measures relating to comparisons of measures of length, yards among themselves and meters among themselves. About the 20th of June he began the preparation of a subsidiary base apparatus and other appliances for the work assigned to him in Colorado.

Subassistant Andrew Braid reported for duty at the office in April; aided Assistant Ogden in the observations made for errors of determination of a vertical plane; examined the magnetic observations of Professor Nipher. of Saint Louis; redetermined constants for geodesic level No. 1; ran trial lines of levels with geodesic levels Nos. 1 and 3, and aided in experiments with different forms of telemeter rods. Early in June, Mr. Braid entered upon duty preparatory to resuming field work.

Subassistant H. W. Blair, who reported for office duty January 15, assisted Mr. Tittmann in comparisons of the standard yards; arranged and classified papers relating to weights and measures; made the verification of a set of grain weights for the United States mint at Philadelphia, and determined the values of a set of metric weights (kilogram to milligram) for the New Orleans mint; discussed the comparisons of relative lengths and expansions of the Committee meter iron No. 6, Lenoir iron meter, and steel meter No. 19; determined the length of four sample pieces of steel for experiments in regard to their expansion to be made in France; made a determination of the absolute and relative lengths of the Brunner centimeter scale, and the new centimeter scale of the Coast and Geodetic Survey; revised and prepared for printing the Bache Fund Magnetic Observations, and tested the office regraduation of theodolite No. 118. Towards the close of June he took up work preparatory for field duty.

Mr. F. H. Parsons, aid, assisted Mr. Blair in his examination of theodolite No. 118, and, under Mr. Hilgard's immediate direction, was occupied in compilations of records for the Bureau of Weights and Measures, in experiments with a drop cylinder specimen cup, in comparisons of thermometers with a Kew standard, and in other miscellaneous work.

Hydrographic Division.—The direction of the Hydrographic Division has remained with Commander E. P. Lull, U. S. N., whose labors as Hydrographic Inspector have been referred to elsewhere in this report.

As chief of this division, he inspects all records and results of hydrographic work; directs the protracting, plotting, and drawing of the hydrographic sheets, their verification by comparison with the original tidal, sounding, and current records, and their reduction to the scales of publication, taking care that such a selection from the soundings is made as to keep in view their equal distribution with special reference to a correct representation of the depths. A verification of the reduced drawings with the tidal, sounding, and current notes, positions of buoys, &c., completes the office work required in this division to prepare a chart for the engraver or photolithographer.

The Hydrographic Inspector performs also the duty of maintaining the correctness of the aids to navigation shown on the charts by taking cognizance of all changes in or additions to buoys, beacons, and lights that are made by the Light-House Service, and preparing guide-copies for engraving the same on the plates, and entering them on the printed editions on hand in the map-room. The changeable nature of the channels on the greater part of our coast occasions a very frequent necessity for corresponding changes in the aids to navigation.

Commander Lull had the aid of Lieut. Commander Philip H. Cooper from July 5 to November 8, 1878, and of Lieuts. Henry E. Nichols and John M. Hawley, the former from February 1 to June 30, and the latter from February 1 to April 9, 1879.

The work of the hydrographic draughtsmen may be summarized as follows:

Mr. E. Willenbucher protracted, plotted, and drew fifteen hydrographic sheets, verified, inked, and finished seven, and plotted and drew additional hydrography upon five sheets.

Mr. W. C. Willenbucher plotted and drew eighteen hydrographic sheets, verified and inked five sheets, and brought up to date the progress sketches for the annual report.

During August, September, and part of October he was employed as hydrographic draughtsman with the party of Assistant Junken on the Delaware River.

Mr. F. C. Donn was assigned to duty as draughtsman in this division October 15, and was engaged in miscellaneous tracings and reductions, and during three months in the preparation for publication of a table of depths. He plotted, verified, and inked eleven hydrographic sheets.

Computing Division.—The Computing Division was in charge of Assistant Charles A. Schott throughout the year. All original and duplicate records of geodetic observations, with the field computation of results, after being duly registered in the office, are sent to Mr. Schott, who makes an examination of them to ascertain whether they are in accordance with the established forms, reports serious irregularities or deficiencies, and has the field computations checked by an entirely independent office computation, the results of these discussions being from time to time brought to the attention of the Assistant in Charge. Discussions of sufficient importance, or such reports relating to the methods and results of the Survey as are deemed worthy of publication, are referred to the Superintendent for ultimate action.

Such final results of the labors of this division as are needed for constant office reference are preserved in the form of registers, in which are systematically arranged all data relating to standards of length, to base lines, to azimuths, to determinations of geographical position, to heights of stations, and to determinations of the magnetic elements, absolute or relative.

Mr. Schott gave his personal attention to the preparation of data for the construction of charts and for the use of field parties, and to replies to requests for information, especially on subjects connected with terrestrial magnetism. He completed two registers arranged by States and Territories—one containing results of all astronomical azimuths measured, the other relating to the measuring apparatus used on the survey, and giving resulting lengths of all base lines measured to date.

Under his direction, Mr. W. Suess set up and put in complete working order a set of Kew magnetographs, by which it was intended to obtain at a station upon the Pacific coast a continuous register of the changes of the magnetic declination, and of the horizontal and vertical components of the magnetic force. The instrumental constants for the magnetograph were determined by Mr. Schott.

He made also, with the aid of Assistant Eimbeck, the usual annual magnetic observations at the station on Capitol Hill; discussed the secular change of the magnetic declination, as modified by the latest available results, with a view to the preparation of a third edition of his paper upon the "secular change," and directed the work at the magnetic observatory, Madison, Wisconsin.

Additions made during the year to the force of computers gave Mr. Schott increased facilities for efficient work in the division, and enabled him to devote personally more time to general discussions and reports.

Details of the labors of the computers are as follows:

Mr. James Main computed the latitude of the following stations: Summit, Cal.; Moore, N. C.; King, N. C.; Mount Diablo, Cal. Revised the latitude of Elliot's Knob, Va., and of Lebanon, Tenn. Computed the astronomical azimuths of Mount Diablo, Cal.; Elliot's Knob, Va.; Mount Helena, Cal.; Vicksburg, Miss.; Helena, Ark.; fort near Vicksburg, Miss.; Donaldsonville, La.; Lebanon, Tenn.; harbor, San Clemente Island, Cal., and Catalina Peak, Cal.; and computed the telegraphic difference of longitude between Summit Station, Cal., and Washington, D. C., and San Francisco, Cal. In accordance with special arrangement five hours' labor constitutes his day's work.

Dr. Gottlieb Rumpf computed the following secondary and tertiary triangulations, viz: Puget Sound, between Nisqually and Budd's Inlet, Wash. Ter.; of Budd's Inlet, Wash. Ter.; Coney Island, N. Y.; Jamaica Bay, N. Y.; Barataria Bay, La.; Indian River, Fla.; Saint John's River, Fla.; vicinity of Cape Canaveral, Fla. Computed the positions of light-houses on the coast of Massachusetts, Rhode Island, Connecticut, and New York, and attended to miscellaneous geodetic work. After March 12 he was detached from the Computing Division for special duty.

Mr. Edward H. Courtenay was engaged in computing the supplementary triangulation near Philadelphia; computed the annual magnetic observations at Madison, Wis., and the magnetic observations made by Assistants Boutelle, Webber, and Eimbeck in South Carolina, Georgia, and California; collected and arranged magnetic constants for various magnetometers; computed the magnetic observations made by Messrs. Baylor and Braid; had charge of copying and the care of the duplicate records; directed work of some of the temporary computers; attended to data for field parties and to the geographical registers of the office; assisted in the preparation of the annual statistics, and made progress with the computation of the triangulation on the Upper Potomac.

Mr. Myrick H. Doolittle was engaged on the least square adjustment of the primary triangulations between Georgia and Alabama, and between Maryland and Georgia, following in general the Blue Ridge; developed the secondary triangulation between San Pedro and Newport Bay, Cal., on Clarke's spheroid; adjusted the primary triangulation vicinity of Eastport and Calais, Me.; computed the length of the Lebanon base, Tennessee, the Spring Green base, Wisconsin, and the Daughtry Island base, Florida; computed the vertical angles and heights of the primary and secondary stations of the Blue Ridge triangulation between Maryland and Georgia; prepared abstracts of directions at stations Elliot's Knob, Va., Mount Helena, Cal., and made good progress with the adjustment of the primary triangulation between Charleston and Savannah.

Dr. Jermain G. Porter assisted Mr. Doolittle in the solution of numerous normal equations arising from adjustment of principal triangulations; computed sides and positions (on Clarke's spheroid) of the primary and secondary triangulation of Santa Barbara Channel, and the same for the primary and secondary triangulation between Maryland and Georgia, along the Blue Ridge. He assisted Mr. Doolittle also in the adjustment of the triangulation near Eastport, Me., and took part in the preparation of horizontal directions at Elliot's Knob, Va., and Mount Diablo, Cal.; computed subordinate triangulations near Staunton, Va., and near Simonton College, N. C.; and assisted in the computation of heights of the Blue Ridge survey.

Mr. Marcus Baker was assigned to duty in the Computing Division September 17, and has since been engaged on the computation of the telegraphic difference of longitude between Washington and Savannah, Ga.; and Savannah and Atlanta, Ga.; and made progress (reduction of transit observations at Washington) with the difference of longitude between Washington and Atlanta. He was on leave of absence for one month and gave but five hours a day to the Computing Division, being on other duty for the remainder of his official time. He also collected magnetic results relating to the Territory of Alaska.

Mr. Alexander S. Christie reported for duty January 15, and has since been engaged on the computation of the following astronomical latitudes: Mount Helena, Cal.; Elliot's Knob, Va.; Aurora, Ala.; Lebanon, Tenn.; and made progress with the latitude of Nashville, Tenn.

Mr. Erasmus D. Preston was assigned to duty in the division toward the close of the fiscal year (June 24), and commenced the reduction of transit observations for time and longitude at Washington, D. C., in connection with the longitudes of Atlanta, Ga., and Statesville, N. C.

The following computers and writers were temporarily connected with the Computing Division, and their work may be briefly summed up as follows:

Assistant Edwin Smith was engaged between November 1 and November 12 in preparing horizontal directions observed at Mount Diablo, Cal., and Mount Helena, Cal.

Mr. P. Lobanoff was engaged in reading off and tabulating photographic traces of the magnetic observatory at Madison, Wis. His connection with the survey ceased October 15.

Mr. F. A. Sawyer was engaged upon miscellaneous computations and copying, especially of geographical positions, and revised spirit-levelling reductions.

Mr. B. F. Warren was engaged in computation of triangle sides and positions during four days in November.

Mr. R. A. Marr was assigned to duty November 11, and after making himself familiar with ordinary geodetic computations, computed the secondary triangulation of Laguna Madre, Tex., computed a number of geographical positions of tertiary objects in the Blue Ridge triangulation between Maryland and Georgia, assisted Dr. Porter in miscellaneous geodetic computations, and made progress in preparing abstract of horizontal directions at staions of the coast ttriangulation of California, north of San Francisco. He was assigned to field duty June 24.

Mr. J. E. McGrath reported for duty December 12, and acquired familiarity with triangle side and position computations. He was principally engaged in reading off and tabulating photographic traces and some thermometric registers taken at the magnetic observatory at Madison. This arduous duty he performed with rapidity and in a satisfactory manner.

Mr. Isaac Winston was assigned to duty January 2, and was chiefly engaged in miscellaneous copying and on plain geodetic computations and revisions under Mr. Courtenay's direction. He also assisted in preparing data for field parties. He was transferred to field duty June 24.

Mr. Carlisle Terry, jr., reported for duty January 6. He was occupied with miscellaneous writing and in inserting geographical positions in the office registers; computed apparent places of stars for latitude work at eight stations and aided Assistant Ogden on field work for a few days.

Mr. T. E. Norelius was assigned to duty in this division May 21, and was engaged in reading off chronograph sheets, under Mr. Baker's direction, and upon miscellaneous clerical duty.

Tidal Division.—Mr. R. S. Avery has had charge, as heretofore, of the Tidal Division. To him are referred records of tidal observations, consisting either of tidal curves automatically recorded on self-registering tide-gauges, or of readings of the height of tide on tide-staffs, records of the establishment of bench-marks, and the observers' tabulations of heights and times of high and low waters. The results of the office discussion of these observations appear in the form of tide tables for charts, and in the tables of tidal data for the principal sea-ports of the United States, published annually a year in advance, the laws of tidal action upon our coast having been determined by long series of observations with sufficient accuracy to admit of the prediction of times and heights. Tide-Tables for the Atlantic and Pacific coasts for 1879 were published in August, 1878.

In the following table are given the localities of the principal stations (all self-registering, with one exception) from which records have been received during the year. Records of short series of tidal observations, received from the hydrographic parties, have been referred to in the statements of hydrographic work under the heads of the several sections.

Section.	Name of station.	Name of observer.	Kind of gauge.	Permanent or temporary.	Time of occupation. From—	To—	Total days.
I	North Haven, Me	J. G. Spaulding	Self-registering	Permanent	Apr. 28, 1878	Apr. 25, 1879	362
I	Clarke's Point, Mass	W. H. Bliss	...do	Temporary	Aug. 19, 1878	Dec. 2, 1878	105
I	Block Island, R. I	W. H. Lawton, jr., I. M. Conley	...do	...do	Aug. 20, 1878	Nov. 9, 1878	81
II	Governor's Island, N. Y	R. T. Bassett	...do	Permanent	May 30, 1878	May 1, 1879	335
II	Sandy Hook, N. J	J. W. Banford	...do	...do	June 1, 1878	June 1, 1879	365
VIII	New Orleans, La	G. Faust	Staff	...do	Dec. 31, 1877	Dec. 31, 1878	365
X	Saucelito, Cal	E. Gray	Self-registering	...do	June 1, 1878	June 1, 1879	365
X	Mare Island, Cal	G. Bradford	.. do	Temporary	Aug. 10, 1878	Mar. 6, 1879	208
	Honolulu, S. I	J. S. Emerson	...do	...do	June 21, 1877	June 16, 1878	360

The self-registering gauges established at Clarke's Point, Mass., and at Block Island, were intended as reference stations for the tidal survey of Buzzard's Bay, observations every fifteen minutes with glass tube box-gauges being made simultaneously at eight other stations for shorter periods, generally about six days.

The self-registering stations at Governor's Island, New York Harbor, and at Fortress Monroe, Va., having been discontinued, both series are ready for discussion.

In view of the speedy resumption of observations at the Fernandina station, Mr. Avery renews the recommendation made in a former report for the establishment of a station at the Bermuda Islands, in order that data may be obtained for comparison of the ocean tides with those of the coast.

In the office work of reductions and other computations, Mr. Avery had the assistance of the following-named persons:

Mr. John Downes was chiefly engaged in the tabulations, reductions, and prediction of tides for the Atlantic coast.

Mr. L. P. Shidy reduced many short series of observations received from hydrographic parties; predicted for ports at which the diurnal inequality was large, and aided in discussions and miscellaneous work.

Miss M. Thomas attended to the simpler computations and to copying; Mrs. M. E. Nesbitt and Miss Turnbull were similarly employed.

Drawing Division.—The scales upon which the topographic and hydrographic sheets are executed being usually $\frac{1}{10000}$, $\frac{1}{20000}$, and $\frac{1}{40000}$, while the published charts vary in scales from $\frac{1}{20000}$ to $\frac{1}{1200000}$, a project is prepared for every chart, in which are defined the limits of the sheets from which it is to be reduced. These projects are based upon sheets which have been approved for registry after passing the careful scrutiny given to them in this division. If the chart is intended to be engraved, the engraver is furnished with a reduced drawing, such details as may be generalized being supplied by photographic reductions upon which the character of the topography is indicated by conventional signs. Charts intended to be published by photolithography are drawn in full detail, and either the original drawings, or tracings from them, supplied for reduction in the camera.

Mr. W. T. Bright, in charge of this division, has kept it up to its usual degree of efficiency, all special calls for information having been promptly met. Appendix No. 3, which gives a statement of copies of charts and maps and other data furnished, shows also how various are the demands made upon the office for results of the work of the survey. In Appendix No. 4 will be found a detailed statement of the charts completed or in progress during the year for which this report is prepared, with the name of the draughtsman who executed the work. Projections have been furnished to field parties and drawings made for illustrations to the annual report.

The distribution of work among the draughtsmen and other persons employed has been as follows:

Mr. A. Lindenkohl, chief draughtsman, has, as usual, reduced all the new material for the small scale sailing-charts, as well as that for the general charts of the coast, and the numerous coast charts upon the $\frac{1}{80000}$ scale; kept up to date the annual additions to the progress sketches, and constructed upon copper the projections necessary for new charts of large extent. Mr. H. Lindenkohl has been employed in reducing the material for habor charts of various scales, compiling and drawing charts for photolithographic publication, and upon engravings upon stone of sketches and illustrations for the annual report. Mr. L. Karcher has continued upon the hydrographic reductions for coast and harbor charts, and supplied a large number of field projections, diagrams, and tracings. Mr. C. Junken made hydrographic drawings, field projections, copper-plate projections, and indicated the longitudes corrected for the latest telegraphic determinations upon the plates of a number of charts. In August he was assigned to make a hydrographic resurvey of a portion of the Delaware River, in the vicinity of Cherry Island Flats, upon the completion of which, in October, he was again attached to the division. Mr. P. Erichsen has been engaged chiefly in drawing for publication in the annual reports, plans and views of many new and improved instruments of precision, upon hydrographic reductions, and upon topographical details upon engraved outlines of harbor charts. Mr. E. J. Sommer has drawn for publication by photolithography several small harbor charts, and has made reduced drawings for the $\frac{1}{80000}$ scale charts. Mr. C. A. Meuth was employed upon the miscellaneous work of the division until February, when he resigned. Messrs. H. Eichholtz and E. Molkow have continued to supply, by hand, to the chart room editions the aids to navigation that were placed after the editions were printed. Miss C. B. Turnbull was given employment in miscellaneous duties from October until May, when she was assigned to the tidal division. Mr. T. L. Moore did practice work in the division from March until May, when he left the office.

It has heretofore been the practice that the original topographical sheets, drawn with hard pencil in the field, were subsequently inked by the persons who had made the survey. This course, while it has the advantage that the final drawing is done with personal knowledge of the ground, has the disadvantage on the other hand that good surveyors are not always good draughtsmen, which resulted in very unequal style of representation on the original maps. This was, indeed, not a matter of great moment so long as for purposes of publication these maps were redrawn in the office, generally on reduced scales. But since the perfection of the processes of reproduction by photolithography and other modes based upon photography, renders practicable the publication of maps obtained directly from the original drawing, either on the same or on a reduced scale, it has become desirable to have the drawing made in a suitable and uniform style. With a view to this end Assistant E. Hergesheimer was instructed to prepare specimens of drawing, on the scale of the original sheets of the various topographical features to be represented, to serve as a guide for the draughtsmen in the office who will hereafter ink the original sheets. Mr. Hergesheimer has discharged this duty with great success, as will be seen from the specimens and explanatory text appended to this report. (Appendix No. 11.)

Engraving Division.—Assistant J. S. Bradford had charge of the Engraving Division during the year. The system of engraving adopted in the office is the result of a careful study of the methods of topographical and hydrographical delineation which have been found most effective for representing the varied features of land and water upon the maps and charts.

In the finished coast and harbor charts a high degree of artistic as well as of mechanical skill is required for the adequate representation of the undulating formations, bold slopes, and broken or irregular contours of the coast line. The style of lettering must also be selected with a view to good effect, and be made to conform to the several scales of publication, and the arrangement of title and explanatory notes must be studied in forming a project for each chart.

Careful inspection is made of the progress and quality of work upon the plates by proofs taken quarterly, which are submitted for inspection to the Superintendent and to the Assistant in charge of the office; final proofs being taken upon the completion of every plate for approval before publication.

Mr. Bradford reports that twelve chart plates have been completed, eight begun, and work upon nineteen continued during the year. Corrections and additions were made upon one hundred and sixty-six plates, including those of the charts for the Atlantic Coast Pilot. For the same work, the engraving of twenty-six views was nearly finished.

In the assignment of work the aptitude of each man for that branch of engraving in which he is most skilled must be kept in view. The force of the division remained about the same as last year: Messrs. J. Enthoffer, H. C. Evans, A. Sengteller, J. J. Young, W. A. Thompson, and R. F. Bartle were continued as topographical engravers; E. A. Maedel, A. Petersen, H. M. Knight, J. G. Thompson, and F. Courtenay as letter engravers, and E. H. Sipe, Wm. H. Davis, Th. Wasserbach and A. C. Ruebsam, as miscellaneous engravers. Mr. J. J. Young was employed during a large part of the year in etching views for the Coast Pilot; and Mr. George McCoy upon standard topographical specimens from the originals by Assistant Hergesheimer.

Appendix No. 5 gives a detailed statement of the work of the several engravers upon the plates completed, continued, or begun during the year.

The clerical duties of the division were satisfactorily performed by Messrs. Leeds C. Kerr and Jno. H. Smoot.

Electrotpying and Photographing Division.—The engraved plates being the standard plates which it is desirable to preserve unimpaired, but a small number of proofs are taken from each before subjecting them to the process of electrotyping, by which the slow labors of the engraver are multiplied rapidly and with perfect fidelity.

As soon as the standard plate is ready for an alto, it is sent to the Electrotyping Division, the operations of which are in charge of Dr. Anton Zumbrock. After being cleaned by rubbing with soft canton flannel, precipitated chalk and water, it is ready for being rubbed with a solution of argento-cyanide of silver, this rubbing being continued until the plate is evenly silvered; the surface is then washed with water; the plate drained; any water remaining washed off with alcohol; and then there is poured over and allowed to dry on it a weak solution (straw-colored) of iodine in alcohol.

This process was devised some years ago in the office, and has proved entirely successful in preventing adhesion between the standard plate and the alto obtained from it in the battery. From the alto, bassos or printing plates are produced as they are needed.

Dr. Zumbrock has made also the photographic reductions from drawings or from field sheets required for the use of the engravers and draughtsmen, duplicate photographs being taken, one upon glass for the engraver to be used in tracing outlines and contours, another on paper for the draughtsman, so that there may be shown upon it the colors and conventional signs adopted in detail representation.

Twenty-six negatives, nine positives, and one hundred and sixteen prints were taken during the year. Fifty altos and thirty-three bassos were made, including four altos for the Hydrographic Office, United States Navy.

The batteries for the office sympathetic clocks and call-bell were kept in order. All of the collodion, varnish, silver solutions, and other preparations used in the work were made in the laboratory. Dr. Zumbrock was assisted as heretofore by Mr. Frank Over.

Miscellaneous Division.—Under this head are classified those branches of office work which relate to the printing and distribution of the charts, reports, and other publications of the survey, the charge of the official blank forms and stationary and their supply for office and field use, the care of the office building, and the general direction of work in the carpenter shop; of the details of these duties Mr. M. W. Wines has had charge. He attended to the systematic distribution of the reports of the Superintendent to the several departments of the Government, and to the principal scientific associations, colleges, and public libraries in the United States and foreign countries; also to the calls made for charts, Coast Pilots, and Tide Tables from the sale agencies established in all of the principal sea-ports.

Following is a list of the publications of the survey received during the year, comprising, it will be seen, a number of extra copies of papers embodying the methods and results of the work, which are published as appendices to the annual reports. Due distribution was made of these publications, the extra copies of appendices being freely furnished to applicants.

One thousand copies Tide Tables for the Pacific coast of the United States for 1879.

Two thousand copies Tide Tables for the Atlantic coast of the United States for 1879.

Three hundred copies Notice to Mariners, No. 17.

Five hundred copies Atlantic Coast Pilot—Boston to New York.

Two hundred copies Atlantic Local Coast Pilot—Boston to Monomoy.

Two hundred copies Atlantic Local Coast Pilot—Nantucket and Vineyard Sounds.

Two hundred copies Atlantic Local Coast Pilot—Buzzard's and Narragansett Bays.

Two hundred copies Atlantic Local Coast Pilot—Block Island and Fisher's Island Sounds and Gardiner's and Peconic Bays.

Two hundred copies Atlantic Local Coast Pilot—Long Island Sound and East River.

Two hundred copies Atlantic Local Coast Pilot—Harbors in Long Island Sound.

Two hundred copies Atlantic Local Coast Pilot—South coast of Long Island, New York Bay and Hudson River.

Two hundred and fifty copies On Registration of Tides—Appendix No. 8, Report for 1876.

Five hundred copies Notice to Mariners, No. 14, second edition.

Five hundred copies A Catalogue of Stars for Observations of Latitude—Appendix No. 7, Report for 1876.

One hundred copies Review of the Characteristics of the South Pass—Appendix No. 12, Report for 1876.

One hundred copies Report on the Physical Survey of New York Harbor—Appendix No. 10, Report for 1876.

There were distributed during the year from the chart room, under the immediate care of Mr. Thomas McDonnell, twenty-three thousand two hundred and thirteen copies of charts. Of this number twelve thousand two hundred and seventy-one copies were sent to sale agents, and seven thousand five hundred and forty-two copies were for the use of the several departments of the government.

Sixteen thousand seven hundred and nine copies of charts were received from the printer, all of these being copper-plate impressions; in addition to these there were sent to the chart room twelve thousand four hundred and ninety-two copies of charts published by the processes of lithography.

Mr. Frank Moore, assisted by Messrs. D. N. Hoover and J. S. Beck, executed the printing from the copper plates; Mr. H. Nissen attended to the preparation of backed drawing paper for field sheets, and to the miscellaneous work of the folding room. He had the aid of Mr. R. T. Bassett after June 1.

Archives.—The care of the original records of the survey in the fire-proof building provided for the purpose remained with Mr. G. A. Stewart. These records are systematically registered as soon as received, the topographic and hydrographic sheets being numbered in order of registry.

Duplicate records of observations are, for convenience of consultation, kept in the Computing Division.

Fifteen topographic and fifty-one hydrographic sheets were received and registered during the year, making the total number of topographic sheets registered to the close of the year fourteen hundred and sixty-five, and the total number of hydrographic sheets fourteen hundred and two. Of original records and computations, eight hundred and eighty-five volumes were added to the archives; and of duplicate records, four hundred and sixty-six volumes.

Library.—The office library, consisting mainly of books of reference, and of publications of a scientific character received in exchange for the publications of the Survey, was in charge of Mr. Samuel Hein. The library now contains nearly four thousand titles and volumes. Two hundred and eighty-one volumes and four hundred and fifty-two copies of pamphlets and periodicals were received during the year.

Instrument Room.—The instrument room was in charge of Mr. G. N. Saegmuller, chief mechanician. Under his direction were made, as far as practicable, the repairs of all instruments required for field and office use, and such instruments of precision were constructed as were needed for the more exact processes of geodesy.

Accountability for instruments furnished to field parties is secured by returns made at the end of every season by each chief of party of all instruments retained in his possession or forwarded to the office. Examination is made as soon as possible of all instruments returned by field parties; those found to be in good order are sent to the fire-proof building; those needing repairs are put in hand in the instrument shop.

Early in the year Mr. Saegmuller began an examination of the limb of the dividing engine in order to form a table of corrections which could be applied in the regraduation of one of the twenty-inch theodolites, and submitted plans for the construction of a new tracing and cutting apparatus intended to secure greater effectiveness and ease of arrangement. This improved apparatus was made during the year, and tests of its working proved to be exceedingly satisfactory. One of the twelve-inch theodolites was regraduated with a high degree of accuracy. An account of these improvements and of the tests applied is given in Appendix No. 12.

Mr. John Clark, mechanician, was occupied in constructing from designs furnished by the office, two levels of precision, intended for use on the several lines of transcontinental levelling. He took part in the experiments with the subsidiary and primary base bars; and made an apparatus to facilitate the processes of comparison of these bars with the standards.

Mr. Saegmuller had the assistance of Messrs. W. Jacobi, E. Eshleman, and P. Vierbuchen, in the miscellaneous work of the instrument shop.

The carpentry work of the office, comprising the woodwork of all instruments, their packing for transportation, and the repairs of office furniture, &c., was done by Mr. A. Yeatman, aided at different times by C. Webster, G. W. Clarvoe, and L. F. Dorn.

In the office of Assistant in Charge the clerical duties were performed by Messrs. W. B. French and W. A. Herbert, with Mr. C. D. Gedney as stenographer during part of the year. Occasional assistance was rendered by Mr. G. A. Morrison and by Mr. F. H. Parsons.

Expenditures for field and hydrographic operations are based on detailed estimates presented by the Assistants for consideration in advance of taking up work; so also the outlay for repairs of vessels and for outfits. Each item is carefully examined, and when approved by the Superintendent the aggregate is allotted from the appropriation, for the work corresponding to the estimate. By the watchful care of the disbursing agent, Mr. J. W. Porter, the means available for carrying out plans of work are known at any time during the year, and contingencies incident to the service have been met without embarrassment.

Under my immediate direction, Assistant W. W. Cooper has met as heretofore the requirements in business details bearing on the administrative duties of the Superintendent.

Respectfully submitted,

C. P. PATTERSON,
Superintendent Coast and Geodetic Survey.

Hon. JOHN SHERMAN,
Secretary of the Treasury.

APPENDICES.

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APPENDIX No. 1.

Distribution of surveying parties upon the Atlantic, Gulf of Mexico, and Pacific coasts and interior of the United States during the fiscal year 1878–'79.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I.				
Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island, including coast and seaports, bays and rivers.	No. 1	Hydrography	Lieut. Commander Theo. F. Jewell, U. S. N., assistant; Lieut. John Garvin, U. S. N.; Masters C. E. Fox and M. K. Schwenk, U. S. N.; Ensign C. H. Amsden, U. S. N.	Hydrography of the approaches to the coast of Maine extended from previous limits, northward and eastward to the entrance of Pleasant Bay, beyond Petit Manan Light-House. (See also Section IX.)
	2	Hydrography	Lieut. Commander C. M. Chester, U. S. N., assistant; Lieut. A. V. Wadhams, U. S. N.; Master T. G. C. Salter, U. S. N.; Ensigns H. F. Reich and M. L. Wood, U. S. N.	Soundings in the eastern approaches to Mount Desert Island, Me. (See also Sections II, VI, and VIII.)
	3	Topography	Edwin Hergesheimer	Views of prominent features on Mount Desert Island, drawn and arranged for the Topographical Manual.
	4	Hydrography	Lieut. S. M. Ackley, U. S. N., assistant; Lieut. H. T. Monahon, U. S. N.; Master F. E. Sawyer, U. S. N.	Hydrography of Frenchman's Bay, Me., adjacent to Stave Island and the Porcupine Islands. (See also Section VI.)
	5	Topography	Charles Hosmer, assistant	Topography of the shores of Skilling River (coast of Maine) completed, and survey of the Porcupine Islands in Frenchman's Bay. (See also Section VIII.)
	6	Topography	A. W. Longfellow, assistant.......	Detailed survey of the shores of Union River Bay extended to the vicinity of Ellsworth, Me.
	7	Topography	H. G. Ogden, assistant	Topographical surveys of Long Island and Bartlett's Island near Mount Desert, coast of Maine.
	8	Hydrography	Lieut. J. M. Hawley, U. S. N., assistant; Masters G. C. Hanus, A. H. Cobb, and Albert Mertz, U. S. N.	Soundings in the southeastern approaches to Deer Isle, including parts of Jericho Bay and Placentia Bay, coast of Maine.
	9	Hydrography	Lieut. J. F. Moser, U. S. N., assistant; Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N.	Hydrography of the approaches to Isle au Haut completed, including the development of numerous ledges; and survey of a ledge in Muscongus Bay. (See also Sections IV and V.)
	10	Tidal observations	J. G. Spaulding	Series of observations continued with self-registering tide-gauge at North Haven, Penobscot Bay, Me.
	11	Geodetic..........	Prof. E. T. Quimby	Geodetic observations completed at Gunstock Mountain, and Starr King Mountain occupied for triangulation, in New Hampshire.
	12	Geodetic..........	Richard D. Cutts, assistant; C. H. Sinclair, aid.	Mount Monadnock, N. H., occupied for connecting the survey of Lake Champlain with that of the coast. (See also Section II.)
	13	Triangulation.....	S. C. McCorkle, assistant	Light-houses at Portsmouth, N. H., and at Newburyport and Cape Ann, Mass., determined in position. (See also Section II.)
	14	Reconnaissance...	Prof. V. G. Barbour...............	Selection of stations southward of Rutland, for triangulation in the State of Vermont.

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I—Continued.	15	Hydrography	Lieut. Commander C. M. Chester, U. S. N., assistant; Lieuts. A. V. Wadhams and Uriel Sebree, U. S. N.; Master T. G. C. Salter, U. S. N.	Hydrography of the entrance and bar of Merrimac River, Mass. (See also Sections II, VI, and VIII.)
	16	Inspection	H. L. Whiting, assistant	Supervision of topography for the harbor commissioners' survey of the upper harbor of Boston, Mass. (See also Section II.)
	17	Hydrography	Master Robert Platt, U. S. N., assistant; Mates John Odendhal and Harold Neilson, U. S. N.	Observation and records of sea currents at stations in the Gulf of Maine. (See also Section VIII.)
	18	Hydrographic reconnaissance.	J. S. Bradford, assistant	Examination for changes desirable in the position of aids to navigation along the coast of Massachusetts and Rhode Island. (See also Section II.)
	19	Tidal observations	C. H. Van Orden	Special observations for developing the tides of Buzzard's Bay, Mass. (See also Section VIII.) Tidal observations continued at Providence, R. I.
SECTION II.				
Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including coast, bays, and rivers.	1	Geodetic operations.	Richard D. Cutts, assistant; C. H. Sinclair, aid.	Mount Prospect, N. Y., occupied for connecting the survey of Lake Champlain with the Hudson River triangulation. (See also Section I.)
	2	Hydrography	Lieut. Commander C. M. Chester, U. S. N., assistant; Lieuts. Uriel Sebree and A. V. Wadhams, U. S. N.; Master T. G. C. Salter, U. S. N.	Hydrographic survey of the vicinity of Block Island (Long Island Sound, N. Y.), including Southwest Ledge. (See also Sections I, VI, and VIII.)
	3	Hydrographic reconnaissance.	J. S. Bradford, assistant	Examination for changes desirable in the position of aids to navigation along the coast of Connecticut, and in Long Island Sound and Hudson River, N. Y. (See also Section I.)
	4	Topography	J. W. Donn, assistant	Detailed survey of the shores of the eastern part of Jamaica Bay, N. Y., including Rockaway Beach. (See also Section III.)
	5	Hydrography	Lieut. W. I. Moore, U. S. N., assistant; Lieuts. W. F. Low and S. H. May, U. S. N.	Hydrography of the eastern part of Jamaica Bay, N. Y.
	6	Tidal observations	R. T. Bassett, J. W. Banford	Tidal observations closed at Governor's Island, New York Harbor; series of observations continued with self-registering gauge at Sandy Hook, N. J.
	7	Topography	H. L. Whiting, assistant; W. C. Hodgkins, aid.	Detailed topographical survey of the shores of Hudson River, continued in the vicinity of Peekskill, N. Y. (See also Section VI.)
	8	Inspection	F. H. Gerdes, assistant	Examination of station marks at triangulation points on the coast of New Jersey. (See also Section IV.)
	9	Geodetic operations.	Prof. E. A. Bowser	Angular measurements completed at Pickles Mountain, and geodetic observations commenced at Mount Horeb, N. J.
	10	Hydrography	Charles Junken, W. C. Willenbucher.	Hydrographic survey of Delaware River, from Marcus Hook to New Castle flats, for the Light-House Board.
	11	Triangulation	S. C. McCorkle, assistant; C. M. Bache, assistant.	Points determined in position along the shores of Delaware River in the special survey for the Philadelphia Board of Trade. (See also Section I.)
	12	Topography	R. M. Bache, assistant	Detailed survey on large scale of the wharf lines and shores of Delaware River at Philadelphia, including the water front of Camden, N. J.

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION II—Continued.	13	Physical hydrography.	H. Mitchell, assistant; H. L. Marindin, assistant; J. B. Weir, aid.	Special observations on the tides and currents, and hydrography of the Delaware River at Philadelphia.
	14	Geodetic operations.	Prof. L. M. Haupt	Observations completed at three stations in Eastern Pennsylvania connecting with geodetic points at Principio and Meeting-House Hill in Maryland.
	15	Special	C. S. Peirce, assistant	Observations with the pendulum for determining the force of gravity at stations in Pennsylvania.
SECTION III.				
Maryland, Virginia, and West Virginia, including bays, seaports, and rivers.	1	Astronomical observations.	G. W. Dean, assistant; Edwin Smith, assistant; F. H. Parsons, aid.	Observations at Washington, D. C., for determining longitude by telegraphic exchanges at Statesville, N. C., and Atlanta, Ga. (See also Sections IV and V.)
	2	Magnetic observations.	Charles A. Schott, assistant	Declination, dip, and magnetic intensity observed at the Standard Station, on Capitol Hill, Washington, D. C.
	3	Special	Master Francis Winslow, U. S. N., assistant; Master H. H. Barroll, U. S. N.	Soundings in the vicinity and investigation of oyster reefs in Tangier Sound, Pocomoke Sound, and James River.
	4	Tidal observations.		Series of tidal observations closed at Fortress Monroe, Va.
	5	Topography	J. W. Donn, assistant	Detailed survey of the shores of James River continued in the vicinity of Richmond, Va. (See also Section II.)
	6	Geodetic	A. T. Mosman, assistant	Triangulation westward of the Blue Ridge, near Harrisonburg, Va., extended toward the Ohio River.
	7	Geodetic	Andrew Braid, subassistant	Geodetic levelling on a course from Hagerstown, Md., westward to Athens, Ohio.
SECTION IV.				
North Carolina, including coast, sounds, seaports, and rivers.	1	Special	F. H. Gerdes, assistant	Life-saving stations on the coast of Virginia and North Carolina determined in position for entry on the engraved charts. (See also Section II.)
	2	Hydrography	Lieut. Fred. Collins, U. S. N., assistant; Masters F. Winslow and H. H. Barroll, U. S. N.	Special examinations in Albemarle and Pamplico Sounds, N. C., and compilations of notes for the Coast Pilot. Development of Lookout Cove as a harbor of refuge.
	3	Hydrography	Lieut. J. F. Moser, U. S. N., assistant; Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N.	Hydrography of the coast of North Carolina from Barren Inlet southward and westward to Cape Fear. (See also Sections I and V.)
	4	Topography	C. T. Iardella, assistant	Topography of Smith's Island completed in the vicinity of Cape Fear, N. C. (See also Section V.)
	5	Astronomical observations.	G. W. Dean, assistant; Edwin Smith, assistant; C. H. Sinclair, aid.	Longitude determined at a station in Simonton College grounds, Statesville, N. C. (See also Sections III and V.)
SECTION V.				
South Carolina and Georgia, including coast, sea-water channels, sounds, harbors, and rivers.	1	Hydrography	Lieut. J. F. Moser, U. S. N., assistant; Masters J. B. Murdock, A. C. Dillingham, and F. E. Greene, U. S. N.	Hydrography of the coast of South Carolina from Murrell's Inlet southward to the approaches of Winyah Bay, and survey of the Sampit River above Georgetown, S. C. (See also Sections I and IV.)
	2	Topography	C. T. Iardella, assistant	Topography of part of the shores of Stone River and Wappoo Creek, near Charleston, S. C. (See also Section IV.)
	3	Astronomical observations.	G. W. Dean, assistant; Edwin Smith, assistant; C. H. Sinclair, aid.	Longitude determined at a station in the City Hall Square of Atlanta, Ga. (See also Sections III and IV.)

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION VI.				
East Florida, from Saint Mary's River to Anclote Keys, on the west coast, including coast approaches, reefs, keys, seaports, and rivers.	1	Tidal observations	M. O'D. White	Series of tidal observations continued with self-registering gauge, at Fernandina, Fla.
	2	Triangulation and topography.	W. I. Vinal, subassistant; W. C. Hodgkins, aid.	Triangulation and topography of Indian River, Fla., including the ocean beach, extended southward from Malabar Point.
	3	Triangulation	Joseph Hergesheimer, subassistant.	Triangulation and beach measurement between Charlotte Harbor and Sarasota Bay, Fla.
	4	Hydrography	Lieut. Commander C. M. Chester, U. S. N., assistant; Lieuts. U. Sebree and A. V. Wadhams, U. S. N.; Master T. G. C. Salter, U. S. N.; Ensign M. L. Wood, U. S. N.	Inshore hydrography of the Gulf of Mexico in the vicinity of Charlotte Harbor. (See also Sections I, II, and VIII.)
	5	Magnetic observations.	Lieut. S. M. Ackley, U. S. N., assistant; Lieut. H. T. Monahon, U. S. N.; Master F. E. Sawyer, U. S. N.; Ensign W. H. Nostrand, U. S. N.	Determinations of the magnetic declination, dip, and intensity at Fernandina and Key West, Fla.; at Nassau (New Providence); South Bemini; Water Cay (Salt Key Bank); Matanzas, Havana, Bahia Honda, and Cape San Antonio (Cuba); at Belize (British Honduras); and at Cozumel and Mujeres, off Yucatan. (See also Section I.)
SECTION VIII.				
Alabama, Mississippi, Louisiana, and Arkansas, including Gulf coast, ports, and rivers.	1	Geodetic	C. O. Boutelle, assistant; F. D. Granger, assistant.	Five geodetic stations occupied in Northern Alabama for extending work westward of the Atlanta base line.
	2	Hydrography	Master Robert Platt, U. S. N., assistant; Ensigns J. W. Stewart and J. C. Colwell, U. S. N.	Currents observed at stations in the Gulf of Mexico, off the mouths of the Mississippi. (See also Section I.)
	3	Tidal observations	G. Faust	Record of observations on the level of the Mississippi River at New Orleans discontinued.
	4	Triangulation	F. W. Perkins, assistant	Triangulation of the Mississippi River, from Donaldsonville north, toward Baton Rouge.
	5	Hydrography	Lieut. Commander C. M. Chester, U. S. N., assistant; Lieuts. U. Sebree and A. V. Wadhams, U. S. N.; Master T. G. C. Salter, U. S. N.; Ensign M. L. Wood, U. S. N.	Hydrography of the Mississippi River between Grand View Reach and Point Houmas; of the mouths of Red River and Atchafalaya; and of the Bonnet Carré, Morganzia, Glascock, and the Diamond Island Crevasse. (See also Sections I, II, and VI.)
	6	Triangulation	W. H. Dennis, assistant; C. H. Van Orden, aid.	Triangulation of the Mississippi River from Natchez upward to Grand Gulf.
	7	Triangulation	Charles Hosmer, assistant; J. B. Weir, aid.	Triangulation of the Mississippi River continued from Vicksburg upward to stations above Milliken's Bend. (See also Section I.)
	8	Triangulation	C. H. Boyd, assistant; Master W. Kilburn, U. S. N.; C. A. Ives, temporary aid.	Triangulation of the Mississippi River extended from Bennett's Landing upward to Memphis, Tenn., and check-base measured at Hopefield, opposite to Memphis.
SECTION IX.				
Texas and Indian Territory, including Gulf coast, bays, and rivers.	1	Hydrography	Lieut. Commander Theo. F. Jewell, U. S. N., assistant; Lieut John Garvin, U. S. N.; Masters C. E. Fox and M. K. Schwenk, U. S. N.; Ensign C. H. Amsden, U. S. N.	Inshore hydrography of the coast of Texas, abreast of Matagorda Peninsula, extended from former limits southward and westward beyond Pass Cavallo. (See also Section I.)
	2	Triangulation	R. E. Halter, assistant	Triangulation of Laguna Madre, Tex., nearly completed.
	3	Hydrography	Commander J. R. Bartlett, U. S. N., assistant; Lieuts. W. O. Sharrer and J. P. Wallis, U. S. N.; Master H. M. Jacoby, U. S. N.; Ensigns G. H. Peters and E. L. Reynolds, U. S. N.	Deep sea soundings; record of serial temperatures; and dredgings in the waters of the Caribbean Sea, and in passages between the Windward Islands.

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION IX—Continued.	4	Magnetic observations.	J. B. Baylor, subassistant	Magnetic declination, dip, and intensity determined at San Antonio, Fort Worth, and Sherman, in Texas; and at Atoka and Eufaula in Indian Territory. (See also Sections XIV, XV, XVI, and XVII.)
SECTION X.				
California, including the coast, bays, harbors, and rivers.	1	Geodetic	D. B. Wainwright, subassistant	Triangulation completing the geodetic connection between the Santa Barbara Islands and the coast of California.
	2	Topography	Stehman Forney, assistant	Detailed topographic survey completed of Catalina Island and San Clemente Island (Santa Babara Channel, Cal).
	3	Hydrography	Commander G. W. Coffin, U. S. N., assistant; Lieuts. C. W. Jarboe and W. H. Driggs, U. S. N.; Ensign C. F. Putnam, U. S. N.	Hydrography of the shore-approaches of Santa Catalina Island and San Clemente Island, Cal.
	4	Hydrography	Lieut. E. H. C. Leutzé, U. S. N., assistant; Lieut. E. K. Moore, U. S. N.; Masters L. C. Heilner, W. P. Elliott, and R. H. Galt, U. S. N.	Inshore hydrography of the coast of California, from Newport Bay to Point Vincente: and hydrography of the southern approach to the Santa Barbara Channel.
	5	Triangulation and topography.	W. E. Greenwell, assistant	Triangulation of the Coast of California, from Point Arguello northward to Point Sal; and topography of the vicinity of Point Purissima.
	6	Hydrography	Gershom Bradford, assistant	Hydrographic resurvey of Suisun Bay, between Army Point and the eastern end of Chipp's Island, and soundings at the mouths of Sacramento and San Joaquin Rivers. Hydrography of San Pablo Bay, in the vicinity of Point Wilson.
	7	Tidal observations	E. Gray	Series of observations continued with self-registering tide-gauge at Saucelito, in San Francisco Bay, Cal.
		Geodetic	George Davidson, assistant; B. A. Colonna and J. J. Gilbert, assistants: E. F. Dickins and J. F. Pratt, subassistants.	Mount Lola, in California, occupied as a geodetic station for angular measurements on stations in Nevada.
	9	Triangulation and topography.	L. A. Sengteller, assistant	Detailed survey of the coast of California, from Fisherman's Bay northward and westward to the vicinity of Haven's Anchorage.
	10	Geodetic	B. A. Colonna, assistant; E. F. Dickins and J. F. Pratt, subassistants.	Extension northward of the main triangulation of the Coast of California, to the vicinity of Point Cabrillo.
	11	Tidal observations		Tidal record from the self-registering gauge in operation at Honolulu (Sandwich Islands), under the direction of W. D. Alexander, superintendent of the government survey.
SECTION XI.				
Oregon and Washington Territory, including coast, interior bays, ports, and rivers.	1	Triangulation	Cleveland Rockwell, assistant	Triangulation of Columbia River, Oreg., extended from Kalama upward to Willamette Slough.
	2	Triangulation	James S. Lawson, assistant	Triangulation across the waters of Washington Sound, W. T., continued by observations at Point Partridge.
	3	Hydrography	Lieut. R. M. Cutts, U. S. N., assistant; Lieuts. A. B. Wyckoff and U. R. Harris, U. S. N.	Hydrography of the southern part of Puget Sound, from Battery Point to Henderson's Inlet.
	4	Triangulation and topography.	J. J. Gilbert, assistant	Triangulation and topography of Hood's Canal, W. T., between Port Gamble and Hazel Point.
	5	Triangulation and Topography.	Eugene Ellicott, subassistant	Triangulation of Case's Inlet, Pickering Passage, Peale's Passage, Eld Inlet, and Totten's Inlet, connecting with Puget Sound, W. T. Topography of the shores of Carr's Inlet.

APPENDIX No. 1—Continued.

Sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION XII.				
Alaska Territory		Office work	W. H. Dall and Marcus Baker	Compilation of material for the Coast Pilot, and also illustrative of the meteorology of Alaska and the Aleutian Islands.
SECTION XIII.				
Kentucky and Tennessee	1	Geodetic	Prof. William Byrd Page	Scheme of geodetic points and site for base line near Louisville, selected for extending the triangulation in Kentucky.
	2	Geodetic	Prof. A. H. Buchanan	Geodetic stations occupied in the vicinity of the base line near Lebanon, Tenn.
SECTION XIV.				
Ohio, Indiana, Illinois, Wisconsin, and Michigan.	1	Reconnaissance	Prof. R. S. Devol	Selection of geodetic points for triangulation between Athens and Columbus, Ohio.
	2	Reconnaissance	Prof. J. L. Campbell	Geodetic points selected for a scheme of triangulation between Indianapolis and New Albany, Ind.
	3	Reconnaissance	G. A. Fairfield, assistant	Selection of geodetic points east of the base line on the American Bottom for triangulation in Illinois.
	4	Magnetic observations.	J. B. Baylor, subassistant; Werner Suess.	Magnetic declination, dip, and intensity determined at Springfield, Ill., and Madison, Wis. (See also Sections IX, XV, XVI, and XVII.)
	5	Geodetic	Prof. John E. Davies	Geodetic work continued in Wisconsin between Madison and the Mississippi River.
SECTION XV.				
Missouri, Kansas, Iowa, Nebraska, Minnesota, and Dakota.	1	Geodetic	J. A. Sullivan, assistant; H. W. Blair, subassistant; Isaac Winston, temporary aid.	Geodetic points selected in Western Missouri, and triangulation extended westward to stations near the Gasconade River, Mo.
	2	Magnetic observations.	J. B. Baylor, subassistant	Magnetic declination, dip, and intensity determined at Great Bend and at Sargent, and declination at Humboldt, Emporia, and Dodge City, Kans. (See also Sections IX, XIV, XVI, and XVII.)
SECTION XVI.				
Nevada, Utah, Colorado, Arizona, and New Mexico.	1	Geodetic	A. F. Rodgers, assistant; William Eimbeck, assistant.	Geodetic station occupied in Nevada and others selected for extending work eastward into Utah Territory.
	2	Geodetic	O. H. Tittmann, assistant; J. E. McGrath, temporary aid.	Reconnaissance for site of a base line in Colorado, and for stations of triangulation along the thirty-ninth parallel.
	3	Magnetic observations.	J. B. Baylor, subassistant	Magnetic declination, dip, and intensity determined at Denver and North Pueblo, Colo., and at Salt Lake City, Utah, and declination at Fort Lyon, Colorado Springs, and Greeley in Colorado, and at Castle Rock and Ogden in Utah. (See also Sections IX, XIV, XV, and XVII.)
SECTION XVII.				
Montana, Idaho, and Wyoming Territories.	1	Magnetic observations.	J. B. Baylor, subassistant	Magnetic declination, dip, and intensity determined at Laramie City, Rock Creek, Creston, and Point of Rocks, and declination at Cheyenne, Fort Steele, Green River, and Carter in Wyoming Territory. (See also Sections IX, XIV, XV, and XVI.)

APPENDIX No. 2.

Statistics of field and office work of the United States Coast and Geodetic Survey to the close of the year 1878.

Description.	Total to December 31, 1877.	1878.	Total to December 31, 1878.
RECONNAISSANCE.			
Area in square statute miles	213, 325	52, 649	265, 974
Parties, number of, in year		7	
BASE LINES.			
Primary, number of	13	0	13
Subsidiary, number of	107	4	111
Primary, length of, in statute miles	79	0	79
Subsidiary and line measure, length of, in statute miles	243¼	7¾	251
TRIANGULATION.			
Area in square statute miles	106, 525	9, 828	116, 353
Stations occupied for horizontal angles, number of	8, 860	378	9, 238
Geographical positions determined, number of	16, 536	690	17, 226
Stations occupied for vertical angles, number of	507	29	536
Elevations determined, number of	1, 293	126	1, 419
Lines of spirit-leveling, length of	677	387	1, 064
Parties (triangulation and leveling), number of, in year		36	
ASTRONOMICAL WORK.			
Azimuth stations, number of	137	11	148
Latitude stations, number of	237	9	246
Longitude stations (telegraphic), number of	92	5	97
Longitude stations (chronometric and lunar), number of	110	0	110
Astronomical parties, number of, in year		12	
MAGNETIC WORK.			
Stations occupied, number of	394	38	432
Permanent magnetic stations, number of, in year		2	
Magnetic parties, number of, in year		4	
TOPOGRAPHY.			
Area surveyed in square miles	26, 319	177	26, 496
Length of general coast, in miles	5, 996	17	6, 013
Length of shore line, in miles (including rivers, creeks, and ponds)	73, 594	814	74, 408
Length of roads in miles	38, 431	418	38, 849
Topographical parties, number of, in year		14	
HYDROGRAPHY.			
Parties, number of, in year		17	
Number of miles run while sounding	312, 467	10, 786	323, 253
Area sounded in square miles	74, 566	2, 776	77, 342
Miles run, additional of outside or deep-sea soundings	58, 430	2, 116	60, 546
Number of soundings	14, 574, 183	407, 157	14, 981, 340
Deep-sea soundings, number of, in year		327	
Deep-sea temperature observations, number of, in year		1, 008	
Tidal stations, permanent	225	8	233
Tidal stations occupied temporarily	1, 656	57	1, 713
Tidal parties, number of, in year		7	
Current stations occupied	468	26	494
Current parties, number of, in year		0	
Specimens of bottom, number of	10, 689	169	10, 858
RECORDS.			
Triangulation, originals, number of volumes	2, 321	201	2, 522
Astronomical observations, originals, number of volumes	1, 257	98	1, 355

APPENDIX No. 2—Continued.

Description.	Total to December 31, 1877.	1878.	Total to December 31, 1878.
RECORDS—Continued.			
Magnetic observations, originals, number of volumes	376	22	398
Duplicates of the above, number of volumes	2, 435	212	2, 647
Computations, number of volumes	2, 592	171	2, 763
Hydrographical soundings and angles, originals, number of volumes	7, 511	196	7, 707
Hydrographical soundings and angles, duplicates, number of volumes	965	117	1, 082
Tidal and current observations, originals, number of volumes	3, 091	95	3, 186
Tidal and current observations, duplicates, number of volumes	2, 031	39	2, 070
Sheets from self-registering tide-gauges, number of	2, 552	87	2, 639
Tidal reductions, number of volumes	1, 683	38	1, 721
Total number of volumes of records	24, 262	1, 189	25, 451
MAPS AND CHARTS.			
Topographical maps, originals	1, 543	30	1, 573
Hydrographic charts, originals	1, 472	46	1, 518
Reductions from original sheets	814	32	846
Total number of manuscript maps and charts, to and including 1878	2, 575	32	2, 607
Number of sketches made in field and office	2, 997	47	3, 044
ENGRAVING AND PRINTING.			
Engraved plates of finished charts, number of	219	4	223
Engraved plates of preliminary charts, sketches, and diagrams for the Coast Survey Reports, number of	572	9	581
Electrotype plates made	1, 289	73	1, 362
Finished charts published (including reissues)	223	52	275
Preliminary charts and hydrographical sketches published	500	0	500
Engraved plates of Coast Pilot charts	6	13	19
Engraved plates of Coast Pilot views	31	15	46
Printed sheets of maps and charts distributed	385, 276	21, 476	406, 752
Printed sheets of maps and charts deposited with sale agents	138, 300	7, 798	146, 098
LIBRARY.			
Number of volumes	6, 405	249	6, 654

APPENDIX No. 3.

Information furnished from the Coast and Geodetic Survey Office, by tracings from original sheets, &c., in reply to special calls, during the fiscal year ending with June, 1879.

Date.	Name.	Data furnished.
1878.		
July 6	Lt. Col. John Newton, United States Corps of Engineers.	Shore-line survey of the south shore of Staten Island and the quarantine buildings, with geographical positions in the vicinity.
16	Capt. W. F. Reynolds, United States Corps of Engineers, light-house engineer fourth district.	Hydrographic survey of Barnegat Inlet and part of the bay, made in 1874, and shore-line of 1839 added.
26	S. T. Abert, United States civil engineer	Hydrographic survey of the Chickahominy River, from Shipyard Landing to Forge Bridges.
Aug. 10	Col. William Ludlow, United States Corps of Engineers	Hydrographic survey of the Delaware River, from Christiana Creek to Marcus Hook, work of 1842.
15	Mr. Benjamin Worcester, Waltham, Mass	Topographic survey of the eastern part of Cape Ann., Mass., from the survey of 1851.
21	Wm. Ham. Hall, State engineer of California	Hydrographic surveys of Suisun Bay, San Joaquin and Sacramento Rivers, Cal.
22	United States Light-House Board	Topographic survey of Tillamook Head, Oreg.
Sept. 10	Col. W. P. Craighill, United States Corps of Engineers	Hydrographic survey of upper part of Patapsco River, including Ridgley's Cove, vicinity of Baltimore; survey of 1845.
14	Col. William Ludlow, United States Corps of Engineers	Hydrographic survey of Mispillion and Duck Creeks, Delaware Bay and River; survey of 1841 and 1842.
16	Hon. Thomas F. White, commissioner police and excise, Brooklyn, N. Y.	Topographic work of Barren Island, south side of Long Island; survey of 1877.
17	Maj. H. W. Closson, U. S. A., Fort Barancas, Fla	Hydrographic sketch of the entrance to Perdido River, between Florida and Alabama.
18	Theodore Wagner, surveyor-general of California	Complete topographic surveys of Santa Barbara, San Miguel, and Anacapa Islands, Cal.; also, geographical positions of triangulation stations, with descriptions.
27	Mayor of Philadelphia	Hydrographic survey, on 1-300 scale, of gravel and shingle bank, foot of Christian street. Delaware River, Philadelphia.
27	Mr. Felipe Fortuño, of Mexico	Drawings illustrating the improvements to the dividing engine.
Oct. 3	Marshall Parks, president Albemarle and Chesapeake Canal Company.	Hydrographic survey of northern part of Currituck Sound, including Cedar and Coanjock Bays, and North Landing River, made in 1877.
18	Hon. F. W. Lincoln, chairman harbor commissioners, Mass.	Topographic survey of the Taunton River, from Fall River to Somerset.
18	Mr. P. Fourchy, New Orleans	Unfinished proof of coast chart No. 91, Lakes Borgne and Pontchartrain, La.
18	Col. William Ludlow, United States Corps of Engineers	Topographic survey, coast of New Jersey, from the head of Barnegat Bay to and including Manasquan River.
Nov. 5	Strong and Spear, lawyers, New York City	Topographic survey of Port Jefferson Harbor and bays, Long Island.
20	Capt. S. L. Clapp, Pacific Mail Steamship Company, New York.	Sketch, on 1-20,000 scale, showing changes in the shore-line of Rockaway Inlet, Long Island, N. Y., from 1835 to 1877.
20	Lt. Col. G. K. Warren, United States Corps of Engineers	Hydrographic survey of Westport Harbor, on the Ocoaksett River, Mass., from survey of 1845.
Dec. 5	Wm. Byrd Page, for Capt. Chas. B. Philips, United States Corps of Engineers.	Proofs of Albemarle, Pamplico, and Core Sounds, Neuse and Pamplico Rivers, and Beaufort Harbor; war maps of North Carolina; and a traced copy, on 1-20,000 scale, of hydrographic sheet of North River, in Albemarle Sound.
6	Mr. T. Crommelin, No. 73 Cedar street, New York	Topographic survey of part of Flushing, Long Island, made in 1837.
20	Mr. Jed. Hotchkiss, Staunton, Va	Distances and positions of tide-stations upon the James River, Va.
21	Mr. J. Herbert Shedd, Providence, R. I.	Topographic survey, of 1839, of Great Swamp and Worden's Pond, R. I.
1879.		
Jan. 6	E. H. Ludlow & Co., New York City	Hydrographic survey of lower part of Newark Bay, vicinity of Shooter's Island, N. Y.
8	Col. W. P. Craighill, United States Corps of Engineers	Hydrographic survey of entrance to the Choptank River, 1848.
	......do	Hydrographic survey of Tredhaven Creek and tributaries, 1848.
	......do	Hydrographic survey of Chester River, from its mouth to its head, including South East Creek, of 1870.

APPENDIX No. 3—Continued.

Date.	Name.	Data furnished.
1879.		
Jan. 17	Lt. Col. John Newton, United States Corps of Engineers..	Hydrographic survey of Staten Island Sound and Arthur Kill, N. J.
23	Col. W. P. Craighill, United States Corps of Engineers...	Hydrographic survey of Saint Michael's and Wye Rivers, and tributaries, to Bennett's and Tilghman's Points, Md.
23	......do	Hydrographic survey of Skipton and Mill Creeks, Md.
23	......do	Hydrographic survey of Oak, Maxmore, and Peach-blossom Creeks, Md.
23	......do	Hydrographic survey of Plaindealing Creek, Md.
25	Maj. J. C. Tidball, U. S. A	Table of maximum velocity of ebb and flood currents in the principal harbors along the coast.
31	Maj. J. W. Barlow, United States Corps of Engineers	Chart showing high and low water lines of Port Jefferson Bays.
Feb. 8	Union College, Schenectady, N. Y	Unfinished proof of coast chart No. 23, coast of New Jersey, from Absecon Inlet to Cape May, brought up by hand.
12	Revenue steamer E. A. Stevens	Unfinished proofs of Pamplico Sound, N. C., scale 1-80,000, brought up by hand.
12	Peter Witzel, city surveyor, Newark, N. J	Hydrographic survey of Newark Bay, and entrance to the Passaic and Hackensack Rivers.
Mar. 1	Hon. Benjamin W. Harris, of Massachusetts	Topographic survey of the coast of Massachusetts north of Scituate survey of 1847.
3	Col. W. P. Craighill, United States Corps of Engineers...	Topography of Saint Michael's and Wye Rivers, and Kent Island, Md.
3	......do	Topography of Saint Michael's and Treadhaven Rivers, Md.
3	......do	Topography of Choptank River, from Cambridge to Cabin Creek, Md
4	Samuel M. Johnson, collector of customs, Corpus Christi, Tex.	Unfinished proofs of coast charts of the coast of Texas, from Pass Cavallo to Corpus Christi, being all the inside waters, brought up by hand.
12	Mr. George K. Wise, Philadelphia, Pa	Proof of general coast chart No. III, scale 1-400,000, with position of life-saving stations along coast of New Jersey shown thereon.
17	Kentucky Geological Survey	Copy of progress sketch, of 1878, of reconnaissance for geodetic work in the State.
20	John Lenthall, U. S. N	Unfinished impression of the plate of coast chart No. 59, Saint Augustine to Halifax River, Fla., with soundings, added by hand, of the inside passages.
28	Mr. M. Keller, Nos. 42 and 44 New street, New York	Topographic survey from Cañada de Isique to Topango Cañon, Los Angeles County, Cal.
April 4	Col. W. P. Craighill, United States Corps of Engineers...	Topographic surveys of parts of the western shore of Delaware Bay, lying between Liston's Tree and Cape Henlopen.
5	J. H. Merryman, inspector United States Life-Saving Service.	Unfinished proof of coast chart No. 108, Pass Cavallo, Lavacca, and other bays, Texas, brought up by hand.
30	Col. W. P. Craighill, United States Corps of Engineers...	Hydrography of Cabin, Secretary, and Tuckahoe Creeks, Choptank River, Md.
30	Mr. George S. Hale, Boston, Mass	Topographic survey of Newport Mountain, Mount Desert, Me.
30	Thomas Bernard, city engineer, Norfolk, Va	Topography, vicinity of Norfolk, Va.
May 6	Mr. John Westcott, Saint Augustine, Fla	Proof of coast chart No. 59, Saint Augustine to Halifax River, with soundings, added by hand, of the inside passages.
7	Col. William Ludlow, United States Corps of Engineers...	Hydrographic survey of the Delaware River, Bridesburg to Kensington, from the resurvey made in May and June, 1878.
9	Rev. B. F. de Costa, New York Historical Society	Unfinished proof, brought up by hand, of east side of Frenchman's Bay, Mount Desert Island, on 1-40,000 scale.
9	Gen. Q. A. Gillmore, United States Corps of Engineers...	Proofs of coast chart No. 91, Lakes Borgne and Pontchartrain, scale 1-80,000, brought up by hand.
17	Hon. H. D. Money, use of Committee on Post-Offices and Post-Roads, United States House of Representatives.	Unfinished proofs of coast charts Nos. 108 and 109, Pass Cavallo to Corpus Christi Bay, Tex.
27	W. W. Dewhurst, postmaster Saint Augustine, Fla	Proof of coast chart No. 59, Saint Augustine to Halifax River, Fla., brought up by hand.
June 2	Col. J. G. Barnard, United States Corps of Engineers.....	Hydrographic survey of the Mississippi River, vicinity of the Jump; scale, 1-20,000.
2	Mr. J. L. Thorndike, Boston, Mass	Topographic survey, vicinity of Boston Harbor, between Winthrop Head and Grover's Cliff.
11	Hon. B. F. Jonas, United States Senator from Louisiana..	Unfinished proof of coast chart No. 91, on 1-80,000 scale, Lakes Borgne and Pontchartrain, La., brought up by hand.
18	Prof. Alex. Agassiz	Sections across the Gulf of Mexico: From north end of Campeche Bank to Santa Rosa Bay, Fla.; horizontal scale, 1-1,200,000; vertical, 1-24,000. From Barrade de Tanguijo, Mexico, to the Triangles, Campeche Bank; horizontal scale, 1-200,000; vertical, 1-24,000.

APPENDIX No. 3—Continued.

Date.	Name.	Data furnished.
1879.		
June 18	Prof. Alexander Agassiz	Sections across the Gulf of Mexico—Continued: From Rio Indios Moralenes to Campeche Bank: horizontal scale, 1-2,400,000; vertical, 1-24,000. From Padre Island, Tex., to Cape Romain, Fla.; horizontal scale, 1-2,400; vertical, 1-2,400. From Cay Nuovo, Campeche Bank, to Marsh Island, Tex.; horizontal scale, 1-2,400; vertical, 1-2,400. Coast of Mexico to Galveston Island, Tex.; horizontal scale, 1-2,400; vertical, 1-2,400.
19	Mr. F. B. Conger	Charts of the Mississippi River, from Delta to Point Houmas, near Donaldsonville.
23	Hon. B. W. Harris, East Bridgewater, Mass	Proofs of coast chart No. 9, on 1-80,000 scale; and an impression from the old plate of Minot's Ledge, published in 1853; scale, 1-10,000.
23	Prof. Alexander Agassiz	Engraved charts, with recent Coast Survey soundings by the steamer Blake, of the Caribbean Sea and Windward Islands.
27	S. T. Abert, United States civil engineer	Hydrographic survey, of 1855, of the Rappahannock River, vicinity of Tappahannock.
	......do	Hydrographic survey of the James River, at mouth of Chickahominy River.

APPENDIX No. 4.

DRAWING DIVISION.

Charts completed or in progress during the fiscal year ending with June, 1879.

1. Topography. 2. Hydrography. 3. Drawing for Photolithographic reproduction. 4. Inking and lettering plane-table sheets. 5. Engraving topography.

Titles of charts.	Scale.	Draughtsmen.	Remarks.
Sailing chart, Gulf of Mexico, including part of Yucatan Channel and part of Caribbean Sea.	1-1,200,000	2. A. Lindenkohl	In progress.
General charts of Atlantic Coast:			
No. I, Quoddy Head, Me., to Cape Cod, Mass	1-400,000	2. A. Lindenkohl	Additions.
No. II, Cape Ann to Gay Head, Mass	1-400,000	2. A. Lindenkohl	Do.
No. VI, Cape Hatteras, N. C., to Cape Romain, S. C	1-400,000	1. A. Lindenkohl	Do.
No. VIII, Saint Mary's River to Cape Canaveral, Fla	1-400,000	1. H. Lindenkohl. 2. A. Lindenkohl	Do.
No. XII, Tampa Bay to Cape San Blas, Fla	1-400,000	1 and 2. A. Lindenkohl	Do.
No. XIII, Cape San Blas to Mississippi River, Fla., Ala., Miss.	1-400,000	2. C. Junken	Do.
Sailing chart, western coast reconnaissance (lower sheet) Section X, Cal.	1-1,200,000	2. C. Junken	Do.
Sailing chart, approaches to Columbia River, Oregon	1-100,000	3. A. Lindenkohl; H. Lindenkohl	Photolithograph; completed.
General charts of Pacific Coast:			
No. 2, Point Vincent to Point Concepcion, Cal	1-200,000	2. A. Lindenkohl. 5. H. Lindenkohl	In progress.
No. 7, Point Arena to Cape Mendocino, Cal	1-200,000	1. A. Lindenkohl. 5. H. Lindenkohl	Do.
Coast charts:			
No. 4, Penobscot and Isle au Haut Bays, Me	1-80,000	2. A. Lindenkohl	Do.
No. 43, Ocracoke Inlet to mouth Pamplico River, N. C	1-80,000	2. C. Junken	Do.
No. 52, Winyah Bay, Cape Romain, &c., S. C	1-80,000	2. C. Junken	Do.
No. 53, Georgetown Harbor to Long Island, S. C	1-80,000	2. A. Lindenkohl; H. Lindenkohl	Do.
No. 60, Halifax River to Mosquito Inlet, Fla	1-80,000	1 and 2. A. Lindenkohl	Do.
No. 80, Cedar Keys to Steinhatchee River, Fla	1-80,000	1. P. Erichsen	Do.
No. 81, Apalachee Bay, Saint Marks, &c., Fla	1-80,000	2. C. Junken	Do.
No. 85, Santa Rosa Bay, Fla	1-80,000	1 and 2. A. Lindenkohl	Completed.
No. 92, Parts of Chandeleur, Isle au Breton Sounds, &c., La.	1-80,000	1. A. Lindenkohl	In progress.
Harbor charts and topographical sheets:			
Isle au Haut Bay and Eggemoggin Reach, Me	1-40,000	1 and 2. C. Junken. 2. H. Lindenkohl	Do.
Head Harbor, Me	1-20,000	3. E. J. Sommer	Photolithograph; completed.
Duck Island Harbor, Me	1-20,000	3. E. J. Sommer	Do.
Lake Champlain, No. 2, N. Y	1-40,000	2. C. Junken	Additions.
Jamaica Bay and Rockaway Inlet, Long Island, N. Y	1-25,000	3. H. Lindenkohl	Photolithograph; completed.
Great South Bay, Long Island, N. Y	1-40,000	3. H. Lindenkohl	Do.
Potomac River (sheet No. 4) Indian Head to Georgetown.	1-40,000	1. H. Lindenkohl	Additions.
Lookout Cove, N. C	1-6,000	3. A. Lindenkohl; H. Lindenkohl	Photolithograph; completed.
Georgetown Harbor, S. C	1-5,000	3. E. J. Sommer	Photolithograph; in progress.
Barataria Bay entrance, La	1-20,000	3. H. Lindenkohl	Photolithograph; completed.
Barataria Lower Bay, La	1-40,000	3. A. Lindenkohl; H. Lindenkohl	Do.
Anacapa Island and east end of Santa Cruz, Cal	1-30,000	1. A. Lindenkohl	New edition; completed.
Seattle Harbor, Puget Sound, Wash. Ter	1-20,000	3. E. J. Sommer	Photolithograph; completed.
Commencement Bay, Puget Sound, Wash. Ter	1-20,000	3. H. Lindenkohl	Do.
Topographical sheet, Coney Island, N. Y		4. H. Lindenkohl	
Topographical sheet, coast of New Jersey		4. C. Meuth	
Topographical sheet, east of Norfolk, Va		4. H. Lindenkohl	

APPENDIX No. 4—Continued.

Titles of charts.	Scale.	Draughtsmen.	Remarks.
Harbor charts and topographical sheets—Continued.			
Topographical sheet, vicinity of Norfolk, Va		4. C. Meuth	
Topographical sheet, Manassas Junction, Va		4. C. Meuth	
Topographical sheet, vicinity of Wilmington, N. C		4. H. Lindenkohl	
Topographical sheet, Cape Fear River, N. C		4. H. Lindenkohl	
Topographical sheet, Crooked River, W. Fla		4. E. J. Sommer	
Topographical sheet, part of Saint John's River, Fla		4. H. Lindenkohl	
Topographical sheet, Mississippi River, Point Houmas, La.		4. E. J. Sommer	
Topographical sheet, Mississippi River above New Orleans, La.		4. H. Lindenkohl	
Topographical sheet, Santa Catalina Island, Cal		4. L. Karcher	
Topographical sheet, south of Monterey Bay, Cal		4. E. J. Sommer	
Topographical sheet, Cape Sebastian to Crook's Point, Oregon.	1-10,000	4. P. Erichsen	
Topographical sheet, Columbia River, Oregon		4. E. J. Sommer	
Miscellaneous:			
Map of the United States for magnetics	1-7,000,000	A. Lindenkohl; H. Lindenkohl	
Annual progress sketch work		A. Lindenkohl	
Plan of optical densimeter		P. Erichsen	
Plan of Geneva stand, &c., for pendulum		P. Erichsen	
Drawing of deep-sea sounding and dredging apparatus		P. Erichsen	
Drawing of water specimen-cup		P. Erichsen	
Drawing of new levelling instrument		P. Erichsen	
Temperature diagrams, Gulf of Mexico		L. Karcher	
Tract chart, North Atlantic Ocean		L. Karcher	
Titles, scales, notes, &c., on unfinished proofs		L. Karcher	

APPENDIX No. 5.

ENGRAVING DIVISION.

Plates completed, continued, or commenced during the fiscal year ending with June, 1879.

1. Outlines. 2. Topography. 3. Sanding. 4. Lettering.

Title of plates.	Scale.	Engravers.
COMPLETED.		
General coast chart 1, Isle-au-Haut to Cape Cod (west)	1-400,000	1 and 2. J. Enthoffer. 3. H. M. Knight and W. A. Thompson. 4. E. A. Maedel.
General coast chart 6, Cape Hatteras to Cape Romain	1-400,000	1 and 2. R. F. Bartle. 3. W. A. Thompson. 4. F. Courtenay.
Coast chart No. 21, Sandy Hook to Barnegat Inlet	1-80,000	1 and 2. H. C. Evans, J. G. Thompson, W. A. Thompson. 3. H. C. Evans, H. M. Knight. 4. E. A. Maedel and J. G. Thompson.
Coast chart No. 22, Barnegat Inlet to Absecon Inlet	1-80,000	1 and 2. H. C. Evans, W. A. Thompson. 3. H. C. Evans. 4. E. A. Maedel.
Coast chart No. 38, Currituck light to Oregon Inlet	1-80,000	1. J. J. Young. 2. W. A. Thompson. 3. W. A. Thompson. 4. A. Petersen and J. G. Thompson.
Coast chart No. 70, Key West, Marquesas Keys, &c	1-80,000	1, 2, and 3. H. M. Knight. 4. J. G. Thompson, E. A. Maedel, and E. H. Sipe.
Coast chart No. 86, Choctawhatchee Inlet to Pensacola entrance.	1-80,000	1 and 2. H. C. Evans. 3. F. W. Benner and H. M. Knight. 4. E. A. Maedel, F. Courtenay, and J. G. Thompson.
Harbor chart, Lake Champlain, No. 1, Rouse's Point to Cumberland Head.	1-40,000	1 and 2. H. C. Evans, J. G. Thompson, W. A. Thompson. 3. W. A. Thompson. 4. E. A. Maedel, A. Petersen.
Harbor chart, Lake Champlain, No. 2, Cumberland Head to Ligonier Point.	1-40,000	1. H. C. Evans and J. G. Thompson. 2. H. C. Evans. 3. W. A. Thompson. 4. E. A. Maedel.
Harbor chart, Annapolis Harbor (1879)	1-60,000	4. J. G. Thompson and W. H. Davis.
Harbor chart, Columbia River, No. 2 (1879)	1-40,000	1, 2, and 3. W. A. Thompson. 4. J. G. Thompson and T. Wasserbach.
Harbor chart, Columbia River, No. 3 (finished edition	1-40,000	2 and 3. W. A. Thompson. 4. J. G. Thompson.
CONTINUED.		
Coast chart No. 4, Penobscot Bay	1-80,000	3. H. M. Knight.
Coast chart No. 23, Absecon Inlet to Cape May	1-80,000	4. E. A. Maedel.
Coast chart No. 42, Pamplico Sound, Roanoke Island to Hatteras Inlet (eastern sheet).	1-80,000	1 and 2. H. M. Knight. 3. W. A. Thompson. 4. H. M. Knight and J. G. Thompson.
Coast chart No. 43, Pamplico Sound, Ocracoke Inlet to mouth of Pamplico River (middle sheet).	1-80,000	3. W. A. Thompson. 4. J. G. Thompson.
Coast chart No. 58, Cumberland Sound to Saint John's River, &c.	1-80,000	1 and 2. A. Sengteller. 3. W. A. Thompson.
Coast chart No. 59, Saint Augustine Inlet to Halifax River.	1-80,000	2. A. Sengteller. 4. F. Courtenay and J. G. Thompson.
Coast chart No. 71, Marquesas Keys to the Tortugas	1-80,000	4. F. Courtenay.
Coast chart No. 77, Tampa Bay	1-80,000	1 and 2. R. F. Bartle. 4. J. G. Thompson.
Coast chart No. 83, Apalachicola Bay to Cape San Blas	1-80,000	3. F. W. Benner. 4. J. G. Thompson.
Coast chart No. 91, Lakes Borgne & Pontchartrain	1-80,000	4. J. G. Thompson.
Coast chart No. 104, Galveston Bay	1-80,000	4. James Loughren.
Harbor chart, Isle-au-Haut Bay and Eggemoggin Reach	1-40,000	2. H. M. Knight. 4. E. H. Sipe, J. G. Thompson, and A. Petersen.
Harbor chart, Lake Champlain, No. 3, Ligonier Point to Cole's Bay.	1-40,000	3. W. A. Thompson. 4. E. A. Maedel.
Harbor chart, Lake Champlain, No. 4, Cole's Bay to Whitehall.	1-40,000	3. H. M. Knight.
Harbor chart, James River, No. 1, Newport News to Deep Water light.	1-50,000	1 and 2. J. Enthoffer.
Harbor chart, James River, No. 2, Point of Shoals light to Sloop Point.	1-50,000	1 and 2. J. Enthoffer.
General chart of the coast, Point Vincent to Point Concepcion.	1-200,000	1 and 2. H. Lindenkohl.
General chart of the coast, Point Arena to Cape Mendocino.	1-200,000	1 and 2. H. Lindenkohl. 4. J. G. Thompson.
Harbor chart, San Francisco Bay entrance (in contours)	1-50,000	1. J. J. Young.

APPENDIX No. 5—Continued.

Title of plates.	Scale.	Engravers.
COMMENCED.		
Sailing chart B, Cape Hatteras to Key West (upper)	1-1, 200, 000 1-80, 000	4. J. G. Thompson.
Sailing chart B, Cape Hatteras to Key West (lower)	1-1, 200, 000 1-80, 000	4. J. G. Thompson.
General coast chart 13, Saint Mary's River to Cape Canaveral	1-400, 000	1 and 2. R. F. Bartle. 4. J. G. Thompson.
Coast chart No. 39, Oregon Inlet to Cape Hatteras	1-80, 000	3. F. W. Benner. 4. F. Courtenay and J. G. Thompson.
Coast chart No. 53, Winyah Bay to Long Island	1-80, 000	1. A. Sengteller.
Coast chart No. 81, Apalachee Bay, Florida	1-80, 000	1 and 2. H. C. Evans. 4. W. H. Davis.
Coast chart No. 82, Saint Mark's River to head of Apalachicola Bay.	1-80, 000	
Harbor chart, Tortugas Harbor and approaches	1-40, 000	1, 2, 3, and 4. William Smith.

List of plates having received additions and corrections during the fiscal year from July 1, 1878, *to June* 30, 1879.

No. of plate.	Title of plates.	Scale.	Date of corrections.
976	Sailing chart No. 2, Nantucket to Cape Hatteras	1-1, 200, 000	October 11, 1878.
1357	Sailing chart A, Upper, Cape Sable to Cape Hatteras	1-1, 200, 000	November 9, 1878.
1367	Sailing chart A, Lower, Cape Sable to Cape Hatteras	1-1, 200, 000	November 19, 1878.
977	Sailing chart 3, Cape Hatteras to Mosquito Inlet	1-1, 200, 000	April 9, 1879.
989	Sailing chart 4, Mosquito Inlet to Key West	1-1, 200, 000	June 13, 1879.
951	Sailing chart 5, Key West to the Rio Grande (eastern part)	1-1, 200, 000	September 14, 1878.
1453	Sailing chart 5, Key West to the Rio Grande (eastern part)	1-1, 200, 000	October 25, 1878.
942	Sailing chart 5, Key West to the Rio Grande (western part)	1-1, 200, 000	August 28, 1878.
1451	Sailing chart 5, Key West to the Rio Grande (western part)	1-1, 200, 000	February 10, 1879.
1242	General coast chart 2, Cape Ann to Gay Head	1-400, 000	June 14, 1879.
1392	General coast chart 3, Gay Head to Cape Henlopen	1-400, 000	January 29, 1879.
1183	General coast chart 4, Cape May to Cape Henry	1-400, 000	January 30, 1879.
1147	General coast chart 5, Cape Henry to Cape Lookout	1-400, 000	February 19, 1879.
1350	General coast chart 7, Cape Romain to Saint Mary's River	1-400, 000	November 10, 1879.
1081	General coast chart 10, Straits of Florida	1-400, 000	August 8, 1878.
1249	Coast chart 5, Penobscot Bay to Kennebec entrance	1-80, 000	May 10, 1879.
1063	Coast chart 6, Kennebec entrance to Saco River	1-80, 000	March 3, 1879.
1271	Coast chart 7, Seguin Island to Kennebunkport	1-80, 000	April 22, 1879.
1201	Coast chart 8, Wells to Cape Ann	1-80, 000	June 10, 1879.
1181	Coast chart 9, Boston Bay and approaches	1-80, 000	June 30, 1879.
1199	Coast chart 10, Cape Cod Bay	1-80, 000	May 27, 1879.
1402	Coast chart 11, Monomoy and Nantucket Shoals to Muskeget Channel (east part)	1-80, 000	May 8, 1879.
1054	Coast chart 12, Muskeget Channel to Buzzard's Bay and entrance to Vineyard Sound (middle)	1-80, 000	May 6, 1879.
1297	Coast chart 13, Cuttyhunk to Block Island, including Narragansett Bay (west part)	1-80, 000	September 13, 1878.
1371	Coast chart 13, Cuttyhunk to Block Island, including Narragansett Bay (west part)	1-80, 000	June 5, 1879.
1363	Coast chart 14, Point Judith and Block Island to Plum Island	1-80, 000	March 25, 1879.
1419	Coast chart 15, Plum Island to Welches' Point (middle sheet)	1-80, 000	June 27, 1879.
1418	Coast chart 16, Welches' Point to New York	1-80, 000	December 7, 1878.
1473	Coast chart 16, Welches' Point to New York	1-80, 000	June 2, 1879.
979	Coast chart 17, Block Island, Montauk Point, &c. (eastern sheet)	1-80, 000	October 7, 1878.
865	Coast chart 18, Napeague Beach to Forge River (middle sheet)	1-80, 000	October 29, 1878.
866	Coast chart 19, Great South Bay, Fire Island, and Long Beaches	1-80, 000	April 1, 1879.
1404	Coast chart 20, New York Bay and Harbor	1-80, 000	April 29, 1879.
1185	Coast chart 24, Delaware Bay and River, Delaware entrance (lower)	1-80, 000	June 28, 1879.
1193	Coast chart 25, Delaware Bay and River, part of Delaware Bay and River (middle)	1-80, 000	June 5, 1879.
1239	Coast chart 26, Delaware Bay and River, Port Penn to Trenton (upper)	1-80, 000	June 5, 1879.
1200	Coast chart 27, Cape May to Isle of Wight	1-80, 000	October 9, 1878.
1230	Coast chart 28, Isle of Wight to Chincoteague Inlet	1-80, 000	October 10, 1878.
1286	Coast chart 29, Chincoteague Inlet to Hog Island light	1-80, 000	November 5, 1878.
1287	Coast chart 30, Hog Island light to Cape Henry	1-80, 000	November 1, 1878.
1219	Coast chart 31, Entrance to Chesapeake, Hampton Roads, &c	1-80, 000	April 15, 1879.
1211	Coast chart 32, Chesapeake Bay, York River to Pocomoke River	1-80, 000	May 3, 1879.
1222	Coast chart 33, Chesapeake Bay, Pocomoke Sound to Potomac River	1-80, 000	October 22, 1878.

APPENDIX No. 5—Continued.

No. of plate.	Title of plates.	Scale.	Date of corrections.
1227	Coast chart 34, Chesapeake Bay, Potomac River to Choptank River	1-80,000	April 1, 1879.
1232	Coast chart 35, Chesapeake Bay, Choptank River to Magothy River	1-80,000	March 12, 1879.
1235	Coast chart 36, Chesapeake Bay, Magothy River to head of bay	1-80,000	October 12, 1878.
1444	Coast chart 37, Cape Henry to Currituck light	1-80,000	October 12, 1878.
890	Coast chart 40, Albemarle Sound, Atlantic Ocean to Pasquotank River (east)	1-80,000	October 14, 1878.
1377	Coast chart 41, Albemarle Sound, Pasquotank River to Roanoke and Chowan Rivers (west)	1-80,000	October 15, 1878.
938	Coast chart 54, Long Island to Hunting Island	1-80,000	June 10, 1879.
1353	Coast chart 55, Hunting Island to Ossabaw Island	1-80,000	February 20, 1879.
884	Coast chart 66, Florida Reefs, Key Biscayne to Carysfort Reef	1-80,000	October 19, 1878.
1094	Coast chart 67, Florida Reefs, Elbow Key to Matecumbe Key	1-80,000	June 14, 1879.
1100	Coast chart 68, Florida Reefs, Long Key to Newfound Harbor Key	1-80,000	November 8, 1878.
1125	Coast chart 69, Florida Reefs, Newfound Harbor Key to Boca Grande Key	1-80,000	May 28, 1879.
1158	Coast chart 88, Mobile Bay	1-80,000	February 4, 1879.
1052	Coast chart 90, Mississippi Sound, Round Island to Grand Island	1-80,000	June 4, 1879.
1280	Coast chart 94, Mississippi River, from the Passes to Grand Prairie	1-80,000	July 19, 1878.
1216	Coast chart 105, Galveston Bay to Oyster Bay	1-80,000	December 11, 1878.
1334	Coast chart 107, Matagorda Bay	1-80,000	March 8, 1879.
1008	Harbor chart, Eastport Harbor	1-40,000	May 31, 1879.
1203	Harbor chart, Moos-a-bec Reach	1-40,000	May 1, 1879.
1191	Harbor chart, Mount Desert, southwest harbor, and Somes' Sound	1-40,000	December 19, 1878.
1354	Harbor chart, Penobscot Bay	1-40,000	May 3, 1879.
1128	Harbor chart, Fox Islands Thoroughfare	1-20,000	December 18, 1878.
1150	Harbor chart, Saint George's River and Muscle Ridge Channel	1-40,000	June 28, 1879.
1261	Harbor chart, Damariscotta and Medomak Rivers	1-40,000	June 21, 1879.
1112	Harbor chart, Kennebec and Sheepscot Rivers	1-40,000	August 12, 1878.
1204	Harbor chart, Casco Bay	1-40,000	June 19, 1879.
1065	Harbor chart, inside passage, Bath to Booth Bay	1-20,000	May 19, 1879.
1333	Harbor chart, Winter Harbor	1-20,000	June 4, 1879.
1015	Harbor chart, Rockport and Camden Harbors	1-20,000	March 11, 1879.
1174	Harbor chart, Portland Harbor	1-20,000	June 16, 1879.
1016	Harbor chart, Isles of Shoals	1-20,000	April 16, 1879.
782	Harbor chart, Ipswich and Annisquam Harbors	1-20,000	February 11, 1879.
1328	Harbor chart, Salem Harbor	1-25,000	September 25, 1878.
1184	Harbor chart, Boston Harbor	1-40,000	May 7, 1879.
1326	Harbor chart, Plymouth, Kingston, and Duxbury Harbors	1-40,000	October 18, 1878.
847	Harbor chart, Wellfleet Harbor	1-50,000	September 17, 1878.
1025	Harbor chart, Provincetown Harbor	1-50,000	October 28, 1878.
415	Harbor chart, Bass River Harbor	1-40,000	November 1, 1878.
1344	Harbor chart, New Bedford Harbor	1-40,000	September 6, 1878.
1240	Harbor chart, Narragansett Bay (lower)	1-40,000	August 26, 1878.
1385	Harbor chart, Fisher's Island Sound	1-40,000	May 17, 1879.
832	Harbor chart, Hempstead Harbor	1-20,000	May 19, 1879.
1268	Harbor chart, New York Bay and Harbor (upper)	1-40,000	March 25, 1879.
1266	Harbor chart, New York Bay and Harbor (lower)	1-40,000	September 3, 1878.
1304	Harbor chart, New York entrance	1-40,000	September 10, 1878
1034	Harbor chart, Hudson River, No. 1, New York to Haverstraw	1-60,000	April 3, 1879.
888	Harbor chart, Hudson River, No. 2, Haverstraw to Poughkeepsie	1-60,000	May 1, 1879.
954	Harbor chart, Hudson River, No. 3, Poughkeepsie to Troy (Sheet A)	1-40,000	April 28, 1879.
990	Harbor chart, Hudson River, No. 3, Poughkeepsie to Troy (Sheet B)	1-40,000	April 22, 1879.
1270	Harbor chart, Little Egg Harbor	1-40,000	April 2, 1879.
453	Harbor chart, Delaware and Chesapeake Bays	1-400,000	June 23, 1879.
1159	Harbor chart, Patapsco River	1-60,000	March 12, 1879.
784	Harbor chart, Patuxent River (lower)	1-60,000	April 15, 1879.
863	Harbor chart, Patuxent River, Point Judith to Nottingham	1-30,000	February 18, 1879.
1135	Harbor chart, Potomac River, No. 1, entrance, and up to Piney Point	1-60,000	November 9, 1878.
1171	Harbor chart, Potomac River, No. 2, Piney Point to Lower Cedar Point	1-60,000	April 7, 1879.
1148	Harbor chart, Potomac River, No. 3, Lower Cedar Point to Indian Head	1-60,000	May 15, 1879.
1319	Harbor chart, Potomac River, No. 4, Indian Head to Georgetown	1-40,000	October 23, 1878.
854	Harbor chart, Rappahannock River, No. 1, entrance to Deep Creek	1-20,000	October 10, 1878.
623	Harbor chart, Rappahannock River, No. 2, Deep Creek to Occupacia Creek	1-20,000	October 11, 1878.
548	Harbor chart, Rappahannock River, No. 3, Occupacia Creek to Saunder's Wharf	1-20,000	October 12, 1878.
547	Harbor chart, Rappahannock River, No. 4, Saunder's Wharf to Port Royal	1-20,000	October 12, 1878.
978	Harbor chart, Rappahannock River, No. 5, Port Royal to Moss Neck	1-40,000	October 14, 1878.
965	Harbor chart, Rappahannock River, No. 6, from near Moss Neck to Fredericksburg	1-40,000	October 15, 1878.

APPENDIX No. 5—Continued.

No. of plate.	Title of plates.	Scale.	Date of corrections.
987	Harbor chart, York River, Va., entrance to King's Creek	1–60, 000	December 12, 1878.
1213	Harbor chart, James River, City Point to Richmond	1–40, 000	April 19, 1879.
953	Harbor chart, Hampton Roads and Elizabeth River	1–40, 000	June 13, 1879.
983	Harbor chart, mouth of Roanoke River	1–30, 000	May 20, 1879.
1223	Harbor chart, Hatteras Shoals	1–80, 000	October 28, 1878.
921	Harbor chart, Hatteras Inlet	1–20, 000	March 1, 1878.
1023	Harbor chart, Cape Lookout Shoals	1–80, 000	March 21, 1879.
1358	Harbor chart, Beaufort Harbor	1–40, 000	January 18, 1879.
1018	Harbor chart, Core Sound and Straits	1–40, 000	February 25, 1879.
1161	Harbor chart, Cape Fear River entrance	1–30, 000	June 25, 1879.
1192	Harbor chart, Charleston Harbor	1–30, 000	June 13, 1879.
1173	Harbor chart, Bull and Combahee Rivers	1–40, 000	May 5, 1879.
1140	Harbor chart, Saint Helena Sound	1–40, 000	October 4, 1878.
1329	Harbor chart, Whale Branch, inside passage, between Coosaw and Broad Rivers	1–40, 000	March 14, 1879.
1070	Harbor chart, Savannah River and Wassaw Sound	1–40, 000	October 11, 1878.
948	Harbor chart, Ossabaw Sound	1–30, 000	June 17, 1879.
946	Harbor chart, Sapelo Sound	1–30, 000	June 25, 1879.
1312	Harbor chart, Doboy and Altamaha Sounds	1–40, 000	February 10, 1879.
1155	Harbor chart, Saint Simon's Sound, Brunswick Harbor, and Turtle River	1–40, 000	January 17, 1879.
1288	Harbor chart, Saint Mary's River and Fernandina Harbor	1–20, 000	June 16, 1879.
1170	Harbor chart, Key West Harbor	1–50, 000	June 9, 1879.
907	Harbor chart, Saint George's Sound (western part), embracing Apalachicola Harbor	1–40, 000	January 4, 1879.
870	Harbor chart, Saint George's Sound (eastern part)	1–40, 000	March 6, 1879.
1391	Harbor chart, entrance to Pensacola Bay	1–30, 000	July 9, 1878.
793	Harbor chart, Atchafalaya Bay	1–50, 000	July 19, 1878.
1036	Pacific Coast sailing chart, San Diego to San Francisco	1–1, 200, 000	June 21, 1879.
1064	General coast chart, Point Pinos to Bodega Head	1–200, 000	June 11, 1879.
536	Harbor chart, Anacapa Island, and eastern part of Santa Cruz Island	1–30, 000	March 24, 1879.
670	Harbor chart, Monterey Bay	1–60, 000	October 18, 1878.
818	Harbor chart, San Francisco Bay, entrance	1–50, 000	April 7, 1879.
1006	Harbor chart, San Pablo Bay	1–50, 000	May 8, 1879.
733	Harbor chart, Humboldt Bay	1–30, 000	April 12, 1879.
1245	Harbor chart, Columbia River, No. 1	1–40, 000	April 23, 1879.
349	Harbor chart, Cape Flattery and Nee-ah Harbors	1–40, 000	June 5, 1879.
742	Harbor chart, Port Townsend	1–40, 000	June 3, 1879.
1144	Harbor chart, Puget Sound	1–200, 000	June 5, 1879.
540	Harbor chart, Bellingham Bay	1–40, 000	June 5, 1879.
1446	Atlantic Coast Pilot chart, current chart, Gulf of Maine	1–1, 200, 000	April 25, 1879.
1505	Atlantic Coast Pilot chart, east entrance to Penobscot Bay	1–80, 000	June 28, 1879.
1504	Atlantic Coast Pilot chart, west entrance to Penobscot Bay	1–80, 000	June 19, 1879.
1506	Atlantic Coast Pilot chart, Penobscot Bay (upper part)	1–80, 000	May 29, 1879.
1480	Atlantic Coast Pilot chart, Whitehead to Pemaquid Point	1–80, 000	April 9, 1879.
1477	Atlantic Coast Pilot chart, Pemaquid Point to Seguin Island	1–80, 000	March 31, 1879.
1478	Atlantic Coast Pilot chart, Seguin Island to Cape Elizabeth	1–80, 000	April 7, 1879.
1497	Atlantic Coast Pilot chart, Cape Elizabeth to Wells	1–80, 000	June 21, 1879.
1484	Atlantic Coast Pilot chart, Wells to Little Boar's Head	1–80, 000	April 21, 1879.
1485	Atlantic Coast Pilot chart, Little Boar's Head to Cape Ann	1–80, 000	June 7, 1879.
1486	Atlantic Coast Pilot chart, Cape Ann to Nahant	1–80, 000	June 6, 1879.
1374	Atlantic Coast Pilot chart, Boston Bay	1–80, 000	April 19, 1879.
1461	Atlantic Coast Pilot chart, Winter Harbor	1–20, 000	February 6, 1879.
1460	Atlantic Coast Pilot chart, Southwest Harbor	1–40, 000	February 25, 1879.
1474	Atlantic Coast Pilot chart, Moos-a-bec Reach	1–40, 000	February 27, 1879.
1471	Atlantic Coast Pilot chart, Fox Islands Thoroughfare (east)	1–40, 000	March 20, 1879.
1472	Atlantic Coast Pilot chart, Fox Islands Thoroughfare (west)	1–40, 000	February 26, 1879.
1492	Atlantic Coast Pilot chart, Castine Harbor	1–40, 000	June 24, 1879.
1491	Atlantic Coast Pilot chart, Belfast Harbor	1–20, 000	June 11, 1879.
1482	Atlantic Coast Pilot chart, Muscle Ridge Channel	1–40, 000	June 11, 1879.
1499	Atlantic Coast Pilot chart, Portland Harbor	1–20, 000	June 9, 1879.
1490	Atlantic Coast Pilot chart, Richmond's Island Harbor	1–20, 000	April 5, 1879.
1498	Atlantic Coast Pilot chart, Isles of Shoals	1–20, 000	June 21, 1879.
1496	Atlantic Coast Pilot chart, Gloucester Harbor	1–20, 000	June 21, 1879.
1559	Atlantic Coast Pilot chart, Nantucket and Vineyard Sounds	1–80, 000	April 7, 1879.

APPENDIX No. 5—Continued.

No. of plate.	Title of plates.	Etching.	Lettering.	Corrections.
1405	Atlantic Coast Pilot view, approaches to Winter Harbor and Frenchman's Bay—Frenchman's Bay from off Schoodic.	....	September 26, 1878.	
1412	Atlantic Coast Pilot view, Isle au Haut, eastward and westward, Blue Hill Bay from the eastward, and entrance to Burnt Coat River.	....	August 10, 1878...	
1413	Atlantic Coast Pilot view, Mount Desert, east part, and approaches to Southwest Harbor from eastward, Southwest Harbor from southward and westward, Bass Harbor between Duck and Gott Islands.	....	August 19, 1878...	
1417	Atlantic Coast Pilot view, Deer Island Thoroughfare, from eastward and westward.	....	October 3, 1878....	
1420	Atlantic Coast Pilot view, eastern entrance to Penobscot Bay, outlying Islands off Penobscot Bay, Matinicus and Ragged Islands, and entrance to Penobscot Bay from westward.	....	September 19, 1878	
1421	Atlantic Coast Pilot view, Fox Islands Thoroughfare, from eastward and westward.	....	August 1, 1878....	
1426	Atlantic Coast Pilot view, Belfast Bay and Harbor from West Penobscot Bay, and entrance to Penobscot River from West Penobscot Bay.	....	October 15, 1878...	
1430	Atlantic Coast Pilot view, Hotel on Scimipuxent Beach, Cape Henry bearing south, Cape Henry light-house west by south, and Cape Charles from the eastward.	....	October 9, 1878....	
1432	Atlantic Coast Pilot view, entrance to Hampton Roads, James, Nansemond, and Elizabeth Rivers.	....	August 26, 1878...	
1434	Atlantic Coast Pilot view, entrance to York River, Cherrystone Inlet, Piankatank and Rappahannock Rivers.	....	September 5, 1878.	October 25, 1878.
1436	Atlantic Coast Pilot view, Harrison's Landing and Westover House......	....	July 26, 1878......	
1440	Atlantic Coast Pilot view, Watts and Tangier Sound, and entrance to Kedge's and Hooper's Straits and Billy's Island.	....	July 26, 1878......	
1457	Atlantic Coast Pilot view, entrance to Choptank River from northward and southward, and east entrance to Eastern Bay.	December 23, 1878.	....	
1470	Atlantic Coast Pilot view, head of Chesapeake Bay—entrance to Elk River, Pool's Island, Patapsco River off Old Road Bay.	January 14, 1879..	....	March 24, 1879.
1479	Atlantic Coast Pilot view, Susquehanna River, above bridge, looking up Susquehanna River; Havre de Grace, above and below bridge.	March 15, 1879....	March 22, 1879....	May 9, 1879.
1487	Atlantic Coast Pilot view, Cape May and Cape Henlopen..................	March 24, 1879....	....	
1488	Atlantic Coast Pilot view, Delaware River—Cohansey light-house, Bombay Hook Woods—up river from off Bombay Hook light-house.	April 5, 1879......	....	
1494	Atlantic Coast Pilot view, Delaware River, looking up from below Reedy Island; Delaware River, off Reedy Island light-house; entrance to Delaware River, Christianna Creek; Delaware River, looking up from off Billingport.	April 25, 1879.....	....	May 7, 1879.
1500	Atlantic Coast Pilot view, approaches to Eastport, through Lubec Narrows.	May 3, 1879.......	May 8, 1879.......	
1502	Atlantic Coast Pilot view, Weskeag River, from near Garden Island Ledge (Muscle Ridge Channel); Owl's Head Bay, approaches to Rockport and Camden Harbors.	June 11, 1879.....	....	
1508	Atlantic Coast Pilot view, entrance to Casco Bay from eastward; Cape Elizabeth, Isles of Shoals.	June 27, 1879.....	....	
1509	Atlantic Coast Pilot view, Kent Point, north entrance to Eastern Bay, approaches to Severn River, Thomas Point light-house, and entrance to Chester River.	June 30, 1879.....	....	
1520	Atlantic Coast Pilot view, Potomac River, Point Lookout, Smith's Point, Piney Point; Potomac River, off Saint Mary's River.	June 30, 1879.....	....	
1342	Atlantic Coast Pilot view, Hudson River Highlands from off Peekskill ...	June 29, 1879.....	....	
1351	Atlantic Coast Pilot view, West Point from near Constitution Island, looking down.	January 27, 1879..	....	January 29, 1879.
1373	Atlantic Coast Pilot view, Hudson River, landing at Barrytown..........	January 25, 1879..	....	
	Views of Mount Desert Island (5 plates), by George McCoy, during the fiscal year, plates retouched.	Retouched........	....	
	Diagrams, eight plates of weather diagrams, coast of Alaska	....	....	
	Diagram, one plate deep-sea soundings, Gulf of Mexico	....	....	

APPENDIX No. 6.

LETTER TO CARLILE P. PATTERSON, SUPERINTENDENT UNITED STATES COAST AND GEODETIC SURVEY, WASHINGTON, D. C., FROM ALEXANDER AGASSIZ, ON THE DREDGING OPERATIONS CARRIED ON FROM DECEMBER, 1878, TO MARCH 10, 1879, BY THE UNITED STATES COAST SURVEY STEAMER BLAKE, COMMANDER J. R. BARTLETT, U. S. N.

(With two maps.)

I joined the Blake at Washington, on November 27, 1878, for a second dredging cruise. According to your instructions we intended to proceed to Nassau, and there devote a few days to dredging and sounding, in order to trace the connection between the fauna of the northern extremity of the Bahama Banks and that of the Straits of Florida. Owing to rough weather this was not deemed prudent, and we were compelled to put into Saint Helena Sound, and, for the same reason, when off Jupiter Inlet, instead of crossing the Gulf Stream to make Nassau, it was thought best to put in to Key West. From there, when the weather moderated, we started for Kingston, Jamaica, calling at Havana for the purpose of making a couple of hauls on the Pentacrinus ground discovered by Captain Sigsbee off Moro Light. We made two casts of the dredge in 175 to 400 fathoms, and obtained a few specimens of Pentacrinus. We kept on along the northern shore of Cuba, through the Old Bahama Channel, without stopping to sound or dredge, Mr. Pourtalès having, in former years, dredged and sounded, in the Bibb, Acting Master Platt, U. S. N., over the greater part of this line.

At the eastern end of the Old Bahama Channel we ran a line of dredgings and soundings across from Caya Cruz to Lobos Light. In the deepest part of the channel we found only 500 fathoms, although the hydrographic maps indicated 900 fathoms, no bottom. This is an excellent example of the uncertainty of the old method of sounding with hemp rope, even in moderately deep water, when there is a strong current, such as we found here.

Nothing of special interest came up in any of the casts made either with the trawl or dredge. Wound around the steel-wire rope on this line, however, we found a few pieces of the deep-sea Siphonophores (Rhizophysa), described lately by Studer in the Zeitschrift f. wissen. Zoologie. Subsequently we frequently found more or less complete specimens of these Siphonophores, generally entangled on the wire rope or attached to the trap of the trawl. Studer gives a long list of the depths from which they came up attached to the sounding-line, but it is by no means certain that these Siphonophores belonged in the depths indicated by the wire. They may have become caught on the wire while it was reeling in at only a short distance from the surface.* The fact that Studer never succeeded in bringing up any of these species in the tow-net, even when lowered to a considerable depth, is as little conclusive, since, at any rate in the Caribbean Sea, their isolated parts and fragments are not uncommon floating on the surface. It is probable that they usually live at a certain depth below the surface, and some of them may, like Cassiopea, prefer to dwell near the bottom; but until we possess a net so constructed as to give some sure indication of the intermediate depths at which the animals living at various distances between the surface and bottom have been gathered in, it seems hazardous to define the bathymetrical range of a large number of pelagic animals, such as the Acalephs, Siphonophores, Heteropods, Pteropods, numerous Foraminifera, Radiolaria, and the like, the habits of which are scarcely known.

In the case of fishes, when dredging in deep water at a moderate distance from the land, we ought not to take it for granted that they invariably live at the depth to which the trawl may have been lowered. The young of many of the deep-water fishes are undoubtedly pelagic, often

*In one case, dredging in 1,000 fathoms, numerous fragments of a Rhizophysa came up after drawing in 100 fathoms of wire! On another occasion the same species came up after drawing in 300 fathoms, while dredging in 500 fathoms.

till a late period of growth, and thus many of the deep-water fishes have probably come to light, especially in the proximity of oceanic islands, or along coasts situated near deep water. We made three casts off the coast of Cuba, between Nuevitas and Cape Maysi. In latitude 21° 2′, N., longitude 74° 44′, W., off Cayo de Moa, in 1,554 fathoms, we found a patch of green sand, made up of large Globigerinæ, similar to that mentioned by Mr. Pourtalès in his "Deep-Sea Corals."

We also obtained, in 994 fathoms off Nuevitas, large blocks of genuine white chalk, composed mainly of Globigerinæ and Rotulinæ. Large quantities of ooze and white clay, which proved to be only the white chalk in different stages of compression, also came up in the trawl. If the conditions now existing at that depth at all resemble those of the time of the white chalk, I could readily understand how perfectly Sea-Urchins or Mollusks would be preserved if once inclosed in this homogeneous substance, to be gradually compressed into solid white chalk.

In one of the hauls taken between Cape Maysi and Jamaica (1,200 fathoms), we obtained the first specimens of Phormosoma I had seen alive. I was much astonished to find them, fully blown up, hemispherical or globular in shape. This was the shape they always took in subsequent hauls, and on several occasions, when they were obtained from comparatively shallow water, near the 100-fathom line, they came up fully alive and retained their globular outline. The alcoholic specimens I had seen in the Challenger collections came up as flat as pocket-handkerchiefs, from great depths, and were naturally regarded as flat Sea-Urchins, although of course endowed with great mobility of test. These Echini, with their globular, flexible tests, recall vividly the Perischoechinidæ, with which they have also points of resemblance of great interest in the structure of their ambulacral and interambulacral plates.

In the dredgings taken off the southeastern end of Jamaica we did not bring up anything of great importance. From Jamaica we were obliged, owing to the strong trades, to keep on toward St. Thomas, without either sounding or trawling till off Porto Rico. During the winter months the trades blow sufficiently hard to make dredging and sounding quite uncomfortable on a vessel of the size of the Blake. We had, therefore, no opportunity of adding anything to the hydrography of that part of the Caribbean Sea.

On arriving at St. Thomas we made a programme for our season's work. This we were fortunate enough to carry out to the letter, as far as the dredging and sounding were concerned. With the exception of the time required for coaling and overhauling the engine at Martinique and St. Lucia, not a single day was lost. Although Lieutenant-Commander Sigsbee, U. S. N., did not command the Blake, yet the improvements which were made this year in the dredging and sounding apparatus were all carried out under his supervision, the vessel having been fitted out for sea before he was relieved by Commander J. R. Bartlett, U. S. N., who commanded the Blake during this winter. It was also my good fortune to find on board the majority of the officers with whom I sailed in the winter of 1877–'78: Lieutenant Sharrer, the executive officer, Messrs. Jacobi, Peters, L. P. Sigsbee, and Dr. Nourse. Now, as before, I was indebted to their cordial interest and efficient assistance, as well as to that of Lieutenant Wallis, Mr. Pemberton, and Mr. E. L. Reynolds, who had joined the Blake for the first time. We thus started under the very best auspices. In the use of the improved machinery, suggested by our former cruise, the experience of the old officers saved us from the annoyances which always accompany the introduction of new methods. The Blake was this year provided with a new double-cylinder reeling-engine, built by Copeland & Bacon, placed at right angles to the reel, on which our steel rope was wound. A small double engine revolved the reel, so that the wire rope was wound independently of the main reeling-engine. The wire rope was led to the port side directly from the main reeling-engine, then by a large wrought-iron sheave along the deck to the mainmast, thence across to the starboard side, and then along the deck to the reel upon which it was wound. This worked admirably, relieving the reel, which thus became a mere spool, from all strain either in winding up or in dredging, the whole strain being taken up by the ten turns of the wire rope on the surging drum of the main reeling-engine. The arrangements for leading off the wire from the bow of the ship, through a large sheave at the end of the dredging-broom, were practically the same as last year. The steel-spring accumulator was, however, replaced this year by one of car-rubber springs, suspended along the foremast, and to this accumulator was attached the pendant running along the dredging-boom which carried the dredging-pulley. As Lieutenant-Commander Sigsbee is soon to publish, in one of the Reports of the Coast and Geodetic Survey, a full account of the dredging and sounding apparatus used on board the Blake, I will not speak in greater detail of our apparatus.

No change was made in our dredges. In the trawls several new forms were tried, but we found that the most satisfactory trawl was of the shape adopted last year, the only important change being the greater height of the runners—30 inches. The bar connecting the runners was used as a frame to stretch a sheet of netting across the whole beam, so as to divide the trawl opening into two halves, each opening into the trap. This enabled us to give a longer lead line to the mouth of the double trawl, without danger of fouling from the lead line of the other side. The only change I could still suggest would be that this lead line should run through rings at the corners of the runners; the strain on the side which fell on the ground would take up the slack of the upper side, and thus increase still further the sweep of the trawl. Our trawl-nets were made much shorter than last year; and for deep work, when so much ooze is always likely to choke the trawl, it would be advisable for a 10-foot beam to have a net of not more than 12 to 15 feet in length.

We also tried dragging a heavy tow-net rapidly over the ground at great depths in hopes of catching the more active crustacea and fishes; but we found that, after all, no deep-sea machine worked better than a trawl, which, when moved rapidly over the ground, at the rate sometimes of two to two and a half miles per hour, invariably brought up a fine harvest of Fishes and Crustacea, in addition to the usual contents of the sedentary and more sluggish forms. Although the deep-sea tow-net was used several times, we never brought up any of the so-called deep-sea Siphonophoræ of Studer, even in localities where they came up on the wire rope.

Captain Sigsbee's new sounding-machine worked admirably, and he has every reason to be entirely satisfied with the improvements he has made upon his former machine.

We carried 6,000 fathoms of new, galvanized steel-wire rope, $1\frac{1}{16}$ inches circumference, made by the Roebling Sons' Company, which, owing to its greater pliability, proved even more satisfactory than the wire rope used on the last cruise. The steel-wire rope continued during our whole cruise to give complete satisfaction, and enabled us, as in the previous year, to work with the greatest possible rapidity consistent with safety and with the proper handling of the trawls and dredges.

We usually lowered in deep water at the rate of four to four and a half or five minutes per 100 fathoms, and reeled in at the same rate. In the many places where we found rough or rocky bottom we used a flat bar of 6-foot beam, to which rings were attached for fastening tangles and a shot. This bar, with from a dozen to fifteen bundles of tangles, proved perhaps our most effective machine in rough bottoms. It rarely fouled, as the dredges or trawls are so apt to do, when working over unfavorable ground. The region over which we chiefly worked this year extended from St. Thomas to Trinidad. Over a limited area like this it was possible to cover the ground very satisfactorily. The work done off the principal islands began usually at the 100-fathom line, and extended into the deepest water off the lee side of the Caribbean Islands. But little could be done in the way of dredging in the passages between the islands or to the windward of them, owing to the strong trades. While working off Barbadoes we undoubtedly obtained a fair representation of the fauna to the windward of the Caribbean Islands, which does not seem to differ from that of the lee side.

During this season we occupied no less than 200 stations, and made over 230 hauls from the 100-fathom line to the depth of 2,412 fathoms. A few hauls were occasionally made in shallow water, but they formed no part of our regular scheme. Although we have obtained from the West India Islands some of the most interesting Invertebrates, yet we did not find the fauna of the eastern extremity of the Caribbean Sea materially different from that of the Gulf of Mexico and the Straits of Florida. It certainly is by no means as rich in animal life at great depths. We rarely got from deep water, say between 1,500 and 2,400 fathoms, the rich hauls so invariably made in the Gulf from depths of between 1,200 and 2,000 fathoms. But we found, what was much more important for our success, that the range of the greater number of the deep-sea species extended within very easy dredging limits, and we soon discovered that by dredging mainly between 300 and 1,000 fathoms we obtained not only nearly all the species extending to the 2,000-fathom line, but obtained them in considerable numbers. This enabled us, of course, to collect a large amount of material, and the collections of this year's cruise, combined with those of the previous year, added to the older collections made by Count Pourtalès on the Bibb, and to those of the Hassler, make our deep-sea collections but little inferior to those of the Challenger.

I was greatly struck with the large number of our species which, if not identical, are at least closely allied to those brought home by the Challenger; and I was specially disappointed at the absence of types not already collected by the great English expedition. I think it can be fairly stated that the great outlines of the deep-sea fauna are now known, and that, although many interesting forms will undoubtedly be dredged in the shallower waters, between 100 and 300 fathoms, we can hardly expect to add materially to the types discovered by the dredging expeditions of the last ten years. As has been well said by Mr. Moseley, of the Challenger, it becomes somewhat monotonous to find constantly the same associations of Invertebrates in the deeper hauls, and it is only in shallower waters that it is possible to keep up one's enthusiasm after a few months' work. I should be inclined, from the experience of the past two years, to carry the range of the deep-sea fauna as high as 300 or 350 fathoms, and to call the littoral fauna the species extending mainly to the 100 or 150 fathom line; from the 100 to the 300 or 400 fathom line extend the species which are neither littoral nor yet have the wide geographical range belonging to species found beyond that depth. But this upper limit of the deep-sea fauna must, of course, depend upon the temperature, and undoubtedly varies greatly from local or partly local causes.

While dredging to the leeward of the Caribbean Islands we could not fail to notice the large accumulations of vegetable matter and of land *débris* brought up from deep water many miles from the shore. It was not an uncommon thing to find at a depth of over 1,000 fathoms, ten or fifteen miles from land, masses of leaves, pieces of bamboo, of sugar-cane, dead land-shells, and other land *débris*, which are undoubtedly all blown out to sea by the prevailing easterly trade-winds. We frequently found floating on the surface masses of vegetation, more or less water-logged and ready to sink. The contents of some of our trawls would certainly have puzzled a palæontologist; between the deep-water forms of Crustacea, Annelids, Fishes, Echinoderms, Sponges, &c., and the mango and orange leaves mingled with branches of bamboo, nutmegs, land shells, both animal and vegetable forms being in such profusion, he would have found it difficult to decide whether he had to deal with a marine or a land fauna. Such a haul from some fossil deposit would naturally be explained as representing a shallow estuary surrounded by forests, and yet the depth might have been 1,500 fathoms. This large amount of vegetable matter thus carried out to sea, seems to have a material effect in increasing, in certain localities, the number of marine forms.

The collections made have all arrived in Cambridge, and will be sent for determination, as fast as practicable, to the naturalists who have undertaken the reports on the different groups of last year's collections. As their preliminary reports are well under way, I need only allude here in general to some of the most interesting types. Among the Foraminifera are a number of the arenaceous types noticed by Mr. Brady in the collections of the Challenger and Porcupine; among the Sponges, a species allied to Pheronema, a small Hyalonema, tufts of large, silicious spicules (Hyalonema proper), covered at one end with Zoanthus very similar to the common Japanese type; fine series of Dactylocalyx, showing the whole mode of growth from a simple globular form, and a gigantic Euplectella. The collection of Starfishes was quite small, and contained nothing worthy of special notice. The collection of Holothurians contained, in addition to the deep-sea forms mentioned in my former letters, a larger number of species than last year—genera allied to Molpadia, Caudina, Echinocucumis, and the like.

Among the Echini, with the exception of the Pourtalesia group, all the types collected by the Challenger are well represented, with a few Spatangoids, hitherto unknown. The number of Echinothuriæ was quite large. Of the Pourtalesia group, but few specimens in good condition were obtained, though the trawl brought up numerous fragments of several of the genera (if I am not mistaken) collected by the Challenger in deep water in the Southern Ocean. The small number of Clypeastroids collected, even when approaching the South American shore, at the 100-fathom line, near Trinidad, where they are so common, shows pretty conclusively that the group, with the exception of Echinocyamus, is an eminently littoral one. A large collection of Comatulæ was made, and a number of specimens of Rhizocrinus were obtained, but only a few were in perfect condition. Of Holopus only a part of a specimen was found. It was collected off Montserrat, and escaped my attention; although, of course, on the lookout for black Holopus, I did not notice this imperfect whitish specimen, which must have been alive, among the numerous Pentacrini with which it came up. Our collection of Pentacrini is quite extensive; we found them at Montserrat, St. Vincent, Grenada, Guadeloupe, and Barbadoes, in several places, in such numbers that on one occasion we brought up no less than one hundred and twenty-four at a single haul of the bar and tangles. We must, of course, have swept over actual forests of Pentacrini, crowded together much as we find the fossil Pentacrini on slabs. Our series is now sufficiently extensive to settle satisfactorily the number of species of the genus found in the West Indies. There are undoubtedly the two species which have thus far been recognized. It is evident that they vary greatly in appearance, *P. Mülleri* being the most variable. I have nothing to add to the general description of their movements given by Captain Sigsbee in my second letter, with the exception of their use of the cirri placed along the stem. These they move more rapidly than the arms, and use them as hooks to catch hold of neighboring objects, and, on account of their sharp extremities, they are well adapted to retain their hold. The stem itself passes slowly from a rigid vertical attitude to a curved or even drooping position. We did not bring up a single specimen showing the mode of attachment of the stem. Several naturalists, on the evidence of large slabs containing fossil Pentacrini, where no basal attachment could be seen, have come to the conclusion that Pentacrini might be free, attaching themselves temporarily by the cirri of the stem, much as Comatulæ do. I am informed, however, by Capt. E. Cole, of the telegraph steamer Investigator, that he has frequently brought up the West India telegraph cable on which Pentacrini were attached, and that they are fixed, the basal extremity of the stem spreading slightly, somewhat after the manner of Holopus, so that it requires considerable strength to detach them.

The collection of Ophiurans is, perhaps, the largest ever made. They seem to play a very important part in determining the facies of a fauna. They occur everywhere, at all depths, and often in countless numbers. I hardly think we made a single haul which did not contain an Ophiuran. They often came up when the trawl brought nothing else. In some places the bottom must have been paved with them, just as the shallows are sometimes paved with Starfishes and Echini, and many species hitherto considered as extremely rare are found to be really abundant. Most, or perhaps all, of the deep-sea Atlantic species obtained by the Challenger have been rediscovered in large numbers. Such rare species as *Sigsbeia murrhina*, *Ophiozona nivea*, *Hemyeuryale pustulata*, and *Ophiocamax hystrix*, were found in plenty. Among the representatives of northern seas may be cited *Astronyx Loveni* (?), while a single specimen of Ophiophyllum represents the great rarities. Of *Astrocnida isidis*, of which only three specimens were known, we have half a dozen. A large Pectinura recalls the shallow fauna of the East Indies, while a new Ophiernus brings to mind the Antarctic deep-sea forms. Finally, the supposed abundance of simple armed Astrophytons is fully confirmed by the various species of Astroschema, and by a new species of Ophiocreas.

The diligent search of Count Pourtalès in the Straits of Florida, the Hassler Expedition, the Challenger explorations, and the two expeditions of the Blake, have evidently brought up the majority of the species of Ophiurans; for among the enormous mass of specimens this time obtained the number of new species is not very great.

The Hydroids and Bryozoa were mainly represented by the same forms as those collected last year, or in former Coast Survey expeditions in the Florida Straits.

The Corals, although abundant in specimens and species, probably contain but few undescribed ones. Very fine specimens of the larger, simple corals obtained by the Challenger Expedition, which were never found in our earlier dredgings in the Gulf of Mexico or Straits of Florida, were dredged here, such as Flabellum, Trochocyathus, Ceratotrochus, &c. Several of the deep sea Actiniæ, described by Moseley, were obtained, generally attached to Sponge spicules, Gorgoniæ, or stems of Umbellulariæ.

The Alcyonarians were also very abundant, and among them we expect to find many novelties. Little can be said of them at first view, as the deep-water forms have thus far received but little attention. One form, growing in a regular spiral, with equidistant branchlets on the outer side of the spire, seems, by this mode of growth, to differ from anything previously known in that order. Several fine specimens of Umbellulariæ were obtained.

Among the Annelids, the tubicolous Annelids are by far the most striking, from the exquisite beauty of some of their tubes, composed of silicious spicules, dead Pteropod shells, and from their strange associations with Corals, Gorgoniæ, Sponges, and even Mollusks. A species of Phorus was frequently accompanied by a large Annelid, comfortably established in the axis of the shell, with the head close to the aperture.

Among the Crustacea we found again the *Bathyonomus giganteus* A. M. Edw., discovered last year. We also brought up from 734 fathoms a Pygnogonium, measuring not less than two feet along the legs when fully extended; a fine *Astacus zaleucus*, and from 416 fathoms a magnificent species, allied to Nephrops, blind, but with rudimentary eye-stalks. An interesting Isopod, with gigantic lateral processes on the posterior segment, was also obtained from 300 fathoms. Many Hermit-crabs occupied tubes of bamboo or cavities in dead wood and Sponges, of which they completely closed the orifice, with one of the large claws flattened like the operculum of a Serpula.

Among the Mollusks the preliminary report of Mr. Dall (in letter No. 2) mentions the most important types. We obtained, however, in addition a good set of Pleurotomaria, one specimen measuring five inches in height, while another was so small that the slit, from which the genus takes its name, existed only as a slight indentation. I hope to supply Mr. Dall with the material necessary for an anatomy of this interesting genus. But by far the most interesting of the Mollusks is a Spirula, from a depth of 950 fathoms, in excellent condition. The small number of Waldheimia collected this year is quite striking. Other species of Terebratulæ were more common. We found, as was usual last year, an immense number of dead Pteropod shells at all depths, playing a most important part in determining the nature of the deep-sea bottom.

The collection of Fishes is excellent; its special characteristic is the large number of Lophioid types it contains. We also obtained many of the genera collected by the Challenger. Some of the rarer pelasgic Fishes, which are occasionally caught at sea, are undoubtedly either full grown deep-sea Fishes or their young. It becomes an interesting problem to know where the young remain, before they become permanently inhabitants of deep water.

The pelasgic fauna of the eastern part of the Caribbean Sea is, during the winter season, rather scanty. Owing to the constant agitation of the water, I had no opportunity, as in the Gulf, to make much use of the surface tow-net. From the number of fragments of Siphonophoræ constantly found they must be very numerous. In the roadstead, under the lee of the islands, there was but little pelasgic life to be found. Everything either remains at a short distance below the surface, or is blown out to seaward of the islands. The phosphorescence, in consequence, is far less brilliant than in the Gulf of Mexico, although occasionally the masses of Ctenophoræ (a species of Mnemiopsis), swimming at different depths, produced a very striking illumination; sudden flashes of light suddenly appearing as if coming from great balls of fire floating a short distance below the surface. The most striking phosphorescent phenomena were produced by a small Annelid allied to Syllis, which moved over the surface of the water with great rapidity, performing the most remarkable gyrations, and tracing its path, which remained phosphorescent for a short time, by a brilliant line of light. Among the deep-water forms several of the species of Gorgoniæ and Antipathes (especially Riisea) showed a bright bluish phosphorescence when coming up in the trawl. One Ophiuran, also, like one of the Mediterranean species mentioned by Panceri, was exceedingly phosphorescent, emitting along the whole length of its arms at the joints a brilliant, bluish-green light.

One of the most interesting results reached by this year's cruise is the light thrown upon the former extension of the South American Continent by the soundings taken while dredging, and those subsequently made in the passages between the islands by Commander Bartlett. These, together with the soundings already known, enable us to trace the outline of the old continent with tolerable accuracy, and thus obtain some intelligible, and at the same time trustworthy, explanation of the peculiar geographical distribution of the fauna and flora of the West India Islands. As is well known, Cuba, the Bahamas, Hayti, and Porto Rico, instead of showing, as we might naturally assume from their present proximity to Florida, a decided affinity in their fauna and flora with that of the Southern United States, show, on the contrary, unmistakable association with that of Mexico, Honduras, and Central America; the Caribbean Islands show in part the same relationship, though the affinity to the Venezuelan and Brazilian fauna and flora is much more marked.

In attempting to reconstruct from the soundings (see sketches No. 33 and No. 34) the state of things existing in a former period, we are at once struck by the fact that the Virgin Islands are the outcropping of an extensive bank. The greatest depth between these islands is less than 40 fathoms, this same depth being found on the bank to the east of Porto Rico, the 100-fathom line forming, in fact, the outline of a large island, which would include the whole of the Virgin Islands, the whole of Porto Rico, and extend some way into the Mona Passage. The 100-fathom line similarly forms a large plateau, uniting Anguilla, St. Martin, and St. Bartholomew. It also unites Barbuda and Antigua, forms the Saba Bank, unites St. Eustatius, St. Christopher, Nevis, and Redonda. It forms an elongated plateau, extending from Bequia to the southwest of Grenada, and runs more or less parallel to the South American coast from the Margarita Islands, leaving a comparatively narrow channel between it and the 100-fathom line south of Grenada, so as to inclose Trinidad and Tobago within its limits, and runs off to the southeast in a direction also about parallel to the shore line. At the western end of the Caribbean Sea the 100-fathom line forms a gigantic bank off the Mosquito coast, extending over one-third the distance from the mainland to the island of Jamaica. The Rosalind and Pedro Banks, formed by the same line, and a few other smaller banks, denote the position of more or less important islands which must have once existed between the Mosquito coast and Jamaica.

On examining the 500-fathom line we thus find that Jamaica is only the northern spit of a gigantic promontory, which once extended toward Hayti from the mainland, reaching from Costa Rica to the northern part of the Mosquito coast, and leaving but a comparatively narrow passage between it and the 500-fathom line encircling Hayti, Porto Rico, and the Virgin Islands, in one gigantic island. The passage between Cuba and Jamaica has a depth of 3,000 fathoms, and that between Hayti and Cuba is not less than 873 fathoms, the latter being probably an arm of the Atlantic. The 500-fathom line connects, as a gigantic island, the banks uniting Anguilla to St. Bartholomew, Saba Bank, the one connecting St. Eustatius to Nevis, Barbuda to Antigua, and from thence extends south so as to include Guadeloupe, Marie-Galante, and Dominica. This 500-fathom line thus forms one gigantic island of the northern islands, extending from Saba Bank to Santa Cruz, and leaving but a narrow channel between it and the eastern end of the 500-fathom line running around Santa Cruz. As Santa Cruz is separated from St. Thomas by a channel of forty miles, with a maximum depth of over 2,400 fathoms, this plainly shows its connection with the northern islands of the Caribbean group rather than with St. Thomas, as is also well shown by the geographical relations of its Mollusca. The 500-fathom line again unites in one gigantic spit, extending northerly from the mouth of the Orinoco, all the islands to the south of Martinique, leaving Barbadoes to the east, and a narrow passage between Martinique and the islands of Dominica and St. Lucia. At the time of this connection, therefore, the Caribbean Sea connected with the Atlantic only by a narrow passage of a few miles in width between St. Lucia and Martinique, and one somewhat wider and slightly deeper between Martinique and Dominica, another between Sombrero and the Virgin Islands, and a comparatively narrow passsage between Jamaica and Hayti. The Caribbean Sea, therefore, must have been a gulf of the Pacific, or have connected with it through wide passages, of which we find the traces in the Tertiary and Cretaceous deposits of the Isthmus of Darien, of Panama, and of Nicaragua. Central America and northern South America at that time must have been a series of large islands with passages between them from the Pacific into the Caribbean. It is further interesting to speculate what must have become of the great equatorial current, or rather of the current produced by the northeast trades. The water banking up against the two large islands then forming the Caribbean Islands must, of course, have been deflected north, have swept round the northern shores of the Virgin Island, Porto Rico, and Hayti, and poured into the western basin of the Caribbean Sea through the passage between Hayti and Cuba. This water being forced into a sort of funnel by the 500-fathom line forming the southern line of the Great Bahama Island, which connected nearly the whole of the Bahamas with Cuba, and formed a barrier to the western flow of the equatorial current, this must, therefore, for the greater part, have been deflected north, and either swept in a northeasterly direction, as the Gulf Stream now does, or round the north end of the Bahamas, across Florida, which did not then exist, across the Gulf of Mexico, and into the Pacific over the Isthmus of Tehuantepec. To

Commander Bartlett's interest in this subject I am indebted for the first information respecting the lines run between the islands:

[Extract from letter of Commander J. R. Bartlett, U. S. N.]

"I connected the islands by running traverses across the ridges. From St. Vincent to St. Lucia the ridge was only from 150 to 170 fathoms below the surface, with a channel of 400 fathoms near St. Vincent. The channel between St. Lucia and Martinique had 500 fathoms in mid-channel, sloping upward to each island. The channel between Martinique and Dominica was a tough one, and I thought I should never find a ridge. The soundings increased regularly on a ridge to 300 fathoms in mid-channel, where I got a sounding of 883 fathoms, and then 1,000 fathoms; beyond this the ridge was some ten miles to the westward, with an average depth of 400 fathoms, but I found two peaks with only 40 fathoms. The deep water from the Caribbean Sea makes in between Guadeloupe and Montserrat, but I found a ridge of about 300 fathoms connecting Antigua with Guadeloupe. In this channel I also found a peak with only 40 fathoms. I finished up the line connecting Saba Bank with St. Croix. I found the connection perfect, but the ridge has 700 fathoms of water on it near St. Croix. There is 1,000 fathoms three miles north, and 1,800 fathoms five miles south of the ridge. I ran a line from Dog Island to White House Shoal, and back to Sombrero. Here I found a channel about ten miles wide, with 1,100 fathoms. The temperature was 38° at 1,100; outside 37½° at 1,600, and 36½° at 2,500. I shall run a number of lines from St. Thomas to Sombrero to be sure that this channel connects with the deep water off St. Thomas. I ran a line of soundings from the south end of Dominica to Avis Island. The soundings were regular at 1,000 fathoms to within ten miles of Avis Island."

The soundings made by Commander Bartlett, after I left the Blake, to determine the ridges uniting the various islands between Sombrero and Trinidad, show plainly that the cold water of the Caribbean can only come in through the passage between Sombrero and the Virgin Islands, which is about 1,100 fathoms, with a bottom temperature of 38°, while the 500-fathom line, as I have said, forms a gigantic island of all the islands to the south of Sombrero, including Dominica, with a narrow passage of 1,000 fathoms between it and Martinique; the 500-fathom line again uniting into one large spit, as a part of South America, all the islands to the south of it. Thus the bulk of the water forced into the Caribbean Sea has a comparatively high temperature—an average, probably, of the temperature of the 300-fathom line. The cold water of the Atlantic is, however, again forced into the western basis of the Caribbean through the Windward Passage, and all this through the Yucatan Channel, between Cape San Antonio and the Yucatan Bank. It is, therefore, incredible that with this huge mass of water pouring into the Gulf of Mexico, there should be anything like a cold current forcing its way uphill into the Straits of Florida, as has been asserted on theoretial grounds. The channel at Gun Key can only discharge the surplus by having a great velocity.

Mr. Garman, who as usual accompanied me, remained in the West Indies, after we left the Blake at Barbadoes, for the purpose of making collections of reptiles and fishes, with a view of throwing additional light on the former connections of the islands, as I have here attempted to trace it. One of the most interesting of the reptiles we collected is a gigantic land tortoise found at Porto Rico, differing only in size from the land turtle still found on Trinidad and adjoining parts of South America. It is closely allied to the gigantic turtles of the Galapagos, and to the fossil land turtles, of which fragments have been described by the late Professor Wyman. These were collected by Mr. A. Julien at Sombrero, in the phosphate beds of the island.

CAMBRIDGE, *May* 10, 1879.

APPENDIX No. 7.

DESCRIPTION OF THE DAVIDSON MERIDIAN INSTRUMENT, BY GEORGE DAVIDSON, ASSISTANT UNITED STATES COAST AND GEODETIC SURVEY.*

In the geographical reconnaissances by the Coast and Geodetic Survey on the Pacific Coast for the determination of the latitudes of numerous points and their differences of longitude from well-established stations, accuracy of results and rapidity of manipulation were especially demanded.

The instruments first used in such work were the 26-inch Würdemann portable transit and the 45-inch zenith telescope, with a single observer, and only one night for observation at each station, frequently landing through the surf at evening and returning to the vessel before morning. For the support of the instruments a wooden block was sunk 2½ feet in the ground, and stood 2½ feet above the surface, and a small portable wooden observatory was used for protection. These required about twenty minutes' labor to be in readiness for the instruments. The transit was placed in the meridian, and observations for instrumental and clock corrections made therewith. The transit was then replaced by the zenith telescope for latitude observations, which generally embraced twelve pairs of stars.

In 1853 this special duty led me to make the proposition to secure a fine level to one of the finders of the transit, and to add a micrometer with vertical movement of the horizontal thread, so that after the completion of the transit observations the same instrument would be at once available for the latitude observations by the zenith telescope method. This involved the lifting of the telescope from its bearings after the observation upon the first star, and reversing the transit axis and directing the telescope to the same zenith distance on the opposite side of the zenith for the second star.

In January, 1858, drawings of such an instrument, with prismatic telescope, &c., were made for the Superintendent of the Coast Survey, and are on file in the archives.

In my geographical reconnaissance along the coast of Alaska in 1867, the peculiarities of the climate especially demonstrated that rapidity of adjustment and of observation were essential to success, and a study of the problem led me to the present improved form of instrument, whereby the zenith telescope as an independent instrument is abandoned, because the new meridian instrument combines all the essentials of the transit and zenith instruments, and affords means for the accurate determination of the instrumental and clock corrections, for the determination of the latitude by meridional zenith distances, and for the determination of the astronomical azimuth of a given mark by observations upon a close circumpolar star at any hour angle.

The *main idea* in this new form is that the cast-iron horizontal frame of the transit stand is divided into two parts horizontally, and that the upper part, for carrying the supports of the transit axis, moves on the lower part by means of a short but large central vertical axis; that the lower frame carries the foot screws; that the two frames can be very firmly clamped together directly over each other, or when making a moderately small angle with each other (15° or 20°); and that the ends of the frames are parts of the same circle, with graduations on the lower and a vernier on the upper frame.

The short vertical axis would, *per se*, afford doubtful stability, but the bearings of the circular ends of the two frames are ground to each other where they come into contact, and, therefore, in latitude observations, the upper frame bears upon the lower as when they are clamped for transit work.

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* See Appendix No. 8, United States Coast Survey Report of 1867, for first printed description.

The size of each frame is 11⅜ inches broad, with an extreme length of 21¼ inches, the ends being arcs of a circle of that diameter.

The first advantage of a double frame is the greater rapidity with which the instrument can be adjusted in the plane of the meridian, or in the plane of the vertical of a close circumpolar star; for, when once levelled, no change of position of the lower frame is required, and repeated levellings after each approximation are avoided. The telescope carried by the upper frame is moved smoothly and uniformly in searching for the star. This movement of the upper frame is effected by means of a horizontal tangential screw attached to the lower frame, and which can be thrown into gear with a depressed screw cut in a brass plate upon the external circular end of the upper frame. When the star is found it is followed with the tangent screw until within reach of the finer azimuth screw. The two frames are then strongly clamped together by four large capstan-headed steel screws, which pass through slots near the four angles of the upper frame, and screw into the lower frame. Then the final adjustment for the meridian is made with the azimuth screw, after a precautionary re-examination of the horizontality of the transit axis level. Another and very decided advantage in the use of the double frame is in placing the instrument in or very close to the plane of the meridian by observations on Polaris, even in daylight and when away from the meridian. Knowing approximately or closely, as the case may be, the hour angle of the star, and computing its zenith distance and azimuth,* the telescope is pointed to the required altitude, and moved by the tangent screw in azimuth until the star is detected. The azimuth of the star at that hour angle is then laid off by the arc graduation on either end of the frame, and the frames clamped. The telescope is then in the plane of the meridian, and transit observations may be commenced.

After the transit observations are furnished, the stops are adjusted upon the lower frame, by which the position of the meridian is readily found; the four clamping screws are relieved, and the upper frame is free to move on the lower, and observations for latitude are at once commenced and are made in precisely the same manner as with the zenith telescope. If transit observations are again needed, the upper frame is simply clamped at the stops.

With telescopes of equal power this new form has advantages over the best form of the zenith telescope in the stability of the supports and the longer transit axis of the telescope.

For astronomical azimuths at the main stations of the triangulation, the instrument affords some decided advantages in being clamped near the vertical of a close circumpolar star at any hour angle, and thus allowing measurements to be made between the star and the azimuth mark or collimator with the ocular micrometer.

The latest arrangement of the instrument has three finder circles. The larger one, reading to 10″, is furnished with a delicate chambered level for the latitude observations, and is placed on the telescope tube between the transit axis and the objective; the two small finders are of four inches in diameter, furnished with small and proportionately delicate levels, and read to one minute of arc.

The telescope also carries a fine ocular micrometer, capable of ready adjustment in the vertical and horizontal planes. When the micrometer is horizontal and clamped, transit threads vertical, a minute steel stop-screw abuts against a small steel stop to recover the position after the clamping has been freed and the micrometer used in the vertical. When the micrometer is in the horizontal position, there are nine vertical transit threads at equatorial intervals of 10 seconds for the transit observations, and also the micrometer thread, which is parallel with the middle transit thread. The adjustment of the system is made in the usual manner.

When the micrometer is turned 90° for latitude observations, the horizontality of the micrometer thread is adjusted by means of a collimator, by a slow moving star, or by a sharply defined terrestrial object. When clamped in this position a second minute steel stop-screw is fixed so as to recover the position after the clamping has been freed.

The diagonal eye-piece has a parallactic movement permitting a range of about fifty minutes of arc, although a range of twenty minutes is very rarely used in latitude observations.

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* Instead of computing these values, take them directly from table of "Azimuth and apparent altitude of Polaris for field use in placing the meridian instrument in the plane of the meridian, computed with polar distance 1° 22′ and mean refraction, by George Davidson, Assistant United States Coast Survey." Appendix XXII of the United States Coast Survey Report for 1870.

In order to measure the inclination of the transit axis in transit observations when the telescope is pointing to or near the zenith, where the ordinary striding level is unavailable, a hanging level was devised for that purpose; but in practice the striding level is preferred, and the form of the transit axis pivots is accurately determined by levelling with the telescope removed from the transit axis.

To prevent unequal expansion of the transit axis pivots by the heat from the illumination lamp both pivots are made hollow, and a lamp used at each extremity, while a very small reflector is inserted at the intersection of the lines of the transit and optical axis.

To prevent irregular cutting of the pivots from grains of sand, &c., the V's are faced with plates of agate having a curved surface of large radius.

One of the Vs for the transit axis pivots has a horizontal movement by means of a large but fine micrometer screw; but in order that no unknown movement shall take place in this V during observations, a horizontal slot has been cut in the body of the V parallel with the transit axis, and a clamping screw passed through the outer brass guide-plate, through this slot, and into the inner brass guide-plate. When the V is in the desired position this clamping screw is tightened, and the V becomes as secure as the pillar itself.

The second V for the transit axis pivots has a vertical movement by means of a large fine screw and two heavy steel guide-pins, &c. Having satisfied myself that this was equally objectionable with the older forms of the azimuth V, even when side guide-pieces were also added, a vertical slot has been cut in the body of the V parallel with the transit axis, and a clamping screw passed through the outer brass guide-plate which I had added, through the slot and into the inner brass guide-plate, which I had also added. When the V is in the desired position this clamping screw is tightened, and the V becomes as secure as the pillar itself.

In the work of geographical reconnaissance, and also in the geodetic work in the great mountain chains of the United States, the question of size, weight, and portability of the instruments in use is a very important one, and therefore I have not introduced reversing apparatus to the instrument. But to prevent the wearing of the pivots of the transit axis by pressure upon the V's and by the weight of the level, graduated springs can readily be secured to the uprights or pillars carrying the V's, and press upward on the under side of the transit axis near the pivots, or on the under side of that part of the pivot which projects beyond the V's. To the inverted V's of the heavy striding level of United States Coast Survey transit No. 3 I have adapted an analogous arrangement whereby most of the weight of the level is borne on the upper surfaces of the V bodies.

In order to make the instrument practically available for the double duty of transit and latitude observations, the telescope must be able to show stars of the seventh magnitude with fair illumination, and to bear a power of at least 100. It had been found that the portable transits of 26 inches focal length would fairly show stars of the sixth magnitude and stand a power of 65. The Troughton and Simms zenith telescopes of 45 inches focal length and 2¾ inches aperture sometimes failed to show stars of the seventh magnitude, and certainly were unavailable for smaller stars.

When the first instrument of the new form was projected it was decided to try a telescope of 30 to 32 inches focal length, and to properly proportion the cast-iron stand thereto. The telescope of the new instrument has a focal length of 31¼ inches, with an object glass of 2⅝ inches diameter, and gives good definition with a power of 100; the length between bearing points of pivots being 17½ inches, and the height of the transit axis 17¼ inches above the horizontal frame.

In experimenting with the instrument for stability when three foot-screws were used I found that horizontal strains upon the vertical support over the single foot-screw had far greater effect in the derangement of its adjustments than with similar strains upon the support over the two foot-screws. The third foot-screw was abandoned, and two foot-screws added at that end and placed similarly to the two at the other end. Of course this involved the practicability of leveling the instrument so that equal bearing should be borne by each of the four foot-screws. This was soon found to be practicable and very satisfactory. The tests consisted in placing the instrument in adjustment, with the striding level on transit axis, latitude level set, and telescope collimated; then equal strains were made upon the supports by spring balance. The test can readily be made without the spring balance. But another decided advantage is obtained with the four foot-screws in this instrument in the level adjustments for the latitude observations. In transit observations the horizontality of the transit axis may be established in less time by three foot-screws than by four; but for the latitude observations it is also required that the vertical axis shall be in the vertical, and the adjustments are much more readily done with the four foot-screws.

The illustration (No. 35) exhibits the instrument with the micrometer in position for transit observations, and with the two frames clamped together by the four capstan-headed screws, two of them being shown. The tangent screw, for moving the upper frame, is also shown in gear. The pin below is for throwing it out of gear, and the milled head key is removed after the instrument is set. There are shown also the small stub set screws of the eye tube for adjustment of horizontality of micrometer thread.

The following memoranda from the record books of my party will indicate some of the practical working points of the instrument. The experiments were made simply for practice during daylight:

SAN FRANCISCO, CAL., *January* 27, 1879.

WASHINGTON SQUARE OBSERVATORY.

(Observer, G. D.)

United States Coast Survey meridian instrument No. 1 set up on spare pier.
Transit axis levelled, and level adjusted very nearly.
Then, with telescope pointing *North*—

Transit axis level reads:		Latitude level reads:	
E. end	W. end	N. end	S. end
30.	30.	39.	39.

Reversed upper frame, telescope pointing *South*—

East end very high; adjusted by estimation, half by foot-screws, half by V screw. South end very high, and bubble against chamber; adjusted by estimation, roughly, half by foot-screws and half by level circle.

Then the levels read:

E.	W.	N.	S.
30	30	36	40

Reversed upper frame, telescope pointing *North*—

E.	W.	
34	26½	North end of bubble against chamber; adjusted by estimation, as before.

Adjusted as before, then the levels read:

30	30½	40	38

Reversed upper frame, telescope pointing *South*—

E.	W.	N.	S.
26½	34½	33	45

Adjusted as before, then levels read:

30½	30½	39	39

Reversed upper frame, telescope pointing *North*—

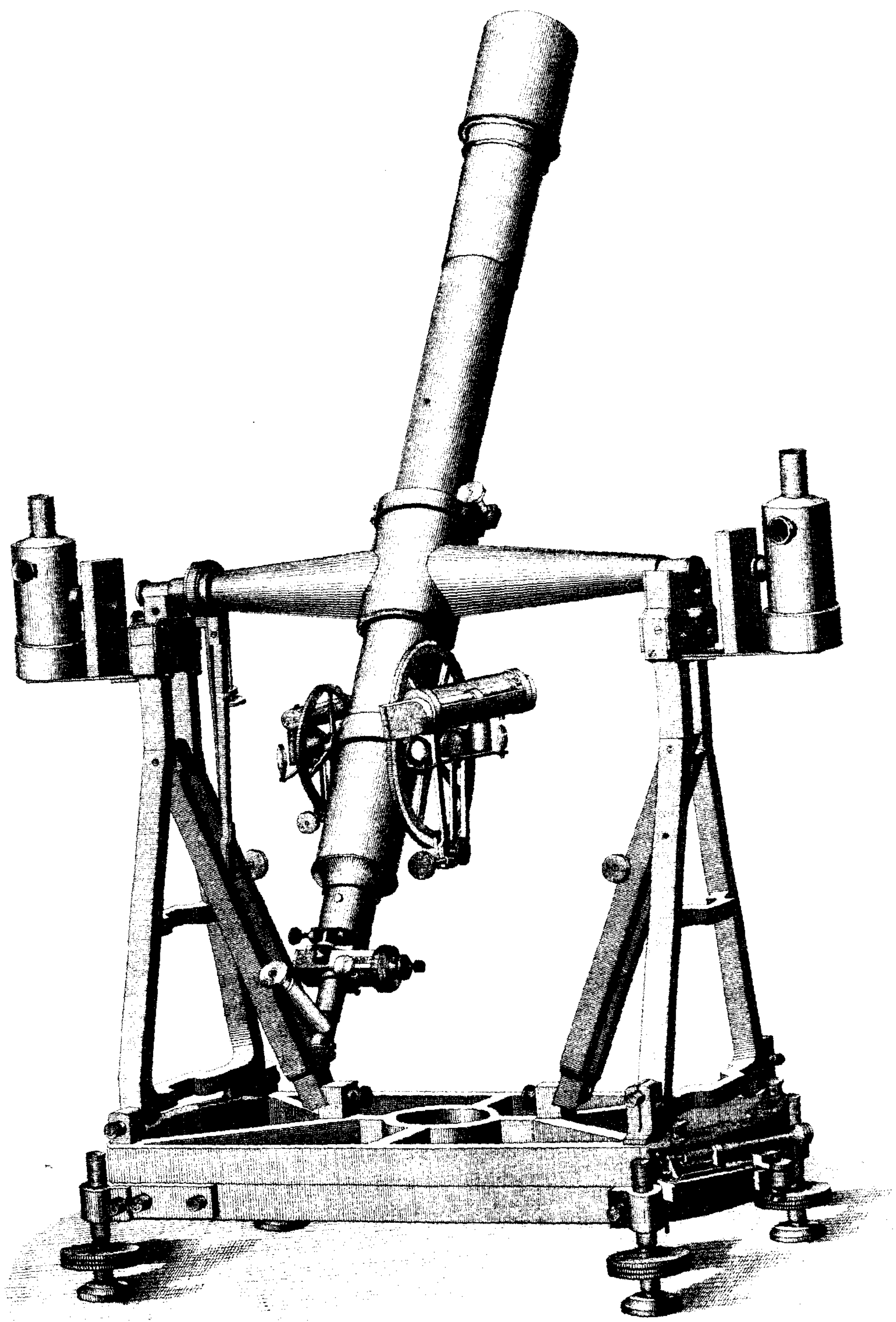
E.	W.	N.	S.
27½	33	42½	36

Reduced this as before, and considered instrument sufficiently near adjustment for work.
Found circular level of upper frame in adjustment.
The above work occupied about ten minutes of time.
At $3^h\ 00^m$ p. m. light clouds flying over and cannot see Polaris.

Turned upper plate about 50° and pointed telescope out of the observatory to see top of flag-pole and test setting of finders and latitude circle. In error one and a half minutes of arc; reduced.

January 29 at 2 p. m. cannot see Polaris. Set up vertical circle, U. S. Coast and Geodetic Survey No. 57, on a box south of meridian instrument, for a collimator.

$2^h\ 30^m$ p. m. found the instrument had an error of collimation for both transit and latitude observations.



THE DAVIDSON MERIDIAN INSTRUMENT

U.S. COAST AND GEODETIC SURVEY.

(REPORT OF 1879.)

First. Adjusted verticality of middle transit thread;* reduced collimation thereof to a small fraction of second; tested verticality; small steel set-screw up to the stop.

Second. Revolved the eye tube carrying the micrometer 90°; found second set-screw out of adjustment; adjusted horizontality of micrometer thread; set-screw adjusted to stop; adjusted collimation; then re-examined horizontality of micrometer thread; made slight corrections by set-screw; re-examined collimation.

Third. Turned back the micrometer 90°; re-examined verticality of middle transit thread and corrected it for a slight error by the two opposing screws. Set screw up to the stop. Re-examined collimation and found it correct.

Fourth. Re-examined horizontality of micrometer thread; correct. Re-examined collimation; correct, Then, at 4 p. m., found Polaris; star very unsteady, diffused, and broken up, but instrument placed near the meridian thereby.

January 31, at 2^h 50^m p. m., turned instrument off meridian and found Polaris; transit axis very nearly level; then from the altitude and azimuth table of Polaris,† with the approximate time, determined the azimuth of the star; moved the upper frame through the required angle and clamped the frames; telescope is now in the meridian, or sufficiently near so for observations, which may be commenced at sunset for the smaller stars, or earlier for the larger ones. In this case a discussion of part of the transit observations shewed that the instrument pointed $1.^s19$ west of north. The stops were adjusted to the lower frame in order to be ready for the latitude observations. A single stud stands out one-eighth of an inch from one end of the upper frame, and care must be taken in adjusting the stop on each end of the lower frame, so that when the telescope is pointing either south or north the stud is against that side of the stop, by which either star may be followed in azimuth off the meridian if necessary by moving the upper frame.

For latitude observations after the transit work is finished, the four heavy screws clamping the two frames are removed. The clamp securing the micrometer tube, when the set-screw is up to its stop, is loosened, the micrometer turned 90° until the stop comes to the second set-screw, and the clamp tightened; the graduated head of the micrometer is downward, and the instrument is ready for work. I find that it is preferable to set the mean of the zenith distances of the given pair of stars by one of the small finder circles, clamp the telescope to the required altitude, and then move the latitude circle until the level thereof is central. This avoids handling the more delicate circle and its attachments, and keeps the level free from the near approach of the reading lamp or candle.

To indicate how rapidly the change may be made from the transit observations to the latitude observations I give an example from the experiment record.

A complete list of transit stars was selected to determine all the instrumental errors and the clock correction. The list ended with the close circumpolar Radcliffe 1311, of the 6½ magnitude I was my own recorder, and had no assistance whatever. I had made out a latitude list of twelve pairs, of which the first pair was Rad. 1311 north and B. A. C. 1544 (5 mag.) south. This pair had a meridional difference of zenith distance of about fourteen minutes, and it was desired to read each star equally distant from the center of the micrometer rack. Rad. 1311 was observed for time upon the first five transit threads, thus including the meridional thread. The micrometer was unclamped, turned 90° to the stop, clamped. The latitude circle had been placed nearly in adjustment, but the telescope was moved slightly in altitude to observe the star near a given part of the micrometer; the latitude level was set and clamped to suit this change. Then three micrometer measures were made upon the star,‡ and the chronometer times and the micrometer readings recorded in sixty-one seconds, and finally the level was read. The third observation was made at 2^m 20^s after the transit of the middle thread, leaving 2^m 42^s to the next star of the pair. The four frame clamping-screws were now removed, the instrument turned to the south, and three micrometer measures and the readings and times noted and level read. Similar observations were made upon

*To the larger transit and to the zenith telescope I have adapted a tangent screw near the eye end of the telescope, at right angles to the optical axis, by which a minute rotary motion can be given to the eye tube, so as to bring the threads vertical or horizontal, as required. In the present case I used the small steel set-screw for the same purpose.

†Already referred to.

‡Usually only one micrometer pointing is made.

three nights, and lest it might be supposed that there were changes of level in making the consecutive readings on the same star, five measures were made on one night upon the North star, and the level read at the third and fifth observations as follows:

	Level: N. end.	S. end.
At third observation,	41.3	34.7
At fifth observation,	41.4	34.6

Indicating the stability of the instrument and the absence of flexure in the telescope or in the vertical clamp.

After the twelve pairs of latitude stars were observed, the two frames were clamped when the stud was at the stop; the micrometer turned 90° to the set-screw and clamped thereat, ready for the transit work of the next night.

Objection has been made to the use of this method of determining the latitude on geographical reconnaissance, on account of the length of time required for the different operations. The actual time and latitude lists observed are appended, to indicate what may be done in a reasonably short time. It will be noticed that the last eight stars for time and azimuth and collimation occupy but one hour, and the first nine pairs for latitude but one hour and twenty-three minutes, in all two hours and twenty-three minutes.

Previous discussions of actual field work show that the probable error of the clock correction does not exceed $\pm$ 0s.03 when eight stars have been employed, and that with twelve pairs of latitude stars the probable error of the latitude therefrom does not exceed $\pm$0.″20.

FORM OF WORKING TRANSIT LIST.

Author.	Star.	Mag.	Chronometer.	Zen. Dist.	Remarks.
			Feb. 1st, 1879 *h. m. s.*	° ′	
A	α Persei	2	3 15 22	N 11 38	Two sets levels before star.
G4	Groom 642	6	15 14* 26 34 37 44	N 48 27	Lose I, VII, VIII, IX threads. Two sets levels on star.
B	Groom 716	5½	31 22	N 25 02	Lose I, II, VIII, IX.
A	δ Persei..........	3	33 00 34 00 34 05	N 9 36	
C	δ Eridani	3½	36 23 37 05 37 50	S 47 56	
A	η Tauri	3	39 11 40 00 40 45	S 14 05	
A	5 Persei...........	3	45 22 46 13 47 03	S 6 17	One set levels between stars.
C	750 Groom	6	50 31 59 14	N 47 26	Two sets levels on star.
			REVERSE.		
C	750 Groom	6	4 01 17 07 56	N 47 26	Two sets levels.
C	o2 Eridani.........	4½	08 38 09 22 10 05	S 45 37	
B	δ1 Tauri...........	4	14 53 15 40 16 24	S 20 33	Level direct.
B	1 Camel...........	6	20 58 22 10 23 23	N 15 51	Level reversed.
A	α Tauri	1	27 55 28 40 29 24	S 21 32	Level direct.
B	τ Tauri	4½	33 54 34 40 35 27	S 15 05	Level reversed.
B	4 Camel...........	5½	36 22 37 40 38 58	N 18 44	
G4 †	Rad. 1311.........	6½	39 46 49 21	N 48 00	Two sets levels.

* The smaller figures indicate the times of transit of the first and ninth threads.

† ☞ After fifth thread turn micrometer for latitude observation.

FORM OF WORKING LATITUDE LIST.

Star. B. A. C.	Mag.	N S	Æ h.	m.	s.	Z D °	′	Microm.	Setting. °	′	
Rad. 1311	6½	N	4	49	05	48	01	27	48	07	N
1544	5	S		54	07	48	14	13			
1585	6	N	5	03	17	35	20	12	35	12	N
1611	5	S		06	58	35	05	28			
1636	6	S	5	12	02	3	58	18	3	55	S
1645	6	N		13	15	3	53	22			
1705	6	N	5	22	12	19	20	20	19	19	N
1726	5½	S		25	08	19	18				
1778	6	S	5	32	14	11	58	20	11	58	S
1804	5½	N		36	33	11	58				
1821	6	S	5	39	48	22	02	20	22	03	S
1849	5	N		44	07	22	04				
1867	7½	S	5	46	27						
1876	5	S		47	13	17	33	20	17	32	S
1887	6	N		49	40	17	31				
1953	7	S	5	59	45	22	15	20	22	15	S
1979	5	N	6	04	47	22	14				
2009	6	S	6	08	27	21	37	20	21	37	S
2020	6	N		11	19	21	37				
2087	6½	S	6	21	01	42	05	15	42	00	S
2095	5½	N		25	38	41	54	24			
2144	6	S	6	28	15	30	08	13	30	01	S
2198	5	N		38	19	29	54	27			
2249	6½	N	6	46	53	19	55	20	19	55	N
2265	7	S		49	14	19	54				

APPENDIX No. 8.

COMPARISON OF LOCAL DEFLECTIONS OF THE PLUMB-LINE IN LATITUDE, LONGITUDE, AND AZIMUTH, AT STATIONS OF THE OBLIQUE ARC ALONG OUR ATLANTIC COAST, AS DEVELOPED ON BESSEL'S AND CLARKE'S SPHEROIDS. BY C. A. SCHOTT, ASSISTANT COAST AND GEODETIC SURVEY.

COMPUTING DIVISION COAST AND GEODETIC SURVEY,
December 9, 1879.

DEAR SIR: The development of the primary triangulation to the southward and westward of Washington, D. C., between the years 1868 and 1878, and which gave an additional extent of nearly 600 statute miles to the oblique arc along our Atlantic Coast, brought out the fact that the geodetic latitudes, used up to the present time in this region, are no longer in close accord with the astronomical measures made during the above period on the southwestern extension of this arc. Before your directions, attached to my report of May 19, 1879, could be carried out, it was essential to submit the local deflections of the plumb-line* of the primary triangulation between Maine and Georgia to a new discussion, and, further, to render this discussion useful for the elucidation or settlement of the important question whether the Besselian or Clarke's spheroid better suited the figure of the earth's surface along which our arc extends. This of course also involved the discussion of the geodetic azimuths, as well as the geodetic longitudes, and it is this last consideration which has delayed this report some months, since the important result of the telegraphic longitude of Atlanta, Ga., was absolutely needed for the completion of the necessary data.

The local deflections were brought out by myself in November, 1878, and the discussion was completed last March, requiring now only the introduction of the new result for telegraphic longitude of Atlanta, Ga., just reached by Mr. M. Baker and Mr. E. D. Preston. The position computation on Clarke's spheroid was made by Mr. J. G. Porter.

DETERMINATION OF THE STANDARD GEODETIC LATITUDE.

The geodetic latitudes of the primary triangulation have necessarily been changed from time to time as the field and office work progressed. Every additional astronomical latitude and every refinement in the adjustment of the triangulation produces a small correction to the value previously used. The last general change was made in 1863† when the standard latitude of Blue Hill, Mass., was increased by 0″.240, and the value so increased (42° 12′ 42″.140) was introduced into the geographical positions about 1866. This value rests on 20 astronomical stations between Cooper, Me., and Sandford, Conn. Our present triangulation comprises 58 stations,‡ and extends to Georgia. The utilization of this accumulated material alone would have demanded a new discussion, even apart from other considerations. The immediate occasion, however, which determined me a year ago to take up this subject was the following fact: When the northern geodetic latitude was carried southward through the Blue Ridge triangulation into North Carolina, and there compared at the junction line with Assistant Boutelle's southern latitudes brought up from Georgia and South Carolina, a discrepancy of 3″.95 appeared; § the triangulations seemed to overlap, and thus plainly indicated that the triangulation had been developed upon a spheroid too small to correspond to the earth's size. The conclusion supposes that our unit of length is correct, but about this there could be no doubt. To determine a standard geodetic latitude relative to an

* Commonly known as station-error, a misleading name, since there is no error in the common acceptation of the word.

† Report of September 17, 1863, to Superintendent A. D. Bache. In this report the values depending on Bessel's & Clarke's spheroids are already compared, but no decided result could be reached on account of the small extent of the arc employed.

‡ Sixty in January, 1880.

§ Report of November 15, 1878.

adopted spheroid (which should be a close approximation to the average figure and to the size of the earth), we use the mean result of all astronomical latitudes reduced geodetically to the middle latitude of the arc, or we satisfy the condition that the sum of the differences of the astronomical and geodetic latitudes shall be zero, as expressed by $\Sigma (A - G) = 0$; that is, the latitudes will balance about the middle point. Practically the astronomical latitudes are irregularly distributed, and in order to obtain a correct result the further condition that the astronomical latitude stations should be *equally distributed* over the arc should be satisfied in some way, otherwise the local deflections of the plumb-line would introduce unequal weights, and thus displace the position of the triangulation on the surface of the spheroid. For instance, near and north of Philadelphia there is a wave of deflection between 6″ and 7″, and if several or more than the average number of astronomical stations *were located within its influence* an erroneous value for the standard geodetic latitude would necessarily be obtained, since the result, as found by $\Sigma (A - G) = 0$, would accommodate itself to this abnormal feature. To secure equal weight to each part of the arc and at the same time make use of all the astronomical stations, no matter whether they are greatly crowded together in number in one place (as near Washington) or sparsely inserted in another (as in North Carolina and Virginia), the following method was employed: The local deflections were plotted as shown by dots in the accompanying diagram, and a smooth curve was drawn between and following them as closely as possible. To do this a mere free-hand curve would be too arbitrary and unsatisfactory, but by applying the process of *successive means*, and limiting ourselves to the third order of means, the smooth curve of local deflections in the meridian was obtained, as shown on the diagram. Ordinates to the central axis, marked 0, which represents the undisturbed or geometrical zenith referring to Bessel's spheroid, were then drawn, or supposed drawn, say for every quarter or for every fifth of a degree of latitude. Thus in the latter case 5 ordinates intersecting the smooth curve of deflections and representing magnitude of deflection, equally distributed, were obtained for each degree of latitude, and the 56 values so found were made to take the place of the 58 differences* A — G depending directly on the observed latitudes. This treatment supposes a continuity, in a general way at least, of the larger waves of deflection as distinct from features quite local, the two however combining to produce the more or less irregular position of dots of deflection, as shown in the diagram. When the principal part of the *local* deflections is removed by the process explained, there remains the wavy outline of the larger or more extended disturbances which have their origin in causes operating in the same sense over large tracts of country. That the greater part of the deflections of the plumb-line may result from unequal distribution of the density of the earth's crust *below* the surface, and the smaller part from its visible irregularities, has been sufficiently demonstrated, and little would be gained for our purpose were we to attempt to correct for the supposed disturbing effect of the presence of the sea, or for surrounding hills.

Appendix A, Table 1, contains in tabular form the astronomical latitudes, and needful information connected therewith.

Appendix A, Table 2, contains the astronomical and corresponding geodetic latitudes, the latter as they actually stand at present in our registers of positions. The last column contains the differences A — G, and the deflections are shown by dots on the diagram. Taking the successive means† of the latitudes, also of the observed apparent deflections corresponding to them,

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* Sixty in January, 1880.

† These may be computed directly, or checked by $\triangle = \frac{1}{8} (\triangle_1 + 3 \triangle_2 + 3 \triangle_3 + \triangle_4)$, and moving down the column, step by step, always keeping 4 consecutive numbers in sight for operation.

the following table of the systematic deflections in the meridian has been formed from ordinates read off the diagram:

Table of systematic apparent deflections in the meridian.

Lat.		Lat.	$\Delta\phi$	Lat.	$\Delta\phi$	Lat.	
° ′	″	° ′	″	° ′	″	° ′	″
45 00	+0.3	42 12	−1.9	39 24	+3.6*	36 36	+6.4
44 48	−2.4	42 00	−1.2	12	+3.9*	24	+6.8
36	+1.3	41 48	−1.0	39 00	+0.4	12	+7.2
24	+1.1	36	−0.9	38 48	+2.2	36 00	+7.4
12	+0.1	24	−1.1	36	+1.4	35 48	+7.6
44 00	+1.0	12	−1.4	24	+1.6	36	+7.7
43 48	+1.6	41 00	−1.6	12	+2.6	24	+7.3
36	+2.0	40 48	−1.0	38 00	+4.1	12	+6.6
24	+1.7	36	+1.0	37 48	+4.8	35 00	+5.7
12	+1.2	24	+3.5	36	+5.2	34 48	+4.7
43 00	+0.3	12	+5.8	24	+5.3	36	+3.5
42 48	−0.4	40 00	+6.2	12	+5.5	24	+2.8
36	−1.7	39 48	+3.0	37 00	+5.7	12	+3.2
42 24	−3.1	39 36	+2.7	36 48	+6.0	34 00	+4.4

* Introducing the new latitudes, "Sugarloaf," Md., and "Atlanta," Ga., the above $\Delta\phi$ become +4″.0 and +5″.2. The value $\frac{\Sigma\Delta\phi}{56}$ changes to +2″.685 and the standard latitude becomes 39° 35′ 36″.722. The correction obtained by the ordinary process or +1″.57 is changed by the introduction of "Sugarloaf" and "Atlanta" to +1″.72. The change in the adopted standard latitude would only amount to +0″.030 and has not been introduced. [Note appended in October, 1880.—SCH.]

This table, as well as Table 2, Appendix A, shows the unequal balance of the geodetic latitude as at present in use; the correction to it is by above $\triangle$'s, $\frac{\Sigma\triangle\varphi}{56} = +2''.655$. Had we followed the ordinary process, taking no cognizance of the distribution of the astronomical latitudes, the correction would have been + 1″.57. The new standard geodetic latitude for the whole arc, and for the station *Principio*, which is nearest to its middle point, becomes accordingly

$$39^\circ\ 35'\ 34''.037 + 2''.655 = 39^\circ\ 35'\ 36''.692 = \varphi_0$$

The probable uncertainty of this value is ± 0″.30. Contrasting this value with the average probable error of a single astronomical latitude determination, ± 0″.07, we see the overwhelming influence of local attraction combined with imperfect assumption as to the figure of the earth. The value φ_0 being introduced in the position computation (together with corrected values for a_0 and λ_0, given further on), will produce the best latitude which the data afford, and if another spheroid be substituted, the same standard values φ_0, a_0, λ_0 should be employed, in order that the two sets of deflections for the spheroids may be directly comparable.

DETERMINATION OF THE STANDARD GEODETIC AZIMUTH.

The treatment of the astronomical and geodetic azimuths is similar to that employed for the latitudes. In 1863 and 1866 the geodetic azimuths were increased by + 2″.2 and + 2″.4, the latter as determined from a comparison at 23 astronomical stations between Howard, Me., and West Hills, N. Y. The standard geodetic azimuth so corrected in 1866 is

Blue Hill to Copecut, 355° 14′ 56″.36.

The present list of azimuths, given in Appendix B, Table 1, contains 48 stations* between Howard, Me., and Lavender, Ga. This table gives the results of the astronomical azimuths; the probable errors given are intended to be the combined errors of observation and of transfer to triangulation; but certain parts of the column need further critical examination if used for other than the present purpose.

Appendix B, Table 2, contains the astronomical and corresponding geodetic azimuths as given by our present registers of positions; also, their differences, or the deflection in the direction of the plane of the meridian. For the full exposition of the deflection of the vertical it is, however, more convenient to convert the azimuthal deflection into prime vertical deflection or into deflection in a plane at right angles to that for which the latitude deflections have already been stated, and

* Forty-nine, including the new azimuth at "Sugarloaf," Md.

further to convert the deflections in longitude into deflections in the prime vertical, thus making the azimuthal and longitudinal differences directly comparable. They are closely related, and the distance and direction of the disturbed from the undisturbed zenith at any one place can be equally deduced either by means of the latitude and azimuth or by means of the latitude and longitude as observed at the place.**

Let $\triangle a$ = deflection in azimuth,

$\triangle p$ = deflection of plumb-line in the prime vertical,

φ = latitude of the place;

then $\triangle p = - \triangle a \cot \varphi$, by which formula the numbers in the last column of Table 2 have been computed. The arrangement of the stations is according to longitude.

The deflections $\triangle p$ are on a uniform scale, and the same as the deflections $\triangle \varphi$. Since all latitudes of the arc are <45°, the numerical values of $\triangle p$ are slightly greater than the corresponding values of $\triangle a$. The deflections in the prime vertical are shown by dots on the accompanying diagram. Taking the successive means of the longitudes, also of the apparent deflections in the prime vertical corresponding to them, the following table of the systematic deflections at right angles to the meridian has been formed from the ordinates read off the diagram:

Table of systematic deflections at right angles to the meridian, resulting from observed azimuths.

Long.	Δp	Long.	Δp	Long.	Δp	Long.	Δp
° ′	″	° ′	″	° ′	″	° ′	″
67 30	+2.0	72 00	−3.5	76 30	−10.4	81 00	+0.8
45	+1.6	15	−4.9	45	−10.1	15	+1.1
68 00	+1.5	30	−5.7	77 00	−10.6	30	+1.2
15	+1.4	45	−6.0	15	− 5.4*	45	+1.3
30	+1.3	73 00	−5.7	30	− 1.4*	82 00	+1.2
45	+1.1	15	−4.5	45	+ 1.2*	15	+1.0
69 00	+0.8	30	−2.8	78 00	+ 1.8	30	+0.6
15	+0.5	45	−1.2	15	+ 2.0*	45	+0.2
30	+0.5	74 00	+0.3	30	+ 1.9	83 00	+0.1
45	+0.6	15	+1.6	45	+ 1.6	15	+0.2
70 00	+1.1	30	+2.5	79 00	+ 1.1	30	+0.6
15	+1.8	45	+2.4	15	+ 0.4	45	+1.2
30	+3.5	75 00	+1.6	30	− 0.4	84 00	+2.0
45	+2.8	15	+0.2	45	− 0.8	15	+3.0
71 00	+1.0	30	−1.9	80 00	− 1.0	30	+3.8
15	−0.6	45	−4.5	15	− 0.8	45	+3.6
30	+2.9	76 00	−6.6	30	− 0.3	85 00	+2.9
45	−1.8	15	−9.0	45	+ 0.2	15	+2.1

* Introducing the new azimuth "Sugarloaf," Md., the above Δp becomes −3″.0, +1″.0, +2″.4, and +1″.8 respectively. The value $\frac{\Sigma \Delta p}{72}$ changes to −0″.333 and the azimuthal correction to +0″.276, hence the standard azimuth becomes 1° 34′ 36″.347. The correction obtained by the ordinary process or +0″.59 is changed to +0″.46. The change in the adopted standard azimuth would only amount to −″.066 and has not been introduced. [*Note appended in October, 1880.*—SCH.]

We have the correction $\frac{\Sigma \triangle p}{72} = -0''.414$, and reverting to the azimuths $\triangle a = - \triangle p \tan \varphi$, where $\varphi = 39° 35'.6$, the azimuthal correction becomes + 0″.342. Had we followed the rough process of deducing the correction from the direct comparison of the azimuths we would have found + 0″.59. The new standard geodetic azimuth for the whole arc, applied to the middle part of it, and referred to the direction Principio to Turkey Point, becomes accordingly—

$$1° 34' 36''.071 + 0''.342 = 1° 34' 36''.413 = a_0$$

The probable uncertainty of this value is ± 0″.3. Contrasting this value with the average probable error of a single astronomical azimuth determination and its connection with the triangulation ± 0″.34, we notice again the great influence of the local deflections. Upon the whole they appear larger in the direction of the prime vertical than in the direction of the meridian. This fact cannot be wholly ascribed to the circumstance that in the former case, depending on azimuths, the *accumulated* probable errors of the angular measures of the triangulation enter more directly,

** See, on this point, Coast Survey Report of 1869, Appendix No. 7.

whereas in the latter case they are more nearly free of them if the arc be a meridional one; but in an oblique arc the angular errors of the triangulation enter more or less in both directions.

DETERMINATION OF THE STANDARD GEODETIC LONGITUDE.

Respecting longitudes our data are comparatively scanty, and as the distribution of the telegraphic longitude stations is tolerably regular, after omitting certain stations as too imperfect (Jersey City, N. J., Philadelphia, H. S., Pa., and Staunton, Va.) and others as too close to principal stations (Duxbury, Mass., to Cambridge, and Seaton to Naval Observatory, Washington), the deflections of the vertical in longitude are easily exhibited. The longitude results are final, except that reaction from additional longitude measures on the present values may change the least square adjustment by a small amount. The standard longitude adopted and introduced in our registers, viz: Cambridge, Mass. (E. transit), $4^h\ 44^m\ 30^s.85$, was approved *April* 2, 1869, and in my report of May 29, 1873, I further show that this standard longitude very nearly equalized the differences between the telegraphic and the geodetic longitudes at the stations Calais, Me., Cambridge, Mass., New York, N. Y., and Washington, D. C. In the place of 4 we now have 7 longitude stations bearing on the arc; the results are given in Appendix C, Table 1. In the second table of this appendix the astronomical longitudes are expressed in arc and compared with the register longitudes. The differences $\triangle\lambda$ are converted into differences $\triangle p$ in the prime vertical by the relation

$$\triangle p = \triangle\lambda \cos\varphi$$

which quantities are shown by crosses on the diagram containing similar quantities derived from the azimuths. We have the correction $\frac{\Sigma\triangle p}{7} = -1''.289$* and reverting to longitude $\triangle\lambda = \triangle p \sec\varphi$ the correction to the longitude becomes $-1''.673$, the value of φ being $39^\circ\ 35'.6$. Nearly one-tenth of a second of time is to subtracted from our register longitudes, and the new standard geodetic longitude of Principio becomes

$$76^\circ\ 00'\ 18''.080 - 1''.673 = 76^\circ\ 00'\ 16''.407 = \lambda_0$$

The probable uncertainty of this value is $\pm 1''.2$, whereas the average probable error of a single longitude determination is but $\pm 0''.8$

If, for any one astronomical station where latitude, azimuth, and longitude were determined, the values of $\triangle p$ as derived from the observed α, and as derived from the observed λ, differ by more than their respective probable observing errors would indicate, the explanation will be found in the fact that the accumulated errors of the angular measures of the triangulation had been left out of account.

EXHIBITION OF THE APPARENT LOCAL DEFLECTIONS OF THE VERTICAL WITH REFERENCE TO BESSEL'S AND CLARKE'S SPHEROIDS.

For the direct comparison of the remaining deflections of the plumb-line on the two spheroids we have only to develop the triangulation upon their respective surfaces, starting with the same standard geodetic latitude, longitude, and azimuth, or with the values $\varphi_0\ \lambda_0\ \alpha_0$ for the middle station Principio, as deduced on the preceding pages. It might appear, at first, as if the old position computation for Bessel's spheroid could be made use of by applying the change in the data, or $+2''.655$ in latitude, $+0''.342$ in azimuth, and $-1''.673$ in longitude as so many constants, but the change in latitude is so great that the *relative* positions become affected, considering the whole arc, to an extent to tell nearly on the tenths of seconds in the latitudes and even on the nearest whole second in azimuth, but less in longitude (about $0''.3$). A partial recomputation of the positions had to be made for Bessel's spheroid, and, of course, a new computation for Clarke's spheroid.† The results are given in full in the following table:

* The values originally reported were $-1''.120$, and, for $\Delta\lambda$, $-1''.453$; but they have now been improved by the introduction of the results from the least square adjustment of the telegraphic longitudes in August, 1880, and by the revised longitude of Statesville, N. C., which before rested upon a rough computation made in the field. [Note added in October, 1880.—SCH.]

† For a similar reason the small corrections in latitude of $+0''.030$, and in azimuth of $-0''.066$, as mentioned in two preceding foot-notes, and which are due to the introduction into the original paper of two additional latitudes and of one azimuth, *were not* introduced here, especially since these corrections are far within the limits of the probable errors of the values of ϕ_0 and of α_0. It is different, however, with the longitude for which the new value or $\lambda_0 = 76^\circ\ 00'\ 16''.407$ has been introduced, and to which value the longitude tables appended have also been made to conform. [Note added in October, 1880.—SCH.]

Comparison of effect of apparent local deflections of the vertical in latitude, for Bessel's and Clarke's Spheroids.

No.	Name of station.	Astrol. latitude.	Geod. φ B.	Geod. φ C.	A—G Deflec'n Bessel.	A—G Deflec'n Clarke.
		° ′ ″	″	″	″	″
1	Calais, Me	45 11 09.41	07.44	05.68	+1.97	+3.73
2	Cooper, Me	44 59 12.63	15.17	13.48	−2.54	−0.85
3	Humpback, Me	44 51 47.13	52.37	50.69	−5.24	−3.56
4	Bangor, Me	44 48 12.86	17.83	16.14	−4.97	−3.28
5	Farmington, Me	44 40 19.55	24.44	22.77	−4.89	−3.22
6	Harris, Me	44 39 54.84	56.52	54.88	−1.68	−0.04
7	Howard, Me	44 37 48.67	48.14	46.58	+0.53	+2.09
8	Mount Desert, Me	44 21 04.62	06.73	05.23	−2.11	−0.61
9	Ragged, Me	44 12 43.35	46.86	45.38	−3.51	−2.03
10	Sebattis, Me	44 08 37.60	39.31	37.83	−1.71	−0.23
11	Mount Pleasant, Me	44 01 36.48	38.15	36.69	−1.67	−0.21
12	Cape Small, Me	43 46 43.48	44.56	43.22	−1.08	+0.26
13	Mount Independence, Me	43 45 34.43	35.10	33.75	−0.67	+0.68
14	Gunstock, N. H	43 31 05.15	05.60	04.32	−0.45	+0.83
15	Agamenticus, Me	43 13 24.98	25.80	24.63	−0.82	+0.35
16	Isles of Shoals, N. H	42 59 12.88	15.94	14.86	−3.06	−1.98
17	Unkonoonuc, N. H	42 58 59.35	60.97	59.86	−1.62	−0.51
18	Thompson, Mass	42 36 38.28	42.88	41.92	−4.60	−3.64
19	Wachusett, Mass	42 29 17.08	21.72	20.78	−4.64	−3.70
20	Harvard Observatory, Mass	42 22 48.05	54.37	53.49	−6.32	−5.44
21	Cloverden Observatory, Mass	42 22 40.97	47.17	46.29	−6.20	−5.32
22	Mount Tom, Mass	42 14 28.53	31.66	30.80	−3.13	−2.27
23	Manomet, Mass	41 55 35.33	39.41	38.70	−4.08	−3.37
24	Sandford, Conn	41 27 40.08	43.40	42.80	−3.32	−2.72
25	Nantucket, Mass	41 17 14.06	17.48	17.00	−3.42	−2.94
26	West Hills, N. Y	40 48 49.96	55.58	55.19	−5.62	−5.23
27	Rutherfurd's Observatory, N. Y	40 43 48.61	51.82	51.45	−3.21	−2.84
28	Beaconhill, N. J	40 22 27.82	26.80	26.55	+1.02	+1.27
29	Mount Rose, N. J	40 22 05.44	03.66	03.41	+1.78	+2.03
30	Gummere's Observatory, N. J	40 04 51.6	56.76	46.53	+4.84	+5.07
31	Yard, Pa	39 58 29.39	24.92	24.80	+4.47	+4.59
32	Old High School Observatory, Pa	39 57 07.5	06.07	05.95	+1.43	+1.55
33	Principio, Md	39 35 32.75	36.69	36.69	−3.94	−3.94
34	Maryland Heights, Md	39 20 31.38	27.61	27.69	+3.77	+3.69
35	Pool's Island, Md	39 17 09.65	07.72	07.82	+1.93	+1.83
*35½	Sugarloaf, Md	39 15 48.49	44.43	44.55	+4.06	+3.94
36	Webb, Md	39 05 25.46	26.39	26.56	−0.93	−1.10
37	Soper, Md	39 05 10.59	11.68	11.85	−1.09	−1.26
38	Taylor, Md	38 59 45.97	48.20	48.39	−2.23	−2.42
39	Causten, D. C	38 55 32.51	35.08	35.29	−2.57	−2.78
40	Georgetown College Observatory, D. C	38 54 25.8	29.72	29.94	−3.92	−4.14
41	Hill, Md	38 53 52.85	54.69	54.91	−1.84	−2.06
42	United States Naval Observatory, D. C	38 53 38.78	42.05	42.27	−3.27	−3.49
43	Washington Four-and-a-half street Observatory, D. C	38 53 30.70	33.90	34.12	−3.20	−3.42
44	Seaton, Washington, D. C	38 53 25.17	28.74	28.96	−3.57	−3.79
45	Bull Run, Va	38 52 56.16	53.35	53.58	+2.81	+2.58
46	Marriott, Md	38 52 24.82	27.33	27.56	−2.51	−2.74
47	Clark, Va	38 18 39.53	40.70	41.11	−1.17	−1.58
48	Elliot's Knob, Va	38 09 57.23	58.89	59.37	−1.66	−2.14
49	Staunton, Va	38 08 50.8	46.07	46.55	+4.73	+4.25
50	Long Mount, Va	37 17 28.70	26.91	27.65	+1.79	+1.05
51	Moore, Va	36 23 54.92	52.58	53.60	+2.34	+1.32
52	Young, N. C	35 44 21.51	13.26	14.49	+8.25	+7.02
53	King, N. C	35 12 29.38	26.48	27.88	+2.90	+1.50
54	Paris, S. C	34 56 31.09	27.77	29.27	+3.32	+1.82
55	Currahee, Ga	34 31 43.96	43.50	45.14	+0.46	−1.18
56	Lavender, Ga	34 19 17.05	17.82	19.58	−0.77	−2.53
57	Sawnee, Ga	34 14 11.09	10.38	12.12	+0.71	−1.03
58	Middle Base, Ga	33 54 22.22	19.91	21.75	+2.31	+0.47
*58½	Atlanta, Ga	33 44 59.42	56.52	58.40	+2.90	+1.02

* Added in October, 1880.

Comparison of effect of apparent local deflections of the vertical in azimuth, for Bessel's and Clarke's spheroids.

No.	Name of direction.	Longitude of first stat'n.	Astronomical azimuth.	Geod. α B.	Geod. α C.	A − G defl'n Bessel.	A − G defl'n Clarke.
		° ′	° ′ ″	″	″	″	″
1	Howard to Pigeon	67 23.7	63 54 45.10	48.48	45.07	− 3.38	+ 0.03
2	Cooper to Howard	67 28.0	351 53 12.05	15.44	12.04	− 3.39	+ 0.01
3	Humpback to Cooper	68 06.6	254 42 32.34	33.00	29.88	− 0.66	+ 2.46
4	Mount Desert to Ragged	68 13.6	78 30 46.82	51.13	48.09	− 4.31	− 1.27
5	Harris to Humpback	69 08.9	254 35 10.71	11.11	08.43	− 0.40	+ 2.28
6	Ragged to Mount Pleasant	69 09.1	81 48 44.99	46.60	43.95	− 1.61	+ 1.04
7	Cape Small to Sebattis	69 50.7	155 19 03.51	04.31	01.96	− 0.80	+ 1.55
8	Sebattis to Independence	70 04.7	24 31 23.55	25.22	22.95	− 1.67	+ 0.60
9	Independence to Agamenticus	70 19.2	26 55 48.62	52.89	50.74	− 4.27	− 2.12
10	Shootflying to Manomet	70 20.8	143 03 22.74	22.36	20.31	+ 0.38	+ 2.43
11	Indian to Copecut	70 40.7	135 35 58.82	66.25	64.33	− 7.43	− 5.51
12	Agamenticus to Thompson	70 41.5	2 36 55.39	60.24	58.26	− 4.85	− 2.87
13	Thompson to Manomet	70 43.8	351 21 41.82	44.62	42.68	− 2.80	− 0.86
14	Mount Pleasant to Mount Blue	70 49.3	205 59 21.56	21.54	19.58	+ 0.02	+ 1.98
15	Copecut to Blue Hill	71 03.6	175 17 06.47	08.09	06.30	− 1.62	+ 0.17
16	Blue Hill to Manomet	71 06.9	305 57 30.02	33.95	32.16	− 3.93	− 2.14
17	Harvard College Observatory to Blue Hill	71 07.7	356 22 57.94	57.65	55.87	+ 0.29	+ 2.07
18	Gunstock to Mount Pleasant	71 22.2	217 43 33.47	31.28	29.56	+ 2.19	+ 3.91
19	Beaconpole to Blue Hill	71 27.0	228 55 17.16	21.42	19.77	− 4.26	− 2.61
20	Spencer to Beaconpole	71 29.7	185 57 33.02	37.96	36.33	− 4.94	− 3.31
21	Unkonoonuc to Gunstock	71 35.3	196 35 20.01	20.50	18.88	− 0.49	+ 1.13
22	Wachusett to Bald Hill	71 53.2	24 17 41.19	35.99	34.50	+ 5.20	+ 6.69
23	Mount Tom to Monadnock	72 38.9	212 37 21.79	18.43	17.23	+ 3.36	+ 4.56
24	Sandford to Ruland	72 57.0	5 50 25.04	17.95	16.88	+ 7.09	+ 8.16
25	West Hills to Wooster	73 25.5	174 57 38.25	36.65	35.76	+ 1.60	+ 2.49
26	Beacon Hill to Weasel	74 13.7	183 35 29.89	31.85	31.24	− 1.96	− 1.35
27	Mount Rose to Mount Holly	74 43.4	7 46 55.59	60.60	60.17	− 5.01	− 4.58
28	Yard to Lippincott	75 23.3	347 17 38.57	39.15	38.94	− 0.58	− 0.37
29	Principio to Turkey	76 00.3	1 34 43.50	36.41	36.41	+ 7.09	+ 7.09
30	Marriott to Hill	76 36.6	96 37 43.24	34.01	34.21	+ 9.23	+ 9.03
31	Webb to Soper	76 40.5	88 59 49.22	42.02	42.24	+ 7.20	+ 6.98
32	Hill to Webb	76 52.9	219 46 58.29	49.67	49.96	+ 8.62	+ 8.33
33	Soper to Webb	76 57.0	268 49 23.38	17.36	17.67	+ 6.02	+ 5.71
34	Seaton to Hill	77 00.0	265 32 53.75	42.38	42.71	+11.37	+11.04
35	Causten to Soper	77 04.4	210 54 41.77	36.39	36.74	+ 5.38	+ 5.03
*35½	Sugarloaf to Bull Run	77 23.6	32 29 16.11	21.72	22.17	− 5.61	− 6.06
36	Bull Run to Stabler	77 42.3	246 35 34.20	35.58	36.14	− 1.38	− 1.94
37	Maryland Heights to Peach Grove	77 43.0	317 48 55.23	57.65	58.21	− 2.42	− 2.98
38	Clark to Bull Run	78 00.2	202 19 27.62	27.74	28.39	− 0.12	− 0.77
39	Long Mount to Spear	79 05.2	223 28 41.73	46.06	47.02	− 4.33	− 5.29
40	Elliott's Knob to Humpback	79 18.9	303 25 23.90	21.38	22.43	+ 2.52	+ 1.47
41	Moore to Buffalo	80 17.0	158 33 31.16	31.43	32.74	− 0.27	− 1.58
42	Young to Poore	80 38.9	126 52 53.82	52.49	53.88	+ 1.33	− 0.06
43	King to Benn	81 18.8	141 33 36.91	39.65	41.22	− 2.74	− 4.31
44	Paris to Wofford	82 24.7	267 18 15.16	15.89	17.75	− 0.73	− 2.59
45	Currahee to Rabun	83 22.6	188 10 27.88	25.70	27.80	+ 2.18	+ 0.08
46	Sawnee to Currahee	84 09.7	245 34 26.20	28.40	30.69	− 2.20	− 4.49
47	Middle Base to Stone Mountain	84 16.7	312 22 28.94	32.16	34.47	− 3.22	− 5.53
48	Lavender to Kenesaw	85 17.4	300 11 59.11	60.23	62.80	− 1.12	− 3.69

* Added in October, 1880.

Comparison of effect of apparent local deflections of the vertical in longitude, for Bessel's and Clarke's spheroids.

No.	Name of station.	Astronomical longitude.	Geod. λ B.	Geod. λ C.	A – G defl'n Bessel.	A – G defl'n Clarke.
		° ′ ″	″	″	″	″
1	Calais (transit), Me	67 16 54.20	47.76	52.76	+6.44	+1.44
2	Bangor (transit), Me	68 46 58.90	56.04	60.15	+2.86	–1.25
3	Cambridge, Harvard College Observatory (dome), Mass	71 07 44.91	41.21	43.89	+3.70	+1.02
4	New York, Rutherfurd's Observatory transit) N. Y	73 59 15.96	13.34	14.42	+2.62	+1.54
5	Washington, United States Naval Observatory (small dome)	77 03 00.54	06.65	06.10	–6.11	–5.56
6	Statesville (transit), N. C	80 53 39.53	42.38	39.93	–2.85	–0.40
7	Atlanta (transit), Ga	84 23 18.39	23.16	19.07	–4.77	–0.68

Respecting the signs in the columns of A – G, they have the following meaning:

For *latitudinal* deflections a + sign indicates zenith thrown to the north (or plumb-line to the south); a – sign the reverse.

For *azimuthal* deflections a + sign indicates zenith thrown to the east (or south meridian thrown to the east); a – sign the reverse.

For *longitudinal* deflections a + sign indicates zenith thrown to the west; a – sign the reverse.

Squaring the numbers of the last two columns, headed A – G, we have the following comparison for the sum of the squares, or $\Sigma(A-G)^2$, and for the square root of the mean square or for the average deflection:

	Bessel's spheroid.	Clarke's spheroid.	Improvement on Bessel's.
Latitudes: $\Sigma(A-G)^2$	631.24	485.16	146.08
Average deflection	3″.30	2″.89	0″.41
Azimuths: $\Sigma(A-G)^2$	859.23	840.09	19.14
Average deflection	4″.23	4″.18	0″.05
Longitudes: $\Sigma(A-G)^2$	138.40	38.57	99.83
Average deflection	4″.45	2″.35	2″.10

For our Atlantic coast the superiority of Clarke's over Bessel's spheroid is therefore demonstrated. While the latitudes are fairly better represented on the surface of Clarke's spheroid, the azimuths are improved but a trifle; in fact, they are almost indifferent as to the one or the other of the spheroids (the signs at the beginning and end of the columns (A – G) simply change from – + to + –). On the other hand the longitudes are very greatly improved, the sum of the new differences being nearly one-half of that of the former differences. In view of these facts, and considering that this paper contains the largest induction the present state of the survey affords, I do not hesitate to respectfully ask your attention to the question whether the survey would not be benefited by the adoption of Clarke's spheroid as its surface of development. It would seem to me that the present time is favorable for making this fundamental change, since nearly all the State surveys are yet in their infancy, so that no time would be lost in starting at once the *Geodetic* survey on Clarke's spheroid, and allowing the Bessel spheroid to gradually disappear with the old Coast Survey work. The use of Clarke's spheroid, as recommended in my report of March 28, 1878, was only partially adopted, *i. e.*, limited to the triangulation of the Pacific coast. At the time this was approved by you we were not in possession of so complete a proof for the Atlantic coast as is now offered for your consideration.

With a few special exceptions (longitudes) the astronomical results given in this paper, and the results of the 600 miles of primary triangulation southwest of Washington, are as yet unpublished. The character of the deflections between Calais, Me., and Washington, D. C., has long been known in this office; the heavy deflections in latitude in the region about Boston had already been brought to light by the Borden survey,* and in January last Prof. Young, of Princeton, N. J.,

* Deflection given in the printed account of the survey of Mass. 7″, this according to the Coast Survey 6″.3, and on Clarke's spheroid 5″.4.

wrote he had a difficulty in reconciling[1] his astronomical and our geodetic latitude and longitude. He was informed of the existence of a wave of deflection in that region. This latitude deflection had already been mapped in 1856.

The deflection of the plumb-line in the vicinity of Washington is very remarkable, the zenith being heavily drawn to the east or the plumb-line attracted to the west. The object of this report, however, is not a discussion of the local deflections, but a comparison of the value of two spheroids with regard to their respective fitness for the Coast and Geodetic Survey. Physically the Atlantic arc, which is now 1200 statute miles in length, can be extended 4½° to Mobile Point, increasing the present length from 17½° to 22°; its value for geodesy would thus be increased 25 per cent., and the Atlantic and Gulf coast triangulations would be united.

I remain, sir, yours, very respectfully,

CHAS. A. SCHOTT,
Assistant in charge Computing Division.

CARLILE P. PATTERSON,
Superintendent United States Coast and Geodetic Survey.

APPENDIX A.—TABLE 1.—*Astronomical latitudes of the oblique arc along the Atlantic.*

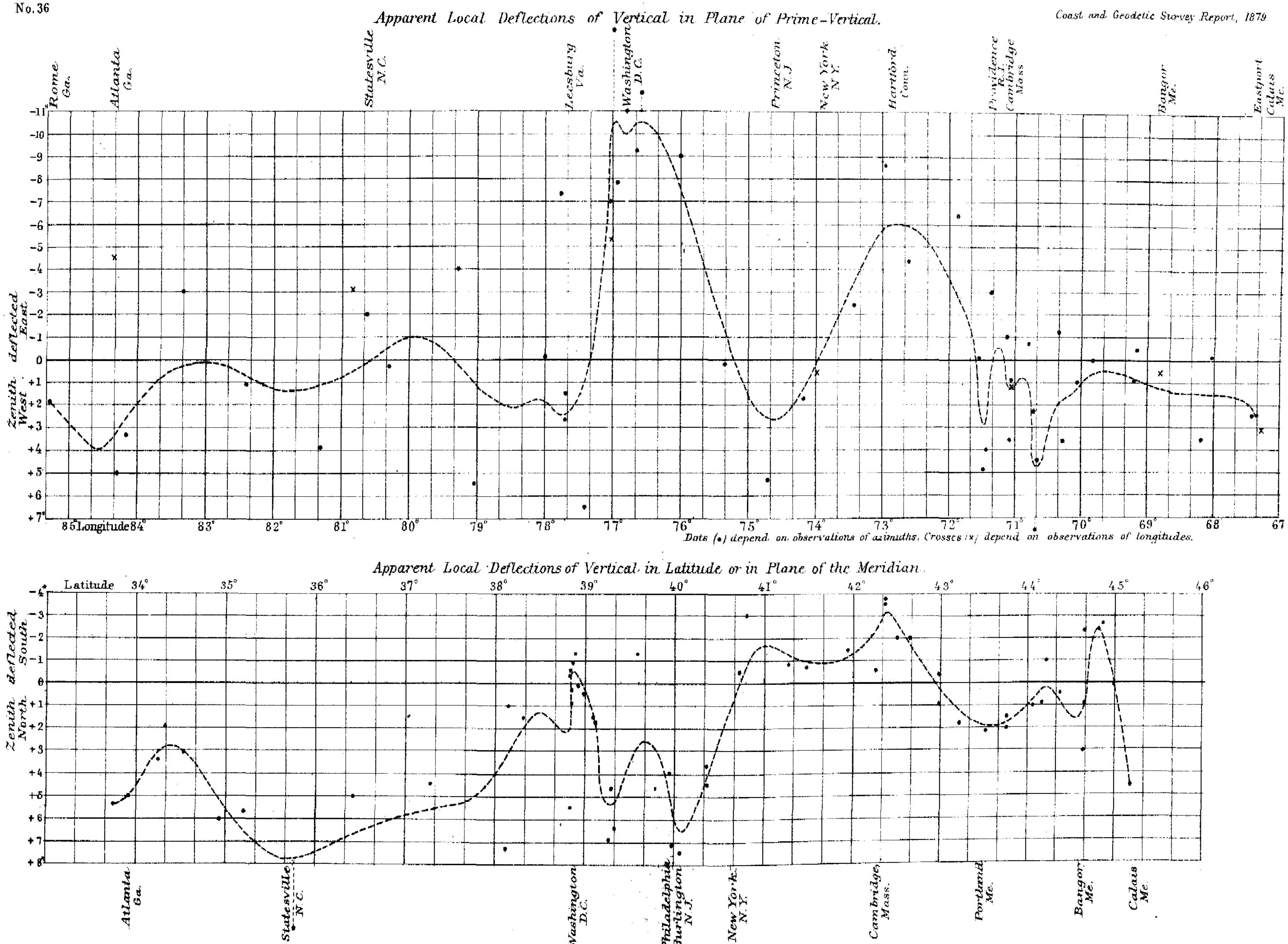
No.	Name of station.	Date of observation.	Observer.	Instrument.	Resulting latitude ⊿			Prob. error.
					°	′	″	″
1	Calais, Me	Sept., 1857	S. Harris	Z. T. 4	45	11	09.41	±0.07
2	Cooper, Me	Sept., 1859	E. Goodfellow	Z. T. 5	44	59	12.63	.05
3	Humpback, Me	July, Aug., 1858	A. T. Mosman	Z. T. 5	44	51	47.13	.05
4	Bangor, Me	Sept., Oct., 1857	E. Goodfellow	Z. T. 5	44	48	12.86	.06
5	Farmington, Me	Oct., Nov., 1866	C. O. Boutelle	Z. T. 5	44	40	19.55	.05
6	Harris, Me	Aug., Sept., 1855	G. W. Dean, E. Goodfellow	Z. T. 2, 10	44	39	54.84	.03
7	Howard, Me	July, 1859	E. Goodfellow	Z. T. 5	44	37	48.67	.05
8	Mount Desert, Me	Aug., Sept., Oct., 1856	S. Harris, E. Goodfellow	Z. T. 5	44	21	04.62	.04
9	Ragged, Me	Aug., Sept., Oct., 1854	G. W. Dean, S. Harris	Z. T. 5	44	12	43.35	.04
10	Sebattis, Me	June, July, 1853	J. E. Hilgard	Z. T. 1	44	08	37.60	.09
11	Mount Pleasant, Me	July, Aug., 1851	G. W. Dean	Z. T. 5	44	01	36.48	.04
12	Cape Small, Me	Sept., Oct., 1851	G. W. Dean	Z. T. 5	43	46	43.48	.04
13	Mount Independence, Me	Sept., Oct., 1849	A. D. Bache, G. Davidson, G. W. Dean.	Z. T. 1, 2	43	45	34.43	.06
14	Gunstock, N. H	July, Aug., 1860	J. H. Toomer	Z. T. 5	43	31	05.15	.04
15	Agamenticus, Me	Sept., Oct., Nov., 1847	T. J. Lee, A. D. Bache, R. H. Fauntleroy, C. O. Boutelle, G. Davidson.	Z. T. (M. A.), Z. S. 1, T. 2.	43	13	24.98	.07
16	Isles of Shoals, N. H	Aug., 1847	T. J. Lee	Z. T. (M. A)	42	59	12.88	.09
17	Unkonoonuc, N. H	Sept., Oct., 1848	J. S. Ruth	Z. T. 3	42	58	59.35	.07
18	Thompson, Mass	Sept., Oct., 1846	T. J. Lee, R. H. Fauntleroy	Z. T. (M. A)	42	36	38.28	.10
19	Wachusett, Mass	Sept., Oct., 1860	J. H. Toomer	Z. T. 5	42	29	17.08	.04
*20	Harvard Observatory, Mass	1844, 1845	W. C. Bond	T. in P. V	42	22	48.05	.22
21	Cloverden Observatory, Mass	Aug., Sept., Oct., 1855	B. A. Gould, J. Searles, C. H. F. Peters.	Z. T. 5	42	22	40.97	.08
22	Mount Tom, Mass	July, Aug., 1862	E. Goodfellow	Z. T. 5	42	14	28.53	.06
23	Manomet, Mass	July, Aug., 1867	C. O. Boutelle, F. H. Agnew	Z. T. 5	41	55	35.33	.05
24	Sandford, Conn	Sept., Oct., 1862	E. Goodfellow	Z. T. 5	41	27	40.08	.08
25	Nantucket, Mass	Nov., Dec., 1866	C. O. Boutelle	Z. T. 5	41	17	14.06	.06
26	West Hills, N. Y	Aug., 1865	A. T. Mosman	Z. T. 5	40	48	49.96	.05
27	Rutherfurd's Observatory, N. Y.	June, 1858	E. Goodfellow	Z. T. 5	40	43	48.61	.09
28	Beaconhill, N. J	July, Aug., 1875	G. W. Dean, J. B. Baylor	Z. T. 4	40	22	27.82	.07
29	Mount Rose, N. J	July, 1852	J. E. Hilgard	Z. T. 2	40	22	05.44	.08
*30	Gummere's Observatory, N. J	1852	J. Gummere	T	40	04	51.6	....
31	Yard, Pa	Oct., Nov., 1854	J. E. Hilgard	Z. T. 6	39	58	29.39	.06
*32	Old High School Observatory, Pa	1849	E. O. Kendall	....	39	57	07.5	....
33	Principio, Md	July, Aug., Sept., 1866	R. D. Cutts	Z. T. 5	39	35	32.75	.05
34	Maryland Heights, Md	Sept., Oct., Nov., 1870	C. O. Boutelle, F. Blake, jr	Z. T. 5	39	20	31.38	.06

[1] He states the difference in latitude 3″.8, and in longitude 5″.5.

Oblique Arc along the Atlantic Coast, from Atlanta Ga. to Calais Me.

No. 36

Coast and Geodetic Survey Report, 1879.



Astronomical latitudes of the oblique arc along the Atlantic—Continued.

No.	Name of station.	Date of observation.	Observer.	Instrument.	Resulting latitude Δ	Prob. error.
					° ′ ″	″
35	Pool's Island, Md	June, July, 1847	T. J. Lee	Z. T. (M. A)	39 17 09.65	±0.12
†35½	Sugarloaf, Md	Oct., 1879	C. O. Boutelle	Z. T. 5	39 15 48.49	.12
36	Webb, Md	Oct., Nov., 1850	G. W. Dean	Z. S. 1	39 05 25.46	.04
37	Soper, Md	June, July, 1850	G. W. Dean	Z. S. 1	39 05 10.59	.09
38	Taylor, Md	May, 1847	T. J. Lee	Z. T. (M. A)	38 59 45.97	.11
39	Causten, D. C	May, June, 1851	G. W. Dean	Z. S. 1	38 55 32.51	.04
*40	Georgetown College Observatory, D. C.	1846	J. Curley	M. C	38 54 25.8	....
41	Hill, Md	Aug., Sept., 1850	G. W. Dean	Z. S. 1	38 53 52.85	.05
*42	United States Naval Observatory, D. C.	1861 to 1864	Various	M. C., T. C	38 53 38.78	.10
43	Washington, Four-and-a-half st. Observatory, D. C.	Sept., Oct., Nov., 1852	G. W. Stevens, C. A. Schott	Z. T. 5	38 53 30.70	.11
44	Seaton, Washington, D. C	June, 1850	L. F. Pourtales	Z. T. 5	38 53 25.17	.17
45	Bull Run, Va	Sept., Oct., 1871	F. Blake, jr	Z. T. 5	38 52 56.16	.07
46	Marriott, Md	June, 1846; May, June, 1849.	T. J. Lee, A. D. Bache, J. Hewston	Z. T. 1, Z. T. (M. A)	38 52 24.82	.06
47	Clark, Va	July, Aug., 1871	F. Blake, jr	Z. T. 5	38 18 39.53	.06
48	Elliot's Knob, Va	July, 1878	A. T. Mosman	Z. T. 6	38 09 57.23	.15
49	Staunton, Va	April, 1869	A. T. Mosman	M. T. 1	38 08 50.8	....
50	Long Mountain, Va	Oct., Nov., 1875	A. T. Mosman	Z. T. 2	37 17 26.70	.09
51	Moore, N. C	Nov., Dec., 1876	J. B. Baylor, W. B. Fairfield	Z. T. 2	36 23 54.92	.09
52	Young, N. C	Oct., 1876	H. W. Blair, J. B. Boutelle	Z. T. 4	35 44 21.51	.12
53	King, N. C	Dec., 1876	H. W. Blair, J. B. Boutelle	Z. T. 5	35 12 29.38	.07
54	Paris, S. C	Oct., 1875	C. O. Boutelle	Z. T. 5	34 56 31.09	.07
55	Currahee, Ga	Sept., Oct., 1874	H. W. Blair, J. B. Boutelle	Z. T. 5	34 31 43.96	.08
56	Lavender, Ga	Oct., Nov., 1874	F. P. Webber	Z. T. 3	34 19 17.05	.12
57	Sawnee, Ga	Oct., Nov., 1873	H. W. Blair, A. H. Scott	Z. T. 5	34 14 11.09	.08
58	Middle Base, Ga	Sept., 1872	F. P. Webber	Z. T. 5	33 54 22.22	.05
†58½	Atlanta, Ga	Jan., 1880	E. Smith, C. H. Sinclair	M. T. 13	33 44 59.42	.12

NOTES.—Stations marked by a * are not Coast and Geodetic Survey stations. In all cases the astronomical station, if different from the geodetic, is reduced to the latter. No. 20 is referred to the center of the dome, also No. 40, and No. 42 to the small or north dome. The column of observers contains the name of the actual observer or observers, and not the chief of the party.

† Added in October, 1880.

APPENDIX A, TABLE 2.—*Comparison of the register latitudes, apparent deflections in the meridian.*

No.	Astronomical latitude of Δ.	Seconds of geodetic latitude from register.	A — G, or apparent local deflection.	No.	Astronomical latitude of Δ.	Seconds of geodetic latitude from register.	A — G, or apparent local deflection.
	° ′ ″	″	″		° ′ ″	″	″
1	45 11 09.41	04.85	+ 4.56	31	39 58 29.39	22.27	+ 7.12
2	44 59 12.63	12.58	+ 0.05	32	39 57 07.50	03.42	+ 4.08
3	44 51 47.13	49.77	— 2.64	33	39 35 32.75	34.04	— 1.29
4	44 48 12.86	15.22	— 2.36	34	39 20 31.38	24.94	+ 6.44
5	44 40 19.55	21.82	— 2.27	35	39 17 09.65	05.07	+ 4.58
6	44 39 54.84	53.91	+ 0.93	35½	39 15 48.49	41.77	+ 6.72
7	44 37 48.67	45.55	+ 3.12	36	39 05 25.46	23.74	+ 1.72
8	44 21 04.62	04.13	+ 0.49	37	39 05 10.59	09.02	+ 1.57
9	44 12 43.35	44.25	— 0.90	38	38 59 45.97	45.54	+ 0.43
10	44 08 37.60	36.70	+ 0.90	39	38 55 32.51	32.42	+ 0.09
11	44 01 36.48	35.53	+ 0.95	40	38 54 25.80	27.06	— 1.26
12	43 46 43.48	41.94	+ 1.54	41	38 53 52.85	52.03	+ 0.82
13	43 45 34.43	32.48	+ 1.95	42	38 53 38.78	39.37	— 0.59
14	43 31 05.15	02.98	+ 2.17	43	38 53 30.70	31.24	— 0.54
15	43 13 24.98	23.18	+ 1.80	44	38 53 25.17	26.08	— 0.91
16	42 59 12.88	13.32	— 0.44	45	38 52 56.16	50.69	+ 5.47
17	42 58 59.35	58.34	+ 1.01	46	38 52 24.82	24.67	+ 0.15
18	42 36 38.28	40.26	— 1.98	47	38 18 39.53	38.03	+ 1.50
19	42 29 17.08	19.09	— 2.01	48	38 09 57.23	56.22	+ 1.01
20	42 22 48.05	51.75	— 3.70	49	38 08 50.80	43.40	+ 7.40
21	42 22 40.97	44.55	— 3.58	50	37 17 28.70	24.24	+ 4.46
22	42 14 28.53	29.03	— 0.50	51	36 23 54.92	49.90	+ 5.02
23	41 55 35.33	36.79	— 1.46	52	35 44 21.51	10.59	+10.92
24	41 27 40.08	40.76	— 0.68	53	35 12 29.38	23.81	+ 5.57
25	41 17 14.06	14.88	— 0.82	54	34 56 31.09	25.10	+ 5.99
26	40 48 49.96	52.93	— 2.97	55	34 31 43.96	40.82	+ 3.14
27	40 43 48.61	49.17	— 0.56	56	34 19 17.05	15.15	+ 1.90
28	40 22 27.82	24.15	+ 3.67	57	34 14 11.09	07.71	+ 3.38
29	40 22 05.44	01.01	+ 4.43	58	33 54 22.22	17.24	+ 4.98
30	40 04 51.60	44.11	+ 7.49	58½	33 44 59.42	53.85	+ 5.57

NOTE.—The numbers of first column and the results of the astronomical latitudes are identical with those of Appendix A, Table 1.

APPENDIX B, TABLE 1.—*Astronomical azimuths of the oblique arc along the Atlantic.*

No.	Name of station.	Date of observation.	Observer.	Astronomical azimuth referred to.	Resulting azimuth of direction △			Prob. error.
					°	′	″	″
1	Howard, Me	July, Aug., 1859	G. W. Dean	Pigeon	63	54	45.10	±0.33
2	Cooper, Me	Sept., 1859	G. W. Dean	Howard	351	53	12.05	.34
3	Humpback, Me	Aug., 1858	G. W. Dean	Cooper	254	42	32.34	.28
4	Mount Desert, Me	Aug., Sept., 1856	A. D. Bache, G. W. Dean	Ragged	78	30	46.82	.23
5	Harris, Me	Aug., Sept., 1855	A. D. Bache, G. W. Dean	Humpback	254	35	10.71	.28
6	Ragged, Me	Aug., Sept., 1854	A. D. Bache, G. W. Dean	Mount Pleasant	81	48	44.99	.27
7	Cape Small, Me	Oct., 1851	A. D. Bache, C. O. Boutelle, W. P. Trowbridge.	Sebattis	155	19	03.51	.38
8	Sebattis, Me	July, 1853	A. D. Bache, G. W. Dean	Mount Independence	24	31	23.55	.34
9	Mount Independence, Me	Sept., Oct., 1849	A. D. Bache	Agamenticus	26	55	48.62	.25
10	Shootflying, Mass	Aug., 1845	A. D. Bache	Manomet	143	03	22.74	.29
11	Indian, Mass	July, 1845	A. D. Bache	Copecut	135	35	58.82	.45
12	Agamenticus, Me	Sept., Oct., 1847	A. D. Bache	Thompson	2	36	55.39	.38
13	Thompson, Mass	Oct., Nov., Dec., 1846	A. D. Bache	Manomet	351	21	41.82	.45
14	Mount Pleasant, Me	July., Aug., 1851	A. D. Bache, C. O. Boutelle, W. P. Trowbridge.	Mount Blue	205	59	21.56	.38
15	Copecut, Mass	Sept., Oct., 1844	A. D. Bache	Blue Hill	175	17	06.47	.31
16	Blue Hill, Mass	Sept., Oct., 1845	A. D. Bache	Manomet	305	57	30.02	.27
17	Harvard College Observatory, Mass.	Jan., Feb., Mar., 1869	A. T. Mosman	Blue Hill	356	22	57.94	.40
18	Gunstock, N. H	July, Aug., 1860	G. W. Dean	Mount Pleasant	217	43	33.47	.24
19	Beaconpole, R. I	Oct., Nov., 1844	A. D. Bache	Blue Hill	228	55	17.16	.26
20	Spencer, R. I	Aug., 1844	A. D. Bache	Beaconpole	185	57	33.02	.46
21	Unkonoonuc, N. H	Sept., Oct., 1848	A. D. Bache	Gunstock	196	35	20.01	.48
22	Wachusett, Mass	Sept., Oct., 1860	G. W. Dean	Bald Hill	24	17	41.19	.19
23	Mount Tom, Mass	July, Aug., 1862	G. W. Dean	Monadnock	212	37	21.79	.22
24	Sandford, Conn	Sept., 1862	G. W. Dean	Ruland	5	50	25.04	.34
25	West Hills, N. Y	Aug., 1865	G. W. Dean	Wooster	174	57	38.25	.19
26	Beaconhill, N. J	Aug., 1875	G. W. Dean	Weasel	183	35	29.89	.47
27	Mount Rose, N. J	Aug., 1852	J. E. Hilgard	Mount Holly	7	46	55.59	.32
28	Yard, Pa	Oct., Nov., 1854	J. E. Hilgard	Lippincott	347	17	38.57	.45
29	Principio, Md	Aug., Sept., 1866	R. D. Cutts	Turkey Point	1	34	43.50	.44
30	Marriott, Md	June, 1849	A. D. Bache, J. Hewston	Hill	96	37	43.24	.53
31	Webb, Md	Oct., Nov., 1850	A. D. Bache, G. W. Dean	Soper	88	59	49.22	.48
32	Hill, Md	Sept., Oct., 1850	A. D. Bache, G. W. Dean	Webb	219	46	58.29	.35
33	Soper, Md	July, 1850	A. D. Bache	Webb	268	49	23.38	.40
34	Seaton, Washington, D. C	Dec., 1868; Jan. 1869	C. O. Boutelle	Hill	265	32	53.75	.44
35	Causten, D. C	May, June, 1851	G. W. Dean	Soper	210	54	41.77	.44
35½	Sugarloaf, Md	Sept., Oct., Nov., 1879	C. O. Boutelle	Bull Run	32	29	16.11	.22
36	Bull Run, Va	Oct., Nov., 1871	C. O. Boutelle	Stabler	246	35	34.20	.28
37	Maryland Heights, Md	Oct., 1870	C. O. Boutelle	Peach Grove	317	48	55.23	.28
38	Clark, Va	Aug., 1871	C. O. Boutelle	Bull Run	202	19	27.62	.28
39	Long Mountain, Va	Nov., 1875	A. T. Mosman	Spear	223	28	41.73	.36
40	Elliot's Knob, Va	July, Aug., 1878	A. T. Mosman	Humpback	303	25	23.90	.31
41	Moore's Mountain, N. C	Nov., Dec., 1876	A. T. Mosman	Buffalo	158	33	31.16	.37
42	Young's Mountain, N. C	Oct., 1876	C. O. Boutelle	Poore	126	52	53.82	.31
43	King's Mountain, N. C	May, June, 1877	C. O. Boutelle	Benn	141	33	36.91	.29
44	Paris Mountain, S. C	Oct., Nov., 1875	C. O. Boutelle	Wofford	267	18	15.16	.34
45	Currahee, Ga	Oct., Nov., 1874	C. O. Boutelle	Rabun	188	10	27.88	.31
46	Sawnee, Ga	Oct., 1873	C. O. Boutelle	Currahee	245	34	26.20	.35
47	Middle Base, Ga	Jan., Feb., 1873	C. O. Boutelle	Stone Mountain	312	22	28.94	.33
48	Lavender, Ga	Nov., Dec., 1874	F. P. Webber	Kenesaw	300	11	59.11	.39

NOTE.—The point of reference for No. 17 is the West Transit.

APPENDIX B, TABLE 2.—*Comparison of the register azimuths, apparent deflections of the meridian, and corresponding apparent deflections in the prime vertical.*

No.	Direction.	Astronomical azimuth.			Seconds of geodetic azimuth from register.	A — G, or apparent local deflection.	Latitude φ.		Longitude λ.		Deflection in prime vertical Δ p.
		°	′	″	″	″	°	′	°	′	″
1	Howard to Pigeon	63	54	45.10	47.56	— 2.46	44	38	67	23.7	+ 2.49
2	Cooper to Howard	351	53	12.05	14.52	— 2.47	44	59	67	28.0	+ 2.47
3	Humpback to Cooper	254	42	32.34	32.12	+ 0.22	44	52	68	06.6	— 0.22
4	Mount Desert to Ragged	78	30	46.82	50.27	— 3.45	44	21	68	13.6	+ 3.53
5	Harris to Humpback	254	35	10.71	10.30	+ 0.41	44	40	69	08.9	— 0.42
6	Ragged to Mount Pleasant	81	48	44.99	45.80	— 0.81	44	13	69	09.1	+ 0.83
7	Cape Small to Sebattis	155	19	03.51	03.56	— 0.05	43	47	69	50.7	+ 0.05
8	Sebattis to Mount Independence	24	31	23.55	24.47	— 0.92	44	09	70	04.7	+ 0.95
9	Mount Independence to Agamenticus	26	55	48.62	52.17	— 3.55	43	46	70	19.2	+ 3.71
10	Shootflying to Manomet	143	03	22.74	21.66	+ 1.08	41	41	70	20.8	— 1.21
11	Indian to Copecut	135	35	58.82	65.57	— 6.75	41	26	70	40.7	+ 7.64
12	Agamenticus to Thompson	2	36	55.39	59.54	— 4.15	43	13	70	41.5	+ 4.42
13	Thompson to Manomet	351	21	41.82	43.94	— 2.12	42	37	70	43.8	+ 2.30
14	Mount Pleasant to Mount Blue	205	59	21.56	20.84	+ 0.72	44	02	70	49.3	— 0.74
15	Copecut to Blue Hill	175	17	06.47	07.43	— 0.96	41	43	71	03.6	+ 1.08
16	Blue Hill to Manomet	305	57	30.02	33.29	— 3.27	42	13	71	06.9	+ 3.60
17	Harvard College Observatory West Transit to Blue Hill	356	22	57.94*	57.01	+ 0.93	42	23	71	07.7	— 1.02
18	Gunstock to Mount Pleasant	217	43	33.47	30.62	+ 2.85	43	31	71	22.2	— 3.00
19	Beaconpole to Blue Hill	228	55	17.16	20.79	— 3.63	42	00	71	27.0	+ 4.04
20	Spencer to Beaconpole	185	57	33.02	37.33	— 4.31	41	41	71	29.7	+ 4.83
21	Unkonoonuc to Gunstock	196	35	20.01	19.87	+ 0.14	42	59	71	35.3	— 0.15
22	Wachusett to Bald Hill	24	17	41.19	35.38	+ 5.81	42	29	71	53.2	— 6.34
23	Mount Tom to Monadnock	212	37	21.79	17.86	+ 3.93	42	14	72	38.9	— 4.32
24	Sandford to Ruland	5	50	25.04	17.41	+ 7.63	41	28	72	57.0	— 8.63
25	West Hills to Wooster	174	57	38.25	36.15	+ 2.10	40	49	73	25.5	— 2.43
26	Beacon Hill to Weasel	183	35	29.89	31.40	— 1.51	40	22	74	13.7	+ 1 77
27	Mount Rose to Mount Holly	7	46	55.59	60.18	— 4.59	40	22	74	43.4	+ 5.40
28	Yard to Lippincott	347	17	38.57	38.77	— 0.20	39	58	75	23.3	+ 0.24
29	Principio to Turkey	1	34	43.50	36.07	+ 7.43	39	36	76	00.3	— 8.97
30	Marriott to Hill	96	37	43.24	33.71	+ 9.53	38	52	76	36.6	—11.82
31	Webb to Soper	88	59	49.22	41.72	+ 7.50	39	05	76	40.5	— 9.23
32	Hill to Webb	219	46	58.29	49.39	+ 8.90	38	54	76	52.9	—11.02
33	Soper to Webb	269	49	23.38	17.08	+ 6.30	39	05	76	57.0	— 7.74
34	Seaton to Hill	265	32	53.75	42.11	+11.64	38	53	77	00.0	—14.43
35	Causten to Soper	210	54	41.77	36.12	+ 5.65	38	56	77	04.4	— 7.00
35½	Sugarloaf to Bull Run	32	29	16.11	21.46	— 5.35	39	16	77	23.6	+ 6.54
36	Bull Run to Stabler	246	35	34.20	35.35	— 1.15	38	53	77	42.3	+ 1.43
37	Maryland Heights to Peach Grove	317	48	55.23	57.42	— 2.19	39	21	77	43.0	+ 2.67
38	Clark to Bull Run	202	19	27.62	27.53	+ 0.09	38	19	78	00.2	— 0.11
39	Long to Spear	223	28	41.73	45.90	— 4.17	37	17	79	05.2	+ 5.47
40	Elliot's Knob to Humpback	303	25	23.90	21.24	+ 2.66	38	10	79	18.9	— 3.38
41	Moore to Buffalo	158	33	31.16	31.35	— 0.19	36	24	80	17.0	+ 0.26
42	Young to Poore	126	52	53.82	52.42	+ 1.40	35	44	80	38.9	— 1.95
43	King to Benn	141	33	36.91	39.63	— 2.72	35	12	81	18.8	+ 3.86
44	Paris to Wofford	267	18	15.16	15.93	— 0.77	34	57	82	24.7	+ 1.10
45	Currahee to Rabun	188	10	27.88	25.79	+ 2.09	34	32	83	22.6	— 3.03
46	Sawnee to Currahee	245	34	26.20	28.54	— 2.34	34	14	84	09.7	+ 3.44
47	Middle Base to Stone Mountain	312	22	28.94	32.29	— 3.35	33	54	84	16.7	+ 4.98
48	Lavender to Kenesaw	300	11	59.11	60.42	— 1.31	34	19	85	17.4	+ 1.92

NOTE.—The numbers in second column are identical with the corresponding astronomical azimuths given in Appendix B, Table 1.

* To reduce to center of dome add 2′ 28″.42.

APPENDIX C, TABLE 1.—*Astronomical (telegraphic) longitudes of the oblique arc along the Atlantic*

No.	Name of station.	Date of observation.	Observer.	Resulting astronomical longitude.	Probable error.
				h. m. s.	s.
1	Calais, Me	Sept., Oct., 1857; Dec., 1866	G. W. Dean, E. Goodfellow, C. O. Boutelle	4 29 07.613	±.07
2	Bangor, Me	Nov., Dec., 1851; Sept., Oct., 1857	L. F. Pourtales, S. C. Walker, G. W. Dean, E. Goodfellow.	4 35 07.927	.06
3	Cambridge, Harvard College Observatory Dome.*	Nov., Dec., 1851; June, 1867	W. C. Bond, S. C. Walker, L. F. Pourtales	4 44 30.994	.04
4	Rutherfurd Observatory, N. Y	July, Aug., 1848	S. C. Walker, W. C. Bond, E. Loomis	4 55 57.064	.06
5	United States Naval Observatory, Washington, dome.*	June, 1867; Feb., Mar., 1874	S. Newcomb, A. Hall, — Thirion, J. Winlock, G. M. Searle, W. Harkness, J. R. Eastman.	5 08 12.036	.05
6	Statesville, N. C	Dec., 1878; Jan., 1879	G. W. Dean, E. Smith	5 23 34.635	.05
7	Atlanta, Ga	Mar., 1874; Jan., Feb., 1879	E. Smith, F. Blake, W. Harkness, J. R. Eastman, G. W. Dean.	5 37 33.226	.05

*See page 182, Coast Survey Report of 1874. Point of reference, center of dome; for other localities, the transit of the astronomical station.

APPENDIX C, TABLE 2.—*Comparison of the register longitudes, apparent deflections in longitude, and corresponding apparent deflections in the prime vertical.*

No.	Name of station.	Latitude.	Astronomical (telegraphic) longitude.	Register seconds of geodetic longitude.	A — G, apparent local deflection.	Deflection in prime vertical Δp.
		° ′	° ′ ″	″	″	″
1	Calais (T), Me	45 11.1	67 16 54.20	49.87	+4.33	+3.05
2	Bangor (T), Me	44 48.3	68 46 58.90	58.07	+0.83	+0.59
3	Cambridge (D), Mass	42 22.9	71 07 44.91	43.11	+1.80	+1.33
4	New York (T), N. Y	40 43.8	73 59 15.96	15.10	+0.86	+0.65
5	Washington (D), D. C	38 53.7	77 03 00.54	08.28	−7.74	−6.02
6	Statesville (T), N. C	35 46.9	80 53 39.53	43.86	−4.33	−3.51
7	Atlanta (T), Ga	33 44.9	84 23 18.39	24.54	−6.15	−5.11

APPENDIX No. 9.

ON THE SECULAR CHANGE OF MAGNETIC DECLINATION IN THE UNITED STATES AND AT SOME FOREIGN STATIONS. BY CHARLES A. SCHOTT, ASSISTANT COAST AND GEODETIC SURVEY.

[Fourth edition, June, 1881.*]

The present investigation incorporates the additional observations made or collected since June, 1879 (date of the last edition), and contains the extended and improved results of old stations as well as those for a number of new localities. The geographical range of the discussion includes a station in Europe, a station in Brazil, two on the Sandwich Islands, and one in Asiatic Russia.

The demand for the contents of this article has been constantly on the increase, not only by scientists and surveyors, but also by lawyers, arising chiefly from cases of disputed land boundaries, which originally had been run by compass and are now required to be retraced. To render this investigation more useful to practical men, I have thought it desirable to preface it by a brief account of the various and principal motions, systematic and irregular, to which the direction of the magnetic needle is subject, and thus clearly to separate and distinguish these changes from the secular change, which is here the special object of treatment. Theoretically, a knowledge of the secular change is of great importance and practically is indispensable in order that the coast charts published by this office may be supplied with the variation of the compass for the date of issue.

The magnetic declination (or variation of the compass, as it was formerly called by surveyors and still is by navigators), at any place, is the angle contained between two vertical planes, one being the astronomical or true meridian, and the other a plane in which the horizontal axis of a freely suspended magnet lies at the time. The former plane is fixed; the latter variable, since it is found that the needle is in a state of continual motion. The magnetic declination varies with respect to space and time; it is, therefore, necessary to give with the statement of its measure the exact time (year, day, and hour) when an observation was made, as well as the geographical position of the place (the latitude and longitude to the nearest minute of arc). The declination is called "west" when the *north* end of the magnet points to the west of true north; algebraically this fact is indicated by a + sign, and if "east" by a − sign. It is a matter of observation that the magnet, when light and delicately suspended (by a single fiber of raw silk), is seldom or never at rest, but is always shifting its direction, or is in a state of oscillation or of tremor, or it may be of sudden changes. These angular motions have been classified as regular (periodic) and irregular variations, and of these we propose to notice briefly the principal ones, such as may generally be exhibited within the limits of the United States.

The *solar-diurnal* variation consists in a systematic movement of the magnet, having for its period the solar day. Its character is the same for the greater part of the northern hemisphere, viz, about the time of sunrise the *north* end of the needle is generally found approaching to or near its most *easterly* deflection from the average magnetic meridian. This phase happens, for instance, at Philadelphia, on the yearly average, about $7\frac{3}{4}^h$ a. m.; at Key West, Fla., about $8\frac{1}{4}^h$ a. m.; and the same at Madison, Wis. It is subject to an annual variation, being about $\frac{3}{4}$ of an hour later in the months when the sun is south of the equator, and about $\frac{1}{2}$ of an hour earlier in the summer months than its yearly average epoch. The north end of the needle then begins its principal daily motion, and reaches the opposite extreme position, or its western elongation, about half past

*This paper originally appeared in Coast Survey Report for 1859, Appendix No. 24, pp. 296–305. In the second edition, in Coast Survey Report for 1874, Appendix No. 8, pp. 72–108, the investigation appears greatly extended; the substitution of a sine for a cosine function was made and the epoch was changed from 1830 to 1850; also some use was made of Cauchy's method of interpolation for the establishment of some second periodic terms. The third edition, issued in June, 1879, appeared in pamphlet form, and is not contained in any annual report of the Coast and Geodetic Survey. The geographical range of the investigation was much enlarged, and the paper was illustrated by two plates.

1 o'clock p. m. It is reached a few minutes earlier in summer and a few minutes later in winter, and hardly varies half an hour for different localities. After this epoch the needle takes up an easterly movement, and gradually returns nearly to the direction from which it set out in the morning. Frequently an interruption, or small reversed motion, is exhibited during the night. The average daily direction is reached in summer about $10\frac{1}{4}^{h}$ a. m. and in winter about $10\frac{3}{4}^{h}$ a. m. at Philadelphia, and generally within half an hour of these times at other places. The magnetic meridian is crossed a second time, generally between 7 and 9 p. m. The angular range between the morning and afternoon elongations, or the diurnal range, is about 8′ on the average at Philadelphia and about $5\frac{1}{2}'$ at Key West; in higher magnetic latitudes more, in lower less. This range is subject to an annual inequality, being much more conspicuous in summer than in winter ($10\frac{1}{2}'$ at Philadelphia in August and 6′ in November). It is further subject to a periodic inequality related to the eleven-year cycle of the sun-spots. It is least in years of minimum sun-spots (as in 1878, for instance) and greatest in years of maximum sun-spots (as in 1870) the factors being 0.7 and 1.3, about, of the average amount of these years respectively. This daily variation appears at times intensified, at other times enfeebled, and during the winter months there are days on which it cannot be recognized. Observations must be corrected for time of day in order to reduce the result to the average direction of the 24 hours; a table given for this purpose is found in Coast Survey Report of 1875, p. 263.

The *annual variation* of the declination is so small that a mere mention of its existence suffices; its amplitude is at most $1\frac{1}{2}$ minute of arc.

The lunar inequalities: These we likewise pass over on account of their small amplitude. The principal inequality is the lunar diurnal variation exhibiting the peculiarity of two maxima and two minima values on each lunar day. The range of this inequality at Philadelphia is about 27″, and at Toronto, Canada, about 38″. Other lunar inequalities are of yet smaller order.

The secular change of the magnetic declination, our subject proper, is most probably also of a periodic character, but since it requires centuries for its full development, and as yet no one cycle has actually been completed within the range of observation, we are obliged, in the absence of any reliable theory, to follow up the phenomena by continuous observations. Thus from time to time our previous deductions or supposed laws need changing or amending in order to preserve the required harmonious relations with facts. The secular motion may be compared with a wave motion or with an oscillation of a pendulum which comes to rest momentarily at its extreme positions or elongations and moves fastest midway between these extremes. Smaller variations within this period have also been detected, but the general movement (of the north end) of the magnet may be described as follows: About the times of maximum deflection the magnet appears almost stationary or oscillating about the same average direction (to ordinary or rough instruments) for several years; soon, however, the effect of the secular change becomes perceptible, increasing gradually, year by year; the progressive motion soon reaches an annual maximum change, after which it slowly diminishes, becoming stationary at the opposite extreme digression and possibly returning again to its first position. Within the area of the United States and south of latitude 49° a complete oscillation of this kind may require between two and a half and three and a half centuries, during which time the magnet would swing twice through an arc of several degrees, generally keeping within the limits of 3° and 7° of total range for our geographical boundaries; in other localities the period and range is very much greater. The great regularity of the motion is well shown on the accompanying diagram for Paris, France, for which place we possess the longest series of observations; the period is about $4\frac{2}{3}$ centuries, and the range nearly 33°. To illustrate further the effect of the secular change we may take the case of New York City. In this locality the needle was observed to be in nearly a stationary condition about 1685, pointing then 9° to the west of north; it then moved easterly and reached its easternmost digression about 1797, showing at that time only 4° west declination. Ever since this epoch the motion has been westerly, its value being now $7\frac{3}{4}$° W.; the greatest annual change (nearly 5′) has apparently been passed. The times of these stationary epochs are different at different localities; the last epoch was noted earliest in Maine, later in Florida and Texas, and has not yet been reached in California. At present, all along our Atlantic and Gulf coasts, and over the middle and eastern parts of the United States, the effect of the secular change is to *increase* west declination, or (what is the same) to *decrease* east declination; but on the Pacific coast and for some distance interior the effect is opposite, viz, an *increase* of east declination. Alaska, however, is to be excepted; there easterly declination seems to decrease slowly. There must, consequently, be a region of no change, which will be noticed further on. It is this motion, known as the secular change, which renders it necessary to reconstruct from time to time our isogonic charts. Although the secular change is perfectly regular it may not always appear so, especially when deduced from few observations made at different stations in the same general locality, either on account of small observing errors and possible local deflections, or for the reason that ordinary periodic variations and disturbances are not fully eliminated. Among the latter must be classed the—

Magnetic disturbances; these may occur at any time, and are, when taken individually, beyond the power of prediction; but attacked by the statistical method, *i. e.*, when classified and averages are taken of many thousands, they are found to be subject to various laws. Their presence is generally indicated by sudden deflections and by rapid and great fluctuations in the direction of the needle as compared with its normal position, which otherwise might have been expected. They often take place simultaneously at distant regions of the globe and in duration may be confined to a few hours, or they may last a day or even for several days. They are frequently accompanied by auroral lights and by strong electric earth-currents. When analyzed in large numbers they exhibit a solar-diurnal variation, the westerly and easterly disturbances, however, following different laws. They also have an annual variation and seem to depend largely on the sun-spot period or an eleven-year cycle. Irrespective of direction of the disturbing forces the most disturbed hours of the day are generally those between 7^h and 10^h a. m., and the least disturbed those between 2^h and 6^h p. m. Westerly disturbances occur most frequently about 8^h a. m. and least about 8^h p. m. They exhibit a single daily progression. Easterly disturbances reach a maximum about 8^h p. m. and a minimum about 2^h p. m.; they exhibit a double daily progression. Westerly and easterly disturbances appear to agree in their annual variation, in their times of maxima, *i. e.*, in August, September, and October, and in their times of minima, *i. e*, in January and June. The disturbances are most frequent and considerable in years of maximum sun-spot activity, and the reverse in years of minimum sun-spots. The following table of the observed disturbances, in a bi-hourly series at Philadelphia in the years 1840 to 1845, will give an idea of their relative frequency and magnitude:

Deviations from normal direction.	Number of disturbances.
3′.6 to 10′.8	2189
10′.8 to 18′.1	147
18′.1 to 25′.3	18
25′.3 to 32′.6	3
Beyond......	0

At Key West, Fla., the maximum deflection noticed between 1860 and 1866 was 21′.4. At Madison, Wis., where the horizontal magnetic intensity is considerably less, very much larger deflections have been noticed. Thus, on October 12, 1877, one of 48′, and on May 28, 1877, one of 1° 24′. We now proceed to the consideration of the secular change of the magnetic declination.

HISTORICAL NOTE.

The following brief historical remarks on the magnetic declination and its secular variation were extracted from Humboldt's Cosmos (Otte's translation, London, 1849–1858), vols. II and V; from the Encyclopædia Britannica, 9th edition, Art. Compass, vol. VI (Boston, 1877), and from E. Walker's treatise Terrestrial and Cosmical Magnetism, Cambridge (England), 1866, in which works fuller references will be found. The Encyclopædia of Experimental Philosophy, London, 1848, Art. Magnetism, as well as Gehler's Physikalishes Wörterbuch, Leipzig, 1825, Art. Compass, were also consulted.

The first notice of the magnetic needle as applied to navigation we meet with among western nations does not date further back than the eleventh or twelfth century of our era, but in China the directive property of the magnetic needle was made use of on land as early as the twelfth century B. C., and, according to tradition, even at a very much earlier time (2634 B. C). In the third and fourth centuries of our era, Chinese vessels were guided by the magnetic needle, and through them a knowledge of the polarity of the needle was conveyed to India, and thence westward. In the ninth century Chinese merchants traded in ships to the Persian Gulf and the Red Sea. Probably through the influence of Arabian navigators, or through the agency of the crusaders, the use of the mariners compass was introduced into Eastern Europe. Among the first European writers of the middle ages who refer to the loadstone or to the compass is the Icelandic historian, Are Frode, who lived about the end of the eleventh century. He states that the directive property of the loadstone was then known to seamen in northern countries. Next, Alexander Neckam, in two treatises, "De Utensilibus" and "De Naturis Rerum," of the twelfth century; Guyot, of Provins, in 1190, and Jaques de Vitry, between 1204 and 1215. Raymond Lully, in 1272 and 1286, remarks that the seamen of his time employed the magnetic needle, and from Torfæus we learn that the compass was in use among the Norwegians about the middle of the thirteenth century. Among western nations the construction of the instrument underwent great improvements, particularly by the hands of Flavio Gioja, of Amalphi, in 1302.

The declination.—From a Chinese work written between 1111 and 1117 A. D., we learn that the needle was then suspended by a thread, and that the mode of measuring the amount of the declination, it being then west (or as expressed east of south), had long been understood, and it can hardly be supposed that the fact of the needle, in general, not pointing to the true north and south could have been overlooked in the twelfth century, on the Mediterranean, in places where the declination reached 6° or 10°. A passage interpolated in a Paris MS., a copy of "Epistola Petri Peregrini, &c.," of 1269, states the declination to have been determined by him in Italy at 5° E. Columbus probably was the first who records the change in the declination with change of position. On starting from the west coast of Spain he had east declination. In September, 1492, in latitude 28° longitude 28° (about) he observed 11° W. He has also the merit of being the first to discover a part of an agonic line. The first scientific work in Europe in which the declination is treated at any length and deduced from actual observations is that by Boroughs, published in 1581, entitled "A discourse on the Variation of the Cumpas or Magneticall needle," and is dedicated to the "travaillers and mariners of England." In 1599, Prince Maurice, of Nassau, the lord high-admiral of the Low Countries, recommended seamen to keep a register of the declination in every part of the world they might visit.

Isogonic Charts.—The declination was marked on the chart of Andrea Bianco, drawn up in the year 1436, and Alonso de Santa Cruz, in 1530, constructed the first general declination chart, though based upon very imperfect material. Upon the chart by Father Christopher Burrus (died in 1632), published at Lisbon, the lines are called "tractus chalyboeliticos." About 170 years after Alonso de Santa Cruz, Edw. Halley published his celebrated isogonic chart for the year 1700, based entirely upon observations. [Tabula Nautica, Variationum Magneticarum Index, juxta observationes anno 1700.] His voyages of the years 1698, 1699, and 1702 were undertaken at the expense of the British Government. This chart comprises the areas of the North and South Atlantic, the Indian, and the extreme western part of the Pacific Ocean. Isogonic charts became quite numerous after Halley's time. Those by Hansteen (Magnetismus der Erde, 1819) deserve special mention; his earliest one is for the year 1600.

The secular variation of the declination.—The discovery of the gradual change of the declination, which for any one place had by philosophers hitherto been supposed constant, is due to Gellibrand, of Gresham College, England. In 1635 he published his work entitled, "A discourse mathematicall on the Variation of the Magneticall Needle, together with its admirable diminution lately discovered." He based his conclusions upon the recorded observations of Boroughs (1580), of Gunter (1622), and his own observations (1633–'34), showing that in the vicinity of London the direction of the needle had changed in the interval fully 7° to the westward. From this time the fact of the secular variation was completely established, and it remained to later times to determine its extent and develop the law governing this change, and endeavor to find its cause. That the velocity was not uniform was soon perceived, and the apparent periodic character of the variation was prominently forced upon the attention of the observers when the needle reached a stationary condition, as for instance, in the eastern part of the United States towards the end of the eighteenth century, and then recommenced its motion in a direction *opposite* to that it had before. Similarly at Paris, France, the secular change was westward between the stationary epochs of 1580 (about) and 1814 (about), since which time the needle has been retracing its course eastwardly. Nearly midway between such stationary epochs the annual change is observed to be a maximum.

ANALYTICAL EXPRESSION OF THE SECULAR CHANGE OF THE DECLINATION.

The secular change can be represented with considerable accuracy by means of a circular or harmonic function, as might be expected from the almost unlimited adaptation of such functions to all forms of periodically recurring phenomena, provided a sufficient number of terms are introduced. The formula employed for our purpose may be written—

$$D = \delta + r \sin (\alpha m + c) + r_{,} \sin (\alpha_{,} m + c_{,}) + r_{,,} \sin (\alpha_{,,} m + c_{,,}) + \ldots\ldots\ldots$$

Where D = magnetic declination at any time t, positive when west, negative when east.

m = number of years and fractions of a year from an epoch t_0 for which 1850 has been adopted; hence $m = t - 1850.00$

$\alpha \;\; \alpha_{,} \;\; \alpha_{,,} \ldots\ldots$ are factors depending on the adopted periods $p \;\; p_{,} \;\; p_{,,} \ldots\ldots$ of the several terms; so that $\alpha = \frac{360^\circ}{p}$, $\alpha_{,} = \frac{360^\circ}{p_{,}}$, $\alpha_{,,} = \frac{360^\circ}{p_{,,}}$, etc.

Thus to $\alpha = 0.9$, 1.0, 1.2, 1.5 correspond periods of 400, 360, 300, and 240 years respectively.

$r \;\; r_{,} \;\; r_{,,} \ldots\ldots$ are parameters, and

$c \;\; c_{,} \;\; c_{,,} \ldots\ldots$ epochal constants of the several periodic terms.

δ = a constant, representing the mean or normal declination about which the periodic fluctuations take place.

The quantities $\delta \quad r \;\; r_{,} \;\; r_{,,} \ldots \quad \alpha \;\; \alpha_{,} \;\; \alpha_{,,} \ldots$ and $c \;\; c_{,} \;\; c_{,,} \ldots$ for any one locality have all to be determined from the observations made there at various times, and their most probable values are to be deduced by application of the method of least squares.

We begin by assuming a suitable value* for the length of the principal period, and the first periodic term of the formula is treated as follows:

Put $\delta = \delta_{,} + x$ where $\delta_{,}$ = an assumed approximate value δ, and x a correction to it; also put

$$r \cos c = y \qquad \text{and} \qquad r \sin c = z,$$

then the conditional equations will take the form

$$0 = \delta_{,} - D + x + \sin \alpha m \cdot y + \cos \alpha m \cdot z + \ldots\ldots\ldots$$

from which the numerical values of $x \;\; y \;\; z$ are to be deduced in the usual way by means of normal equations. To determine the value of α (and similarly of $\alpha_{,} \; \alpha_{,,} \ldots$) the computation is repeated three times (or more if necessary) using the slightly changed values $\alpha + \Delta\alpha$ and $\alpha - \Delta\alpha$, and that value is found and finally retained which renders the sum of the squares of the differences of observed and computed declinations a minimum. In some cases where certain observations were evidently less trustworthy than others, yet which nevertheless could not be dispensed with owing to the small number of observations, or on account of their special value with reference to time, special weights were assigned to these observations; generally each observation received the weight unity, a few imperfect observations the weight one-half. In these cases the conditional equations were multiplied by the square root of their respective weight. Of observations evidently grossly in error no notice whatever was taken. In finally selecting what seemed to be the best expression for the secular change at a station, I have also occasionally been guided by the accord of the various values entering into the equation when compared with corresponding values in the equations for surrounding stations. When applying Cauchy's method of interpolation the form

$$D = \delta + r \cos c \cdot \sin m\alpha + r \sin c \cdot \cos m\alpha + \ldots$$

was found more convenient in use. This method was employed for establishing such second or third periodic terms as appeared demanded by the observations, but only a few of these could be determined and they generally failed on account of insufficiency of observations or for want of sufficient accuracy.

* It may be found graphically in the first instance.

The annual change v of the magnetic declination due to the secular motion, positive when increasing west (or decreasing east) and negative when in the opposite direction; also the epoch of minimum west declination (or of maximum east); also the amount of the declination at this epoch and the apparent probable error of an observation—are found as follows:

Differentiating the expression for D we have

$$dD = r\alpha \cos(\alpha m + c)\, dm + r_{,}\alpha_{,} \cos(\alpha_{,} m + c_{,})\, dm + \ldots\ldots$$

hence for any time t and for minutes of arc,

$$v = 60 \sin 1^{\circ} [r\alpha \cos(\alpha m + c) + r_{,}\alpha_{,} \cos(\alpha_{,} m + c_{,}) + \ldots]$$

Maxima and minima are deduced from the equation:

$$0 = r\alpha \cos(\alpha m + c) + r_{,}\alpha_{,} \cos(\alpha_{,} m + c_{,}) + \ldots\ldots$$

from which expression m can be found.

The apparent probable error e_0 of an observation is deduced from the differences Δ of the n observed and computed declinations by the formula $e_0 = \sqrt{\frac{0.455\, \Sigma\Delta^2}{n - n_{,}}}$, where $n_{,}$ equals the number of unknown quantities in the expression for D which was found from the observations themselves; when weights w enter we substitute $w\Delta^2$ for Δ^2. The greater part of this apparent probable error is due to the fact that the observations collected at any one place were not generally made at precisely the same spot, thus admitting the effect of possible local irregularities in the distribution of magnetism in addition to the ordinary observing errors. In other cases the observations evidently were not corrected for diurnal variation, and the hour of the day of observation not being known the received imperfect value had to be accepted.

There are a few stations where from want of a sufficient number of observations, or from shortness of record between the first and last observation, no period of the secular change could be made out. In such cases the *annual change* due to the secular motion may be expressed by means of an exponential function, thus:

$$D = d_0 + y\,(t - t_0) + z\,(t - t_0)^2 + \ldots.$$

where d_0 = magnetic declination at epoch t_0. I adopt, as in the preceding formulæ, $t_0 = 1850.0$ and put $d_0 = \delta + x$, where δ = an approximate value of d_0, and x a correction to it to be determined, as well as y and z, &c., from the observations themselves. For this purpose we have the conditional equation

$$0 = \delta - D + x + y\,m + z\,m^2 + \ldots.$$

which equations are to be treated, as customary, by the method of least squares.

D = resulting magnetic declination $\left\{ \begin{matrix} + \text{when W} \\ - \text{when E} \end{matrix} \right\}$ for the time t

a = annual change $= y + 2z\,(t - t_0) = y + 2z\,.\,m$; also

T = time of maximum declination $= t_0 - \frac{y}{2z}$

In case the change of declination can be represented by a straight line, we have

$D = d_0 + a\,(t - t_0)$ and the conditional equation $0 = d_0 - D + a\,(t - t_0)$

where d_0 = mean of all observed declinations, and t_0 = mean of corresponding times.

The principal uncertainty in the investigation thus arises partly from large observing or instrumental errors in the older observations made with ordinary compasses or with rude instruments generally, and partly, in modern observations, since the introduction of more refined instruments (the magnetometer, with collimator magnet and theodolite) from change of local position and imperfect elimination of irregular variations from the normal direction of the magnet. From the extended use of iron and the rapid growth of cities, it is difficult to select and preserve at such places a suitable locality for use at future times. Accurate investigations of the secular change can only be made at permanent magnetic observatories or in localities not liable to disturbing influences.

In applying at present a periodic function for representing the secular change it should be understood that this *does not necessarily* imply that the phenomenon is a periodic one, or has a period of the length assigned, or that it must exhibit a second and other periods of like character to the first, or even that a first period will be completed without change of law.* The aim is simply to represent by a suitable and comprehensive formula the changes which are observed in the direction of the resultant horizontal magnetic force, and to provide the means for the further study of the phenomenon as well as for predicting, at least for a few years in advance, the probable direction of the needle as required for use on our hydrographic charts.

The process is thus one of a tentative character, and the formulæ are empirical. Employing a formula of interpolation capable of representing the phenomenon as far as observed, it would manifestly be unsafe to extend the numerical results beyond the limits of observation, and they are here given within safe limits and should not be extended unless it should be found that additional observations sustain them.

COLLECTION OF MAGNETIC DECLINATIONS FOR THE DISCUSSION OF THE SECULAR CHANGE.

The collection of the material is presented first, the stations being arranged in approximately geographical order, beginning in the northeast, passing to the south and west, and ending in the northwest. This approximates to an arrangement proceeding from the greatest western to the greatest eastern declination. For each locality the observed declinations are given in chronological order, together with such notes and references respecting observer, place, publication, etc., as could be supplied. The stations here given are the only ones, as far as known, at present suitable for a discussion of the secular change, but it is expected that future accumulation and collection of data will render the character of the work more comprehensive and reliable than it can now be made.

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* If we suppose for the moment that the secular change consists simply of a swing about a mean position, the deflecting force being a maximum at the times of elongation and zero for the epoch midway between, we may obtain some rough evaluation of the magnitude of the horizontal deflecting force when greatest. Thus at Philadelphia the half-amplitude or the secular deflection either way from the normal equals nearly $3^\circ.3$, and the last extreme deflection happened about 1807. At that time, then, the deflecting force corresponded to $\frac{3.3}{57.3} = \frac{1}{17}$ nearly of the normal horizontal force acting in the plane of the meridian. This deflecting force is very much greater than the deflecting force which produces the daily solar variation, the latter being at most, at Philadelphia, for an average amplitude of $8'.0$ only $\frac{4.0}{3437.7} = \frac{1}{860}$ nearly of the same normal horizontal force.

COLLECTION OF MAGNETIC DECLINATIONS, OBSERVED AT VARIOUS PLACES IN THE UNITED STATES AND AT SOME FOREIGN STATIONS, FROM THE EARLIEST TO THE PRESENT TIME, AND FOUND SUITABLE FOR THE INVESTIGATION OF THE SECULAR CHANGE.

PARIS, FRANCE.

$\phi = 48° 50'.2$ $\lambda = -2° 20'.2.$

(Paris observatory.)

		°	′	
1	1541	7	E.	Bellarmatus*.
2	1550	8		Orontius Finaeus.
3	1580	11	30	Sennertus.
4	1603	8	45	Nantonnier.
5	1610	8	0	
6	1630	4	30	Petit.
7	1642	2	30	
8	1659 and 1660	1	30	
9	1664	0	40 E.	Picard.
10	1666 and 1667	0	08 W.	Picard.
11	1670	1	30	Picard.
12	1680-81-82-83-84	3	08	Picard and La Hire.
13	1685-86-87-88-89	4	52	La Hire and Cassini.
14	1691-92-93-95-96-97-98	6	37	La Hire and Cassini; mean of 2 values of 1698.
15	1699, 1700-1-2-3-4-5-6-7	9	00	La Hire and Cassini; mean of 2 values for 1700-1-2-3-4, and of 3 values for 1705.
16	1708-9-10-11-12-13-14-15-16	11	11	La Hire and Cassini; 1 value for 1715, 3 for 1716, and 2 values each for other years.
17	1717-18-19-20-21-22-23-24-25	12	52	Cassini, La Hire, and Maraldi; 2 values for 1717-18-21-22-23, 3 for 1725, and 1 for 1719-20-24.
18	1726-27-28-29-30-31-32-33-34	14	37	Maraldi and Buache: 2 values for 1734.
19	1735-36-37-38-39-40-41-42-43	15	23	Maraldi and Cassini; 2 values for 1735-36-38-40-42 each.
20	1744-45-46-47-48-49-50-51-52	16	37	Fouchy.
21	1753-54-55-57-58-59-60	17	49	Maraldi.
22	1765	19	00	Maraldi.
23	1770-71-72-73-74	20	01	Maraldi and Le Monnier; 2 values each for 1772-73-74.
24	1777-78-79-80-81	20	40	Le Monnier; 2 values for 1778, 6 for 1779, 46 for 1780, and 12 for 1781.
25	1782-83-84-85-86	21	25	Le Monnier; 3 values for 1782-83 each, and 2 for 1784-86 each.
26	1789-90-91-92-93	22	18	Le Monnier; 2 values for 1790-91 each.
27	1798-99-1800-1	22	14	Le Monnier; 2 values for 1799.
28	1802-3-4	21	58	Le Monnier, Bouvard, and Cotte; 3 values for 1802.
29	1807	22	34	Bouvard.*
30	1814	22	34	Bouvard.*
31	1816, October 12, 3 p. m	22	25	Arago; Terrestrial and Cosmical Magnetism, by E. Walker, Cambridge (England), 1866. [United into a mean and corrected for diurnal variation 22° 18′ for 1816-19.—Sch.]
31	1817, February 10, $0^h 30^m$ p. m	22	19	Arago; Terrestrial and Cosmical Magnetism, by E. Walker, Cambridge (England), 1866. [United into a mean and corrected for diurnal variation 22° 18′ for 1816-19.—Sch.]
32	1835.5	22	04	Arago; Gen. Sir E. Sabine, Phil. Trans. Roy. Soc., vol. 162, part ii, 1872. $\phi = 48°$ 53′, $\lambda = -2° 20'$.
33	1838, February	21	38	Darondeau; Phil. Trans. Roy. Soc., 1849, part ii.
34	1842.5	21	29	Lamont; Gen. Sir E. Sabine in Phil. Trans. Roy. Soc., vol. 162, part ii, 1872.
35	1858, January 1	19	36.3	Rev. S. J. Perry; Magnetic Survey of the East of France; Phil. Trans. Roy. Soc., vol. 162, 1872, London, 1873.
36	1865	18	44	Encyclopædia Britannica; 9th ed., 1877, Art. Compass.
37	1869, September 1	17	08.4 W.	Rev. S. J. Perry; Mag. Survey of the East of France.

* All the values between 1541 and 1814 inclusive, were taken from the Encyclopædia of Experimental Philosophy (part of the Ency. Metropolitana), London, 1848. Art. Magnetism, by Peter Barlow. The values were combined by me into suitable groups and their means were separately taken, as indicated above.—SCH.

Collection of Magnetic Declinations, etc.—Continued.

HALIFAX, NOVA SCOTIA.*

$\phi = 44° 39'.6$ $\lambda = 63° 35'.3$ W. of Gr.

(Naval-yard observatory.)

		°	'		
1	1700	13		W.	According to chart by Edw. Halley: Tabula Nautica; Variationum Magneticarum index juxta observationes anno 1700. [Greenwich astronomical observations, 1869.]
2	1756	12	50		From MS. map by Charles Morris, assistant surveyor.
3	1775	13	35		Des Barres' Sailing Directions.
4	1798	16	30		Plan published by Thomas Backhouse.
5	1818 (about)	17	28		Remark-book of J. Napier, master R. N., as given by Anthony Lockwood, esq.
6	1821, June and November	17	36		Remark-book of J. Napier, master R. N., as observed by himself, viz, in June, 17° 38'.2; in November, 17° 33'.5
7	1852-53	18	10		Captain Bayfield, MS. survey.
8	1852-53	18	51		Remark-book of J. Hill, master, R. N., viz, August, 1852, 18° 46'; September, 1852, 19° 21'; August, 1853, 18° 25'.
9	1860, July 22	19	55		Captain Orlebar, R. N.
10	1866, April	21	05.6		Halifax dock-yard, in $\phi = 44° 40'$, $\lambda = 63° 25'$ W.; declination, April 1, 9 a.m., 20° 55'.0; April 3, 3 p.m., 21° 16'.3.
11	1879, September 8-10	20	43.3	W.	J. B. Baylor, U. S. Coast and Geodetic Survey. In southeast end of Dock Yard.

* For the collection and communication of the observed values, Nos. 2 to 10, at Halifax, Nova Scotia, the Coast and Geodetic Survey is indebted to Staff-Commander Fred. Jno. Evans, R. N. (now Hydrographer to the Admiralty). Letters dated January 5, 1866, and April 26, 1867. According to Champlain's observations in this region the declination at Halifax would appear to have been about 16¾° west for 1604 to 1612. Our formula gives 19° west. Champlain's observations are not certain within ± 4 or 5°.

QUEBEC, CANADA.

$\phi = 46° 48'.4$ $\lambda = 71° 14'.5$ W. of Gr.

(Wolfe's Monument.)

		°	'		
1	1642	16		W.	Padre Bressani; Hansteen's Magnetismus der Erde, 1819; also Trans.† of the Lit. and Hist. Soc. of Quebec, 1865. Hansteen's date, 1649, changed to 1642, according to President J. Langton, Art. x of Trans.
2	1686	15	30		De Hayes; Hansteen's Mag. der Erde, 1819.
3	1700	16			Edm. Halley's Isogonic Chart for 1700, Greenwich Observations for 1869.
4	1785	12	35		Surveyor-General Holland; E. T. Fletcher, in Trans.† of the Lit. and Hist. Soc. of Quebec, 1865, Art. ix.
5	1789, June 30	11	45		Louis Perrault, P. L. S.; reference as above.
6	1791, June 22	13	00		Pierre Beaupré, P. L. S.; reference as above.
7	1792, March 24	12	15		J. B. Demers, P. L. S.; reference as above.
	1792, May 9	13	09		A. Dezery, P. L. S.; reference as above.
	1792, May 16	12	00		Ch. Turgeon, P. L. S.; reference as above.
	1792, May 16	12	15		Fr. Legendre, P. L. S.; reference as above.
8	1793	12	05		Surveyor-General Holland; reference as above.
	1793, November 19	13	00		J. C. Antill, P. L. S.; reference as above.
9	1805, April	11	35		Reg. A, folio 117, Dept. of Crown Lands; reference as above.
10	1810	11	00		Becquerel's Traité du Magnétisme, Paris, 1846.
	1810, June 5	12	15		Reg. A, folio 131; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
11	1811, June	12	15		Reg. A, folio 143; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
12	1814	11	50		Kent; Becquerel's Traité du Magnétisme, Paris, 1846.
13	1820, October 2	12	30		Bourdages, P. L. S.; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
	1820, November	12	35		Livingstone, P. L. S.; reference as above.
14	1821, August 25	12	15		Jno. McNaughten, P. L. S.; reference as above.
	1821, September	13	00		A. Cattanach, P. L. S.; reference as above.
	1821, September	13	00		W. Ware, P. L. S.; reference as above.
	1821, November 28	13	20		E. Tetu, P. L. S.; reference as above.
15	1822, January 21	13	00		Jos. Hamel, P. L. S.; reference as above.
	1822, January 21	13	00		Ph. Verrault, P. L. S.; reference as above.
	1822, April 26	13	00		P. J. Bureau, P. L. S.; reference as above.
	1822, May	13	00		Reg. A, folio 162½; reference as above.
16	1823, March 26	13	00		N. Le François, P. L. S.; reference as above.
	1823, May 12	13	00		D. S. Ballantyne, P. L. S.; reference as above.
	1823, October 3	13	00		Jos. Gamahe, P. L. S.; reference as above.
	1823, October 23	13	00		A. Bochet, P. L. S.; reference as above.
	1823, November 14	13	00	W.	L. Dorval, P. L. S.; reference as above.

† I am indebted to Mr. Marcus Baker, of the Computing Division C. and G. S., for pointing out and procuring this volume for me.

Collection of Magnetic Declinations, etc.—Continued.

QUEBEC, CANADA—Continued.

		°	′		
17	1824, March 2	12	40	W.	A. Cattanach, P. L. S.; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
	1831	13	38		Capt. Bayfield; Becquerel's Traité du Magnétisme, Paris, 1846.
	1831, July 20	13	10		Thos. Carrol, P. L. S.; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
18	1831, autumn	13	00		Jos. Hamel, P. L. S.; reference as above.
	1831, September 6	14	00		H. Corey, P. L. S.; reference as above.
	1831, December 10	13	12		John Newman, P. L. S.; reference as above.
19	1832, May	13	00		Reg. B, fol. 36; reference as above.
20	1833, May	12	30		Reg. B, fol. 43; reference as above.
	1833, July	13	00		Reg. B, fol. 43; reference as above.
	1834	14	14		Capt. Bayfield; Trans. Roy. Soc., June, 1872, Gen. Sir E. Sabine, Contributions to Terr. Mag., No. xiii.
21	1834, March 10	13	00		Reg. A, fol. 197; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
	1834	13	00		Reg. B, fol. 61; reference as above.
	1834, July	13	00		Reg. B, fol. 69; reference as above.
22	1835, December	13	10		Reg. B, fol. 85; reference as above.
	1838 and 1839	13	00		Reg. B, fol. 66; reference as above.
23	1839, May	13	30		Reg. B, fol. 144, reference as above.
	1839	13	35		Reg. B, fol. 154; reference as above.
24	1840, May 20	13	50		R. M. Moore, P. L. S.; reference as above.
	1840, September 14	13	35		Procès-Verbal, by Jos. Bouchette, D. S. G.; reference as above.
25	1842, December 7	13	50		Reg. B, fol. 281, Anse des Meres; reference as above.
	1842	14	12		Capt. Lefroy, R. E., Phil. Trans. Roy. Soc. 1849, part ii.
26	1846	14	32		Reg. B, fol. 318, La Canardière; E. T. Fletcher, Trans. Lit. and Hist. Soc. of Quebec, 1865.
	1847, September 17	15	30		Reg. B, fol. 316; reference as above.
27	1847, September 20	14	45		Reg. B, fol. 262; reference as above.
	1847, October 13	13	40		Reg. B, fol. 269; reference as above.
	1848, February	15	15		Reg. B, fol. 277; reference as above.
28	1848, June 28	14	00		Reg. B, fol. 299; reference as above.
	1848, October	14	30		N. Le François, P. L. S., field-book C, 50; reference as above.
29	1849, March 8	15	30		Reg. B, fol. 316; reference as above.
	1849, July 8	15	15		Reg. C, fol. 5; reference as above.
30	1850, April	15	15		Reg. C, fol. 13; reference as above.
31	1851, autumn	15	00		Reg. C, fol. 33; reference as above.
32	1853, January 19	15	30		Reg. B, fol. 320; reference as above.
33	1858, October 8	15	34		Capt. Orlebar, R. N.; communicated by Capt. F. J. Evans, Hydrographic Department, Admiralty, London.
34	1859, July 19	16	17		C. A. Schott, assistant U. S. Coast Survey, C. S. Report, 1859, p. 296, station near Wolfe's Monument.
35	1860, October 12	16	28		Capt. Orlebar, R. N.; communicated by Capt. F. J. Evans, Hyd. Dept., Admiralty.
36	1865	16	40		E. T. Fletcher, surveyor to Department of Crown Lands.
37	1879, September 16, 19	17	13.7	W.	J. B. Baylor, U. S. Coast and Geodetic Survey; station of 1859.

Observations of the same year are united into a mean value for that year.

MONTREAL, CANADA.

$\phi = 45° 30'.5 \qquad \lambda = 73° 34'.9$.

(McGill University.)

		°	′		
1	1749	10	38	W.	M. Gillion } V. Colvin, Sup't Adirondack survey, N. Y., 7th annual report, Albany, 1880, p. 492.
2	1785	8	24		Holland, Surv. Gen. of Canada } V. Colvin, Sup't Adirondack survey, N. Y., 7th annual report, Albany, 1880, p. 492.
3	1793, July 26	8	15		Jer. McCarthey, Trans. Lit. and His. Soc. of Quebec, session of 1864-'65, new series, Quebec, 1865, p. 3.
4	1814	7	45		Becquerel's Traité du Magnétisme, Paris, 1846.
5	1834	8	00		Capt. Bayfield; Phil. Trans. Roy. Soc., 1840, Gen. Sabine's Contributions, No. ix; in $\phi = 45° 32'$, $\lambda = 73° 34'$.
6	1835	9	50		Reference: 7th annual report Adirondack survey, N. Y.; V. Colvin, Sup't, Albany, 1880, p. 492.
7	1842, August	8	58		Capt. Lefroy, R. A., Coast Survey Report, 1855, p. 304.
8	1859, July 20	12	21		C. A. Schott, Assistant Coast Survey, MS. in Coast Survey Archives, grounds of McGill University, in $\phi = 45° 30'.5$, $\lambda = 73° 34'.9$.
9	1879, September 25	13	40′.5	W.	J. B. Baylor, U. S. Coast and Geodetic Survey, grounds of McGill University.

Collection of Magnetic Declinations, etc.—Continued.

YORK FACTORY, HUDSON BAY.

$\phi = 57^\circ\ 00'$ $\lambda = 92^\circ\ 26'$ W. of Gr.

		° ′		
1	1725	19	W.	Capt. Middleton; Hansteen's Magnetismus der Erde, 1819; also Gen. Sir E. Sabine, Proc. of the Roy. Soc., 1858.
2	1787	5	W.	Hansteen's map; references as above.
3	1819, September	6 00	E.	Sir J. Franklin, in $\phi = 57^\circ\ 00'$, $\lambda = 92^\circ\ 26'$; Gen. Sir E. Sabine, Proc. Roy. Soc., 1858, and Cont. to Terr. Mag., No. xiii, Phil. Trans. Roy. Soc., 1872.
4	1843, July	9 25		Capt. Lefroy, R. A.; references as above.
5	1857, August	7 37		Capt. Blakiston, R. A.; references as above.
6	1878	5 30		Alfred R. C. Selwyn, director Geological Survey of Canada; report of 1878–'79, Appendix VII, Montreal, 1880, S. W. side of fort. In 1878 he found only 5°30′ at the N. E. side, but there appeared to be local attraction. [Use − 6° 30′ for the present.—SCH.]
	1879	7 00	E.	

PORTLAND, ME.

$\phi = 43^\circ\ 38'.8$ $\lambda = 70^\circ\ 16'.6$ W. of Gr.

(Bramhall Hill.)

		° ′		
1	1763	7 45	W.	Prof. John Winthrop, at Falmouth, in $\phi = 43^\circ\ 39'$, $\lambda = 70^\circ\ 19'$; Sill. Jour., vol. xvi, 1829; see also Prof. E. Loomis' remarks on the Winthrop Table in Sill. Jour., vol. xxxiv, 1838.
2	1775	8 30		J. F. W. Des Barres' Atlantic Neptune, London, 1781.
3	1845, June 4	11 28.3		Dr. J. Locke, in $\phi = 43^\circ\ 41'$, $\lambda = 70^\circ\ 20'$; Smithsonian Contributions to Knowledge, vol. iii, 1852.
4	1851, August 18, 20	11 41.1		J. E. Hilgard, assistant Coast Survey, at Bramhall Hill, in $\phi = 43^\circ\ 38'.8$, $\lambda = 70^\circ\ 16'.6$; Coast Survey Report for 1854, p. *143.
5	1859, July 15	12 20		C. A. Schott, assistant Coast Survey, at Bramhall Hill; Coast Survey Report of 1859, p. 296.
	1863, July 6	12 18.1		C. A. Schott, assistant Coast Survey, at Mount Joy Observatory, in $\phi = 43^\circ\ 39'.9$, $\lambda = 70^\circ\ 14'.9$; Coast Survey Report of 1863, p. 204. [Not used.]
6	1863, July 15	12 28.2		C. A. Schott, assistant Coast Survey, at Bramhall Hill, in $\phi = 43^\circ\ 38'.8$, $\lambda = 70^\circ\ 16'.6$; Coast Survey Report of 1863, p. 204.
7	1864, August to December	12 43.7		Prof. H. W. Richardson, observer for United States Coast Survey, at Bramhall Hill; monthly determinations on four days, about the middle of each month; MS. in Coast Survey archives.
8	1865, January to December	12 42.3		
9	1866, January to March (inclusive)	12 42.9		
10	1873, September 8, 9, 11	12 43.6	W.	Dr. T. C. Hilgard, observer for United States Coast Survey, at Mount Joy Observatory, two stations; MS. in Coast Survey archives; to refer to Bramhall Hill, add 10′.

BURLINGTON, VT.

$\phi = 44^\circ\ 28'.2$ $\lambda = 73^\circ\ 12'.3$ W. of Gr.

(Coast Survey astronomical station.)

		° ′		
1	1793	7 38	W.	Dr. Williams; Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838; in $\phi = 44^\circ\ 28'$, $\lambda = 73^\circ\ 14'$.
2	1805	6 12		J. Johnson, in Thompson's History of Vermont; from repeated comparisons. Declination believed by him to have been the minimum.
3	1818	7 30		J. Johnson .... } Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838; in $\phi = 44^\circ\ 28'$, $\lambda = 73^\circ\ 14'$.
4	1822	7 42		J. Johnson .... }
5	1826	7 36		Prof. G. W. Benedict; Prof. E. Loomis' collection in Sill. Jour., vol. xxxix, 1840; in $\phi = 44^\circ\ 27'$, $\lambda = 73^\circ\ 10'$.
6	1830	8 10		J. Johnson .... } Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838.
7	1831	8 15		J. Johnson .... }
8	1832	8 25		J. Johnson .... }
9	1834	8 50		J. Johnson .... }
10	1837	9† 45		Prof. Benedict; Thompson's History of Vermont.
	1840	9 42		J. Johnson; Thompson's History of Vermont. [Not used.]
11	1845, June 26	9 22		Dr. J. Locke, in $\phi = 44^\circ\ 27'$, $\lambda = 73^\circ\ 10'$; Smithsonian Contributions to Knowledge, vol. iii, 1852.
12	1855, August 28	9 57.1		C. A. Schott, assistant Coast Survey, in $\phi = 44^\circ\ 29'.3$, $\lambda = 73^\circ\ 13'.4$, at encampment flag-staff, near shore of the lake; Coast Survey Report of 1855, p. 337.
13	1873, October 14, 15	11 19.0	W.	Dr. T. C. Hilgard, observer for United States Coast Survey; MS. in Coast Survey archives.

†Supposed misprint for 8°.

Collection of Magnetic Declinations, etc.—Continued.

RUTLAND, VT.

$\phi = 43° 36'.5$ $\lambda = 72° 55'.5$ W. of Gr.

(Post-office.)

		° ′	
1	1789, April	7 03 W.	Dr. Williams; Sill. Jour., vol. xvi, 1829.
2	1810, May	6 04	
3	1811, September	6 01	
4	1859, July 21	9 49	C. A. Schott, assistant Coast Survey; near new post-office; Coast Survey Report for 1859, p. 296.
5	1873, October 17, 18	10 40.2	Dr. T. C. Hilgard, observer for United States Coast Survey; MS. in Coast Survey archives.
6	1879, October 14, 15	11 09.0 W.	J. B. Baylor, U. S. Coast and Geodetic Survey, station of 1873; north and west of post-office, $\phi = 43° 36'.5$, $\lambda = 72° 55'.5$.

PORTSMOUTH, N. H.

$\phi = 43° 04'.2$ $\lambda = 70° 42'.5$ W. of Gr.

(New Castle Lighthouse.)

		° ′	
1	1771	7 46 W.	Holland, at Kittery, Me.; in $\phi = 43° 06'$, $\lambda = 70° 45'$, Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838.
	1771	7 48	Holland, in $\phi = 43° 05'$, $\lambda = 70° 45'$; reference as above. [Not used.]
2	1775	7 45	J. F. W. Des Barres' Atlantic Neptune, London, 1781.
3	1844.5	9 47	Major Graham at Boiling Rock Boundary Survey. Gen. Sir E. Sabine in Phil. Trans. Roy. Soc., 1872, $\phi = 43° 05'$, $\lambda = 70° 45$.
4	1850, August 28, September 2	10 30.2	J. E. Hilgard, assistant Coast Survey, at Kittery Point, Me.; Coast Survey Report of 1854, p. *143.
5	1859, July 14	11 15	C. A. Schott, assistant Coast Survey, at Kittery Point, Me.; Coast Survey Report of 1859, p. 296.
6	1879, August 13, 14	12 31.3 W.	J. B. Baylor, U. S. Coast and Geodetic Survey, station of 1850 and 1859, in $\phi = 43° 04'.8$, $\lambda = 70° 43'.0$.

NEWBURYPORT, MASS.

$\phi = 42° 48'.4$ $\lambda = 70° 49'.0$ W. of Gr.

(Plum Island lights.)

		° ′	
1	1775	6 45 W.	J. F. W. Des Barres' Atlantic Neptune, London, 1781; north of Cape Ann, opposite Newburyport.
2	1781	7 18	Dr. Williams, in $\phi = 42° 48'$, $\lambda = 70° 52'$; Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838.
3	1850, September 18–20	10 05.6	J. E. Hilgard, assistant Coast Survey, on Plum Island, in $\phi = 42° 48'.0$, $\lambda = 70° 48'.8$, Coast Survey Report for 1854, p. *143.
4	1859, July 13	10 58 W.	C. A. Schott, assistant Coast Survey, same position as above; Coast Survey Report for 1859, p. 296.

SALEM, MASS.**

$\phi = 42° 31'.9$ $\lambda = 70° 52'.5$ W. of Gr.

(Fort Lee.)

		° ′	
1	1781, August	7 02 W.	President Willard, at Beverly, in $\phi = 42° 33'$, $\lambda = 70° 54'$, mean of seven observations; Sill. Jour., vol. xvi, 1829; reduction to Salem−8′.
2	1805, November	5 57	Dr. Bowditch, in Summer street, Salem, from 115 observations.
	1808, June	5 20	Dr. Bowditch, one-eighth of a mile south of above place, from 112 observations. [Not used.]
3	1810, April	5 47.7 5 13.4	Dr. Bowditch, about one-fourth of a mile east of the place of 1805. [Second value not used.]
	1810, April, to 1811, May	6 22.6	Dr. Bowditch, result by a third needle from 5125 observations of monthly values. Mean of two needles, +6°.09 in 1810.5. Reference to Nos. 2, 3, Sill. Jour., vol. xvi, 1829.
4	1849, August 20	10 14.5	Prof. G. W. Keely, observer for United States Coast Survey, at Fort Lee; Coast Survey Report for 1854, p. *143.
5	1855, August 25	10 49.7	C. A. Schott, assistant Coast Survey, at Fort Lee; Coast Survey Report for 1855, p. 337.
6	1877.5	11 30 W.	I. K. Harris, communicated in a letter to Superintendent, dated Lynn, Feb. 18, 1878.

** The vicinity of Salem is subject to local magnetic deflections, which have been traced as far as Cape Ann.

Collection of Magnetic Declinations, etc.—Continued.

BOSTON, MASS.

$\phi = 42° 21'.5$ $\lambda = 71° 03'.8$ W. of Gr.

(State-house.)

		° ′	
1	1700	10 W.	Prof. J. Winthrop's table,‡ Sill. Jour., vol. xvi, 1829 (also Mem. Am. Acad., vol. ii, new series, Cambridge, 1846); also Coast Survey Report for 1855, p. 316.†
2	1708	9	Mathews, observer, Sill. Jour. for 1829, Dr. N. Bowditch; also Encyc. Met., 1848.
3	1741	7 30	Mathews; Encyc. Met., 1848.
4	1775–76	7 40	Des Barres' Atlantic Neptune, London, 1781.
5	1782	7 00	Sill. Jour. for 1829, Dr. N. Bowditch; see also first vol. Mem. Am. Acad.
6	1793	6 30	Mean of 1644 observations; Mem. Am. Acad., new series, Cambridge, 1846.
7	1807	6 05	Communicated by W. Rotch, letter dated Fall River, February 17, 1874.
8	1839	9 06	W. C. Bond, at Dorchester, in $\phi = 42° 19'$, $\lambda = 71° 04'$; Prof. E. Loomis' collection in Sill. Jour., vol. xxxix, 1840.
9	1846, September 6–8	9 31.4	Lieut. T. J. Lee, assistant Coast Survey, at Dorchester Heights, South Boston, in $\phi = 42° 20'.0$, $\lambda = 71° 02'.5$; Coast Survey Report for 1854, p. *143.
10	1855, August 24	10 13.7	C. A. Schott, assistant Coast Survey, in South Boston, locality as above; Coast Survey Report of 1855, p. 337.
11	1872, September 28, 30, October 1	11 15.2	A. H. Scott, United States Coast Survey, locality as above; MS. in Coast Survey archives.
12	1877.5	11 36 W.	At meridian line on Boston Common, from records at the City Hall, communicated by I. K. Harris, February 18, 1878.

‡In this table the observed and interpolated values were pointed out by Prof. E. Loomis; no notice is taken of the latter values. The table was published in the "Boston Post Boy," July 2, 1764. (Information by J. H. Trumbull.)

†See also E. Halley's isogonic chart for the epoch 1700, reproduced by photolithography in the "Greenwich observations of 1869;" it gives about 10° W. for Boston.

CAMBRIDGE, MASS.

$\phi = 42° 22'.9$ $\lambda = 71° 07'.7$ W. of Gr.

(Harvard College observatory.)

		° ′	
1	1708	9 W.	Brattle, observer; Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838 (same reference for Nos. 2, 3, 4, 7, and 9); Mem. Am. Acad., vol. ii, new series, Cambridge, 1846; also Encyc. Met., 1848; also Coast Survey Report for 1855, p. 317.
2	1742	8	Prof. J. Winthrop's table ¶ Sill. Jour., vol. xvi, 1829; also Mem. Am. Acad., vol. ii, new series, Cambridge, 1846.
3	1757	7 20	Prof. J. Winthrop; reference as above.
4	1761	7 14	Dr. Williams, Mem. Am. Acad., vol. ii, 1846.
5	1763	7 00	Prof. J. Winthrop; Sill. Jour., vol. xvi, 1829.
6	1780	7 02	Dr. Williams; Encyc. Met., 1848.
7 {	1782	6 45	Dr. Williams; Encyc. Met., 1848; in Mem. Am. Acad., 1846, 6° 46′.
	1782	6 44	Prof. Sewall (mean of extremes 6° 21′ and 7° 08′); Sill. Jour. for 1829. See also first vol. of Mem. Am. Acad.
8	1783	6 52	Dr. Williams; Mem. Am. Acad., 1846; also Encyc. Met., 1848.
9	1788	6 38	Dr. Williams; Mem. Am. Acad., 1846.
10	1810	7 30	} Prof. Farrar; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
11	1835	8 51	
12	1837	9 09	Mem. Am. Acad.; Cambridge, 1846.
13	1840.4	9 18	W. C. Bond, director Havard College observatory, observer. Mem. Am. Acad., 1846. See also Phil. Trans. Roy. Soc., 1849.
14	1842.2	9 34.9	Prof. J. Lovering; Mem. Am. Acad., vol. iv, 1850. Half-hourly observations during one year, October, 1841, to October, 1842.
15	1844	9 39	W. C. Bond, director Har. Coll. observatory; MS. communicated by Prof. Lovering.
16	1845, June 2	9 32	Dr. J. Locke, Smithsonian Contributions to Knowledge, vol. iii, 1852.
17	1859, August 9	9 30	Lieut. J. C. Ives, at Har. Coll. observatory; Coast Survey Report for 1856, p. 222.
18	1852	10 08	} W. C. Bond, director Har. Coll. observatory. Communicated in a letter by Prof. Lovering (May 29, 1855).
19 {	1854	10 39	
	1854, May 10	9 46	ieut. J. C. Ives, at Har. C . observatory. [Used mean value for 1854.]
20	1855, May 22, 23	10 54.6	C. Bond, director Har. Coll. observatory. Communicated by him, Dec. 24, 1858.
21 {	1856, May 16	10 50.3	W. C. Bond; reference as above.
	1856, July 17	10 06	Karl Friesach, at Cambridge observatory; Berichte der Kais. Acad. der Wiss., Vienna, vol. 29, 1858. Result corrected for diurnal variation.
22	1859, March	10 48	Lieut. W. P. Smith, U. S. T. E., at Har. Coll. observatory. Communicated by Capt. G. G. Meade, U. S. T. E.
23	1866–67–68	10 41	Prof. J. Winlock, director Har. Coll. observatory; from a large number of observations communicated in November, 1872 [and computed by me.—Sch.]. Mean epoch 1867.5.
24	1879, August 7, 9	11 46.3 W.	J. B. Baylor, U. S. Coast and Geodetic Survey. Grounds of Harvard College observatory, $\phi = 42° 22'.8$, $\lambda = 71° 07'.6$.

¶In this table the observed and interpolated values were pointed out by Prof. E. Loomis: no notice is taken of the latter values. The table was published in the "Boston Post Boy," July 2, 1764.

Collection of Magnetic Declinations, etc.—Continued.

NANTUCKET, MASS.

$\phi = 41° 17'.0$ $\lambda = 70° 06'.0$ W. of Gr.

(Mitchell's observatory.)

		° ′	
1	1775	6 30 W.	J. F. W. Des Barres' Atlantic Neptune, London, 1781.
	1776	6 30	From a chart, Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838. Probably of the same origin as No. 1. [Not used.]
2	1834	8 27	W. Mitchell; in Sill. Jour., vol. xlvi.
3	1838.9	9 02.3	
4	1842, August and September	9 09	
5	1843, September	9 10	
6	1846, July 30, 31	9 14.0	Lieut. T. J. Lee, U. S. T. E., assistant United States Coast Survey; near Mitchell's house. Coast Survey Report of 1854, p. *143.
7	1855, August 22	9 58.3	C. A. Schott, assistant United States Coast Survey; near Nantucket Harbor light, north of Mitchell's house, on beach, in $\phi = 41° 17'.5$, $\lambda = 70° 06'.0$. Coast Survey Report of 1855, p. 337.
8	1867, May 28, 29, 30	10 19.9	C. O. Boutelle, assistant United States Coast Survey; at Nantucket Cliff, in $\phi = 41° 17'.2$, $\lambda = 70° 06'.3$. MS. in Coast Survey archives.
9	1879, July 31, August 2	11 27.9 W.	J. B. Baylor, United States Coast and Geodetic Survey; at Cliff Station.

PROVIDENCE, R. I.

$\phi = 41° 49'.5$ $\lambda = 71° 24'.1$ W. of Gr.

(Brown University.)

		° ′	
1	1717**	9 36 W.	The recorded declinations between 1717 and 1843 inclusive are given by M. B. Lockwood, civil engineer, from actual observations and recorded bearings of a number of permanent objects. Sill. Jour., vol. xliv, 1843.
2	1720	9 28	
3	1725	9 14	
4	1730	8 54	
5	1735	8 39	** NOTES. Observation of 1717, R. Jackson, on a map of Providence. Observation of 1769, Dr. B. West. Observation of 1815 by M. Brown, B. Lockwood, and G. Sheldon. Observation of 1835; since this time the observations were made more carefully. [There can be no doubt that this table, like the Winthrop table for Boston and that of Hatboro', Pa., depends in part on interpolation. It is well graduated, and unquestionably rests on reliable observations —SCH.]
6	1740	8 15	
7	1745	7 59	
8	1750	7 40	
9	1755	7 21	
10	1760	6 57	
11	1765	6 43	
12	1769**	6 30	
13	1775	6 20	
14	1780	6 16	
15	1785	6 13	
16	1790	6 10	
17	1795	6 10	
18	1800	6 15	
19	1805	6 19	
20	1810	6 24	
21	1815**	6 30	
22	1819	6 37	
23	1825	6 51	
24	1830	7 10	
25	1835**	7 34	
26	1840	8 25	
27	1841	8 31	
28	1842	8 39	
29	1843	8 46	
30	1855, August 20	9 31.5 W.	C. A. Schott, assistant Coast Survey, grounds east of Brown University, in $\phi = 41° 49'.5$, $\lambda = 71° 24'.1$; Coast Survey Report for 1855, p. 337.

Collection of Magnetic Declinations, etc.—Continued.

HARTFORD, CONN.

$\phi = 41° 45'.9$ $\lambda = 72° 40'.4$ W. of Gr.

(State-house.)

		° ′	
1	1786	5 25 W.	Dr. Williams; Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838.
2	1810	4 46	Asher Miller, at East Hartford, in $\phi = 41° 46'$, $\lambda = 72° 38'$; reference as above.
3	1824	5 45	N. Goodwin; reference as above.
4	1828	6 03	N. Goodwin; reference as above.
4	1829	6 03	N. Goodwin; reference as above.
5	1859, July 27	7 17	C. A. Schott, assistant Coast Survey, in City Park; Coast Survey Report for 1859, p. 296.
6	1867, August 15, 17	7 49.3	C. A. Schott, assistant Coast Survey, in $\phi = 41° 45'.9$, $\lambda = 72° 40'.5$, near the Athenæum; MS. in Coast Survey archives.
7	1879, July 24, 25, 26	8 34.0 W.	J. B. Baylor, United States Coast and Geodetic Survey; station of 1859 in City Park, $\phi = 41° 45'.9$, $\lambda = 72° 40'.5$.

NEW HAVEN, CONN.

$\phi = 41° 18'.5$ $\lambda = 72° 55'.7$ W. of Gr.

(Yale College.)

		° ′	
1	1761	5 47 W.	President Stiles — Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
2	1775	5 25	Prof. Strong — Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
3	1780	5 15	President Stiles — Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
4	1811	5 10	Nathan Redfield — Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
	1818, August	5 45	Hon. De Witt, Sill. Jour., vol. xvi, 1829. [Not used.]
	1819	4 35	Prof. Fisher, of Yale College; Prof. E. Loomis' collection of 1838. [Not used. See below.]
5	1819, May; 1820, April	4 25.2	Prof. Fisher, from hourly observations; Sill. Jour., vol. xvi, 1829.
6	1828	5 17	N. Goodwin; Prof. E. Loomis' collection, 1838.
7	1834, November; 1835, November	5 40.6	Prof. E. Loomis, from hourly observations; Sill. Jour., vol. xxx, 1836.
	1835	5 52	Prof. E. Loomis, in his collection of 1838. [Not used.]
8	1836	5 55	E. C. Herrick; Prof. E. Loomis' collection of 1838.
9	1837, November	5 50	E. C. Herrick; Sill. Jour., vol. xxxiv, 1838.
10	1840	6 10	E. C. Herrick; Prof. E. Loomis' collection, Sill. Jour., vol. xxxix, 1840.
11	1844	5 45.1	Prof. J. Renwick, observer for United States Coast Survey at Yale College, $\phi = 41° 18'.5$, $\lambda = 72° 55'.7$; Coast Survey records.
12	1845, September 10	6 17.3	Prof. J. Renwick, observer for United States Coast Survey, Pavilion Hotel, south of college, near bay; Coast Survey Report for 1854, p. *143.
	1847, September 25 and October 2.	7 27.2	R. H. Fauntleroy, assistant Coast Survey, at Fort Wooster, in $\phi = 41° 16'.9$, $\lambda = 72° 53'.6$; Coast Survey Report for 1854, p. *143. [Not used.]
	1848, August 21 to 29	7 25.5	J. S. Ruth, subassistant Coast Survey; references as above. [The observations at Fort Wooster are not used; the result is affected by local attraction.]
13	1848, August 10 to 14	6 37.9	J. S. Ruth, United States Coast Survey, Pavilion Hotel; Coast Survey Report for 1854; p. *143.
13	1848, August 30, September 1	6 31.9	J. S. Ruth, United States Coast Survey, at Oyster Point, in $\phi = 41° 17'.0$, $\lambda = 72° 55'.7$ (meridian of Yale College); Coast Survey Report for 1854, p. *143.
14	1855, August 17	7 02.7	C. A. Schott, assistant Coast Survey, at Oyster Point, in $\phi = 41° 16'.9$, $\lambda = 72° 55'.8$; Coast Survey Report for 1855, p. 337.
	1871, March.	7 22	G. H. Mann, C. E., United States Engineers' survey of harbor of New Haven, on College Green; MS. communication. [Not used.]
15	1872	8 27.5	R. M. Bache, assistant Coast Survey; topographic and hydrographic survey of New Haven Harbor and vicinity, from bearings of trigonometric lines. Hydrographic chart No. 1170.
16	1878, July 18	8 41.2 W.	Dr. T. E. Thorpe, Proceedings of the Roy. Soc., No. 200, 1880. In Professor Silliman's garden, $\phi = 41° 18'.7$, $\lambda = 72° 55'.6$.

Collection of Magnetic Declinations, etc.—Continued.

ALBANY, N. Y.

$\phi=42° 39'.2$ $\lambda=73° 45'.8$ W. of Gr.

(State Capitol.)

		°	′		
1	1817, October	5	44	W.	De Witt, in $\phi=42° 39'$, $\lambda=73° 44'$; Sill. Jour., vol. xvi, 1829.
2	1818, August	5	45		
3	1825, April	6	00		
4	1828	6	14		Geological Report, State of New York, and Sill. Jour., vol. xxxix, 1840.
	1828, September	6	16		
	1828, September	6	18		
5	1830, June	6	18		
6	1831, May	6	25		
	1831	6	32		
	1831, November	6	40		Regents' Report.
7	1834, October	6	40		Regents' Report, and Sill. Jour., vol. xxxiv, 1838.
8	1836, October	6	47		
9	1847, November	7	35		Regents' Report.
10	1855, August 31	7	54.7		C. A. Schott, assistant Coast Survey, at Greenbush, in $\phi=42° 37'.8$, $\lambda=73° 44'.3$; Coast Survey Report of 1855, p. 337.
11	1856, September 1	8	39.2		Karl Friesach, in Berichte der Kai. Acad. Vienna, vol. 29, 1858; 8° 35′ when corrected for diurnal variation.
12	1858, May 12–14	8	17.0		G. W. Dean, assistant Coast Survey, at Dudley Observatory, in $\phi=42° 39'.8$, $\lambda=73° 44'.9$; Coast Survey Report of 1858, p. 191.
13	1879, October 21, 24	9	51.7	W.	J. B. Baylor, United States Coast and Geodetic Survey; Station of 1858, grounds of Dudley Observatory.

OXFORD, CHENANGO COUNTY, N. Y.

$\phi=42° 26'.5$ $\lambda=75° 40'.5$ W. of Gr.

		°	′		
1	1792 to 1795	3		W.	E. B. McCall, surveyor, in a letter to the Superintendent of the Coast Survey, dated December 22, 1858.
2	1817	3			E. B. McCall, in $\phi=42° 26'.5$, $\lambda=75° 42'$.
3	1828, July 7	4	30		
4	1834, October 9	3	52		Regents' Report, in $\phi=42° 28'$, $\lambda=75° 33'$; also Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
5	1836, October 5	4	09		
6	1837	4	30		Sill. Jour., 1838; also Regents' Report of 1839.
7	1838, July 6	4	30		At Guilford, in $\phi=42° 24'$, $\lambda=75° 26'$; Regents' Report; Sill. Jour., 1838; when referred to Oxford, 4° 27′ W.
8	1849, November 27	5	11		E. B. McCall, as above.
9	1857, April 4	5	44		
10	1858, February 4	5	47		
11	1858, December	5	50		
12	1873, December 1	6	52		Erving Taintor, local surveyor (azimuth determined from observations of Polaris).
13	1874, May 29, 30, June 2, 3, 4, 5, 6	6	55.7	W.	Dr. T. C. Hilgard, observer for United States Coast Survey, on hill about three-fourths of a mile north of railroad depot; MS. in Coast Survey archives.

BUFFALO, N. Y.

$\phi=42° 52'8$ $\lambda=78° 53'.5$ W. of Gr.

(Light-house in the harbor.)

		°	′		
1	1797	0	00	W.	Amry Atwater, surveyor, east end of Lake Erie; MS. collection by Charles Whittlesey, communicated to the Coast Survey, March 26, 1860.
2	1798	0	30		Buffalo Reservation, Lake Shore. August Porter, in Twenty-second Report of Regents of University, New York. Albany, 1869,
3	1837	1	25		R. W. Haskins, $\phi=42° 53'$, $\lambda=78° 55'$; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
4	1839	1	15		At Fort Erie, $\phi=42° 54'$, $\lambda=78° 59'$; United States Lake Survey chart.
5	1845	1	25		Capt. Lefroy, Gen. Sir E. Sabine's Contributions, xiii, in Phil. Trans. Roy. Soc. 1872.
6	1859, June	2	56.5		Lieut. W. P. Smith, United States Lake Survey, $\phi=42° 53'$, $\lambda=78° 55'$, near south pier; Report of the United States Lake Survey, by Capt. Meade, Appendix B, Detroit, 1859.
7	1872, June 14	3	52.4		Capt. A. N. Lee, United States Lake Survey, $\phi=42° 53'$, $\lambda=78° 58'$; magnetic results, 1870–'73, Report of the Chief of Engineers for 1873, pp. 1195, 1197.
8	1873, June 3, 13	3	58.3	W.	

Collection of Magnetic Declinations, etc.—Continued.

TORONTO, PROVINCE OF ONTARIO, CANADA.

$\phi = 43° 39'.4$ $\lambda = 79° 23'.4$ W. of Gr.

(Magnetical and Meteorological Observatory.)*

		° ′	
1	1840, January	1 27 W.	Capt. C. J. B. Riddell, R. A. Phil. Trans. Roy. Soc., 1849.
2	1841	1 14.3	Vol. I, Toronto Observations, p. xi. Mean annual declinations. † 1° 19′.1 in the publication of 1875.
3	1842	1 18.9†	
4	1845	1 29.1	Vol. II. Toronto Observations, pp. iii-v. Mean annual declinations.
5	1846	1 30.8	
6	1847	1 33.2	
7	1848	1 35.4	
8	1849	1 36.9	
9	1850	1 38.6	
10	1851	1 40.9	
11	1853	1 46.1	Observations in July and August (Values corrected for annual and secular variations.)
12	1854	1 48.0	Observations in February, March, April, and June (Values corrected for annual and secular variations.)
13	1855	1 52.3	Observations from August to December, both inclusive (Values corrected for annual and secular variations.)
14	1856	1 56.3	Mean annual declinations.
15	1857	2 00.5	
16	1858	2 04.5	
17	1859	2 07.4	
18	1860	2 10.6	
19	1861	2 14.3	
20	1862	2 15.7	
21	1863	2 19.1	
22	1864	2 21.9	
23	1865	2 24.8	
24	1866	2 27.6	
25	1867	2 29.8	
26	1868	2 33.2	
27	1869	2 37.1	Abstracts and results of magnetical and meteorological observations at the Magnetic Observatory, Toronto, Canada, from 1841 to 1871, inclusive, 1875. Mean annual declinations.
28	1870	2 41.9	
29	1871	2 47.9	
30	1872	2 53.0	Mean annual declinations, communicated February 28, 1881, by Charles Carpmael, director of the Toronto Magnetic Observatory, and superintendent of the Meteorological Service, Toronto, Ontario.
31	1873	2 58.3	
32	1874	3 04.1	
33	1875	3 11.7	
34	1876	3 18.5	
35	1877	3 24.9	
36	1878	3 31.4	
37	1879	3 37.3	
38	1880, Oct. 18	3 41.1 W.	Communicated by C. Carpmael, director of Observatory, January 14, 1881.

*Results published by G. T. Kingston, M. A., director of the Magnetic Observatory, in the Canadian Journal especially from two communications, "Monthly absolute values of the Magnetic Elements at Toronto, from 1856 to 1864, inclusive"; and "Monthly absolute values of the Magnetic Elements at Toronto, from 1865 to 1868, inclusive, with the annual means from 1841 to 1868."

Collection of Magnetic Declinations, etc.—Continued.

ERIE, PA.

$\phi = 42° 07'.8$ $\lambda = 80° 05'.4$ W. of Gr.

(Court-house.)

		° ′		
1	1786, October	0 32	W.	New York and Pennsylvania boundary line; monument on French Creek, in $\phi = 42° 00'$, $\lambda = 79° 58'$, about 10 miles S.SE. of Erie. Geological Survey of New York. See also a map in the State Department of New York, on which the observed variations are given, "protracted by Abm. Hardenberg, one of the Commissioners for the State of New York, October 29, 1787."
2	1795	0 43	E.	Andrew Ellicott, in $\phi = 42° 08'.2$, $\lambda = 80° 05'.2$. Stone monument corner Parade and Front streets; Am. Alm. of 1861, p. 54.
3	1841, August 9	0 30	W.	Dr. A. D. Bache, magnetic survey of Pennsylvania; Coast Survey Report of 1862, p. 213.
4	1855	1 33		Annual Report of Secretary of Internal Affairs of Pennsylvania for 1877. Harrisburg, 1878.
5	1859, April	1 34		Samuel Low, at meridian line established by him in cemetery. Mean of 9 years' observations, 1855 to 1863, inclusive. From Annual Report of Secretary of Internal Affairs, Commonwealth of Pennsylvania. Harrisburg, 1876, p. 20 A.
6	1862, August 6, 7	1 33		C. A. Schott, assistant Coast Survey. Same place as in Dr. Bache's survey, near Mr. Reed's house, Seventh street, in $\phi = 42° 07'.5$, $\lambda = 80° 05'.3$; Coast Survey Report of 1862, p. 212.
7	1867, April	2 13		Samuel Wilson, at meridian line in cemetery; mean of 7 years of observations, 1864 to 1870, inclusive. Annual Report of Secretary of Internal Affairs of Pennsylvania, 1876.
8	1873, June, 11, 12	2 00.7		Capt. A. N. Lee, United States Lake Survey, in $\phi = 42° 08'.2$, $\lambda = 80° 05'.3$. Magnetic results, 1870 to 1873; Report of Chief of Engineers for 1873, pp. 1195, 1197.
	1873, October	2 36		Samuel Wilson, at meridian line in cemetery; mean of 6 years of observations, 1871 to 1876, *inclusive. Annual Report of Secretary of Internal Affairs of Pennsylvania, 1876.*
9	1876	2 50		Annual Report of Secretary of Internal Affairs of Pennsylvania, 1876.
10	1877, November	3 00	W.	Annual Report of Secretary of Internal Affairs of Pennsylvania for 1877. Harrisburg, 1878.

CLEVELAND, OHIO.

$\phi = 41° 30'.3$ $\lambda = 81° 42'.0$ W. of Gr.

		° ′		
1	1796, September	2 00	E.	Aug. Porter and Seth Pease, in $\phi = 41° 30'$, $\lambda = 81° 40'$; MS. compiled by Charles Whittlesey, March, 1860, Coast Survey archives.
2	1830	1 20		Ahaz Merchant; Prof. E. Loomis' collection, Sill. Jour., vol. xxxix, 1840.
3	1831, August	1 15		Edwin Foote; MS. compiled by Charles Whittlesey, 1860.
4	1834 (winter)	0 50		Ahaz Merchant; Prof. E. Loomis' collection, as above.
5	1838 (winter)	0 35		Ahaz Merchant; reference as above.
6	1840	0 19		Prof. E. Loomis; Phil. Trans. Roy. Soc., 1872, General Sabine's Contributions, xiii. Misprinted = 1° 19′ E. See Dr. C. Davies on "Surveying."
7	1841, May 1	0 05.2		J. N. Pillsbury; MS. compiled by Charles Whittlesey, 1860.
8	1845	0 39	E.	From a chart of survey of North and Northwest Lakes, Topographical Engineers; beacon-light, in $\phi = 41° 31'$, $\lambda = 81° 41'.5$.
9	1859, July	0 46	W.	Lieut. W. P. Smith, Topographical Engineers, in $\phi = 41° 30'$, $\lambda = 81° 43'$; MS. by Charles Whittlesey, also MS. by W. F. Raynolds, major of Engineers, Survey of North and Northwest Lakes.
	1865	1 12	E.(?)	MS. (December, 1865) by W. F. Raynolds, major of Engineers, as above. [Value not used.—SCH.]
10	1871, November, 9–11	0 32.6	W.	E. Goodfellow, assistant Coast Survey; Coast Survey archives; at Marine Hospital, in $\phi = 41° 30'.4$, $\lambda = 81° 41'.5$.
11	1872, June 17, 18	0 44.9		Capt. A. N. Lee, United States Lake Survey; Report of Chief of Engineers for 1873.
12	1873, June 16, 17	0 50.9		Capt. A. N. Lee, United States Lake Survey; reference as above.
13	1880, July 9, 10–12	1 38.5	W.	J. B. Baylor, United States Coast and Geodetic Survey. Station of 1871, grounds of the City Hospital.

Collection of Magnetic Declinations, etc.—Continued.

DETROIT, MICH.

$\phi = 42° 20'.0 \quad \lambda = 83° 03'.0$ W. of Gr.

		° ′	
1	1810	2 48 E.	J. Mansfield; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838. Position assigned, $\phi = 42° 30'$, $\lambda = 82° 58'$.
2	1822	3 13	L. Lyons } Prof. E. Loomis' collection, in Sill. Jour., vol. xxxix, 1840. Position assigned, $\phi = 42° 24'$, $\lambda = 82° 58'$.
3	1828	2 50	L. Lyons
4	1835	2 10	Geological Report
5 {	1840	2 00	Geological Report
	1840	1 56	Prof. E. Loomis; Gen. Sir E. Sabine, Phil. Trans. Roy. Soc., 1872. Contributions, No. xiii.
6	1859	0 42	} United States Lake Survey, MS. communicated by Col. W. F. Raynolds, United States Engineers. Position, $\phi = 42° 20'$, $\lambda = 83° 03'$.
7	1865	0 40	
8	1872, May 8–29	0 25.2	} United States Lake Survey, Gen. C. B. Comstock, U. S. A., superintendent; Report of the Chief of Engineers for 1873, pp. 1195–1197; Capt. A. N. Lee, U. S. A., observer. Positions assigned, $\phi = 42° 20'.0$, $\lambda = 83° 02'.5$.
9	1873, May 5–17	0 17.3	
10	1876, June 3, 6	0 04.7 E.	U. S. Lake Survey; Report of Chief of Engineers for 1877, vol. 2. Lieut. T. N. Bailey, observer. Position, $\phi = 42° 20'.0$, $\lambda = 83° 03'.1$.

ST. LOUIS, MO.

$\phi = 38° 38'.0 \quad \lambda = 90° 12'.2$ W. of Gr.

(Washington University.)

		° ′	
1	1819, June 17	10 47.6 E.*	Major S. H. Long; at St. Louis, in $\phi = 38° 36'$, $\lambda = 90° 06'$. [Longitude about 5′ in error.—SCH.] Account of an expedition from Pittsburg to the Rocky Mountains in 1819 and 1820, by Maj. S. H. Long, Philadelphia, 1823.
2 {	1835	8 49	Col. Nicolls; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
	1838	7 45	De Ward, surveyor. In City Commons. Letter of Thomas Featherson, of June 18, 1877. Communicated by Assistant Eimbeck, Coast Survey.
3 {	1855	8 00	Colton's General Atlas, New York, 1873.
	1856, October 31	6 23.1	Karl Friesach, Berichte der Kais. Akad. der Wiss., Vienna, vol. xxix, 1858.
4	1872, June, July, and August	6 37.5	Dr. T. C. Hilgard, observer; Bache-Fund Magnetic Survey; MS. communication. Two stations, south and west of court-house; first, on Compton Hill, −6° 35′.2 in $\phi = 38° 37'.1$, $\lambda = 90° 14'.0$; second, near City Hospital, −6° 39′.9 in $\phi = 38° 36'.5$, $\lambda = 90° 12'.7$. [Mean −6° 37′.5.—SCH.]
5	1877, June	6 30.5	Thomas Featherson, deputy county surveyor, St. Louis Co. From comparisons of 17 old lines run in the City Commons in 1838 by De Ward, surveyor. Communicated by W. Eimbeck, assistant Coast Survey. Annual change since 1838, + 1′.91.
6	1878, August 14, 15	6 33.7	Prof. F. E. Nipher, Washington University; Trans. St. Louis Acad. Sciences; observations in vacant square, SE. corner Garrison ave. and Dickson st.; used Coast Survey instruments.
7	1879, Sept. 9	6 13.3 E.	Prof. F. E. Nipher, corner Garrison ave. and Glasgow Place. Communicated Oct. 14, 1879.

* This value is probably somewhat too great.—SCH.

NEW YORK AND VICINITY, N. Y.

$\phi = 40° 42'.7 \quad \lambda = 74° 00'.4$ W. of Gr.

(New York City Hall.)

		° ′	
	1609, September 2	8 W.	Hudson, on his third voyage, near the Jersey shore, a little below the mouth of Hudson River. The day before he found not above 2° W. [See reference below. Observation not used.] Hudson, on his third voyage, a few miles up the Hudson River, found, 1609, Sept. 13, 13° W. This observation may have been made on shore. Prof. E. Loomis' collection, in Sill. Jour., vol. xxxix, 1840; extract furnished by Prof. J. Sparks from 3d vol. of Purchas' Pilgrims. [Observation not used.]
1	1684	8 45	Philip Welles, Surveyor-General; Report of the N. Y. Commissioners on the Connecticut Boundary, made to the New York Legislature in April, 1857 [Sen. Doc. 165, p. 155]. Received from J. H. Trumbull, April, 1876.
2	1686	9 0	George Keith, at Sandy Hook. Line run between E. and W. New Jersey. Records of proprietors of New Jersey. Communicated by Prof. G. H. Cook, State Geologist of N. J., Oct. 11, 1879.
3	1691	8 45	On Staten Island; Geological Survey of New York, 1858, E. Duxbury's patent. [See also E. Halley's isogonic chart for the epoch 1700, reproduced by photolithography in the "Greenwich Observations of 1869." It gives about 8° W. for New York.]
	1714	8 45	John Beatty, deputy surveyor, on map of Livingston's Manor (N. Y.). Engraved in O'Callaghan's Doc. Hist. N. Y., iii, 414. Received from J. H. Trumbull. [Not used.]

Collection of Magnetic Declinations, etc.—Continued.

NEW YORK AND VICINITY, N. Y.—Continued.

		°	′		
4	1723	7	20	W.	G. Burnet; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
	1724	7	20		Cadwallader Colden, one of the commissioners of the New York and Connecticut boundary, of 1724. (See Report of Commissioners of 1857, as above.) Received from J. H. Trumbull.
5	1750	6	22		Mr. Alexander; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
6	1755	5	00		Mr. Evans; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
	1775	7			J. F. W. Des Barres' Atlantic Neptune, London, 1781, at Sandy Hook, New York Bay. [Not used.]
7	1789	4	20		Prof. Loomis' collection of 1838; also Encyc. Metrop., 1848.
8	1824	4	40		Blunt's map; Prof. E. Loomis' collection of 1838.
9	1834	4	50		Capt. Owen; Prof. E. Loomis' collection of 1838.
10	1837	5	40		Prof. J. Renwick, Columbia College; Prof. E. Loomis' collection of 1838.
11	1840, June 16 to July 11	5	01		Lieut. S. C. Rowan, U. S. N., observer for United States Coast Survey, at Howard, Staten Island, in $\phi = 40° 37'.6$, $\lambda = 74° 05'.4$; MS. in Coast Survey archives.
	1840, July 18 to October 16	5	53		Lieut. S. C. Rowan, U. S. N., observer for United States Coast Survey, at Bergen Neck, in $\phi = 40° 45'.8$, $\lambda = 74° 02'.6$; MS. in Coast Survey archives.
12	1841	6	06		Douglass' map of New Jersey; Coast Survey archives.
	1842, September	5	32.5		Coast Survey determination (observer not stated) at Sandy Hook, in $\phi = 40° 27'.7$, $\lambda = 74° 00'.2$; MS. in Coast Survey archives.
	1844, January	5	51.1		Lieuts. G. M. Bache and J. Hall, U.S.N., observers for United States Coast Survey, at Sandy Hook (same place as in 1842); MS. in Coast Survey archives.
	1844, August 20–22	5	51.0		Prof. J. Renwick, observer for United States Coast Survey at Sandy Hook, in $\phi = 40° 27'.7$, $\lambda = 74° 00'.2$; Coast Survey Report for 1854, p. 144*.
13	1844, August 24	6	13.1		Prof. J. Renwick, observer for United States Coast Survey, at Columbia College (old position), in $\phi = 40° 42'.7$, $\lambda = 74° 00'.5$; reference as above.
14	1845, September 4	6	25.3		Prof. J. Renwick, observer for United States Coast Survey, at Columbia College; reference as above.
15	1846, April 30	5	09.7		Dr. J. Locke, observer for United States Coast Survey, at Bloomingdale Asylum, in $\phi = 40° 50'.3$, $\lambda = 73° 56'.7$; Coast Survey Report for 1854, p. 144*.
	1846, May 4	5	54.7		Dr. J. Locke, observer for United States Coast Survey, at Mount Prospect (formerly Flatbush), Brooklyn, in $\phi = 40° 40'.3$, $\lambda = 73° 58'.0$; reference as above.
					Other observations at this place are given in the Regents' Report of the University of the State of New York, viz: Oct., 1834, 4° 25′ W. — Dec. 22, 1840, 5° 00′ W. Oct., 1835, 4 45 — Dec. 30, 1841, 5 12 Oct., 1837, 4 45 — Dec. 30, 1842, 5 10 Dec. 18, 1838, 4 45 — Dec. 20, 1847, 5 30 Jan. 4, 1840, 4 55 — Oct. 26, 1848, 5 15 Assigned position $\phi = 40° 37'$, $\lambda = 73° 58'$.
	1846, May 14	5	35.1		Dr. J. Locke, observer for United States Coast Survey, at Newark, in $\phi = 40° 44'.8$, $\lambda = 74° 07'.3$; Coast Survey Report for 1854, p. 144*.
16	1847, October 16, 20	5	41.0		R. H. Fauntleroy, assistant Coast Survey, at Legget, in $\phi = 40° 48'.9$, $\lambda = 73° 53'.4$; reference as above.
17	1855, August 7	6	39.6		C. A. Schott, assistant Coast Survey, at Governor's Island, in $\phi = 40° 41'.5$, $\lambda = 74° 01'.0$; Coast Survey Report for 1855, p. 337.
	1855, August 8	7	02.1		C. A. Schott, at Bedloe's Island, in $\phi = 40° 41'.4$, $\lambda = 74° 02'.7$; reference as above.
	1855, August 11	6	28.0		C. A. Schott, at Receiving Reservoir (now in Central Park), in $\phi = 40° 46'.7$, $\lambda = 73° 58'.2$; reference as above.
	1855, August 14	6	11.2		C. A. Schott at Sandy Hook; position same as in 1844; reference as above. To reduce to New York add 22′.4 or 0°.37 [not used].
18	1860, September 21, 22	6	44.0		C. A. Schott, at site at Mount Prospect, now Brooklyn (new) water-works, in $\phi = 40° 40'.3$, $\lambda = 73° 58'.0$; Coast Survey Report for 1860, p. 352.
	1872, October 31, November 1 and 2.	8	45.8		A. H. Scott, United States Coast Survey, at Central Park, west of Mall, in $\phi = 40° 46'.2$, $\lambda = 73° 58'.2$; MS. in Coast Survey archives [Not used.]
19	1873, November 5, 6, 7, 9	7	09.0		Dr. T. C. Hilgard, observer for United States Coast Survey, at Sandy Hook; station as in 1844; MS. in Coast Survey archives. To reduce to New York, add 0°.37.
20	1874, August	7	23		Report of Chief of Engineers U.S.A. for 1875; chart of Way Reef, Hell Gate.
21	1879, July 17, 18	7	32.0	W.	J. B. Baylor, United States Coast and Geodetic Survey. Station of 873, at Sandy Hook, N. J. To reduce to New York add 0°.37

Collection of Magnetic Declinations, etc.—Continued.

HATBOROUGH, MORELAND TOWNSHIP, MONTGOMERY COUNTY, PA.

$\phi = 40° 12'$ $\lambda = 75° 07'$ W. of Gr.

		° ′		
1	1680	8 28	W.	Table communicated to the Superintendent of the Coast Survey in a letter, by Mr. E. W. Beans, dated Hatborough, March 1, 1852 (see Coast Survey Report for 1855, p. 312). [It is not to be presumed that this table presents direct observations, as the regularity of decennial values sufficiently attests; but it is not doubted that it rests upon *reliable* observations of numerous bearings of old (and new) lines which were submitted to some process of interpolation, probably graphical.—SCH.]
2	1690	8 15		
3	1700	7 55		
4	1710	7 28		
5	1720	7 00		
6	1730	6 25		
7	1740	5 35		
8	1750	4 55		
9	1760	4 00		
10	1770	2 55		
11	1780	2 05		
12	1790	1 50		
13	1800	1 55		
14	1810	2 00		
15	1820	2 27		
16	1830	3 00		
17	1840	3 50		
18	1850	4 25	W.	

PHILADELPHIA, PA.

$\phi = 39° 56'.9$ $\lambda = 75° 09'.0$ W. of Gr.

(State-house.)

		° ′		
1	1701	8 30	W.	By Mr. Scull, as stated by G. Gillet, Sill. Jour., vol. xxiii, 1833. [See also Coast Survey Report for 1855, pp. 313, 314.]
2	1710	8 30		Th. Whitney; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
3	1750	5 45		Kalm's Travels; reference as above.
4	1793	1 30		Th. Whitney; reference as above.
4	1793	1 30		By Mr. Brooks; Sill. Jour., vol. xxiii, 1833.
5	1802	1 30		By Mr. Howell; reference as above.
6	1804	2 00		By several men of science; reference as above.
6	1804	2 10		Th. Whitney; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
7	1813	2 25		D. McClure; reference as above.
7	1813	2 27		By Mr. Whitney; Sill. Jour., vol. xxiii, 1833.
8	1837	3 52		W. R. Johnson; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
9	1840, June	3 37		Dr. A. D. Bache, at Girard College, $\phi = 39° 58'.3$, $\lambda = 75° 10'.3$; annual change from *differential observations* between 1840, June, and 1845, December, $= 4'.4$ (Coast Survey Reports for 1859, p. 285, and 1860, p. 311); subtracting 5′.3 from his observation, 3° 53′.7 July 20 and November 1, we find 3° 48′ for June, 1840; again subtracting 26′ from Dr. Locke's observation, 3° 51′.1, in May, 1846, we find 3° 25′; mean adopted, 3° 37′.†
10	1841, July 20 and November 1	3 53.7		Dr. A. D. Bache, at Girard College; magnetic survey of Pennsylvania; Coast Survey Report for 1862, p. 213.
11	1846, May 23	3 51.1		Dr. J. Locke, Girard College magnetical observatory; Coast Survey Report for 1854, p. 144.*
12	1855, September 5	4 31.7		C. A. Schott, assistant Coast Survey, east of main building, Girard College; Coast Survey Report for 1855, p. 337.
13	1862, August 15, 16	5 00.0		C. A. Schott, assistant Coast Survey, at site of old magnetical observatory, Girard College; Coast Survey Report for 1862, p. 212.
14	1872, October 19, 20, 21	5 27.8		A. H. Scott, United States Coast Survey, at site of old magnetical observatory, Girard College; MS. in Coast Survey archives.
15	1877, October 2, 3, 5, 6	6 02.2	W.	J. B. Baylor, United States Coast Survey, Girard College, SW. of main building.

† Which is preferred to the values given in Coast Survey Report for 1864 p. 204.—SCH.

Collection of Magnetic Declinations, etc—Continued.

HARRISBURG, PA.

$\phi = 40° 15'.9$ $\lambda = 76° 52'.9$ W. of Gr.

(State Capitol.)

		° ′	
1	1795, August 19	0 26 E.	From a map of the borough of Harrisburg on file in office of register and recorder of this county, made by Thomas Foster. Communicated by W. W. Wright, March 10, 1875.
2	1840, July 25	3 12.5 W.	Dr. A. D. Bache; in the grounds east of the capitol; Coast Survey Report of 1862, p. 212.
3	1843	2 35	From a map of the borough of Harrisburg, on file in the city register's office, made by John Roberts. Communicated by W. W. Wright, March 10, 1875.
4	1854 (autumn)	3 06	John Roberts and Samuel Hoffer, surveyors, established a true meridian east of the State House. Communicated by W. W. Wright, February, 1875. [See also Annual Report of Secretary of Internal Affairs of Pennsylvania for 1876.]
5	1857, April 29	3 18.3	James Ferguson, James Aspach, and Daniel Hoffman, surveyors. Results recorded at county commissioner's office. Communicated by W. W. Wright, February, 1875.
	1857, June 3	3 20	Samuel Hoffer. Reference as above.
6	1860–61	3 30	From surveys made by Hather Page;† map in the city register's office at Harrisburg. Communicated by W. W. Wright, March 10, 1875.
7	1862, July 28, 29	3 44.5	C. A. Schott, assistant Coast Survey; grounds of the State House, near eastern entrance; Coast Survey Report of 1862, p. 212.
8	1874, October and November	4 51	H. Alricks, jr., J. Simpson Africa; Annual Report of Secretary of Internal Affairs of Pennsylvania, 1876; W. McCandless, secretary.
9	1876, December 2	5 10	Annual Report of Secretary for 1876, as above.
10	1877, September 25, 26	4 53.5 W.	E. Smith and J. B. Baylor, United States Coast Survey; grounds east of capitol, near astronomical station and near station of 1862, $\phi = 40° 15'.8$, $\lambda = 76° 52'.9$

†Name not clearly legible.

BALTIMORE, MD.

$\phi = 39° 17'.8$ $\lambda = 76° 37'.0$ W. of Gr.

(Washington Monument.)

		°	
1	1679.0	5.25 W.	T. Kelbaugh, from resurvey of old lines.* $D_{1679.0} = D_{1814.5} + 4°.50$ Adopted value for second epoch + 0°.75
2	1683.5	6.25	$D_{1683.5} = D_{1814.5} + 5°.50$ Adopted value for second epoch + 0.75
3	1703.5	5.12	$D_{1703.5} = D_{1811.8} + 4°.43$ Adopted value for second epoch + 0.69
4	1720.5	4.21	$D_{1720.5} = D_{1816.0} + 3°.42$ Adopted value for second epoch + 0.79
5	1729.2	4.02	$D_{1729.2} = D_{1807.1} + 3°.39$ Adopted value for second epoch + 0.63
6	1754.5	2.28	$D_{1754.5} = D_{1855.5} - 0°.37$ Adopted value for second epoch + 2.65
7	1756.9	2.88	$D_{1756.9} = D_{1815.0} + 2°.12$ Adopted value for second epoch + 0.76
8	1771.0	1.11	$D_{1771.0} = D_{1846.5} - 1°.00$ Adopted value for second epoch + 2.11
9	1776.1	1.75	$D_{1776.1} = D_{1811.4} + 1°.07$ Adopted value for second epoch + 0.68
10	1780.5	0.77	$D_{1780.5} = D_{1861.5} - 2°.25$ Adopted value for second epoch + 3.02
11	1787.5	0.37	$D_{1787.5} = D_{1851.0} - 2°.00$ Adopted value for second epoch + 2.37
12	1808.5	0° 12′.5	D. Byrnes, from numerous observations in Baltimore in different localities; Sill. Jour., vol. xviii, 1830.
13	1840, August 27	2 16.5	Dr. A. D. Bache; Coast Survey Report for 1862, p. 213.
14	1847, April 29	2 18.6	Capt. T. J. Lee, United States Engineers, assistant Coast Survey; at Fort McHenry, in $\phi = 39° 15'.8$, $\lambda = 76° 34'.8$; Coast Survey Report for 1854, p. 144.
15	1856, September 13	2 29.3	C. A. Schott, assistant Coast Survey; just outside Fort McHenry, in $\phi = 39° 15'.9$, $\lambda = 76° 34'.9$; Coast Survey Report for 1858, p. 191.
16	1875.5	3°.74	See note *. $D_{1875.5} = D_{1857.0} + 1°.00$. Adopted value for second epoch + 2°.74
17	1877, October 10, 11, 12	4° 10′.8 W.	J. B. Baylor, United States Coast Survey; at Fort McHenry, near station of 1856.

* Mr. Thomas Kelbaugh, surveyor at Mt. Carmel, Baltimore County, Maryland, communicated to the Coast Survey Office (letters dated August 17 and 24, 1877, and April 28, 1879) 52 cases of observed or allowed for changes of magnetic declinations between given dates, mostly from redeterminations of magnetic bearings of old lines, made with the common surveyor's compass, by different individuals and with different instruments, and generally within a radius of 15 statute miles of Baltimore City, on the N., NE., and NW. of it. These surveys were made by order of the Baltimore County circuit court, arising from disputed land cases. Other values were copied from the record-book of the county surveyor and his assistants, between 1805 and 1825.

The 52 differential values, after scrutiny, were properly combined; the 12 results, Nos. 1 to 11, inclusive, thus obtained are given in the above table. The adopted values for the epochs of the resurvey are likewise given, and are those resulting from a formula established by me in August, 1877. At that time but 25 differential values had been communicated by Mr. Kelbaugh.—[Sch.]

Collection of Magnetic Declinations, etc.—Continued.

WASHINGTON, D. C.

$\phi=38^\circ\ 53'.3$ $\lambda=77^\circ\ 00'.6$ W. of Gr.

(United States Capitol.)

No.	Date	° ′		Authority
	1792	0 51	E.	Maj. A. Ellicott, surveyor-general; inscription on fourth milestone northwesterly from east corner of District; reported by G. Mathiot. [Supposed affected by local deviation; not used.]
1	1792	0 19		A. Ellicott; inscription on first milestone northwesterly from east corner of District; reported by J. Wiessner.
	1792	0 10	E.	A. Ellicott; inscription on east corner-stone, District; reported by J. Wiessner.
2	1809, December	0 52	W.	Nicholas King, surveyor of the city of Washington; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
3	1841.0	1 20.2		J. M. Gilliss, U. S. N.; Capitol Hill, north of Capitol; Sen. Doc., 2d sess. 28th Cong., 1844-45.
4	1842.0	1 23.9		J. M. Gilliss, U. S. N.; reference as above.
5	1855, July	2 24		C. A. Schott, assistant Coast Survey; Coast Survey Report for 1855, p. 334, on Capitol Hill, near Gilliss station.
6	1856, August 14, 20	2 21.4		C. A. Schott, at (old) Coast Survey Office, Capitol Hill; also 2° 01′ W., August 15, in park east of the Capitol; Coast Survey Report for 1856, p. 227.
7	1857, March 9	2 24.8		W. Read; near Capitol, south side; Coast Survey Report for 1858, p. 196. Communicated by observer.
8	1860, August 16 to September 26	2 26.7		C. A. Schott, at (old) Coast Survey Office; $\phi=38^\circ\ 53'.1$, $\lambda=77^\circ\ 00'.6$; Coast Survey Report for 1860, p. 352.
9	1862, August 18, 19	2 39.4		C. A. Schott, at (old) Coast Survey Office; Coast Survey Report for 1862, p. 212.
10	1863, June 18 to July 28	2 41.8		C. A. Schott, at (old) Coast Survey Office; Coast Survey Report for 1863, p. 204.
11	1866, November 1	2 44.2		Prof. W. Harkness, U. S. N.; United States Naval Observatory grounds, in $\phi=38^\circ\ 53'.7$, $\lambda=77^\circ\ 03'.1$; Smithsonian Contributions to Knowledge, No. 239, p. 61, Washington, 1873.
12	1867, January to December	2 48.1		C. A. Schott, at magnetic observatory, corner Second street east and C street south, Capitol Hill, in $\phi=38^\circ\ 53'.1$, $\lambda=77^\circ\ 00'.2$; Monthly Determinations, Coast Survey Report for 1869, pp. 199-207.
13	1868, January to December	2 51.2		
14	1869, January to June, inclusive	2 53.0		
15	1870, June 13, 14, 15	2 53.6		C. A. Schott, at magnetic observatory, corner Second and C streets southeast; Coast Survey Report for 1870, Appendix No. 14.
16	1871, June 14, 15, 16	2 56.9		
17	1872, June 14, 15, 17	3 00.0		
18	1873, June 14, 16, 17	3 00.1		Observer and locality as before; MS. Coast Survey archives.
19	1874, June 13, 15, 16	3 07.4		
	1874, July 20, 21, 22	3 05.2		
20	1875, June 12, 14, 15	3 15.5		Observer and locality as before; MS. Coast Survey archives.
21	1876, May 1, 2	3 18.8		
22	1877, June 14, 15, 16	3 42.1		C. A. Schott, at new magnetic observatory, near corner First and B streets southeast; $\phi=38^\circ\ 53'.2$, $\lambda=77^\circ\ 00'.4$; MS. in Coast Survey archives.
	1877, August 17	3 36.8		A. Braid, United States Coast Survey; same place.
23	1878, June 14, 15, 17	3 47.5		C. A. Schott; locality as above.
	1878, September 8	3 43.0		Dr. T. E. Thorpe; locality as above.
24	1879, June 9, 10, 11	3 50.4		W. Eimbeck and C. A. Schott, assistants Coast and Geodetic Survey; locality as in 1877 and 1878.
25	1880, February 23, 24, 25	3 52.4		M. Baker, United States Coast and Geodetic Survey; locality as above.
	1880, June 12, 14, 17	3 57.1	W.	J. B. Baylor, United States Coast and Geodetic Survey; locality as above.

CAPE HENRY, VA.

$\phi=36^\circ\ 55'.5$ $\lambda=76^\circ\ 00'.5$ W. of Gr.

(Light-house, 1857.)

No.	Date	° ′		Authority
1	1728, March 6	3 00	W.	W. Byrd, at head of Currituck Sound, in $\phi=36^\circ\ 30'$; Westover MS. (Two printed copies in Library of Congress.) Reduction to Cape, + 20′
	1732	4 42		W. Hoxton, seven miles from Cape Henry, in $\phi=36^\circ\ 50'$; Hansteen's Magnetismus der Erde, 1819.
	1732	4 40		Douglass' History, in $\phi=37^\circ\ 07'$, $\lambda=75^\circ\ 30'$; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
	1775	5 00		J. F. W. Des Barres' Atlantic Neptune, London, 1781. [Not used.]
2	1809	0 00		President Madison, at Norfolk, in $\phi=36^\circ\ 51'$, $\lambda=76^\circ\ 19'$; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838. Reduction to Cape, −8′; by observations of 1856.
	1823-24	1 32		State map of Virginia, of 1859, by H. Boye. [Not used.]
3	1832, June 9, 11	0 45		Prof. J. N. Nicollet; Coast Survey Report for 1864, p. 210.
4	1856, September 11, 12	1 28		C. A. Schott, assistant Coast Survey, in $\phi=36^\circ\ 55'.6$, $\lambda=76^\circ\ 00'.4$; Coast Survey Report for 1856, p. 227.
5	1874, November 26, 27, 28	2 39.5		Dr. T. C. Hilgard, observer for United States Coast Survey; MS. in Coast Survey archives.
6	1879, May and June	2 32	W.	Lieut. Samuel W. Very, U. S. N. From 50 observations at the Rip Raps. [Reduction to Cape Henry, according to my observations of 1856, + 13′.—SCH.]

Collection of Magnetic Declinations, etc.—Continued.

CHARLESTON, S. C.

$\phi = 32° 46'.6$ $\lambda = 79° 55'.8$ W. of Gr.

(St. Michael's Church.)

		° '	
	1700	0 30 E.	E. Halley's isogonic chart for 1700; reproduced by photolithography in the Greenwich observations for 1869. [Not used.]
	1742	5 23	English Pilot, published on Tower Hill in 1794; extracted from a paper by Andrew Hughes. [Not used.]
1	1775	3 48	Des Barres' Atlantic Neptune, London, 1781.
	1777	3 48	From a chart; Prof. E. Loomis' Collection, in Sill. Jour., vol. xxxiv, 1838, probably the same as that given in the Neptune. [Not used.]
2	1784, February	5 15	Joseph Purchell, surveyor; see pamphlet by Charles Parker, Charleston, 1849. [Observations said to come from a reliable source.]
3	1785, October	5 45	
4	1824–25	3 45	Lieut. Sherburne, U. S. N.; Blunt's chart of 1824–25.
5	1837	2 54	Capt. Missroom; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838. Position $\phi = 32° 47'$, $\lambda = 79° 57'$.
6	1840	2 44	Dr. C. Davies, in his treatise on surveying.
7	1841, May	2 24	Barnet; Phil. Trans. Roy. Soc., vol. for 1849.
8	1847, October	2 15	Charles Parker; see his pamphlet (Charleston, 1849).
9	1849, April 1 and 22	2 16.5	C. O. Boutelle, assistant Coast Survey, at Breach Inlet, in $\phi = 32° 46'.3$, $\lambda = 79° 48'.9$, Sullivan's Island; Coast Survey Report for 1854, p. *145.
10	1874, May 27, 28, 29	0 58.1	C. O. Boutelle, assistant Coast Survey, at Fort Marshall, same position as for Breach Inlet; MS. in Coast Survey archives.
11	1880, January 21, 22	0 25.6 E.	J. B. Baylor, United States Coast and Geodetic Survey, at Breach Inlet, Sullivan's Island; $\phi = 32° 46'.4$, $\lambda = 79° 48'.8$.

SAVANNAH, GA.

$\phi = 32° 04'.9$ $\lambda = 81° 05'.5$ W. of Gr.

(Savannah Exchange.)

		° '	
1	1817	4 E.	Becquerel's Traité du Magnétisme. Paris, 1846; Cartes du Dépôt, in $\phi = 32\ 04'$, $\lambda = 80° 40'$.
2	1838	5 05	Geological Survey, in $\phi = 32° 05'$, $\lambda = 81° 07'$; Prof. E. Loomis' collections, in Sill. Jour., vol. xxxix, 1840.
	1839	3 31	Dr. Posey; reference as above.
3	1852, April 26–28	3 40.3	J. E. Hilgard, assistant Coast Survey, in $\phi = 32° 05'.0$, $\lambda = 81° 05'.1$, on Hutchinson's Island; Coast Survey Report for 1854, p. *145.
4	1857, May 1 and 2	3 27.5	C. A. Schott, assistant Coast Survey, position as above; Coast Survey Report for 1858, p. 192.
5	1874, March 8, 9, 10	1 58.5 E.	F. Blake and C. Tappan, United States Coast Survey, position on Hutchinson's Island, opposite Savannah, as above; MS. in Coast Survey archives.

KEY WEST, FLA.

$\phi = 24° 33'.5$ $\lambda = 81° 48'.5$ W. of Gr.

(Tift's observatory.)

		° '	
1	1829, February	6 25 E.	W. A. Whitehead; from a map of Florida, by the Topographical Engineers, of 1846.
2	1843	6 02	Report of Commander L. M. Powell, U. S. N., at custom-house.
3	1849, August 19–21	5 28.8	J. E. Hilgard, assistant Coast Survey, at Sand Key, in $\phi = 24° 27'.2$, $\lambda = 81° 53'.1$; Coast Survey Report for 1854, p. *145.
4	1860, February, March, June, and December.	4 46.6	Prof. W. P. Trowbridge, assistant United States Coast Survey; subsequent observer, S. Walker; Coast Survey Report for 1860, p. 340.
5	1861, February, March, April	4 44.5	Observer, S. Walker.
6	1862, monthly, May to December.	4 39.9	
7	1863, monthly, January to December.	4 36.8	
8	1864, monthly, January to December.	4 33.9	
9	1865, monthly, January to December.	4 31.5	
10	1866, January to April, inclusive.	4 29.8	The above observations, between 1860 and 1866, inclusive, were taken at the Coast Survey magnetic observatory at Key West, in $\phi = 24° 33'.1$, $\lambda = 81° 48'.5$. The results are corrected for daily variation.
11	1879, March, 24, 25, 26	3 33.9 E.	Lieut.-Com'g S. M. Ackley, U. S. N., assistant Coast and Geodetic Survey; grounds of Army Hospital, $\phi = 24° 33'.3$, $\lambda = 81° 47'.9$.

Collection of Magnetic Declinations, etc.—Continued.

HAVANA, CUBA.

$\phi = 23° 09'.3$ $\lambda = 82° 21'.5$ W. of Gr.

(Morro light.)

		° ′	
	1700	6 E.	E. Halley's isogonic chart for 1700; Greenwich observations for 1869. [Not used.]
1	1726	4 24	Mathews, in $\phi = 23° 02'$, $\lambda = 81° 44'$; Encyc. Metrop., 1848.
2	1732, March and April	4 30	J. Harris, off Havana, in $\phi = 23° 08'$, $\lambda = 82° 32'$; Phil. Trans. Roy. Soc., vol. vii (abridged), 1724-34; also Encyc. Metrop., 1848.
3	1815	7 00	Encyc. Brit., seventh edition, 1842.
4	1816, August	5 30	Bentley, Encyc. Brit., seventh edition.
5	1857, January 28	5 15	Karl Friesach; Imp. Acad. of Sci., Vienna, vol. xxix, 1858.
6	1858	5 45	From a map of Cuba, 1860.
7	1879, March 13, 14, 15	3 53.8 E.	Lieut.-Com'g S. M. Ackley, U. S. N., assistant Coast Survey, at the College de Belen. Annual change observed at the Colegio de Belen, according to Padre P. B. Viñes, S. J., director of observatory, 4½ minutes decreasing for several years past. [Letter of Lieut Ackley to C. A. S., dated March 21, 1879.] The Morro light is in $\phi = 23° 09'.3$, $\lambda = 82° 21'.5$. Determination by Lieut. Com. F. M. Green, U. S. N.

KINGSTON, PORT ROYAL, JAMAICA.

$\phi = 17° 55'.9$ $\lambda = 76° 50'.6$ W. of Gr.

(Port Royal flagstaff.)

		° ′	
	1660	6 30 E.	In Jamaica, according to J. Robertson; Phil. Trans. Roy. Soc., 1806. [Not used.]
	1700	6 30	According to Mountain's chart, constructed in the year 1700 from Dr. Halley's tables; Long's History of Jamaica; E. Halley's chart for 1700 gives 7° E.; Greenwich observations for 1869. [Not used.]
1	1732, March and April	6° to 6 05	At Black River, J. Harris; Phil. Trans. Roy. Soc., 1733.
2 {	1789 to 1793	6 50	J. Leard; chart of Port Royal.
	1791 to 1792	6 45	
3	1806	6 30	J. Robertson; Phil. Trans. Roy. Soc., 1806. Variation in Jamaica said to have been constant for 130 or 140 years.
4 {	1819	4 50	De Mackau, in $\phi = 17° 55'$, $\lambda = 76° 09'$; Becquerel's Traité du Magnétisme, Paris, 1846.
	1821	4 50	De Mayne, in $\phi = 17° 55'$, $\lambda = 76° 53'$; Becquerel, as above.
5	1822	4 54	Owen; Becquerel, as above.
6	1832	5 13	Foster; Becquerel, as above.
7	1833 (?)	4 30	From a map of Kingston of 1854.
8	1837, October	4 18	Milne, in $\phi = 17° 56'$, $\lambda = 76° 51'$; contributions to Terr. Mag., No. ix, by Lieut. Col. E. Sabine, Phil. Trans. Roy. Soc., 1849, part ii.
9	1847, April	3 40	Barnett, in $\phi = 17° 56'$, $\lambda = 76° 51'$; contributions to Terr. Mag., No. ix, by Lieut. Col. E. Sabine, Phil. Trans. Roy. Soc., 1849, part ii.
10	1857, March 2	3 40	Karl Friesach; Imp. Acad. of Sci., Vienna, vol. xxix, 1858.
	1866	4 57	English Admiralty Chart of Jamaica, No. 446. Variation in 1866 nearly stationary. [Not used.]
11 {	1875	4 00	Port Royal and Kingston Harbor; English Admiralty Chart, No. 456. Annual decrease 2′.
	1876	3 35 E.	West India Islands and Caribbean Sea: English Admiralty Chart No. 762. [Used mean value −3°.79.—SCH.]

Collection of Magnetic Declinations, etc.—Continued.

PANAMA, NEW GRANADA.

$\phi = 8° 57'.1$ $\lambda = 79° 32'.2$ W. of Gr.

(Cathedral.)

		° ′		
	1700	10	E.	Approximate value according to E. Halley's isogonic chart for 1700. Greenwich observations for 1869. [Not used.]
1	1775, November	7 49		Encyc. Brit., 7th edition, 1842.
2	1790, October 3	7 49		Don A. Malaspina; Berliner Ast. Jahrbuch, vol. 53, for 1828, p. 188.
	1791, December	7 49		Encyc. Brit., 7th edition, 1842. [Probably same as preceding authority; not used.]
3	1802	8 00		Encyc. Brit., 7th edition, 1842.
4	1822	7 00		Hall, in $\phi = 8° 58'$, $\lambda = 79° 21'$; Becquerel's Traité du Magnétisme, Paris, 1846.
5	1837	7 02		Sir E. Belcher, in $\phi = 8° 57'$, $\lambda = 79° 29'$; Phil. Trans. Roy. Soc., 1843.
6	1849	7 15		Hughes, Brit. Admiralty Chart.
	1849	6 55		Maj. W. H. Emory, Mexican Boundary Survey, in $\phi = 8° 57'$, $\lambda = 79° 29'$. See also Coast Survey Report for 1856, p. 223.
7	1858	6 17		Karl Friesach; $\phi = 8° 57'$, $\lambda = 79° 31'$. Sir E. Sabine's Conts. to Terr. Mag., Phil. Trans. Roy. Soc., vol. 165, 1875.
8	1866, May 14	5 56		Prof. W. Harkness, U. S. N., in $\phi = 8° 55'$, $\lambda = 79° 30'.5$; Smithsonian Contributions to Knowledge, No. 239, Washington, 1873.
9	1873, December 25	6 57	E.	Hydrographic Office, Washington, D. C., from log-books of the Benicia and Richmond, in $\phi = 7° 26'$, $\lambda = 79° 54'$, off Point Mala. [Reduction to Panama, −22′; hence at Panama, 6° 35 E.—Sch.]

RIO JANEIRO, BRAZIL.**

$\phi = -22° 54'.8$ $\lambda = 43° 09'.5$ W. of Gr.†

(Fort Villegagnon flagstaff.)

		° ′		
1	1768	7 34	E.	Cook } Voyages of the Adventure and Beagle, 1826-36, vol. 1, Capt. P. P. King, London, 1839, p. 523. Discussion by Major Sabine.
2	1787	6 12		Hunter }
3	1820	2 54		Freycinet }
4	1821	3 21		Rumker }
5	1830	2 10		Erman }
6	1836	2 00	E.	Fitz Roy }
7	1857	1 20	W.	Capts. E. O. Stanley and G. H. Richards, and Lieut. Bullock, R. N.; Admiralty Chart No. 541. Fort Villegagnon $\phi = -22° 54'.7$, $\lambda = 43° 09'.0$ W.
8	1866, January 8	2 41.8		Prof. W. Harkness, U. S. N.; position near north face of Fort Caraguata, in $\phi = -22° 54'.1$, $\lambda = 43° 06'.5$ W. of Gr. Smithsonian Contributions to Knowledge, No. 239, Washington, 1873, p. 61.
9	1876.5	4 26	W.	Samuel W. Very, Lieutenant U. S. N. From numerous observations at various times and different places. MS. communication of December 13, 1879.

** At this place the secular change is progressing perhaps at the most rapid rate known within the tropics, and close to the magnetic equator.
† Longitude from telegraphic determinations of longitudes, Lieut. Comdrs. Green and Davis, U. S. N., 1878-'79. Washington, D. C., 1880.

MOBILE, ALA.

$\phi = 30° 41'.4$ $\lambda = 88° 02'.5$ W. of Gr.

(Episcopal Church.)

		° ′		
	1809	8 10	E.	J. H. Weakly, in $\phi = 30° 40'$, $\lambda = 88° 11'$ (probably a misprint for 88° 01′); Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838. [Apparently more than 1½° too great. Not used.—Sch.]
1	1814	6 30		Kent; Encyc. Brit., seventh edition, 1842; for Mobile Bay, in $\phi = 30° 13'$, $\lambda = 88° 21'$.
2	1835	7 12		J. H. Weakly; Prof. E. Loomis' collection in Sill. Jour., vol. xxxiv, 1838.
3	1840	7 05		Chart of Mobile Bay, by E. and G. W. Blunt; Coast Survey Report of 1845, p. 42.
4	1843	6 56		Commander L. M. Powell, U. S. N. (in a report), at Mobile Point Light; $\phi = 30° 13'.8$, $\lambda = 88° 01'.5$; reduction to Mobile City insensible; Coast Survey Report of 1855, p. 323.
5	1847, May 21-30	7 04.1		R. H. Fauntleroy, assistant Coast Survey, at Fort Morgan, in $\phi = 30° 13'.8$, $\lambda = 88° 01'.4$; Coast Survey Report of 1854, p. *145.
6	1857, February 14-18	6 52.2		Edward Goodfellow, assistant Coast Survey, at Mobile City, near Episcopal Church, in $\phi = 30° 41'.4$, $\lambda = 88° 02'.5$; Coast Survey Report of 1858, p. 192.
7	1875, May 27	6 07.0	E.	J. M. Poole, observer for National Academy of Sciences; Bache fund series; MS. communication.

Collection of Magnetic Declinations, etc.—Continued.

NEW ORLEANS, LA.

$\phi = 29° 57'.2$ $\lambda = 90° 03'.9$ W. of Gr.

(Custom-house.)

		° ′	
1	1720	2 E.	Father Laval; Prof. E. Loomis' collection; Sill. Jour., vol. xxxiv, 1838.
2	1768	7 50	Gauld; Gauld's Survey of the Delta, [10′ added to declination at Pass à Loutre to refer to New Orleans.—SCH.]
3	1796	5 06	A. G. Blanchard, city surveyor; change 2° E., from 1796 to 1870.
4	1806	8 03	Lason, from 372 observations; Prof. E. Loomis' collection, Sill. Jour., vol. xxxiv, 1838.
5	1840	8 20	From information in General Land Office.
6	1856, December 28	8 00	Karl Friesach; Berichte der Kais. Acad., Vienna, vol. xxix, 1858.
7	1858, April 6, 7	7 51.5	G. W. Dean, assistant United States Coast Survey; near Canal and Basin streets, $\phi = 29° 57'.4$, $\lambda = 90° 04'.4$; Coast Survey Report of 1858, p. 192.
8	1870	7 06	M. J. Thompson, State engineer.
9	1872, February 10, 12, 14, 15	6 39.6	Dr. T. C. Hilgard, observer; Bache-Fund Magnetic Survey; MS. communication, June 7, 1879; at City Park, —6° 39′.8; at Fair Grounds —6° 39′.5.
10	1880, March 24, 25	6 27.6 E.	J. B. Baylor, U. S. Coast and Geodetic Survey; at Fair Grounds, $\phi = 29° 59'.1$, $\lambda = 90° 04'.8$.

VERA CRUZ, MEXICO.

$\phi = 19° 11'.9$ $\lambda = 96° 08'.8$ W. of Gr.

(Castle San Juan d'Ulloa.)

		° ′	
1	1726 to 1727	2 15 E.	Joseph Harris; Phil. Trans. Roy. Soc. (abridged), 1824-34.
2	1769	6 40	Encyc. Brit., seventh edition, 1842.
	1769, March 15	6 28	
3	1776	7 30	Don Ulloa; Encyc. Brit., seventh edition.
4	1815	10 37	Malony; Encyc. Brit., seventh edition.
5	1819, April 27	9 16	Wise; Encyc. Brit., seventh edition.
6	1839	8 22	Behard; $\phi = 19° 12'$, $\lambda = 96° 09'$; Phil. Trans. Roy. Soc., Sir E. Sabine's Conts. to Terr. Mag., No. xiv, vol. 165; 1875.
7	1856, August 7 and 8	8 17	August Sonntag, in $\phi = 19° 12'$, $\lambda = 96° 09'$, at the villa La Guaca, 200 yards south of the city; Smithsonian Contributions to Knowledge, Washington, 1860; also Coast Survey Report of 1856, p. 214.
8	1861	8 20	English Admiralty Chart No. 523, corrected to 1861.
9	1880, February 10, 11, 12	7 26.3 E.	Lieut. S. M. Ackley, U. S. N., assistant U. S. Coast and Geodetic Survey; Northeast bastion of Castle San Juan d'Ulloa, $\phi = 19° 12'.2$, $\lambda = 96° 08'.5$.

CITY OF MEXICO, MEXICO.

$\phi = 19° 25'.9$ $\lambda = 99° 06'.0$ W. of Gr.

		° ′	
1	1769, June	5 20 E.	Don Alzate; Hansteen's Magnetismus der Erde, 1819.
	1769, December	5 35	Don Alzate; reference as above.
2	1775	6 42	Velasquez de Leon; Memoria del Observatorio Meteorologico Central de Mexico, Por V. Reyes, Mexico, 1880.
3	1803	8 08	Alex. von Humboldt; Hansteen's Magnetismus der Erde, 1819.
4	1849	8 30.2	Gomez de la Cortina; Memoria del Observatorio Meteorologico Central de Mexico, Por V. Reyes, Mexico, 1880.
5	1850	8 35.2	Velasquez y Terán; F. Diaz Covarrubias, Tratado de Topografia y Geodesia, México, 1869, tomo 1, p. 221.
6	1856, December 10–17	8 46	Aug. Sonntag; Observations on Terr. Mag. in Mexico, Smithsonian Contributions to Knowledge, Washington, 1860; also Coast Survey Report of 1856, p. 214.
7	1858	8 22.3	Alamazan*; F. Diaz Covarrubias' Tratado, as above.
8	1860	8 30	Salazar Ilarreguit†; Tratado, as above.
9	1862	8 20.5	Diaz Covarrubias; Tratado, as above.
	1862	8 34.8	Iglesias; Memoria del Observatorio Meteorologico Central de Mexico, Por V. Reyes, Mexico, 1880.
10	1866	8 08.5	Ponce de Leon; Tratado de Topografia y Geodesia, Mexico, 1869, tomo 1, p. 221.
	1867	8 09.3	
11	1868	8 10.0 E.	Fernandez y Diaz Covarrubias; Tratado, as above.

* Almazan in Mem. del Obser'o Central. † Llarregui in Mem. del Obser'o Central.

Collection of Magnetic Declinations, etc.—Continued.

ACAPULCO, MEXICO.

$\phi = 16° 50'.5$ $\lambda = 99° 52'.3$ W. of Gr.

(South of Fort San Diego.)

		° ′	
1	1744	3 E.	Anson; Hansteen's Magnetismus der Erde, 1819.
2	1791, April 29	7 44	Don A. Malaspina, observed on land; Berliner Astronomisches Jahrbuch, vol. 53, for 1828.
3	1822	8 40	Hall, in $\phi = 16° 50'$, $\lambda = 99° 51'$; Becquerel's Traité du Magnétisme, Paris, 1846.
4	1828	9 07	Beechey; Becquerel, as above.
5	1837	8 23	Sir E. Belcher, San Diego Fort, in $\phi = 16° 50'.9$, $\lambda = 99° 52'.2$; Admiralty Chart of Acapulco.
5	1838	8 13	Sir E. Belcher; Phil. Trans. Roy. Soc., 1843.
5	1838	8 17	Du Petit Thouars; Voyage of the Frigate Venus.
	1841	8 17	Duflot de Mofras' Exploration of Oregon, Paris, 1844. [Probably Du Petit Thouars' value; not used.]
6	1866, May 30	8 22	Prof. W. Harkness, U. S. N., in $\phi = 16° 50'.1$, $\lambda = 99° 52'.3$; Observations on Terr. Mag., Smithsonian Contributions to Knowledge, No. 239, 1873, p. 61.
7	1874, March 17	8 38.7 E.	Commander G. Dewey, U. S. Steamer Narragansett; Lieut's Z. L. Tanner and E. J. Young, observers, in $\phi = 16° 50'.5$, $\lambda = 99° 55'4$.

SAN BLAS, MEXICO.

$\phi = 21° 32'.6$ $\lambda = 105° 15'.7$ W. of Gr.

		° ′	
1	1791, April 12	7 28 E.	Don A. Malaspina, observed on shore; Berliner Ast. Jahrbuch, vol. 53, for 1828; also Encyc. Brit., 7th edition, 1842.
2	1821-22	8 40	Hall; Encyc. Brit., 7th edition.
	1828	11 06	Beechey; Beechey's Voyage to the Pacific, 1825-28; also Becquerel's Traité du Magnétisme, Paris, 1846. [Not used.]
3	1837	8 34	Sir E. Belcher; in $\phi = 21° 32'$, $\lambda = 105° 16'$; Phil. Trans. Roy. Soc., 1843.
3	1837	9 09	Voyage de la Vénus, Paris, 1841. Gen. Sir E. Sabine's Conts. to Terr. Mag.; Phil. Trans. Roy. Soc., No. xiv, vol. 165, pt. 1, 1875. Position, $\phi = 21° 32'$, $\lambda = 105° 16'$.
4	1838	8 47	Sir E. Belcher in the Sulphur. Reference as above.
5	1839	9 00	Sir E. Belcher; Phil. Trans. Roy. Soc., 1843.
6	1841	9 12	Duflot de Mofras' Exploration of Oregon, Paris, 1844.
7	1874, February 23, 24, 26	9 08.2 E.	Commander G. Dewey, U. S. Steamer Narragansett; Lieuts. Z. L. Tanner and E. J. Young, observers, in $\phi = 21° 32'.4$, $\lambda = 105° 18'.7$.

MAGDALENA BAY, LOWER CALIFORNIA.

$\phi = 24° 38'.4$ $\lambda = 112° 08'.9$ W. of Gr.

(Near village, on Man of War Cove.)

		° ′	
1	1837	8 15 E.	Du Petit Thouars; Voyage of the Frigate Venus.
1	1837	8 17	Frigate Venus } Gen. Sir Edward Sabine in Phil. Trans. Roy. Soc., vol. 165, pt. 1, 1875. Conts. to Terr. Mag., No. xiv.
2	1839	9 15	Sir Edward Belcher, in $\phi = 24° 38'$, $\lambda = 112° 07'$. } Gen. Sir Edward Sabine in Phil. Trans. Roy. Soc., vol. 165, pt. 1, 1875. Conts. to Terr. Mag., No. xiv.
	1841	8 15	Duflot de Mofras; Exploration of Oregon, Paris, 1844; in $\phi = 24° 36'$, $\lambda = 112° 05'$. [Not used.]
3	1866, June 9	10 40.5	Prof. W. Harkness, U. S. N.; cruise of the Monadnock, 1865-66. Smithsonian Contributions to Knowledge, No. 239, Washington, 1873; in $\phi = 24° 40'$, $\lambda = 112° 07'$.
4	1871, March to June	11 00	G. Bradford, assistant Coast Survey; near village, on Man of War Cove; in $\phi = 24° 37'.5$, $\lambda = 112° 13'.3$. Chart in Coast Survey archives.
5	1873, March 5, 6, 7	10 36.6	W. Eimbeck, assistant Coast Survey; near village, on Man of War Cove; in $\phi = 24° 38'.4$, $\lambda = 112° 08'.9$. [Near Belcher's and Bradford's Stations.] Record in Coast Survey archives.
5	1873, June 23	10 30.8 E.	Commander G. Dewey, U. S. Steamer Narragansett; Lieuts. Z. L. Tanner and E. J. Young, observers.

Collection of Magnetic Declinations, etc.—Continued.

SAN DIEGO, CAL.

$\phi = 32° 42'.1$ $\lambda = 117° 14'.3$ W. of Gr.

(La Playa, Point Loma.)

		° ′	
1	1792.	11 E.	Vancouver; in $\phi = 32° 39'$, $\lambda = 117° 17'$; Capt. G. Vancouver's Voyage of Discovery, etc., 1790-95, vol. 2, p. 475, London, 1798; also Hansteen's Magnetismus der Erde, 1819.
	1793, December	11	Reference as above; in $\phi = 32° 42'$, $\lambda = 116° 53'$. Observed on board ship on or near the coast. [Not used.]
2	1839	12 20.6	Sir E. Belcher; in $\phi = 32° 41'$, $\lambda = 117° 13'$; Phil. Trans. Roy. Soc., 1841.
	1841	11	Duflot de Mofras; Exploration of Oregon, Paris, 1844; in $\phi = 32° 39'.5$, $\lambda = 117° 17'$. [Not used.]
3	1851, April 28 to May 7	12 28.8	G. Davidson, assistant Coast Survey; near La Playa, in $\phi = 32° 42'.2$, $\lambda = 117° 14'.6$; Coast Survey Report of 1856, p. 229.
4	1853, October 15	12 31.7	Lieut. W. P. Trowbridge, assistant Coast Survey; at La Playa, near the custom-house; Coast Survey Report of 1856.
5	1866, June 15	13 09.4	Prof. W. Harkness, U. S. N.; in $\phi = 32° 42'$, $\lambda = 117° 13'$, at La Playa; Smithsonian Contributions to Knowledge, No. 239, Washington, 1873.
	1871, May 28-30	14 46.7	G. Davidson, assistant Coast Survey; at New San Diego, in $\phi = 32° 43'.1$, $\lambda = 117° 09'.7$; MS. in Coast Survey archives. [Not used; distance from La Playa too great, reduction uncertain.]
	1872, November 19-21	13 19.4 E.	G. Davidson and S. R. Throckmorton, United States Coast Survey; near La Playa, in $\phi = 32° 42'.2$, $\lambda = 117° 14'.6$, station of 1851; MS. in Coast Survey archives.

MONTEREY AND POINT PINOS, CAL.

$\phi = 36° 36'.1$ $\lambda = 121° 53'.6$ W. of Gr.

(Custom-house.)

		° ′	
1	1791, September 23	10 56 E.	Don A. Malaspina; Berliner Ast. Jahrbuch, vol. 53, for 1828. Observation made on shore.*
	1792, December	12 22	Vancouver; in $\phi = 36° 36'$, $\lambda = 121° 34'$; Capt. G. Vancouver's Voyage of Discovery, etc., 1790-95, vol. 2, p. 51, London, 1798; also Hansteen's Magnetismus der Erde, 1819. [Not used.]
2	1794, November 13	12 22	Vancouver; in $\phi = 36° 36'$, $\lambda = 121° 51'$; Capt. G. Vancouver's Voyage of Discovery, etc., vol. iii, p. 337; also Hansteen's Magnetismus der Erde, 1819. Probably taken on shore.
	1827.	15 38	Beechey; Phil. Trans. Roy. Soc., vol. 165, 1875; Sir E. Sabine's Conts. to Terr. Mag., No. xiv. [Not used; apparently about 2° in error.]
3	1837	14 30	Du Petit Thouars; Voyage of the Frigate Venus; near Monterey.
4	1839	14 13	Sir E. Belcher; in $\phi = 36° 36'$, $\lambda = 121° 53'$; Phil. Trans. Roy. Soc., 1841.
5	1841	15 00	Duflot de Mofras; Exploration of Oregon, Paris, 1844; at Presidio, Monterey, in $\phi = 36° 36'$, $\lambda = 121° 53'$.
6	1843	14 00	Chart of the harbor of Monterey, surveyed by Commander T. A. Dornin; position of fort, $\phi = 36° 36'.4$, $\lambda = 121° 52'.4$.
7	1851, February 8	14 58.3	G. Davidson, assistant Coast Survey; at Point Pinos astronomical station, $\phi = 36° 37'.8$, $\lambda = 121° 55'.5$; Coast Survey Report for 1856, p. 229.
8	1854, May 29, 30.	14 58.9	Lieut. W. P. Trowbridge, U. S. A., assistant Coast Survey. Station near Barracks of Redoubt, in $\phi = 36° 36'.2$, $\lambda = 121° 53'.8$.
9	1873, August 30, 31, September 1.	15 55.3 E.	G. Davidson and S. R. Throckmorton, United States Coast Survey; near astronomical station, in $\phi = 36° 37'.8$, $\lambda = 121° 55'.6$; MS. in Coast Survey archives.

* The Coast Survey Report for 1856, p. 229, gives the erroneous date 1790.

Collection of Magnetic Declinations, etc.—Continued.

SAN FRANCISCO, CAL.

$\phi = 37^\circ 47'.5$ $\lambda = 122^\circ 27'.2$ W. of Gr.

(Presidio.)

		° ′	
1	1792, November 20	12 48 E.	Vancouver; in $\phi = 37^\circ 48'$, $\lambda = 122^\circ 08'$; Hansteen's Magnetismus der Erde, 1819. Probably on shore.
	1815, November 1	16 05	Kotzebue's Voyage of Discovery, 1815-'18: in $\phi = 37^\circ 48'.6$, $\lambda = 122^\circ 12'.5$ [Not used.]
	1824	16 00	Kotzebue. [Not used.] } Becquerel's Traité du Magnétisme, Paris, 1846.
2	1827	15 27	Beechey } Becquerel's Traité du Magnétisme, Paris, 1846.
3	1829	15 06	Erman } Becquerel's Traité du Magnétisme, Paris, 1846.
4	1830	14 51	Erman; Phil. Trans. Roy. Soc., vol. 165, 1875; Sir E. Sabine's Conts. to Terr. Mag., No. xiv.
5 {	1837	15 20	Sir E. Belcher; in $\phi = 37^\circ 48'$, $\lambda = 122^\circ 23'$; Phil. Trans. Roy. Soc., 1841.
	1837	15 00	Du Petit Thouars; Voyage of the Frigate Venus.
6	1839	15 20	Sir E. Belcher; in $\phi = 37^\circ 48'$, $\lambda = 122^\circ 23'$; Phil. Trans. Roy. Soc., 1841.
7 {	1841, October	15 30	Duflot de Mofras; Exploration of Oregon, Paris, 1844; in $\phi = 37^\circ 48'.5$, $\lambda = 122^\circ 28'.4$.
	1842, January	15 30	Duflot de Mofras; as above; at Fort Point.
8	1849-50	15 40.8	Commander Ringgold, U. S. N., at *Alcatraz Island, harbor of San Francisco.*
9 {	1852, February 18-28	15 27.6	} G. Davidson, assistant Coast Survey; in $\phi = 37^\circ 47'.5$, $\lambda = 122^\circ 27'.2$; at Presidio; mean of daily maximum and minimum; Coast Survey Report, 1856, p. 229, and MS. in Coast Survey archives; mean 15° 28′.8 E.
	1852, March 24	15 28.8	
	1852, April 21	15 27.8	
	1852, May 28	15 31.1	
10	1866, June 26	16 25.5	Prof. W. Harkness, U. S. N., in $\phi = 37^\circ 49'$, $\lambda = 122^\circ 21'$; east side of Yerba Buena Island; Smithsonian Contributions to Knowledge, No. 239. Washington, 1873.
11	1871, December 14, 15, 16	16 23.1	G. Davidson and S. R. Throckmorton, United States Coast Survey; at Presidio station of 1852; MS. in Coast Survey archives.
12	1872, October 26, 27, 28	16 25.7	} Reference as above.
13 {	1873, June 25, 26, 27	16 25.4	} Reference as above.
	1873, August 19, 20, 21, 22, 23	16 24.0	} Reference as above.
	1873, November 12 to 16	16 25.4	G. Davidson and W. Eimbeck, United States Coast Survey; at Presidio; MS. in Coast Survey archives. Mean for 1873.7, 16° 24′.8
14 {	1874, January 10, 12, 13, 14 } 1874, February 19, 20, 21 }	16 26.9	Reference as above.
15	1879, March 12, 13, 14, 15	16 34.0	G. Davidson and B. A. Colonna, assistants United States Coast Survey; at Presidio astronomical station.
16	1880, Nov. 20	16 39.5 E.	W. H. Dall and M. Baker, United States Coast and Geodetic Survey; at the Presidio station.

CAPE DISAPPOINTMENT, COLUMBIA RIVER, WASHINGTON TERRITORY.

$\phi = 46^\circ 16'.7$ $\lambda = 124^\circ 02'.0$ W. of Gr.

(South shore of Baker's Bay.)

		° ′	
1	1792, April 27	18 E.	Vancouver;* in $\phi = 46^\circ 14'$, $\lambda = 123^\circ 59'$, near mouth of Columbia River; Hansteen's Magnetismus der Erde, 1819.
	1792, December	20	Vancouver's voyage;† reference as above; in $\phi = 46^\circ 19'$, $\lambda = 123^\circ 53'$. [Value evidently too high; not used.]
2	1839	19 11	Sir E. Belcher; in $\phi = 46^\circ 17'$, $\lambda = 124^\circ 02'$; Phil. Trans. Roy. Soc., 1841; on Baker's Bay.
3	1842	20 00	Duflot de Mofras; Exploration of Oregon, Paris, 1844; at mouth of Columbia River.
4 {	1851, July 5-9	20 19.1	G. Davidson, assistant Coast Survey; in $\phi = 46^\circ 16'.7$, $\lambda = 124^\circ 02'.0$, near beach of Baker's Bay, Cape Disappointment; Coast Survey Report of 1856, p. 230.
	1851, July 14-19	20 45.3	Reference as above; on top of cape, in $\phi = 46^\circ 16'.6$, $\lambda = 124^\circ 02'.0$, at astronomical station.
	1858	21 00	Communication by S. Garfield, surveyor-general Washington Territory, dated August 24, 1866.
5 {	1873, October 24-27	21 26.5	W. Eimbeck, United States Coast Survey; near beach of Baker's Bay, in $\phi = 46^\circ 16'.7$, $\lambda = 124^\circ 02'.0$; MS. in Coast Survey archives.
	1873, October 19-23	21 46.9 E.	W. Eimbeck, United States Coast Survey; at old astronomical station, top of cape; MS. in Coast Survey archives.

*Vancouver's observations made on board ship. † Observation by Broughton.

Collection of Magnetic Declinations, etc.—Continued.

KAILUA (KAIRUA), HILO, AND KEALAKEKUA (KARAKAKOA) BAYS, ISLAND OF HAWAII (OWHYHEE), SANDWICH ISLANDS.

$\phi = +19° 37'$ $\lambda = 156° 01'$ W. of Gr.

(Kailua Bay.)

		° ′		
1	1779	8 06	E.	Cook; in $\phi = 19° 28'$, $\lambda = 156° 00'$ W. of Gr.; P. Barlow, in Encyc. Metropol., London, 1848.
2	1791	8 15		Capt. Marchand. West of Hawaii.*
3	1793, March	7 47		Capt. G. Vancouver; A Voyage of Discovery, 1790 to 1795, vol. 2, p. 170, London, 1798. At Hilo.
4	1796	8 15		Broughton; Encyc. Metropol., London, 1848.
		9 12		Broughton; Encyc. Metropol., London, 1848. [Not used.]
5	1819	9 50		Freycinet; at Kawaihae; $\phi = 20°.5$; NW. Hawaii.
	1824	10 14		Byron; Island of Owhyhee, in $\phi = 19° 43'$, $\lambda = 156° 10'$. Gen. Sir E. Sabine's Conts. to Terr. Mag., No. xiv, in Phil. Trans. Roy. Soc., vol. 165, pt. 1, 1875. [Not used.]
6	1825	8 51		Byron. At Hilo.*
	1836	7 43		Voyage de la Venus, Paris, 1841. Position and reference as above for 1824. [Not used.]
7	1841	8 50		Com. Wilkes, U. S. N. At Hilo.*
8	1853	8 15		C. J. Lyons; Haw. Government Survey. On shore at Kawaihae.* N. B.—The British Admiralty Chart No. 782 gives the declination for 1875, 9° 15′ E.
9	1877	8 10	E.	C. J. Lyons; Haw. Government Survey. In Hamakua and North Hilo, NE. coast of Hawaii. Reported to W. D. Alexander, Superintendent Government Survey. [10′ may be subtracted to refer to latitudes of Hilo and Kailua.—SCH.]

HONOLULU, ISLAND OF OAHU (WOAHOO), SANDWICH ISLANDS.

$\phi = 21° 18'.2$ $\lambda = 157° 55'.0$ W. of Gr.

(Fort near town.)

		° ′		
	1793	5 52	E.	Capt. G. Vancouver. At Waikiki, S. of Honolulu.* [Not used.]
1	1816	10 57		Kotzebue. At Honolulu.*
2	1819	10 24		Capt. Freycinet. At Honolulu.*
3	1824 ('25)	9 52		Byron; from L. S. Kaemtz MSS. } Oahu Island, in $\phi = 21° 17'$, $\lambda = 158° 00'$. Gen. Sir E. Sabine's Conts. to Terr. Mag., No. xiv, Phil. Trans. Roy. Soc., vol. 165, pt. 1, 1875.
4	1827	10 26		Beechey; from L. S. Kaemtz MSS. } (as above)
5	1836	10 11		Voyage de la Bonite, Paris, 1842. } Honolulu, in $\phi = 21° 19'$, $\lambda = 157° 48'$. Gen. Sir E. Sabine, in Phil. Trans., as above.
6	1837	10 00		Voyage de la Venus, Paris, 1841. } (as above)
6	1837	10 39		Beechey } Oahu Island. Reference as above.
7	1838	10 39		Belcher } Oahu Island. Reference as above.
8	1840	9 17		Berghaus; from L. S. Kaemtz MSS. } Honolulu.
	1841	8 15		Com. Wilkes, U. S. N. At Honolulu.* [Not used.] } Honolulu.
	1852	9 10		Collinson; MS. in British Hydrographic Office. Reference as above. [Not used.] } Honolulu.
9	1859	9 42		Karl Friesach; Memoirs of the Imperial Academy of Sciences, vols. xxix to xliv. Reference as above.
	1867, August	11 15		Capt. W. Reynolds, U. S. N., in the Lackawanna (chart No. 6). Wharf near court-house, in $\phi = 21° 18'.2$, $\lambda = 157° 50'.1$ W. of Gr. [Not used.]
10	1871	9 36		C. J. Lyons; Haw. Government Survey. North side entrance to Honolulu Harbor.*
11	1872	9 18		C. J. Lyons; Haw. Government Survey. South side of entrance, on Fisherman's Point.*
12	1875	9 16		W. D. Alexander. Entrance of Pearl Lochs, Oahu, and throughout Ewa District.*
12	1875	9 15	E.	W. D. Alexander. Shore at Waikiki, south of Honolulu.*

* These observations were communicated to the Superintendent of the Coast Survey by W. D. Alexander, Superintendent of the Hawaiian Government Survey, in a letter dated Makawao, Maui, Hawaiian Islands, December 11, 1877.

Collection of Magnetic Declinations, etc.—Continued.

SITKA, ALASKA.

$\phi = 57° 02'.9$ $\lambda = 135° 19'.7$ W. of Gr.

(Parade Grounds, Sitka.)

No.	Date	°	′		Authority
	1775, August 23	22		E.	F. A. Maurelle; Journal of a Voyage to N.W. coast of America; D. Barrington, Miscellanies, London, 1781. $\phi = 57° 08'$, at sea, near coast. [Not used.—Sch.]
1	1787, June	24			Capt. G. Dixon; Voyage Round the World, London, 1789. At anchor near White's Point, $\phi = 57° 03'$, $\lambda = 135° 38'$ [compass bearing].
2	1791, August 8, 11, 21	27	46		Capt. E. Marchand; a Voyage Round the World, London, 1801, 2 vols. Mean of 3 values given in vol. ii. One mile north of above station, in $\phi = 57° 04'$, $\lambda = 137° 59'$ (from Paris). In vol. i observer gives 28° 45′.
3	1804, August 20	26	45		Capt. U. Lisiansky; a Voyage Round the World, London, 1814. $\phi = 57° 03'$, $\lambda = 135° 30'$.
4	1818, July	27	15		Capt. V. M. Golovnine; Voyage Round the World, St. Petersburg, 1822, vol ii. Mean of several observations between 24° and 30½ E. In $\phi = 57° 02'.8$, $\lambda = 135° 06'.6$.
5	1824	27	30		Kotzebue quoted from Becquerel, Traité du Magnétisme, Paris, 1846.
6	1827.5	28	30		Capt. F. P. Lütke; Gen. Sir E. Sabine's Conts. to Terr. Mag., Phil. Trans. Roy. Soc., 1872, No. xiii. In $\phi = 57° 03'$, $\lambda = 135° 23'$.
7	1829, November 10	28	18.8		Ad. Erman; Reise um die Welt, Berlin, 1835, vols. i and ii. A careful determination on shore, behind the church, in $\phi = 57° 02'.7$, $\lambda = 137° 45'.7$ (from Paris).
8	1837, September 12-16	27	42		Sir E. Belcher; Sir E. Sabine in Phil. Trans. Roy. Soc., 1841, part i. In $\phi = 57° 03'$, $\lambda = 135° 26'$; a careful determination on shore, near governor's house.
	1839, July 15-19	29	32.5		Sir E. Belcher; Sir E. Sabine, in Phil. Trans. Roy. Soc., 1843, part i. In $\phi = 57° 03'$, $\lambda = 135° 22'$, at summer-house in governor's garden. A careful determination. [Mean of these 2 determinations used, viz, for 1838.6,— 28°.62.—Sch.]
9	1842, every month except January, February, and October.	28	32.4		At Magnetic Observatory, Japonski Island, founded in 1842. Hourly observations. In $\phi = 57° 02'.9$, $\lambda = 135° 20'.1$. Annuaire Mét. et Mag. du Corps des Mines de Russie, St.-Pétersbourg, 184- to 184-.
10	1843, January-December	28	54.0		
11	1844, January-December	28	57.3		
12	1845, January-December	29	00.0		
13	1847, May-December	28	58.9		At Magnetic Observatory, Japonski Island; Annales de l'Observ. phys. Central du Russie, St.-Pétersbourg, 184- to 185-.
14	1848, January-December	29	04.5		
15	1849, January, February, March.	29	03.6		
16	1851.0	29	14		Capt. Richard Collinson; MS. in Brit. Hyd. Off.; Sir E. Sabine in Phil. Trans. Roy. Soc., 1872; Conts. to Terr. Mag., No. xiii.
17	1867, August 17, 18, 19, 20	28	49		A. T. Mosman, assistant U. S. Coast Survey; at old Russian observatory on Japonski Island, harbor of Sitka; in $\phi = 57° 02'.9$, $\lambda = 135° 20'.1$; Coast Pilot of Alaska, by the U. S. Coast Survey, 1869, p. 120.
18	1874, May 4, 5	28	59.5		M. Baker, U. S. C. S. observer; W. H. Dall, acting asst. C. S. in charge of party; station on Parade Ground, in $\phi = 57° 02'.9$, $\lambda = 135° 19'.7$; MS. in Coast Survey archives.
19	1876, January 15 to March 20	28	20.5		Capt. J. B. Campbell and Lieut. W. R. Quinan, U. S. A.; Report of Chief of Engineers, 1876, part 3, p. 751.
20	1879, April	28	54		Lieut. J. E. Craig, U. S. S. Alaska; report to Capt. G. Brown, U. S. N., May 7, 1879; at Coast Survey station.
21	1880, May 17-18	29	03.5	E.	W. H. Dall and M. Baker, U. S. Coast and Geodetic Survey, near old Russian observatory on Japonski Island, in $\phi = 57° 02'.9$, $\lambda = 135° 20'.3$

N. B.—For the collection of the values Nos. 0, 1, 2, 4, 9, 10, 11, 12, 13, 14, and 15 I am indebted to Mr. Marcus Baker, of the Computing Division, Coast and Geodetic Survey Office. He discussed the hourly differential observations made at the Magnetic Observatory between 1842 and 1849, basing the annual means upon the absolute determinations, January 4, 1843, D = − 28° 48′ 54″; March 4, 1843, D = − 28° 57′ 20″; the first corresponding to 419.3, the second to 432.4, scale divisions of the differential declinometer.—Sch.

Collection of Magnetic Declinations, etc.—Continued.

CAPTAIN'S HARBOR, UNALASHKA ISLAND, ALASKA TERRITORY.

$\phi = 53° 52'.6$ $\lambda = 166° 31'.5$ W. of Gr.

(Greek Church, Iliuliuk Village.)

		° ′	
	1778, October 12	19 59.2 E.	Capt. J. Cook; Voyage to the Pacific Ocean, London, 1784. Position on shore of Samganuda Harbor, $\phi = 53° 55'$, $\lambda = 166° 30'$ W. [Not used.—SCH.]
1	1790, June 4-13	19 35	Commodore J. Billings; M. Sauer, an account of a geographical and astronomical expedition to the northern parts of Russia, London, 1802. On shore of Beaver Bay, in $\phi = 53° 56'$, $\lambda = 165° 40'$.
2	1792	19 00	Sarycheff, old Russian chart; no date, year doubtful. At Iliuliuk, $\phi = 53° 57'$, $\lambda = 166° 32'$. Communicated by Dr. W. H. Dall, acting assistant Coast Survey, November, 1873.
3	1817, June	19 24	Otto v. Kotzebue; Voyage of Discovery into the South Sea, London, 1821. Iliuliuk Village, in $\phi = 53° 52'.4$, $\lambda = 166° 31'.9$. Communications by Dr. Dall and Mr. M. Baker, of the United States Coast Survey. [In the edition of this paper of 1874 the date 1806 was in error.]
4	1827, August 11	19 50	Capt. F. P. Lütke; Lenz in Mem. St. Pet. Acad. Sc., vi serie Math. et Phys. Sc., vol. 1, 1838. In $\phi = 53° 54'$, $\lambda = 166° 30'$.
	1829.0	19 54	Capt. F. P. Lütke; Gen. Sir E. Sabine, in Phil. Trans. Roy. Soc., London, 1872. vol. 162. Supposed to be derived from above observation of 1827 and reduced to 1829. [Not used.—SCH.]
5	1831	19 30	Vasilieff? At sea, north of Akutan; Reuss. Hydr. Ch. No. 1379 1847; $\phi = 54°.4$, $\lambda = 166°.0$
	1848	19 30.5	Is supposed to be identical with preceding observation; hence is omitted in this edition.
6	1849	20 00	Tebenkoff's Atlas, chart No. xxv; near church of Iliuliuk, in $\phi = 53° 52'$, $\lambda = 166° 25'$. Observation doubtful.
7	1867, September 8, 9	19 47.4	A. T. Mosman, assistant United States Coast Survey; party in charge of Assistant G. Davidson. At Captain's Harbor (on shore), at Spithead, in $\phi = 53° 53'.9$, $\lambda = 166° 30'.4$ MS. in Coast Survey archives.
8	1870	19 45	Kadin; MS. chart of Iliuliuk and Captain's Harbor. Communicated by Dr. W. H. Dall.
	1871, November 11	18 36	Dr. W. H. Dall, observer; Amaknak Island, opposite village. [Not used.—SCH.]
9 {	1873, May 26, 27	19 07.2	W. H. Dall, observer; near church of Iliuliuk, in $\phi = 53° 52'.6$, $\lambda = 166° 31'.6$.
	1873, September 17	18 59.7	M. Baker, observer; Amaknak Island, off village, in $\phi = 53° 52'.9$, $\lambda = 166° 31'.7$. [Mean used, $-19°.06$—SCH.].
10	1874, September 15	18 42.8	M. Baker, observer; MS. of observations for Nos. 10 and 11 in Coast Survey archives.
11	1880, July 28-29	18 38 E.	W. H. Dall and M. Baker, United States Coast and Geodetic Survey, Iliuliuk Harbor. Position the same as in 1873.

N. B.—For the collection and communication of observations Nos. 0, 1, 4, and 5, I am indebted to Mr. Marcus Baker, of the Computing Dvision, Coast and Geodetic Survey.

Collection of Magnetic Declinations, etc.—Continued.

PETROPAVLOVSK, KAMTCHATKA.

$\phi = 53° 01'$ $\lambda = 201° 19'$ W. of Gr.

		° ′		
1	1779, June	6 18.7	E.	Capt. J. King; A Voyage to the Pacific Ocean, London, 1784. West side of village, $\phi = 53° 00'.6$, $\lambda = -158° 43'.3$.
2	1792	6 00		G. Sarycheff; F. P. Lütke's Voyage Round the World, St. Petersburg, 1835.
3	1804, September	5 20		A. J. von Krusenstern; Voyage Round the World, London, 1813. On the spot on which the village stands, in $\phi = 53° 00'.2$, $\lambda = -158° 47'.7$.
	1804, September	5 39		Observer and references as above; on Avatcha Bay. [Used mean of the two values, $-5°.49$]
	1825.5	4 13		Gen. Sir E. Sabine's Conts. to Terr. Mag., No. xiii, in Phil. Trans. Roy. Soc., 1872; $\phi = 53° 00'$, $\lambda = 201° 20'$ W. [This is supposed to refer to Capt. Beechey's observation of 1827. Not used.—SCH.]
4	1827, July	4 13.3		Capt. F. W. Beechey; Narrative of a Voyage to the Pacific, 1825 to 1828; London, 1831; in $\phi = 53° 01'$, $\lambda = -158° 43'.5$. Mean of 9 determinations.
	1827, September 30	3 43		Capt. F. P. Lütke; Lenz, in Mem. St. Peters. Acad. Sc., vi, vol. 1, 1838. In $\phi = 53° 01'$, $\lambda = -158° 44'$.
	1827, September 30	4 05.8		A. Erman; Reise um die Erde, Berlin, 1835. In $\phi = 53° 00'.5$, $\lambda = -156° 19'.8$ from Paris. [Mean of 3 determinations used, giving the middle one ½ weight; hence, for 1827.6, $D = -4°.07$—SCH.]
	1829.5	4 04		Gen. Sir E. Sabine's Conts. to Terr. Mag., in Phil. Trans. Roy. Soc., 1872. [This is supposed to refer to Erman's value of 1827. Not used.—SCH.]
	1837, September 4	3 27		Du Petit Thouars, Voyage Autour du Monde, Paris, 1843. In front of Auchard's house, in $\phi = 53° 01'$, $\lambda = -156° 23'$ from Paris.
6	1849.5	2 37		Capt. H. Kellet; Gen. Sir E. Sabine in Phil. Trans. Roy. Soc. London, 1872, vol. 162.
7	1854, July	3 40		Frigate Aurora; Compte-Rendu Annuel de l'Observ. Phys. Cent. de Russie; année 1854; St. Pétersb., 1855. In $\phi = 53° 00'$, $\lambda = -158° 43'.5$ [Apparently anomalous; weight assigned ½—SCH.]
	1856, October	3 24		Admiralty chart No. 2460. Position of Petropavlovsk in Encyc. Brit., 7th edition, $\phi = 53° 01'$, $\lambda = 201° 17'$ W. of Gr. [Probably deduced value; not used.—SCH.]
8	1866	1 25.1		K. S. Staritzky; Onazevich's collection of observations made during hydr. explor. in the Pacific, 1874–77; St. Petersb., 1878.
9	1876, June 11, 13, September 15	1 09	E.	M. L. Onazevich. Reference as above.

N. B.—This important Asiatic station is included in the discussion on account of its proximity to the Western Aleutian or Rat Islands. Fo information Nos. 3, part of 4, 5, 7, and 9, I am indebted to Mr. Marcus Baker, of the Computing Division, Coast and Geodetic Survey Office.

The following magnetic declinations have not yet been incorporated in the discussion, but they will be worked up whenever the data become sufficiently complete for the purpose:

ST. JOHN'S, NEWFOUNDLAND.

$\phi = 47° 34'$ $\lambda = 52° 42'$ W. of Gr.

(Government House.)

		° ′		
1	1844, October	29 36	W.	Capt. Bayfield, R. N., in Phil. Trans. Roy. Soc., 1849, p. 211.
2	1857, July	31 21		Capt. Dayman, R. N. Account of deep-sea soundings in the North Atlantic Ocean, 1858, p. 61.
3	1862, September 11	31 20		Capt. Orlebar, R. N.
4	1863, September 22	31 18		Capt. Orlebar, R. N.
5	1864, June 3	31 00		Capt. Orlebar, R. N.
6	1866, April to October	30 55	W.	Near Government House.

N. B.—The above declinations were communicated in 1866 and 1867, by Staff-Commander F. J. Evans, hydrographer, British Admiralty. [According to Halley's chart the declination in 1700 was nearly 15° W.—SCH.]

Collection of Magnetic Declinations, etc.—Continued.

EASTPORT, ME.

$\phi = 44° 54'.4$ $\lambda = 66° 59'.2$ W. of Gr.

(Fort Sullivan.)

		° ′	
	1604 to 1612	17 32 W.	Champlain; Douchet's Island, St. Croix River. [Not used.]
	1700	13	According to E. Halley's isogonic chart of 1700.* [Not used.]
1	1775	12 40	At Grand Manan Island; J. F. W. Des Barres' Atlantic Neptune, London, 1781.
	1797	12 19	From a chart; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838; at the mouth of St. Croix, in $\phi = 45° 05'$, $\lambda = 67° 12'$; reduction to Eastport about −5′ [Not reliable.]
	1857, September 16-19	15 21.1	G. W. Dean, assistant Coast Survey; at Calais, in $\phi = 45° 11'.1$, $\lambda = 67° 16'.8$; Coast Survey Report for 1858, p. 191; reduction to Eastport −12′ [Not used; probable local deflection.]
2	1860, August to December	17 57.1	G. B. Vose, observer for United States Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
3	1861, January to December	17 59.2	G. B. Vose and S. Walker, observers for United States Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
4	1862, January to December	18 00.6	S. Walker, R. H. Talcott, E. Goodfellow, observers for United States Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
5	1863, January to December	18 02.3	E. Goodfellow, assistant Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
6	1864, January to December	18 03.7	E. Goodfellow, A. T. Mosman, and H. W. Richardson, observers for United States Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
7	1865, July 22, 23, 24, 25	18 06.1	H. W. Richardson, observer for United States Coast Survey. (Coast Survey Report 1865, Appendix No. 18; all observations made at Fort Sullivan.)
8	1873, September 2, 3	18 56.0	Dr. T. C. Hilgard, observer for United States Coast Survey; at Fort Sullivan; MS. in Coast Survey archives.
9	1879, August 27, 28	19 07.8 W.	J. B. Baylor, United States Coast and Geodetic Survey, station of 1860; parade ground of Fort Sullivan, in $\phi = 44° 54'.4$, $\lambda = 66° 59'.2$.

*Tabula Nautica. Variationum magneticarum index juxta observationes anno 1700 (Greenwich astronomical observations of 1869).

HANOVER, N. H.

$\phi = 43° 42'.3$. $\lambda = 72° 17'.1$ W. of Gr.

(Dartmouth College Observatory.)

		° ′	
1	1765	7 00 W.	President Wheelock; in $\phi = 43° 41'$, $\lambda = 72° 10'$; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
2	1810	4 15	President Wheelock; in $\phi = 43° 41'$, $\lambda = 72° 10'$; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838.
3	1839	9 15	Prof. Young; in $\phi = 43° 42'$, $\lambda = 72° 10'$; Prof. E. Loomis' collection, in Sill. Jour., vol. xxxix, 1840.
4	1873, October 4, 6, 9, 10, 11	10 49.6	Dr. T. C. Hilgard, observer for United States Coast Survey; MS. in Coast Survey archives.
5	1879, October 6	10 50.5	J. B. Baylor, United States Coast and Geodetic Survey. Station of Oct. 6 same as that of 1873, a little north of Observatory. Station of Oct. 7, ¼ mile west of Observatory hill, in $\phi = 43° 42'.3$, $\lambda = 72° 18'.0$
5	1879, October 7	11 38.4 W.	J. B. Baylor, United States Coast and Geodetic Survey. Station of Oct. 6 same as that of 1873, a little north of Observatory. Station of Oct. 7, ¼ mile west of Observatory hill, in $\phi = 43° 42'.3$, $\lambda = 72° 18'.0$

Collection of Magnetic Declinations, etc.—Continued.

CHESTERFIELD, N. H.*

$\phi = 42° 53'$ $\lambda = 72° 23'$ W. of Gr.

	° ′	
1812	6 26 W.	Nathan Wilde.
1813	6 25	
1814	6 17	
1815	6 07	
1816	6 03	
1817	6 02	
1818	6 00	
1819	6 03	
1820	6 00	
1821	6 07	
1822	6 12	
1823	6 30	
1824	6 40	
1825	6 35	
1826	6 35	
1827	6 45	
1828	6 52	
1829	7 00	
1830	7 06	
1831	7 10	
1832	7 15	
1833	7 30	
1834	7 35	
1835	7 40	
1836	7 45	
1837	8 05 W.	A. C. Twining.

* From Prof. E. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838; position assigned, $\phi = 42° 53'$, $\lambda = 72° 20'$.

SAULT DE STE. MARIE, MICH.

$\phi = 46° 29'.9$ $\lambda = 84° 20'.1$

(Garden of Fort Brady.)

		° ′	
1	1843	1 08 E.	Capt. Lefroy. Sir E. Sabine, Phil. Trans. Roy. Soc., Cont. xiii, 1872.
2	1845	0 46	Capt. Lefroy. Sir E. Sabine, Phil. Trans. Roy. Soc., Cont. xiii, 1872; assigned position in $\phi = 46° 31'$, $\lambda = 84° 32'$.
3	1846, November	0 40	Lieut. G. C. Westcott, U. S. A. Information by Mr. J. B. Baylor.
4	1856, September 29	0 32.1 E.	Karl Friesach, Kais. Acad. der Wiss., vol. 29; Vienna, 1858; assigned position $\phi = 46° 30'$, $\lambda = 84° 34'$.
5	1873, July 22, 23	0 04.9 W.	Capt. A. N. Lee, U. S. Engineers. Survey of the N. and N. W. Lakes, Gen. C. B. Comstock in charge; MS. of 1873; also report of Chief of Engineers, 1874, app. CC; $\phi = 46° 30'.1$, $\lambda = 84° 20'.0$
6	1879, November 12	1 01.0	City Surveyor at Fort Brady. Information by Mr. J. B. Baylor.
7	1880, July 11, 13, 14, 17, 19	0 53.7	Lieut. S. W. Very, U. S. N., Act. Assist., Coast and Geodetic Survey. At vegetable garden of Fort Brady. $\phi = 46° 29'.9$, $\lambda = 84° 20'.1$
	1880, August 6, 7	1 04.5 W.	J. B. Baylor, U. S. Coast and Geodetic Survey. Military post garden, about 30 yards N. W. of Lieutenant Very's station of 1880. Position as above.

GRAND HAVEN, MICH.

$\phi = 43° 05'.2$ $\lambda = 86° 12'.6$ W. of Gr.

1	1825	3¾° to 6° E.	L. Lyon; at Grand River, $\phi = 42° 55'$, $\lambda = 86° 10'$. Prof. E. Loomis, Sill. Jour. vol. xxxix, 1840. [Giving double weight to second value, we may use—5.° 25—SCH.]
		° ′	
2	1837	4 30 E.	Geological Report; reference as above. $\phi = 42° 55'$, $\lambda = 86° 10'$.
		6 15	Geological Report; reference as above. $\phi = 43° 19'$, $\lambda = 85° 59'$ [Weighted mean, first value double weight,—5.° 08—SCH.]
3	1859, August	4 24.2	Lieut. W. P. Smith, Survey N. and N. W. Lakes; report by Capt. G. G. Meade, Detroit, 1859; $\phi = 43° 05'.2$, $\lambda = 86° 12'.6$
4	1865	4 15	Survey of N. and N. W. Lakes; MS. by Colonel Raynolds, Dec., 1865; $\phi = 43° 04'$, $\lambda = 86° 13'$
5	1873, August 27, 28	3 28.2	Capt. A. N. Lee; Survey of N. and N. W. Lakes; MS., 1873; see also report of Chief of Engineers, 1874.
6	1880, July 20, 21	2 25.7 E.	J. B. Baylor, U. S. Coast and Geodetic Survey; in grounds of county court-house; $\phi = 43° 04'.7$, $\lambda = 86° 12'.6$

Collection of Magnetic Declinations, etc.—Continued.

WILLIAMSBURGH, JAMES CITY COUNTY, VA.

$\phi = 37° 16'.2$ $\lambda = 76° 42'.4$ W. of Gr.

		° '		
1	1694	5	W.	Bishop Madison, president of William and Mary's College, in $\phi = 37° 15'$, $\lambda = 76° 35'$; Prof. E. Loomis' collection, in Sill. Jour. vol. xxxiv, 1838.
2	1780	0 50	W.	
3	1809	0 33	E.	
4	1874, December 4, 5, 6, 8, 9	2 12	W.	J. B. Baylor, aid United States Coast Survey; $\phi = 37° 16'.3$, $\lambda = 76° 42'.7$; MS. in Coast Survey archives.

NEW BERNE, N. C.

$\phi = 35° 06'$ $\lambda = 77° 02'$ W. of Gr.

		° '		
1	1796	2 40	E.	Jonath. Price; from Prof. E. Loomis' collection in Sill. Jour. vol. xxxiv 1838; position assigned, $\phi = 35° 20'$, $\lambda = 77° 05'$.
2	1806	2 00		
3	1809	1 45	E.	
4	1874 December 21, 23, 24	1 20.4	W.	J. B. Baylor, aid United States Coast Survey; $\phi = 35° 07'.4$, $\lambda = 77° 03'.3$; MS. in Coast Survey archives.

FLORENCE, ALA.

$\phi = 34° 47'.2$ $\lambda = 87° 41'.5$ W. of Gr.

(Coast Survey station.)

		° '		
1	1818	6 35	E.	J. H. Weakly; Prof. Loomis' collection, in Sill. Jour., vol. xxxiv, 1838; position assigned, $\phi = 34° 50'$, $\lambda = 87° 47'$.
2	1835	6 28		
3	1865, April 17	5 24		A. T. Mosman, assistant Coast Survey; MS. in Coast Survey archives.
4	1875, May 29	5 14.4	E.	F. E. Hilgard; Bache-Fund observer, Nat. Acad. of Sciences.

BERMUDA ISLANDS.

$\phi = 32° 23'$ $\lambda = 64° 42'$ W. of Gr.

(Signal station, St. George's Town.)

		° '		
1	1831	6 59	W.	Austin and Foster; Sir Edw. Sabine in Phil. Trans. Roy. Soc., 1874, Conts., xiv. In $\phi = 32° 23'$, $\lambda = 64° 47'$.
2	1837	6 40		Milne; reference as above.
3	1845, October	7 01		Captain Barnett, Royal Engineers; Bermuda Royal Gazette. At signal station, $\phi = 32° 32'$, $\lambda = 64° 40'$.
4	1846	6 53		Captain Barnett, Royal Engineers; Sir Edw. Sabine, Phil. Trans. Roy. Soc., 1874, Conts., xiv. Position $\phi = 32° 23'$, $\lambda = 64° 47'$.
5	1876	7 45	W.	Admiralty Chart 360, issued Feb., 1877. Annual increase of declination about 3'.

SAN ANTONIO, TEXAS.

$\phi = 29° 25'.4$ $\lambda = 98° 29'.3$ W. of Gr.

(Arsenal grounds.)

		° '		
1	1825	10 30	E.	Land Office record at San Antonio. Communicated by Mr. J. B. Baylor.
2	1836	9 45		
3	1874	9 30		
4	1878, June 10, 11, 12	9 22.3	E.	J. B. Baylor, U. S. Coast and Geodetic Survey; arsenal grounds, position as given above.

Collection of Magnetic Declinations, etc.—Continued.

OMAHA, NEB., AND COUNCIL BLUFFS, IOWA.

$\phi = 41° 15'.7$ $\lambda = 95° 56'.5$.

(Astronomical Station, grounds of High School.)

		° ′	
1	1819, September 22	12 58.8 E.	Major St. H. Long, U. S. A., Expedition to the Rocky Mountains, Phila., 1823 (two volumes). At Engineer's Cantonment, $\phi = 41° 25'$, $\lambda = 96° 00'$.
2	1869, January 25, 26, 27; February 12, 13.	10 42.6	E. Goodfellow, assistant Coast Survey; at Astronomical Station.
3	1872, October 31	10 44.2	Dr. T. C. Hilgard; Bache-Fund Observer to National Academy; station as above.
4	1877, October 13, 15, 16, 17, 18	10 22.0	A. Braid, U. S. Coast Survey, station of 1869.
5	1878, August 30	10 39.7	Dr. T. E. Thorpe; Proc. Roy. Soc. No. 200, 1880. At Council Bluffs, near railroad depot. $\phi = 41° 15'.3$, $\lambda = 95° 52'.4$
6	1880, October 15, 17	10 06.2 E.	J. B. Baylor, U. S. Coast and Geodetic Survey. Station on High School grounds as in 1869, 1872, and 1877.

SALT LAKE CITY, UTAH.

$\phi = 40° 46'.1$ $\lambda = 111° 53'.8$ W. of Gr.

(Astronomical Station, Temple Square.)

		° ′	
1	1850	15 34 E.	Major W. H. Emory, U. S. A., Amer. Acad. of Science, vol. vi, new series, 1856; in $\phi = 40° 46'$, $\lambda = 112° 08'$.
2	1866, August	16 30	Jesse W. Fox; Letter from Surveyor-General's office dated August 29, 1866. $\phi = 40° 46'$, $\lambda = 111° 54'$.
3	1869, May 6 to 15	16 36.4	G. W. Dean, assistant Coast Survey; Temple Square near astronomical station.
4	1872	17 01	Report of Chief of Engineers, 1879, part iii, p. 2099. At Camp Douglass, near astronomical monument, in $\phi = 40° 45'.8$, $\lambda = 111° 50'.2$
5	1878, August 15	16 48.1	Dr. T. E. Thorpe; Proc. Roy. Soc. No. 200, 1880. East of the President's house, in $\phi = 40° 46'.1$, $\lambda = 111° 53'.7$
	1878, October 26, 28, 29	16 44.2 E.	J. B. Baylor, U. S. Coast and Geodetic Survey, near Fourth street south and Second street east of Temple. [Mean of the two determinations of 1878,—16° 46'.2]

CAPE MENDOCINO, CAL.

$\phi = 40° 26'.3$ $\lambda = 124° 24'.2$ W. of Gr.

(Cape Mendocino light-house.)

		° ′	
1	1693	2 E.	Carreri; C. Hansteen's Magnetismus der Erde, 1819; in $\phi = 40° 29'$, $\lambda = 124° 29'$. [Declination probably much in error.—Sch.]*
2	1786, September 8	14 24	La Pérouse; C. Hansteen's Magnetismus der Erde, 1819; same position assigned.*
3	1792, April 18	16 00	Capt. G. Vancouver; near the cape, about ten leagues from it; it bore N. 36° W [This would put him in about $\phi = 39° 58'$, $\lambda = 124° 12'$—Sch.] Vancouver's Voyage of Discovery, etc., 1790–95, London, 1798, vol. 1, p. 197.
	1792, April 19	15 00	Same authority, vol. 1, p. 198; on board ship, in $\phi = 40° 03'$, $\lambda = 124° 09'$; Cape Mendocino bore N. 2° W. four leagues from shore.
	1792, April 22	16 00 E.	Same authority, vol. 1, p. 200; in $\phi = 40° 32'$, $\lambda = 124° 32'$.

* The latitude given would indicate that this navigator refers to False Cape Mendocino (now called Cape Fortunas), in $\phi = 40° 30'.5$ $\lambda = 124° 22'.8$—Sch.

PORT TOWNSHEND, WASHINGTON TERRITORY.

$\phi = 48° 07'.0$ $\lambda = 122° 44'.9$.

(Point Hudson.)

		° ′	
1	1792, May	21 30 E.	Vancouver; at Port Discovery, $\phi = 48° 02'$, $\lambda = 122° 38'$; Hansteen's Magnetismus der Erde, 1819.
2	1841	20 40	Chart by the U. S. Exploring Expedition, at Carr Point. $\phi = 48° 03'.3$, $\lambda = 122° 50'.8$
3	1856, August 17, 18, 19, 20	21 39.5	G. Davidson, assistant Coast Survey; at Point Hudson. $\phi = 48° 06'.9$, $\lambda = 122° 44'.9$
4	1857	21 54	S. Garfielde, Surveyor General of Washington Territory; at Admiralty Head, Whitbey Island. $\phi = 48° 09'$, $\lambda = 122° 41'$. Letter of August 24, 1866. [Reduction to Port Townshend + 8'—Sch.]
5	1859	20 45	Reference as above. $\phi = 48° 07'$, $\lambda = 122° 45'$.
6	1862	22 00	Reference as above. $\phi = 48° 01'$, $\lambda = 122° 51'$ at Mill.
7	1876, February	21 59 E.	Capt. G. H. Burton, U. S. A.; report of Chief of Engineers, 1876, p. 3.

Collection of Magnetic Declinations, etc.—Continued.

NEE-AH BAY, STRAIT OF JUAN DE FUCA, WASHINGTON TERRITORY.

$\phi = 48° 21'.8$ $\lambda = 124° 38'.0$ W. of Gr.

(Scarborough Harbor, Astronomical Station.)

		° ′	
1	1792, April 30	18 0 E.	Vancouver; Hansteen's Magnetismus der Erde, 1819. Inside Cape Flattery, $\phi = 48° 19'$, $\lambda = 123° 41'$ (possibly misprint for 124° 41').
2	1841	22 30	Chart of U. S. Exploring Expedition, Commander Wilkes; Scarborough Harbor, North point Nee-ah Island. $\phi = 48° 21'.8$, $\lambda = 124° 38'.0$
3	1852, August 17, 18, 19, 20, 21, 22, 23	21 29.9	G. Davidson, assistant Coast Survey and J. Rockwell, Coast Survey; Scarborough Harbor, Astronomical station, in $\phi = 48° 21'.8$, $\lambda = 124° 38'.0$
4	1855, August 13, 15, 16, 18	21 48.2 E.	Lieut. W. P. Trowbridge, assistant Coast Survey; Nee-ah Bay, near Wa-addah Island.

NOOTKA, VANCOUVER ISLAND.

$\phi = 49° 35'.5$ $\lambda = 126° 37'$ W. of Gr.

(Friendly Cove.)

		° ′	
1	1778, April 4	19 45 E.	Cook; in Resolution Cove, $\phi = 49° 35'$, $\lambda = 126° 37'$; Hansteen's Magnetismus der Erde, 1819; also Encyc. Metrop., 1848.
2	1791, August 16, 17	22 30	Don A. Malaspina; observed on shore; Berliner Astronomisches Jahrbuch, vol. 53, for 1828.
3	1792, October	18 22	Vancouver; in $\phi = 49° 34'$, $\lambda = 126° 28'$, in Nootka Sound; Hansteen's Magnetismus der Erde, 1819.
4	1863	23 05 E.	Capt. G. H. Richards, R. N.; in Friendly Cove, $\phi = 49° 35'.5$, $\lambda = 126° 37'.5$; Admiralty Chart of Nootka Sound, No. 1916, 1865; magnetic variation increasing about 2′ annually.

ANALYTICAL EXPRESSIONS OF THE OBSERVED DECLINATIONS.

The resulting empirical expressions for the secular change of the magnetic declination, given below, were derived from the preceding observations by applying to them the harmonic analysis as explained in the preface. The stations are arranged geographically, as far as practicable, and their positions are given by latitude and longitude (west of Greenwich). Total number of stations 55, and of observations about 644. The epoch to which the formulæ refer is 1850 or $m = t - 1850.0$

TABLE I.—FORMULÆ EXPRESSING THE MAGNETIC DECLINATION AT VARIOUS PLACES; DEDUCED *FROM THE PRECEDING COLLECTION OF OBSERVATIONS.*

Locality.	Latitude.	Longitude.	Expression for magnetic declination.
	° ′	° ′	
Paris, France	+ 48 50.2	− 2 20.2	$D = +6.516° + 16.00° \sin (0.775\,m + 120.14°) + 0.44° \sin (3.83\,m + 218°)$.
Halifax, Nova Scotia	44 39.6	+ 63 35.3	$D = +16.49 + 4.08 \sin (1.1\,m + 44.7)$.
Quebec, Canada	46 48.4	71 14.5	$D = +14.64 + 2.85 \sin (1.50\,m + 3.8) + 0.61 \sin (4.0\,m + 0.3)$.
Montreal, Canada	45 30.5	73 34.9	$D = +11.83 + 4.17 \sin (1.5\,m - 18.5) + 0.53 \sin (4.9\,m + 19)$.
York Factory, on Hudson Bay	57 00	92 26	$D = +5.68 + 14.12 \sin (1.6\,m - 79.4)$.*
Portland, Me	43 38.8	70 16.6	$D = +10.72 + 2.68 \sin (1.33\,m + 24.1)$.
Burlington, Vt	44 28.2	73 12.3	$D = +10.81 + 3.65 \sin (1.39\,m - 20.5) + 0.18 \sin (7.0\,m + 132)$.
Rutland, Vt	43 36.5	72 55.5	$D = +10.03 + 3.82 \sin (1.5\,m - 24.3)$.
Portsmouth, N. H	43 04.8	70 43.0	$D = +10.63 + 3.17 \sin (1.44\,m - 4.7)$.
Newburyport, Mass	42 48.4	70 49.0	$D = +10.07 + 3.10 \sin (1.4\,m + 1.9)$.
Salem, Mass	42 31.9	70 52.5	$D = +9.80 + 3.61 \sin (1.50\,m - 1.0)$.
Boston, Mass	42 21.5	71 03.8	$D = +9.52 + 2.93 \sin (1.30\,m + 5.0)$.
Cambridge, Mass	42 22.9	71 07.7	$D = +9.58 + 2.69 \sin (1.3\,m + 7.0) + 0.18 \sin (3.2\,m + 44)$.
Nantucket, Mass	41 17.0	70 06.0	$D = +9.29 + 2.78 \sin (1.35\,m + 5.5)$.
Providence, R. I	41 49.5	71 24.1	$D = +9.10 + 2.99 \sin (1.45\,m - 3.4) + 0.19 \sin (7.2\,m + 116)$.
Hartford, Conn	41 45.9	72 40.4	$D = +8.06 + 2.90 \sin (1.25\,m - 26.4)$.
New Haven, Conn	41 18.5	72 55.7	$D = +7.78 + 3.11 \sin (1.40\,m - 22.1)$.
Albany, N. Y	42 39.2	73 45.8	$D = +8.17 + 3.02 \sin (1.44\,m - 8.3)$.
Oxford, N. Y	42 26.5	75 40.5	$D = +6.19 + 3.24 \sin (1.35\,m - 18.9)$.
Buffalo, N. Y	42 52.8	78 53.5	$D = +3.66 + 3.47 \sin (1.4\,m - 27.8)$.
Toronto, Canada	43 39.4	79 23.4	$D = +3.60 + 2.82 \sin (1.4\,m - 44.7) + 0.09 \sin (9.3\,m + 136) + 0.08 \sin (19\,m + 247)$.
Erie, Pa	42 07.8	80 05.4	$D = +2.26 + 2.71 \sin (1.55\,m - 29.7)$.
Cleveland, Ohio	41 30.3	81 42.0	$D = +0.10 + 2.07 \sin (1.40\,m - 6.2)$.
Detroit, Mich	42 20.0	83 03.0	$D = -0.97 + 2.21 \sin (1.50\,m - 15.3)$.
Saint Louis, Mo	38 38.0	90 12.2	$D = -7.15 + 2.33 \sin (1.4\,m - 20.1)$.*
New York, N. Y	40 42.7	74 00.0	$D = +6.40 + 2.29 \sin (1.6\,m - 5.5) + 0.14 \sin (6.3\,m + 64)$.
Hatborough, Pa	40 12	75 07	$D = +5.23 + 3.28 \sin (1.54\,m - 13.0) + 0.22 \sin (4.1\,m + 157)$.
Philadelphia, Pa	39 56.9	75 09.0	$D = +5.38 + 3.29 \sin (1.55\,m - 23.9) + 0.39 \sin (4.0\,m + 161)$.
Harrisburg, Pa	40 15.9	76 52.9	$D = +2.93 + 2.98 \sin (1.50\,m + 0.2)$.
Baltimore, Md	39 17.8	76 37.0	$D = +3.20 + 2.55 \sin (1.45\,m - 21.2)$.
Washington, D. C	38 53.3	77 00.6	$D = +2.47 + 2.47 \sin (1.40\,m - 14.6)$.
Cape Henry, Va	36 55.5	76 00.5	$D = +2.54 + 2.41 \sin (1.50\,m - 35.4)$.
Charleston, S. C	32 46.6	79 55.8	$D = -2.14 + 2.74 \sin (1.35\,m - 1.3)$.
Savannah, Ga	32 04.9	81 05.5	$D = -2.54 + 2.32 \sin (1.5\,m - 28.6)$.
Key West, Fla	24 33.5	81 48.5	$D = -3.90 + 2.93 \sin (1.4\,m - 33.5)$.
Havana, Cuba	23 09.3	82 21.5	$D = -4.52 + 2.00 \sin (1.3\,m - 26.7)$.*
Kingston, Jamaica	17 55.9	76 50.6	$D = -4.64 + 2.04 \sin (1.2\,m + 15.9)$.
Panama, New Granada	+ 8 57.1	79 32.2	$D = -6.80 + 1.82 \sin (0.9\,m + 10.4)$.*
Rio Janeiro, Brazil	− 22 54.7	43 07.8	$D = +0.282 + 0.1395\,m + 0.000545\,m^2$.
Mobile, Ala	+ 30 41.4	88 02.5	$D = -4.40 + 2.69 \sin (1.45\,m - 76.4)$.
New Orleans, La	29 57.2	90 03.9	$D = -5.61 + 2.57 \sin (1.4\,m - 61.9)$.
Vera Cruz, Mexico	19 11.9	96 08.8	$D = -4.38 + 5.04 \sin (1.10\,m - 65.0)$.
Mexico, Mexico	19 25.9	99 06	$D = -4.06 + 4.78 \sin (1.0\,m - 76.5)$.
Acapulco, Mexico	16 50.5	99 52.3	$D = -4.36 + 4.61 \sin (1.0\,m - 85.3)$.
San Blas, Mexico	21 32.6	105 15.7	$D = -5.76 + 3.40 \sin (1.0\,m - 93.9)$.
Magdalena Bay, Lower Cal	24 38.4	112 08.9	$D = -7.50 + 3.61 \sin (1.3\,m - 144.7)$.
San Diego, Cal	32 42.1	117 14.3	$D = -12.54 + 1.64 \sin (1.2\,m - 180.0)$.
Monterey, Cal	36 36.1	121 53.6	$D = -12.82 + 3.54 \sin (1.0\,m - 142.9)$.
San Francisco, Cal	37 47.5	122 27.2	$D = -13.34 + 3.23 \sin (1.00\,m - 130.3)$.
Cape Disappointment, Wash. Ter	46 16.7	124 02.0	$D = -20.72 + 2.81 \sin (1.2\,m - 188.8)$.
Kailua, Sandwich Islands	19 37	156 01	$D = -8.75 + 0.0200\,m + 0.00048\,m^2$.
Honolulu, Sandwich Islands	21 18.2	157 55.0	$D = -9.98 + 0.0227\,m + 0.00030\,m^2$.
Sitka, Alaska	57 02.9	135 19.7	$D = -26.72 + 2.41 \sin (1.6\,m - 107.1)$.
Unalashka, Alaska	53 52.6	166 31.5	$D = -18.34 + 1.45 \sin (1.4\,m - 67.8)$.
Petropavlovsk, Kamtchatka	+ 53 01	+201 19	$D = -3.35 + 2.97 \sin (1.3\,m + 12.2)$.

* Approximate expression.

In the second table are exhibited for each locality discussed: in column (1) the year and fraction of a year when the observations were made; in columns (2) and (3) *the observed and computed declinations, the latter by the preceding formulæ; and in column (4) the differences of these values or observed minus computed declinations.*

TABLE II.—COMPARISON OF OBSERVED AND COMPUTED MAGNETIC DECLINATIONS.

Year.	Obs'd dec.	Comp'd dec.	O—C.
PARIS, FRANCE.			
	°	°	°
1541.5	− 7.00	− 7.09	+0.09
1550.5	8.00	8.11	+0.11
1580.5	11.50	9.93	−1.57
1603.5	8.75	8.65	−0.10
1610.5	8.00	7.89	−0.11
1630.5	4.50	5.30	+0.80
1642.5	2.50	3.66	+1.16
1660.0	1.50	0.99	−0.51
1664.5	− 0.67	−0.25	−0.42
1667.0	+ 0.13	+0.23	−0.10
1670.5	1.50	0.88	+0.62
1682.5	3.13	3.41	−0.28
1687.5	4.87	4.59	+0.28
1695.1	6.62	6.44	+0.18
1703.5	9.00	8.49	+0.51
1712.5	11.18	10.58	+0.60
1721.5	12.87	12.56	+0.31
1730.5	14.62	14.29	+0.33
1739.5	15.38	15.76	−0.38
1748.5	16.62	17.02	−0.40
1757.1	17.82	18.13	−0.31
1765.5	19.00	19.14	−0.14
1772.5	20.02	19.94	+0.08
1779.5	20.67	20.73	−0.06
1784.5	21.42	21.25	+0.17
1791.5	22.30	21.92	+0.38
1800.0	22.23	22.54	−0.31
1803.5	21.97	22.72	−0.75
1807.5	22.57	22.86	−0.29
1814.5	22.57	22.94	−0.37
1816.9	22.30	22.91	−0.61
1835.5	22.07	21.79	+0.28
1838.2	21.63	21.51	+0.12
1842.5	21.48	21.04	+0.44
1858.0	19.60	19.00	+0.60
1865.5	18.73	17.95	+0.78
1869.7	+17.14	+17.35	−0.21
HALIFAX, NOVA SCOTIA.			
1700.0	+13.00	+12.97	+0.03
1756.5	12.83	13.03	− .20
1775.5	13.58	14.02	− .44
1798.5	16.50	15.65	+ .85
1818.0	17.47	17.16	+ .31
1821.7	17.60	17.45	+ .15
1852.5	18.17	19.50	−1.33
1853.9	18.85	19.52	−0.67
1860.5	19.92	19.88	+0.04
1866.3	21.09	20.11	+0.98
1879.7	+20.72	+20.47	+0.25
QUEBEC, CANADA.			
1642.5	+16.00	+16.33	−0.33
1686.5	15.50	17.70	−2.20
1700.0	16.00	17.05	−1.05
1785.5	12.58	12.39	+0.19
1789.5	11.75	12.33	−0.58
1791.5	+13.00	+12.29	+0.71
QUEBEC, CANADA—Continued.			
	°	°	°
1792.3	+12.42	+12.29	+0.13
1793.7	12.54	12.26	+0.28
1805.3	11.58	12.08	−0.50
1810.5	11.63	12.06	−0.43
1811.5	12.25	12.06	+0.19
1814.5	11.83	12.10	−0.27
1820.8	12.54	12.27	+0.27
1821.7	12.90	12.30	+0.60
1822.2	13.00	12.32	+0.68
1823.6	13.00	12.38	+0.62
1824.2	12.67	12.42	+0.25
1831.7	13.40	12.91	+0.49
1832.4	13.00	12.97	+0.03
1833.5	12.75	13.07	−0.32
1834.4	13.31	13.15	+0.16
1835.9	13.17	13.28	−0.11
1839.3	13.37	13.63	−0.26
1840.5	13.71	13.75	−0.04
1842.7	14.02	13.98	+0.04
1846.5	14.53	14.42	+0.11
1847.7	14.64	14.56	+0.08
1848.5	14.58	14.65	−0.07
1849.4	15.37	14.77	+0.60
1850.3	15.25	14.86	+0.39
1851.7	15.00	15.03	−0.03
1853.1	15.50	15.19	+0.31
1858.8	15.57	15.82	−0.25
1859.5	16.28	15.90	+0.38
1860.8	16.47	16.02	+0.45
1865.5	16.67	16.47	+0.20
1879.7	+17.23	+17.30	−0.07
MONTREAL, CANADA.			
1749.5	+10.63	+10.55	+0.08
1785.5	8.40	8.58	−0.18
1793.6	8.25	8.28	−0.03
1814.5	7.75	7.65	+0.10
1834.5	8.00	8.60	−0.60
1835.5	9.83	8.71	+1.12
1842.6	8.97	9.60	−0.63
1859.5	12.35	12.01	+0.34
1879.7	+13.67	+13.79	−0.12
YORK FACTORY, HUDSON BAY.			
1725.5	+19.0	+19.04	− .04
1787.5	+ 5.0	+ 4.93	+ .07
1819.7	− 6.0	− 6.06	+ .06
1843.5	9.42	9.05	− .37
1857.6	− 7.62	− 7.95	+ .33
PORTLAND, ME.			
1763.5	+ 7.75	+ 8.05	− .30
1775.5	8.50	8.14	+ .36
1845.4	11.47	11.55	− .08
1851.6	11.69	11.91	− .22
1859.5	+12.33	+12.33	.00
PORTLAND, ME.—Continued.			
	°	°	°
1863.5	+12.47	+12.52	− .05
1864.8	12.73	12.58	+ .15
1865.5	12.71	12.61	+ .10
1866.1	12.72	12.64	+ .08
1873.7	+12.89	+12.94	− .05
BURLINGTON, VT.			
1793.5	+ 7.63	+ 7.35	+0.28
1805.5	6.20	7.22	−1.02
1818.5	7.50	7.43	+ .07
1822.5	7.70	7.62	+ .08
1826.5	7.60	7.88	− .28
1830.5	8.17	8.18	− .01
1831.5	8.25	8.26	− .01
1832.5	8.42	8.34	+ .08
1834.5	8.83	8.50	+ .33
1837.5	8.75	8.75	.00
1845.5	9.37	9.37	.00
1855.7	9.95	10.01	− .06
1873.8	+11.32	+11.31	+ .01
RUTLAND, VT.			
1789.3	+ 7.05	+ 6.58	+ .47
1810.4	6.07	6.23	− .16
1811.7	6.02	6.25	− .23
1859.6	9.82	9.37	+ .45
1873.8	10.67	10.79	− .12
1879.8	+11.15	+11.36	− .21
PORTSMOUTH, N. H.			
1771.5	+ 7.77	+ 7.82	− .05
1775.5	7.75	7.69	+ .06
1844.5	9.78	9.94	− .16
1850.7	10.50	10.42	+ .08
1859.5	11.25	11.12	+ .13
1879.6	+12.52	+12.58	− .06
NEWBURYPORT, MASS.			
1775.5	+ 6.75	+ 7.04	− .29
1781.5	7.30	6.98	+ .32
1850.7	10.09	10.23	− .14
1859.5	+10.97	+10.88	+ .09
SALEM, MASS.			
1781.6	+ 6.90	+ 6.29	+ .61
1805.8	5.95	6.47	− .52
1810.5	6.09	6.67	− .58
1849.6	*10.24	9.70	+ .54
1855.6	10.83	10.27	+ .56
1877.5	+11.50	+12.13	− .63
BOSTON, MASS.			
1700.5	+10.0	+10.00	.00
1708.5	+ 9.0	+ 9.47	− .47
BOSTON, MASS.—Continued.			
	°	°	°
1741.5	+ 7.50	+ 7.48	+ .02
1776.0	7.67	6.59	+1.08
1782.5	7.00	6.61	+0.39
1793.5	6.50	6.80	−0.30
1807.5	6.08	7.27	−1.19
1839.5	9.10	9.07	+0.03
1846.7	9.52	9.56	−0.04
1855.6	10.23	10.14	+0.09
1872.7	11.25	11.18	+0.07
1877.5	+11.60	+11.43	+0.17
CAMBRIDGE, MASS.			
1708.5	+ 9.0	+ 9.30	− .30
1742.5	8.0	7.70	+ .30
1757.5	7.33	7.28	+ .05
1761.5	7.23	7.17	+ .06
1763.5	7.00	7.13	− .13
1780.5	7.03	6.90	+ .13
1782.5	6.75	6.89	− .14
1783.5	6.87	6.90	− .03
1788.5	6.63	6.93	− .30
1810.5	7.50	7.52	− .02
1835.5	8.85	9.02	− .17
1837.5	9.15	9.15	.00
1840.4	9.30	9.36	− .06
1842.2	9.57	9.49	+ .08
1844.5	9.65	9.65	.00
1845.4	9.53	9.72	− .19
1850.6	9.50	10.07	− .57
1852.5	10.13	10.20	− .07
1854.5	10.21	10.33	− .12
1855.4	10.91	10.39	+ .52
1856.5	10.47	10.46	+ .01
1859.2	10.80	10.63	+ .17
1867.5	10.70	11.09	− .39
1879.6	+11.77	+11.62	+ .15
NANTUCKET, MASS.			
1775.5	+ 6.50	+ 6.52	− .02
1834.5	8.45	8.55	− .10
1838.9	9.04	8.83	+ .21
1842.7	9.15	9.08	+ .07
1843.7	9.17	9.15	+ .02
1846.6	9.23	9.33	− .10
1855.6	9.97	9.92	+ .05
1867.4	10.33	10.64	− .31
1879.6	+11.46	+11.27	+ .19
PROVIDENCE, R. I.			
1717.5	+ 9.60	+ 9.73	− .13
1720.5	9.47	9.49	− .02
1725.5	9.23	9.14	+ .09
1730.5	8.90	8.85	+ .05
1735.5	8.65	8.59	+ .06
1740.5	8.25	8.33	− .08
1745.5	7.98	8.02	− .04
1750.5	+ 7.67	+ 7.66	+ .01

TABLE II.—Continued.

PROVIDENCE, R. I.—Continued.

Year.	Obs'd dec.	Comp'd dec.	O − C.
	°	°	°
1755.5	+ 7.35	+ 7.27	+ .08
1760.5	6.95	6.88	+ .07
1765.5	6.72	6.53	+ .19
1769.5	6.50	6.29	+ .21
1775.5	6.33	6.15	+ .18
1780.5	6.27	6.12	+ .15
1785.5	6.22	6.17	+ .05
1790.5	6.17	6.25	− .08
1795.5	6.17	6.32	− .15
1800.5	6.25	6.37	− .12
1805.5	6.32	6.40	− .08
1810.5	6.40	6.45	− .05
1815.5	6.50	6.55	− .05
1819.5	6.62	6.75	− .13
1825.5	6.85	7.06	− .21
1830.5	7.17	7.45	− .28
1835.5	7.57	7.90	− .33
1840.5	8.42	8.36	+ .06
1841.5	8.52	8.45	+ .07
1842.5	8.65	8.53	+ .12
1843.5	8.77	8.60	+ .17
1855.6	+ 9.52	+ 9.42	+ .10

HARTFORD, CONN.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1786.5	+ 5.42	+ 5.28	+ .14
1810.5	4.77	5.25	− .48
1824.5	5.75	5.60	+ .15
1829.0	6.05	5.76	+ .29
1859.6	7.29	7.34	− .05
1867.6	7.82	7.84	− .02
1879.6	+ 8.57	+ 8.59	− .02

NEW HAVEN, CONN.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1761.5	+ 5.78	+ 6.04	− .26
1775.5	5.42	5.28	+ .14
1780.5	5.25	5.07	+ .18
1811.5	5.17	4.76	+ .41
1819.8	4.42	4.97	− .55
1828.5	5.28	5.32	− .04
1835.3	5.68	5.67	+ .01
1836.5	5.92	5.74	+ .18
1837.9	5.83	5.82	+ .01
1840.5	6.17	5.98	+ .19
1844.6	5.75	6.24	− .49
1845.7	6.29	6.32	− .03
1848.6	6.58	6.51	+ .07
1855.6	7.05	7.01	+ .04
1872.5	8.46	8.29	+ .17
1878.5	+ 8.69	+ 8.73	− .04

ALBANY, N. Y.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1817.8	+ 5.73	+ 5.71	+ .02
1818.6	5.75	5.74	+ .01
1825.3	6.00	6.08	− .08
1828.6	6.27	6.26	+ .01
1830.5	+ 6.30	+ 6.38	− .08

ALBANY, N. Y.—Continued.

Year.	Obs'd dec.	Comp'd dec.	O − C.
	°	°	°
1831.6	+ 6.54	+ 6.45	+ .09
1834.8	6.67	6.65	+ .02
1836.8	6.78	6.78	.00
1847.9	7.58	7.58	.00
1855.7	7.91	8.17	− .26
1856.7	8.58	8.24	+ .34
1858.4	8.28	8.37	− .09
1879.6	+ 9.86	+ 9.87	− .01

OXFORD, N. Y.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1794.0	+ 3.0	+ 2.96	+ .04
1817.5	3.0	3.31	− .31
1828.5	4.50	3.79	+ .71
1834.8	3.87	4.13	− .26
1836.8	4.15	4.26	− .11
1837.5	4.50	4.30	+ .20
1838.5	4.45	4.36	+ .09
1849.9	5.18	5.14	+ .04
1857.3	5.73	5.68	+ .05
1858.1	5.78	5.74	+ .04
1859.0	5.83	5.81	+ .02
1873.9	6.87	6.94	− .07
1874.4	+ 6.93	+ 6.97	− .04

BUFFALO, N. Y.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1797.5	+ 0.00	+ 0.26	− .26
1798.5	0.50	0.24	+ .26
1837.5	1.42	1.19	+ .23
1839.5	1.25	1.31	− .06
1845.5	1.42	1.71	− .29
1859.5	2.94	2.79	+ .15
1872.5	3.87	3.89	− .02
1873.5	+ 3.97	+ 3.97	.00

TORONTO, CANADA.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1840.1	+ 1.45	+ 1.36	+ .09
1841.5	1.24	1.40	− .16
1842.5	1.32	1.45	− .13
1845.5	1.48	1.52	− .04
1846.5	1.51	1.54	− .03
1847.5	1.55	1.56	− .01
1848.5	1.59	1.57	+ .02
1849.5	1.62	1.59	+ .03
1850.5	1.64	1.62	+ .02
1851.5	1.68	1.66	+ .02
1853.5	1.77	1.76	+ .01
1854.5	1.80	1.82	− .02
1855.5	1.87	1.88	− .01
1856.5	1.94	1.95	− .01
1857.5	2.01	2.02	− .01
1858.5	2.07	2.08	− .01
1859.5	2.12	2.14	− .02
1860.5	2.18	2.20	− .02
1861.5	2.24	2.25	− .01
1862.5	2.26	2.29	− .03
1863.5	+ 2.32	+ 2.33	− .01

TORONTO, CANADA—Continued.

Year.	Obs'd dec.	Comp'd dec.	O − C.
	°	°	°
1864.5	+ 2.36	+ 2.37	− .01
1865.5	2.41	2.41	.00
1866.5	2.46	2.45	+ .01
1867.5	2.50	2.50	.00
1868.5	2.55	2.55	.00
1869.5	2.62	2.62	.00
1870.5	2.70	2.69	+ .01
1871.5	2.80	2.78	+ .02
1872.5	2.88	2.88	.00
1873.5	2.97	2.98	− .01
1874.5	3.07	3.09	− .02
1875.5	3.19	3.20	− .01
1876.5	3.31	3.30	+ .01
1877.5	3.41	3.41	.00
1878.5	3.52	3.50	+ .02
1879.5	3.62	3.58	+ .04
1880.8	+ 3.68	+ 3.67	+ .01

ERIE, PA.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1786.8	+ 0.53	+ 0.12	+ .41
1795.5	− 0.72	− 0.21	− .51
1841.6	+ 0.50	+ 0.42	+ .08
1855.5	1.55	1.28	+ .27
1859.3	1.57	1.54	+ .03
1862.6	1.55	1.78	− .23
1867.3	2.22	2.12	+ .10
1873.6	2.31	2.59	− .28
1876.5	2.83	2.79	+ .04
1877.9	+ 3.00	+ 2.89	+ .11

CLEVELAND, OHIO.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1796.7	− 2.00	− 1.95	− .05
1830.5	1.33	1.04	− .29
1831.6	1.25	1.00	− .25
1834.1	0.83	0.89	+ .06
1838.1	0.58	0.70	+ .12
1840.5	0.32	0.59	+ .27
1841.3	0.09	0.55	+ .46
1845.5	− 0.65	− 0.35	− .30
1859.5	+ 0.77	+ 0.36	+ .41
1871.8	0.54	0.95	− .41
1872.5	0.75	0.98	− .23
1873.5	0.85	1.03	− .18
1880.5	+ 1.64	+ 1.33	+ .31

DETROIT, MICH.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1810.5	− 2.80	− 3.10	+ .30
1822.5	3.22	2.82	− .40
1828.5	2.83	2.60	− .23
1835.5	2.17	2.30	+ .13
1840.5	1.97	2.06	+ .09
1859.5	0.70	1.01	+ .31
1865.5	0.67	0.66	− .01
1872.4	0.42	0.28	− .14
1873.4	0.29	0.22	− .07
1876.4	− 0.08	− 0.06	− .02

ST. LOUIS, MO.

Year.	Obs'd dec.	Comp'd dec.	O − C.
	°	°	°
1819.5	−10.79	− 9.22	−1.57
1837.0	8.29	8.59	+ .30
1856.1	7.20	7.62	+ .42
1872.6	6.63	6.69	+ .06
1877.5	6.51	6.41	− .10
1878.6	6.56	6.36	− .20
1879.7	− 6.22	− 6.30	+ .08

NEW YORK, N. Y.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1684.5	+ 8.75	+ 8.77	− .02
1686.5	9.00	8.77	+ .23
1691.5	8.75	8.65	+ .10
1724.0	7.33	7.47	− .14
1750.5	6.37	5.82	+ .55
1755.5	5.00	5.43	− .43
1789.5	4.33	4.27	+ .06
1824.5	4.67	4.61	+ .06
1834.5	4.83	5.14	− .31
1837.5	5.67	5.34	+ .33
1840.6	5.45	5.58	− .13
1841.5	6.10	5.65	+ .45
1844.6	6.22	5.89	+ .33
1845.7	6.42	5.98	+ .44
1846.3	5.56	6.02	− .46
1847.8	5.68	6.13	− .45
1855.6	6.72	6.70	+ .02
1860.7	6.73	7.00	− .27
1873.8	7.52	7.56	− .04
1874.6	7.38	7.59	− .21
1879.5	+ 7.90	+ 7.92	− .02

HATBOROUGH, PA.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1680.5	+ 8.47	+ 8.49	− .02
1690.5	8.25	8.30	− .05
1700.5	7.92	7.94	− .02
1710.5	7.47	7.49	− .02
1720.5	7.00	6.95	+ .05
1730.5	6.42	6.30	+ .12
1740.5	5.58	5.56	+ .02
1750.5	4.92	4.67	+ .25
1760.5	4.00	3.75	+ .25
1770.5	2.92	2.89	+ .03
1780.5	2.08	2.21	− .13
1790.5	1.83	1.84	− .01
1800.5	1.92	1.79	+ .13
1810.5	2.00	2.07	− .07
1820.5	2.45	2.56	− .11
1830.5	3.00	3.20	− .20
1840.5	3.83	3.89	− .06
1850.5	+ 4.42	+ 4.60	− .18

PHILADELPHIA, PA.

Year.	Obs'd dec.	Comp'd dec.	O − C.
1701.5	+ 8.50	+ 8.17	+ .33
1710.5	8.50	8.00	+ .50
1750.5	5.75	5.59	+ .16
1793.5	1.50	1.97	− .47
1802.5	+ 1.50	+ 1.94	− .44

TABLE II.—Continued.

Year.	Obs'd dec.	Comp'd dec.	O—C.
PHILADELPHIA, PA.—Continued.			
	°	°	°
1804.5	+ 2.08	+ 1.97	+ .11
1813.5	2.43	2.22	+ .21
1837.5	3.87	3.49	+ .38
1840.5	3.62	3.65	− .03
1841.7	3.90	3.72	+ .18
1846.4	3.85	3.97	− .12
1855.7	4.53	4.49	+ .04
1862.6	5.00	4.92	+ .08
1872.8	5.46	5.66	− .20
1877.7	+ 6.04	+ 6.06	− .02
HARRISBURG, PA.			
1795.6	− 0.43	− 0.02	− .41
1840.5	+ 3.21	+ 2.21	+1.00
1843.5	2.58	2.44	+0.14
1854.8	3.01	3.31	− .30
1857.4	3.32	3.51	− .19
1861.0	3.50	3.79	− .29
1862.6	3.74	3.90	− .16
1874.8	4.85	4.74	+ .11
1876.9	5.17	4.86	+ .31
1877.7	+ 4.89	+ 4.91	− .02
BALTIMORE, MD.			
1679.0	+ 5.25	+ 5.77	− .52
1683.5	6.25	5.75	+ .50
1703.5	5.12	5.27	− .15
1720.5	4.21	4.45	− .24
1729.2	4.02	3.93	+ .09
1754.5	2.28	2.31	− .03
1756.9	2.88	2.16	+ .72
1771.0	1.11	1.41	− .30
1776.1	1.75	1.19	+ .56
1780.5	0.77	1.02	− .25
1787.5	0.37	0.82	− .45
1808.5	0.21	0.66	− .45
1840.7	2.27	1.76	+ .51
1847.3	2.31	2.11	+ .20
1856.7	2.49	2.69	− .20
1875.5	3.74	3.90	− .16
1877.8	+ 4.18	+ 4.04	+ .14
WASHINGTON, D. C.			
1792.5	− 0.24	+ 0.01	− .25
1809.9	+ 0.87	0.14	+ .73
1841.0	1.34	1.34	.00
1842.0	1.40	1.40	.00
1855.5	2.40	2.17	+ .23
1856.6	2.36	2.23	+ .13
1857.2	2.41	2.28	+ .13
1860.7	2.44	2.49	− .05
1862.7	2.66	2.61	+ .05
1863.6	2.70	2.66	+ .04
1866.8	2.74	2.85	− .11
1867.5	2.80	2.89	− .09
1868.5	2.85	2.95	− .10
1869.3	+ 2.88	+ 3.00	− .12

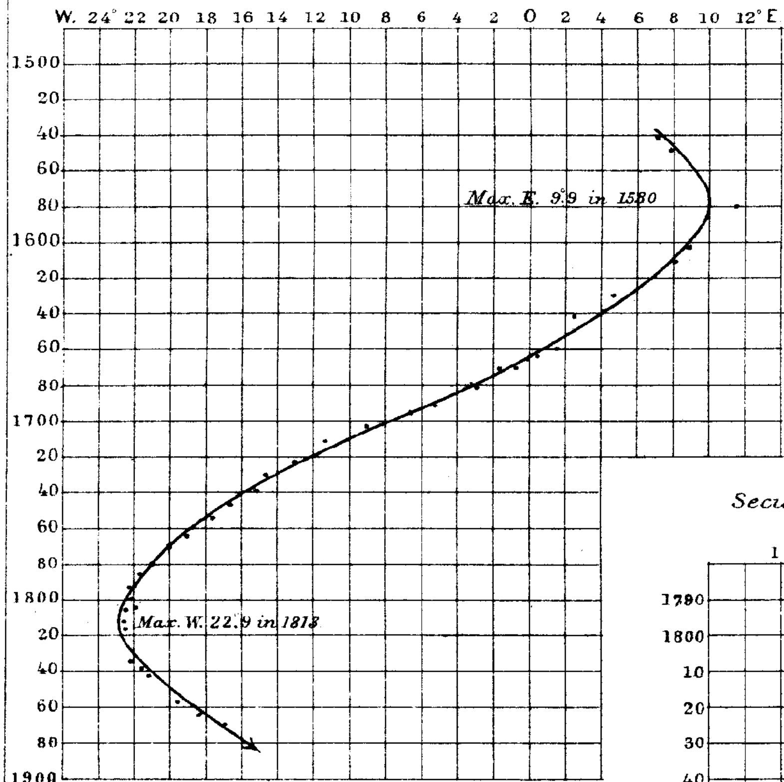
Year.	Obs'd dec.	Comp'd dec.	O—C.
WASHINGTON, D. C.—Continued.			
	°	°	°
1870.5	+ 2.89	+ 3.07	− .18
1871.5	2.95	3.13	− .18
1872.5	3.00	3.19	− .19
1873.5	3.00	3.25	− .25
1874.5	3.11	3.30	− .19
1875.5	3.26	3.36	− .10
1876.3	3.31	3.40	− .09
1877.5*	3.66	3.47	+ .19
1878.6	3.75	3.53	+ .22
1879.4	3.84	3.58	+ .26
1880.3	+ 3.91	+ 3.62	+ .29
CAPE HENRY, VA.			
1730.0	+ 4.0	+ 3.93	+ .07
1809.5	− 0.13	0.14	− .27
1832.5	+ 0.75	0.42	+ .33
1856.7	1.47	1.51	− .04
1874.9	2.66	2.62	+ .04
1879.4	+ 2.75	+ 2.90	− .15
CHARLESTON, S. C.			
1775.5	− 3.80	− 4.84	+1.04
1784.1	5.25	4.88	−0.37
1785.8	5.75	4.88	−0.87
1825.0	3.75	3.72	− .03
1837.5	2.90	2.99	+ .09
1840.5	2.73	2.88	+ .15
1841.4	2.40	2.75	+ .35
1847.8	2.25	2.35	+ .10
1849.3	2.28	2.24	− .04
1874.4	0.97	0.70	− .27
1880.1	− 0.43	− 0.43	.00
SAVANNAH, GA.			
1817.5	− 4.0	− 4.68	+ .68
1839.0	4.30	4.18	− .12
1852.3	3.67	3.52	− .15
1857.3	3.46	3.24	− .22
1874.2	− 1.98	− 2.23	+ .25
KEY WEST, FLA.			
1829.1	− 6.42	− 6.50	+ .08
1843.5	6.03	5.88	− .15
1849.6	5.48	5.54	+ .06
1860.7	4.78	4.83	+ .05
1861.2	4.74	4.80	+ .06
1862.7	4.67	4.69	+ .02
1863.5	4.61	4.64	+ .03
1864.5	4.57	4.57	.00
1865.5	4.53	4.50	− .03
1866.2	4.50	4.45	− .05
1879.2	− 3.56	− 3.52	− .04
HAVANA, CUBA.			
1726.5	− 4.4	− 4.27	− .13
1732.3	4.5	4.53	+ .03

Year.	Obs'd dec.	Comp'd dec.	O—C
HAVANA, CUBA—Continued.			
	°	°	°
1815.5	− 7.0	− 6.42	− .58
1816.6	5.5	6.40	+ .90
1857.1	5.25	5.12	− .13
1858.5	5.75	5.05	− .70
1879.2	− 3.90	− 4.13	+ .23
KINGSTON, JAMAICA.			
1732.2	− 6.0	− 6.30	+ .30
1791.8	6.78	6.29	− .49
1806.0	6.5	5.86	− .64
1820.5	4.8	5.32	+ .52
1822.5	4.9	5.24	+ .34
1832.5	5.2	4.82	− .38
1833.5	4.7	4.78	+ .08
1837.8	4.3	4.59	+ .29
1847.3	3.67	4.19	+ .52
1857.2	3.67	3.79	+ .12
1876.0	− 3.79	− 3.14	− .65
PANAMA, NEW GRANADA.			
1775.8	− 7.82	− 8.32	+ .50
1790.8	7.82	8.04	+ .22
1802.5	8.0	7.77	− .23
1822.5	7.0	7.25	+ .25
1837.5	7.03	6.83	− .20
1849.5	7.08	6.48	− .60
1858.5	6.28	6.24	− .04
1866.4	5.93	6.03	+ .10
1874.0	− 6.58	− 5.84	− .74
RIO JANEIRO, RAZIL.			
1768.5	− 7.57	− 7.47	− .10
1787.5	6.20	6.31	+ .11
1820.5	2.90	3.26	+ .36
1821.5	3.35	3.25	− .10
1830.5	2.17	2.23	+ .06
1836.5	− 2.00	− 1.50	− .50
1857.5	+ 1.33	+ 1.36	− .03
1866.0	+ 2.70	+ 2.65	+ .05
1876.5	+ 4.43	+ 4.36	+ .07
MOBILE, ALA.			
1814.5	− 6.50	− 6.52	+ .02
1835.5	7.20	7.07	− .13
1840.5	7.08	7.09	+ .01
1843.5	6.93	7.08	+ .15
1847.4	7.07	7.05	− .02
1857.1	6.87	6.86	− .01
1875.4	− 6.12	− 6.11	− .01
NEW ORLEANS, LA.			
1720.5	− 2.0	− 3.31	+1.31
1768.5	7.83	5.79	−2.04
1796.5	5.10	7.37	+2.27
1806.5	− 8.05	− 7.77	−0.28

Year.	Obs'd dec.	Comp'd dec.	O—C
NEW ORLEANS, LA.—Continued.			
	°	°	°
1840.5	− 8.33	− 8.10	−0.23
1857.0	8.00	7.69	−0.31
1858.3	7.86	7.59	−0.27
1870.5	7.10	7.02	−0.08
1872.1	6.66	6.93	+0.27
1880.2	− 6.46	− 6.47	+0.01
VERA CRUZ, MEXICO.			
1727.0	− 2.25	− 2.63	+ .38
1769.4	6.57	6.61	+ .04
1776.5	7.50	7.21	− .29
1815.5	10.62	9.29	−1.33
1819.3	9.27	9.36	+ .09
1839.5	8.37	9.28	+ .91
1856.6	8.28	8.64	+ .36
1861.0	8.33	8.40	+ .07
1880.1	− 7.44	− 7.04	− .40
MEXICO, MEXICO.			
1769.7	− 5.46	− 5.94	+ .48
1775.5	6.70	6.38	− .32
1804.0	8.13	8.09	− .04
1849.5	8.50	8.72	+ .22
1850.5	8.59	8.70	+ .11
1856.9	8.77	8.54	− .23
1858.5	8.37	8.49	+ .12
1860.5	8.50	8.43	− .07
1862.5	8.46	8.36	− .10
1867.0	8.15	8.19	+ .04
1868.5	− 8.17	− 8.11	− .06
ACAPULCO, MEXICO.			
1744.5	− 3.0	− 3.50	+ .50
1791.3	7.73	7.07	− .66
1822.5	8.67	8.61	− .06
1828.5	9.12	8.77	− .35
1838.0	8.29	8.93	+ .64
1866.5	8.37	8.66	+ .29
1874.2	− 8.64	− 8.39	− .25
SAN BLAS, MEXICO.			
1791.3	− 7.47	− 7.32	− .15
1822.0	8.67	8.65	− .02
1837.5	8.85	9.02	+ .17
1838.5	8.79	9.04	+ .25
1839.5	9.00	9.05	+ .05
1841.5	9.20	9.08	− .12
1874.1	− 9.14	− 8.95	− .19
MAGDALENA BAY, LOWER CAL.			
1837.5	− 8.27	− 8.68	+ .41
1839.5	9.25	8.84	− .41
1866.4	10.67	10.51	− .16
1871.3	11.00	10.72	− .28
1873.3	−10.56	−10.79	+ .23

* Change of station between 1876 and 1877.

Secular Change of the Magnetic Declination at Paris, France.



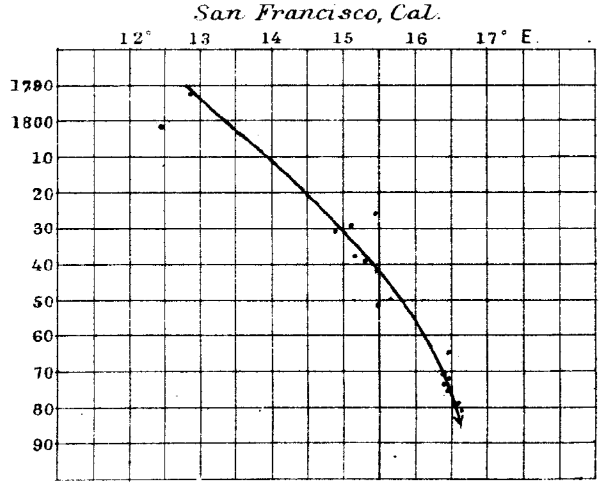
U. S. Coast and Geodetic Survey

Carlile P. Patterson, Supt.

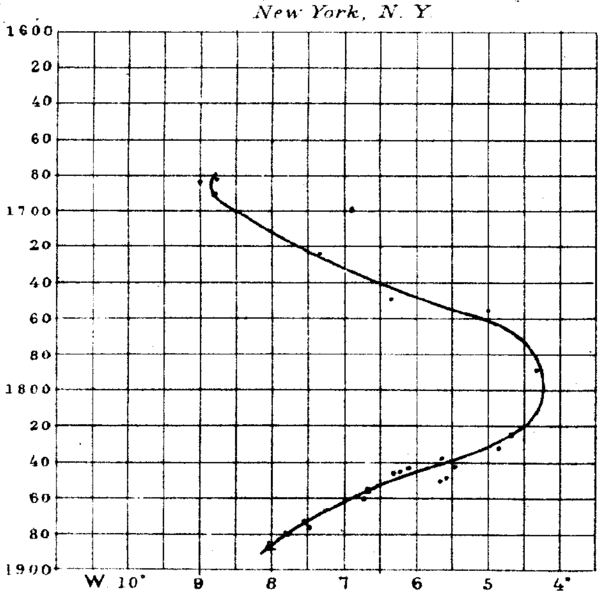
To Report of 1879, Appendix 9

May, 1881.

Secular Change of the Declination at San Francisco, Cal.



Secular Change of the Declination at New York, N. Y.



Secular Change of the Declination at Sitka, Alaska.

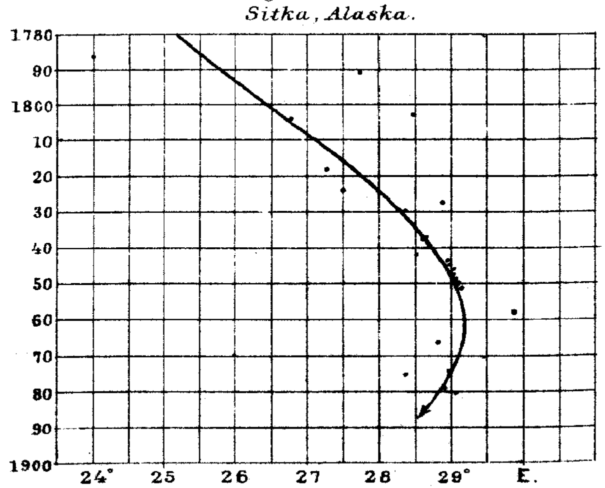


TABLE II.—Continued.

Year.	Obs'd dec.	Comp'd dec.	O—C.
SAN DIEGO, CAL.			
	°	°	°
1792.5	−11.0	−11.01	+ .01
1839.5	12.34	12.18	− .16
1851.3	12.48	12.58	+ .10
1853.8	12.53	12.67	+ .14
1866.4	13.16	13.09	− .07
1872.9	−13.32	−13.29	− .03
MONTEREY, CAL.			
1791.7	−10.93	−11.53	+ .60
1795.5	12.37	11.76	− .61
1837.5	14.50	14.29	− .21
1839.5	14.22	14.40	+ .18
1841.5	15.00	14.51	− .49
1843.5	14.00	14.62	+ .62
1851.1	14.97	15.01	+ .04
1854.4	14.98	15.17	+ .19
1873.7	−15.92	−15.91	− .01
SAN FRANCISCO, CAL.			
1792.9	−12.8	−12.92	+ .12
1827.5	15.45	14.81	− .64
1829.5	15.10	14.91	− .19
1830.5	14.85	14.96	+ .11
1837.5	15.17	15.29	+ .12
1839.5	15.33	15.38	+ .05
1841.9	15.50	15.48	− .02
1850.0	−15.68	−15.80	+ .12
SAN FRANCISCO, CAL.—Continued			
	°	°	°
1852.3	−15.48	−15.88	+ .40
1866.5	16.42	16.29	− .13
1871.9	16.39	16.40	+ .01
1872.8	16.43	16.41	− .02
1873.7	16.41	16.43	+ .02
1874.0	16.45	16.43	− .02
1879.2	16.57	16.50	− .07
1880.9	−16.66	−16.53	− .13
CAPE DISAPPOINTMENT, WASH. TER.			
1792.3	−18.0	−17.98	− .02
1839.5	19.18	19.70	+ .52
1842.5	20.00	19.86	− .14
1851.5	20.54	20.38	− .16
1873.8	−21.61	−21.67	+ .06
KAILUA, SANDWICH ISLANDS.			
1779.5	− 8.10	− 7.77	− .33
1791.5	8.25	8.28	+ .03
1793.3	7.78	8.34	+ .56
1796.5	8.25	8.45	+ .20
1819.5	9.83	8.91	− .92
1825.5	8.85	8.95	+ .10
1841.5	8.83	8.88	+ .05
1853.5	8.25	8.67	+ .42
1877.5	− 8.00	− 7.84	− .16
HONOLULU, SANDWICH ISLANDS.			
	°	°	°
1816.5	−10.95	−10.30	− .65
1819.5	10.40	10.32	− .08
1824.9	9.87	10.35	+ .48
1827.5	10.43	10.35	− .08
1836.5	10.18	10.30	+ .12
1837.5	10.33	10.28	− .05
1838.5	10.65	10.27	− .38
1840.5	9.28	10.25	+ .97
1859.5	9.70	9.80	+ .10
1871.5	9.60	9.32	− .28
1872.5	9.30	9.28	− .02
1875.5	− 9.26	− 9.14	− .12
SITKA, ALASKA.			
1787.5	−24.00	−25.62	+1.62
1791.6	27.77	25.88	−1.89
1804.6	26.75	26.73	−0.02
1818.5	27.25	27.64	+0.39
1824.5	27.50	28.00	+0.50
1827.5	28.83	28.17	−0.66
1829.9	28.31	28.29	−0.02
1838.6	28.62	28.69	+0.07
1842.6	28.54	28.83	+0.29
1843.5	28.90	28.86	−0.04
1844.5	28.95	28.89	−0.06
1845.5	29.00	28.92	−0.08
1847.7	28.98	28.97	−0.01
1848.5	29.07	28.99	−0.08
1849.1	29.06	29.00	−0.06
1851.0	−29.23	−29.05	−0.18
SITKA, ALASKA—Continued.			
	°	°	°
1867.6	−28.82	−29.08	+0.26
1874.3	28.99	28.96	−0.03
1876.1	28.34	28.91	+0.57
1879.3	28.90	28.81	−0.09
1880.4	−29.06	−28.78	−0.28
UNALASHKA, ALASKA.			
1790.4	−19.59	−19.04	− .55
1792.5	19.00	19.10	+ .10
1817.5	19.40	19.67	+ .27
1827.6	19.83	19.77	− .06
1831.5	19.50	19.79	+ .29
1849.5	20.00	19.69	− .31
1867.7	19.79	19.33	− .46
1870.5	19.75	19.26	− .49
1873.5	19.06	19.17	+ .11
1874.7	18.71	19.13	+ .42
1880.6	−18.63	−18.95	+ .32
PETROPAVLOVSK, KAMTCHATKA.			
1779.5	− 6.31	− 6.27	− .04
1792.5	6.00	5.98	− .02
1804.7	5.49	5.51	+ .02
1827.6	4.07	4.21	+ .14
1837.7	3.45	3.54	+ .09
1849.5	2.62	2.75	+ .13
1854.5	3.67	2.43	−1.24
1866.5	1.42	1.70	+ .28
1876.6	− 1.15	− 1.18	+ .03

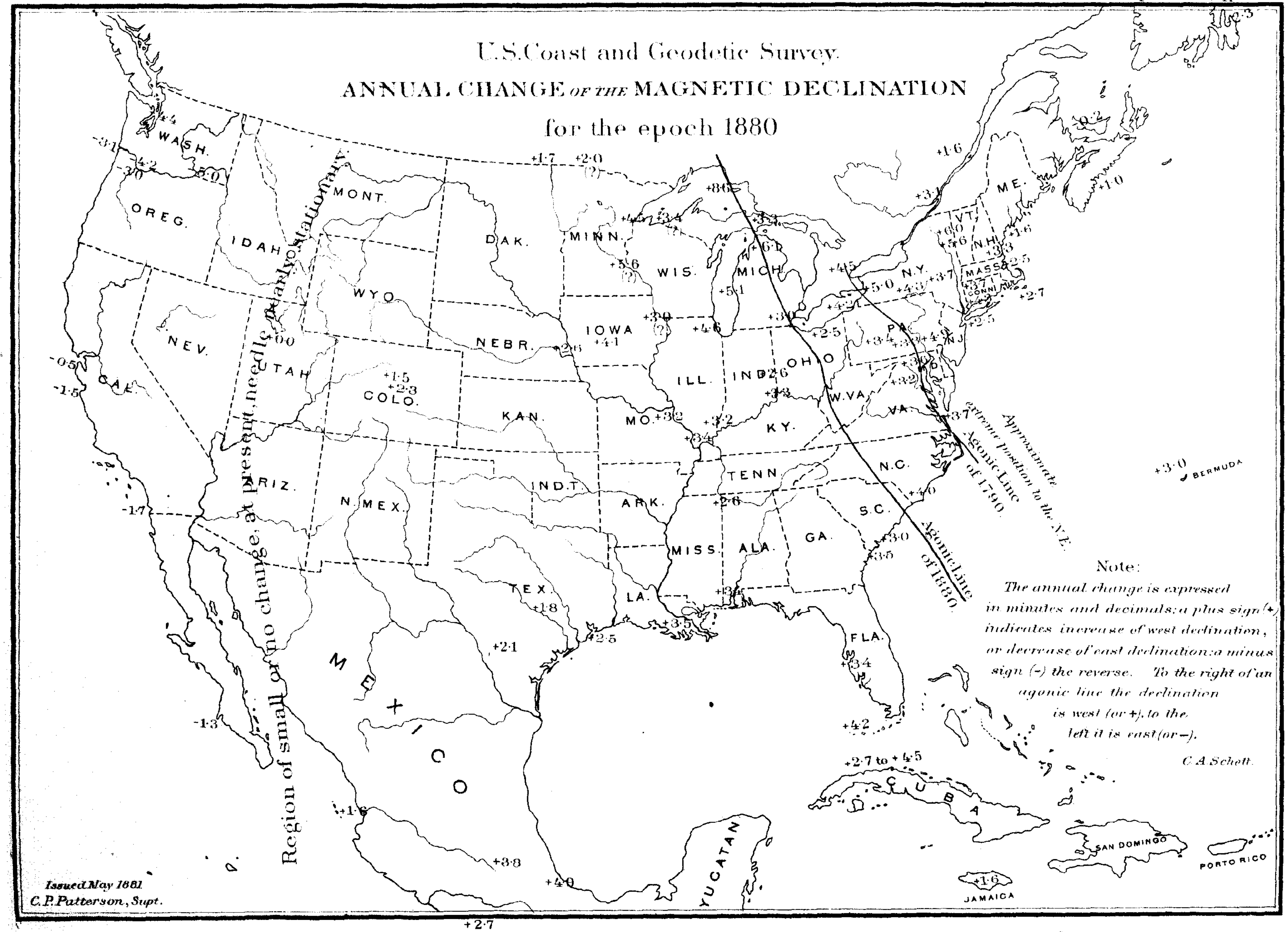
To facilitate the comparison of the results at widely different localities there has been added to this paper the accompanying plate, headed "Secular change of the magnetic declination." It exhibits the observed and computed declinations for Paris, France, for New York, San Francisco, and for Sitka. The first-named station has been introduced for the special purpose of showing in a conspicuous manner the great regularity of the secular motion, and thus impressing the mind with the fact that the explanation of the secular change must ultimately be referred to forces of a periodic character acting for centuries with great regularity. So far no approach has yet been made towards the discovery of the cause of this motion. The diagrams also assist in connecting the phases of the secular change as exhibited for places in the United States with the corresponding phases of the motion in Western Europe and Eastern Asia.

The following Table III shows for each station: (1) the number of observations used in the discussion of the secular change, numbers in parentheses uncertain; (2) the apparent probable error, in minutes of arc, of one observation (including all sources of error, namely, those caused by imperfect value of the average declination due to variations of the needle, those caused by difference of location of station, those arising from purely instrumental defects, and those due to imperfection of formula); (3) the computed epoch of greatest easterly deflection reached in the secular motion, *i. e.*, the date when last reached or the date (in parentheses) when it is next expected to be in that position; (4) the amount, in degrees and fractions, and direction (+ west, — east) at this the nearest stationary epoch; (5) (6) and (7) the computed annual changes for the epochs 1870, 1880, and 1885, expressed in minutes of arc, a + sign indicating north end of needle moving westward, a — sign north end moving eastward.

TABLE III.

Locality.	Number of observations.	Apparent probable error of an observation.	Nearest stationary epoch of easterly digression.	Amount at easterly digression.	Annual change. In 1870.	Annual change. In 1880.	Annual change. In 1885.
		′		°	′	′	′
Paris	37	± 22	1580*	− 9.9*	− 8.6	− 8.9	− 9.2
Halifax, Nova Scotia	11	30	1728	+12.4	+ 1.8	+ 1.0	+ 0.5
Quebec, Canada	37	20	1809	+12.1	+ 4.2	+ 1.6	+ 0.5
Montreal, Canada	9	30	1816	+ 7.6	+ 5.1	+ 3.1	+ 2.8
York Factory, Hudson Bay	5	14	1843	− 9.0	+16.0	....	....
Portland, Me	10	± 9	1764	+ 8.0	+ 2.4	+ 1.6	+ 1.2
Burlington, Vt	13	13	1810	+ 7.2	+ 5.0	+ 6.0	+ 5.8
Rutland, Vt	6	16	1806	+ 6.2	+ 6.0	+ 5.6	+ 5.3
Portsmouth, N. H	6	6	1791	+ 7.5	+ 4.4	+ 3.7	+ 3.3
Newburyport, Mass	4	13	1784	+ 7.0	+ 3.9	+ 3.3	+ 2.9
Salem, Mass	6	± 33	1791	+ 6.2	+ 5.0	+ 4.1	+ 3.5
Boston, Mass	12	24	1777	+ 6.6	+ 3.4	+ 2.9	+ 2.5
Cambridge, Mass	24	11	1783	+ 6.9	+ 2.9	+ 2.1	+ 1.8
Nantucket, Mass	9	7	1779	+ 6.5	+ 3.3	+ 2.7	+ 2.4
Providence, R. I	(30)	7	1780	+ 6.1	+ 3.8	....	....
Hartford, Conn	7	± 12	1799	+ 5.2	+ 3.8	+ 3.7	+ 3.6
New Haven, Conn	16	11	1802	+ 4.7	+ 4.6	+ 4.3	+ 4.1
Albany, N. Y	13	6	1793	+ 5.2	+ 4.3	+ 3.7	+ 3.4
Oxford, N. Y	13	9	1797	+ 3.0	+ 4.5	+ 4.3	+ 4.0
Buffalo, N. Y	8	10	1806	+ 0.2	+ 5.1	+ 5.0	+ 4.8
Toronto, Canada	38	± 2	....	....	+ 4.8	+ 4.5	+ 2.3
Erie, Pa	10	13	1811	− 0.5	+ 4.4	+ 4.2	+ 4.0
Cleveland, Ohio	13	13	1790	− 2.0	+ 2.8	+ 2.5	+ 2.2
Detroit, Mich	10	10	1800	− 3.2	+ 3.4	+ 3.0	+ 2.8
Saint Louis, Mo	7	23	1800	− 9.5	+ 3.4	+ 3.2	+ 3.0
New York, N. Y	21	± 15	1797	+ 4.0	+ 2.4	+ 2.5	+ 2.6
Hatborough, Pa	(18)	6	1797	+ 1.8	+ 4.6	+ 4.5	....
Philadelphia, Pa	15	14	1800	+ 1.9	+ 4.9	+ 4.9	+ 5.3
Harrisburg, Pa	10	15	1790	0.0	+ 4.1	+ 3.3	+ 2.8
Baltimore, Md	17	17	1802	+ 0.6	+ 3.9	+ 3.6	+ 3.2
Washington, D. C	25	± 8	1796	0.0	+ 3.5	+ 3.2	+ 3.0
Cape Henry, Va	6	11	1814	+ 0.1	+ 3.8	+ 3.7	+ 3.6
Charleston, S. C	11	23	1784	− 4.9	+ 3.5	+ 3.0	+ 2.7
Savannah, Ga	5	15	1809	− 4.9	+ 3.6	+ 3.5	+ 3.3
Key West, Fla	11	3	1810	− 6.8	+ 4.3	+ 4.2	+ 4.1
Havana, Cuba	7	± 26	1801	− 6.5	+ 2.7	+ 2.7	+ 2.6
Kingston, Jamaica	11	21	1762	− 6.7	+ 2.0	+ 1.6	+ 1.4
Panama, New Granada	9	24	1739	− 8.6	+ 1.5	+ 1.4	+ 1.3
Rio Janeiro, Brazil	9	11	....	....	+ 9.7	+10.3	+10.7
Mobile, Ala	7	4	1841	− 7.1	+ 2.8	+ 3.4	+ 3.7
New Orleans, La	10	± 20	1830	− 8.2	+ 3.1	+ 3.5	+ 3.7
Vera Cruz, Mexico	9	25	1827	− 9.4	+ 4.2	+ 4.9	+ 5.2
Mexico, Mexico	11	10	1836	− 8.8	+ 2.8	+ 3.4	+ 3.7
Acapulco, Mexico	7	24	1845	− 9.0	+ 2.0	+ 2.7	+ 3.1
San Blas, Mexico	7	8	1846	− 9.2	+ 1.0	+ 1.6	+ 1.8
Magdalena Bay, Lower Cal	5	± 17	(1892)	−11.1	− 2.3	− 1.3	− 0.8
San Diego, Cal	6	6	(1925)	−14.2	− 1.9	− 1.7	− 1.6
Monterey, Cal	9	21	(1903)	−16.4	− 2.0	− 1.5	− 1.1
San Francisco, Cal	16	8	(1890)	−16.6	− 1.0	− 0.5	− 0.3
Cape Disappointment, Wash. Ter	5	12	(1932)	−23.5	− 3.4	− 3.1	− 2.7
Kailua, Sandwich Islands	9	± 20	1829	− 9.0	+ 2.4	+ 2.9	+ 3.2
Honolulu, Sandwich Islands	12	17	1812	−10.4	+ 2.1	+ 2.4	+ 2.6
Sitka, Alaska	21	18	1861	−29.1	+ 1.0	+ 2.1	+ 2.5
Unalashka, Alaska	11	16	1834	−19.8	+ 1.6	+ 1.9	+ 2.0
Petropavlovsk, Kamtchatka	9	16	1771	− 6.3	+ 3.2	+ 2.5	+ 2.2

* The maximum or westerly digression was reached in 1813, amount + 22°.9 nearly; hence, range between extremes, 32°.8 and half period, 233 years.


U.S. Coast and Geodetic Survey.
ANNUAL CHANGE OF THE MAGNETIC DECLINATION
for the epoch 1880
Region of small or no change, at present needle nearly stationary
Approximate present position to the N.E.
Agonic Line of 1790.
Agonic Line of 1880.
Note:
The annual change is expressed in minutes and decimals; a plus sign (+) indicates increase of west declination, or decrease of east declination; a minus sign (-) the reverse. To the right of an agonic line the declination is west (or +), to the left it is east (or -).
C. A. Schott.
Issued May 1881.
C. P. Patterson, Supt.
WASH.
OREG.
IDAHO
MONT.
WYO.
DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
NEV.
CAL.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W.VA.
VA.
KY.
TENN.
N.C.
S.C.
GA.
ALA.
MISS.
ARK.
LA.
TEX.
IND.T.
N.MEX.
ARIZ.
FLA.
PA.
N.Y.
N.J.
VT.
N.H.
ME.
MASS.
CONN.
MEXICO
YUCATAN
CUBA
SAN DOMINGO
PORTO RICO
JAMAICA
BERMUDA
+2·7 to +4·5
+3·0
+1·6
+2·7

The actual number of observations at Providence, R. I., and Hatborough, Pa., are unknown, and probably are less than one-fourth of the values used in the discussion. The probable errors given will serve to convey some idea of the relative value of each series of observations. The imperfections in the instrumental means and methods of the older observations in many cases react unfavorably on the modern observations, which are made with more precise instruments and by more refined methods. If we take, for instance, the observations of Hudson, made in 1609, in the vicinity of New York, we find each fairly chargeable with a probable error of about $\pm 4^\circ$. While these observations are very imperfect, those of Champlain of about the same period (1604 to 1612) are still cruder. These two navigators differ nearly 9° at the mouth of the Penobscot, Maine, and double this amount at Cape Cod. The observations made by Vancouver on our western coast, between 1792 and 1794, are subject to a probable uncertainty of $\pm 1^\circ$ (each). Increased precision was attained with the improvement of the azimuth compass and by allowance for disturbing effect of the ship's iron, and, with respect to shore stations, greater accuracy was obtained by the introduction of the theodolite for determining the astronomical meridian. With a portable magnetometer and a collimator magnet, the instrumental means need not introduce a greater uncertainty than about one minute; but the actual probable error of any determination is dependent also on the accidental variations in the mean direction of the magnetic force from day to day, thus making it desirable and indispensable for precise work to continue the observations for three or more days and to correct the results for diurnal variation. The amount of the probable error of the observed declination depends also on the intensity of the horizontal component of the magnetic force at the place, *i. e.*, in general the smaller the horizontal force the larger the apparent probable error.

To facilitate the use of the deduced annual change for bringing observations up to date, and for a more comprehensive general view of its distribution in sign and amount, the values of the last column but one of Table III were laid down on the accompanying chart bearing the title "Annual change of the magnetic declination," to which a few results derived from other sources, and discussed by means of exponential functions, have been added. It will be seen that the annual change has the positive sign for by far the greater part of the United States, a belt of negative sign lying along the western coast. Between these two areas there is a region of present little or no change, the outlines of which cannot now be exactly defined, nor has it been found, as yet, practicable to construct a system of curves of *equal annual change* (such as was attempted for a limited area in Coast Survey Report for 1865, plate No. 28). The maximum amount of annual change, as charted, is in the vicinity of Lake Champlain, with an indication that it may be surpassed in Wisconsin. The present motion of the isogonic curves is southward along our Atlantic and Pacific seaboards, but slowly northward in the vicinity of Sitka, thus pointing to a region of no annual change between that place and Vancouver's Island. There are also presented two agonic lines (or lines of zero declination, the magnetic needle pointing due north), one for the epoch 1790, when it and the system of isogonic lines in its neighborhood had reached nearly their extreme position to the northeast; the other for the epoch 1880; the space between them showing the shifting to the southwest of the first-named agonic line during the last 90 years. The agonic line is now in rapid motion to the south and west, carrying with it the system of other isogonic lines in its vicinity.

A cursory examination of the column containing the epoch of the greatest *easterly* digression, at which time the deflecting force producing the secular change had an easterly maximum, shows that in Western Europe (Paris) this phase of the secular motion occurred about 1580; but near the coast of the New England States the needle became stationary in direction and then reversed its previous angular motion at a very much later epoch, viz, about or before 1780. Going westward or southward, this epoch was observed later, about 1800, in Indiana or Illinois, and about 1810 in Florida. It occurred as late as 1836 (about) in Mexico, and 1835 (about) in Mississippi. The needle has not yet reached this state in Lower California and along the western coast south of Vancouver's Island. This stationary condition may be expected on our western coast south of the Columbia River toward the close of the present or early in the next century.

We are thus directed to look to the extreme northeastern limit of the United States for probable indications of the magnetic change, which may be expected to follow and spread from the seaboard westward and southward. Respecting this secular change the phases of the phenomenon on the coast of Maine and the coast of California are almost in opposition. At the time when the needle took up its *westerly* motion in our Northeastern States in the last quarter of the past century, it had but for a short time acquired its *easterly* motion in the States of the western coast. At present in Nova Scotia the motion appears to be approaching its westerly extreme, and in California it is tending toward its easterly extreme.

If we fix now for a moment our attention to the opposite or *western* extreme of stationary condition, which happened at Paris about 1813, or 68 years ago, we find that at Saint John's, Newfoundland, the needle had arrived at this phase about 1859, and at Halifax, Nova Scotia, we are led to expect it to occur shortly (about 1891). In the State of Maine, and further on to the west and south, this phase is expected to occur some time in the next century. We thus see the progressive motion of the secular change from eastern to western countries, and are enabled to take a more comprehensive view of the whole phenomenon.

Looking over the numerical values of a in Table I, they would imply a secular-change cycle for stations in the United States extending over or varying between the limits of about 220 and 360 years; the numbers themselves are, however, yet very uncertain.

On a third plate appended to this paper I have delineated the secular change of the agonic line of the North Atlantic, to illustrate the effect of the change in the declination in a manner quite different from tabular numbers. It shows the position of this agonic line for the epochs 1500, 1600, 1700, 1800, also for 1880 and 1900. The earliest position is more or less conjectural, and rests on the authority of Columbus for its place near the Middle Atlantic; we also know that it must have passed over a region near Paris, France, and not far from a region including the Antilles. The position for 1600 is taken from Hansteen's work (1819) and may be considered as a rough approximation; it has been corrected by me near its western end. The position for 1700 is more reliable, since it depends on numerous observations collected by Halley; it is taken from his chart. The positions for 1800 and 1880 require no further explanation. The position for 1900, though prospective, is quite certain. Upon the whole, the azimuthal motion of the isogonic system in the vicinity of the agonic line of the North Atlantic, and as represented by this line, has been, since 1600, in the direction of the hands of a watch.

TABLE OF DECENNIAL VALUES OF THE MAGNETIC DECLINATION COMPUTED FROM PRECEDING EQUATIONS.

Table IV has been constructed for the purpose of facilitating the reduction of observed declinations from one epoch to another, and for supplying the Coast Survey charts with the latest deducible declinations. These values will be found especially useful when old lines, originally run by compass needle, have to be retraced at a later date, and they are also required for the construction of isogonic charts for a given epoch.

Two places of decimals are given for all localities and dates for which the observations were considered reliable; one place of decimals indicates a less satisfactory result, and blanks indicate that no trustworthy results, or no results at all, could be had. The table should *not be extended* either by interpolation or by extrapolation beyond its given limits except when supported by new evidence or new observations. The declinations are given in degrees and decimals of a degree, a + sign indicating west and a − sign east declination. The epoch is the first day of the year given.

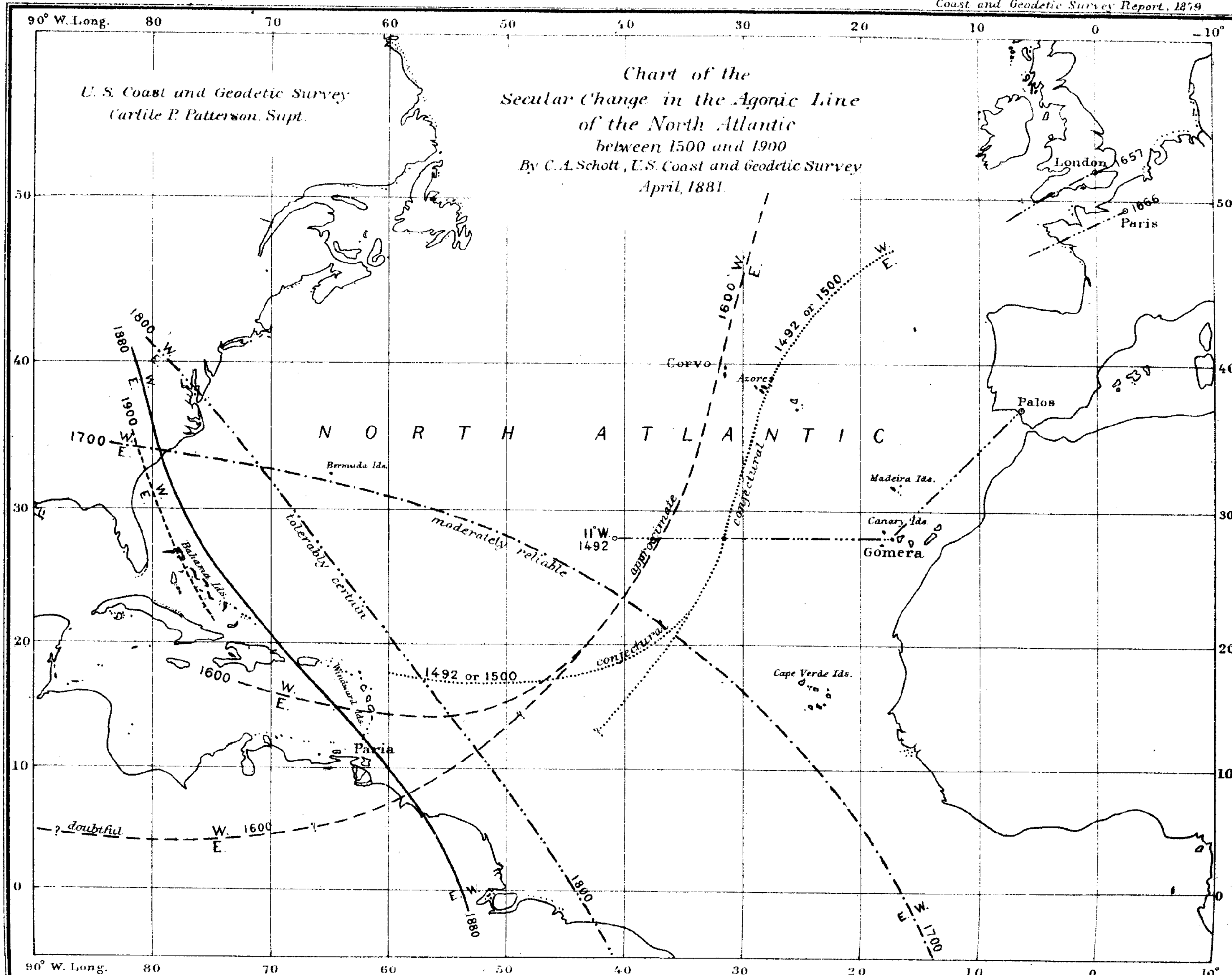


Chart of the
Secular Change in the Agonic Line
of the North Atlantic
between 1500 and 1900
By C. A. Schott, U.S. Coast and Geodetic Survey
April, 1881
U. S. Coast and Geodetic Survey
Carlile P. Patterson, Supt.
90° W. Long.
NORTH ATLANTIC
Bermuda Ids.
Bahama Ids.
Windward Ids.
Paria
Corvo
Azores
Madeira Ids.
Canary Ids.
Gomera
Cape Verde Ids.
Palos
London
Paris
1657
1666
11° W. 1492
1492 or 1500
1600
1700
1800
1880
1900
moderately reliable
tolerably certain
approximate
conjectural
doubtful

TABLE IV.

Year.	Paris, France.	Halifax, N. S.	Quebec, Canada.	Montreal, Canada.	York Factory, Hudson Bay.	Portland, Me.	Burlington, Vt.	Rutland, Vt.	Portsmouth, N. H.	Newburyport, Mass.	Salem, Mass.	Boston, Mass.	Cambridge, Mass.	Nantucket, Mass.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1540	− 6.9	....	....	....	....	....	....	....	....	....	....	....	....	....
50	8.1	....	....	....	....	....	....	....	....	....	....	....	....	....
60	9.0	....	....	....	....	....	....	....	....	....	....	....	....	....
70	9.7	....	....	....	....	....	....	....	....	....	....	....	....	....
80	9.9	....	....	....	....	....	....	....	....	....	....	....	....	....
90	− 9.7	....	....	....	....	....	....	....	....	....	....	....	....	....
1600	− 9.0	....	....	....	....	....	....	....	....	....	....	....	....	....
10	7.9	....	....	....	....	....	....	....	....	....	....	....	....	....
20	6.7	....	....	....	....	....	....	....	....	....	....	....	....	....
30	5.4	....	....	....	....	....	....	....	....	....	....	....	....	....
40	4.0	....	+16.2	....	....	....	....	....	....	....	....	....	....	....
50	2.6	....	....	....	....	....	....	....	....	....	....	....	....	....
60	− 1.0	....	....	....	....	....	....	....	....	....	....	....	....	....
70	+ 0.8	....	....	....	....	....	....	....	....	....	....	....	....	....
80	2.9	....	....	....	....	....	....	....	....	....	....	....	....	....
90	+ 5.2	....	+17.6	....	....	....	....	....	....	....	....	....	....	....
1700	+ 7.6	+13.0	+17.1	....	....	....	....	....	....	....	....	+10.0	+ 9.8	....
10	10.0	12.6	+16.1	....	....	....	....	....	....	....	....	9.4	9.2	....
20	12.3	12.5	....	....	+18.6	....	....	....	....	....	....	8.7	8.7	....
30	14.2	12.4	....	....	19.2	....	....	....	....	....	....	8.1	8.3	....
40	15.8	12.5	....	+11.9	18.8	....	....	....	....	....	....	7.6	7.9	....
50	17.2	12.8	....	10.5	17.2	....	....	....	....	....	....	7.1	7.5	....
60	18.5	13.2	....	9.5	14.8	+ 8.1	....	....	....	....	....	6.8	7.2	....
70	19.7	13.7	+12.5	8.9	11.6	8.1	....	....	+ 7.9	+ 7.2	....	6.6	7.0	+ 6.6
80	20.8	14.3	12.44	8.7	7.9	8.2	....	+ 7.1	7.6	7.0	+ 6.3	6.6	6.9	6.5
90	+21.8	+15.0	+12.33	+ 8.4	+ 4.0	+ 8.5	+ 7.4	+ 6.6	+ 7.5	+ 7.0	+ 6.2	+ 6.72	+ 6.9	+ 6.6
1800	+22.5	+15.8	+12.15	+ 8.0	+ 0.1	+ 8.9	+ 7.3	+ 6.3	+ 7.6	+ 7.2	+ 6.3	+ 6.98	+ 7.1	+ 6.8
10	22.9	16.5	12.06	7.7	− 3.3	9.4	7.23	6.23	7.8	7.6	6.6	7.38	7.5	7.2
20	22.8	17.3	12.23	7.7	6.1	10.0	7.49	6.46	8.3	8.1	7.2	7.88	8.0	7.69
30	22.3	18.1	12.78	8.2	8.1	10.6	8.14	6.93	8.88	8.7	7.9	8.47	8.64	8.27
40	21.3	18.7	13.70	9.3	9.0	11.23	8.95	7.61	9.59	9.4	8.8	9.11	9.33	8.90
50	20.1	19.4	14.83	10.7	8.8	11.82	9.66	8.46	10.37	10.17	9.7	9.78	10.03	9.55
60	18.7	19.9	15.95	12.1	7.5	12.35	10.26	9.41	11.16	10.92	10.7	10.43	10.67	10.20
70	17.3	20.2	16.82	13.1	− 5.3	12.80	10.98	10.41	11.92	11.6	11.5	11.03	11.21	10.78
80	+15.8	+20.5	+17.31	+13.8	....	+13.13	+11.91	+11.38	+12.60	+12.2	+12.3	+11.56	+11.63	+11.29
188[illegible]	+15.1	+20.5	+17.40	+14.1	....	+13.25	+12.41	+11.84	+12.90	....	+12.6	+11.78	+11.78	+11.50

Table IV—Continued.

Year.	Providence, R. I.	Hartford, Conn.	New Haven, Conn.	Albany, N. Y.	Oxford, N. Y.	Buffalo, N. Y.	Toronto, Canada.	Erie, Pa.	Cleveland, Ohio.	Detroit, Mich.	St. Louis, Mo.	New York, N. Y.	Hatborough, Pa.	Philadelphia, Pa.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1600	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	....	....	....	....	....	....
70	....	....	....	....	....	....	....	....	....	....	....	....	....	....
80	....	....	....	....	....	....	....	....	....	....	....	+8.8	+8.5	....
90	....	....	....	....	....	....	....	....	....	....	....	+8.8	+8.3	....
1700	....	....	....	....	....	....	....	....	....	....	....	+8.5	+7.9	+8.9
10	+ 10.4	....	....	....	....	....	....	....	....	....	....	8.0	7.5	8.5
20	9.5	....	....	....	....	....	....	....	....	....	....	7.6	7.0	7.7
30	8.9	....	....	....	....	....	....	....	....	....	....	7.2	6.3	7.3
40	8.4	....	....	....	....	....	....	....	....	....	....	6.6	5.6	6.6
50	7.7	....	....	....	....	....	....	....	....	....	....	5.9	4.7	5.7
60	6.9	....	+ 6.14	....	....	....	....	....	....	....	....	5.2	3.8	4.6
70	6.3	....	5.55	....	....	....	....	....	....	....	....	4.6	2.9	3.5
80	6.12	+ 5.4	5.09	....	....	....	....	+ 0.45	....	....	....	4.4	2.2	2.6
90	+ 6.24	+ 5.2	+ 4.79	....	+ 3.01	+ 0.25	....	− 0.02	− 2.0	....	....	+4.26	+1.8	+2.1
1800	+ 6.37	+ 5.16	+ 4.67	....	+ 2.96	+ 0.03	....	− 0.33	− 1.9	− 3.18	....	+4.25	+1.8	+1.9
10	6.45	5.24	4.74	+ 5.4	3.10	0.02	....	0.45	1.7	3.11	−9.4	4.27	2.03	2.11
20	6.73	5.46	4.98	5.81	3.40	0.22	....	0.37	1.4	2.90	9.2	4.44	2.53	2.54
30	7.43	5.80	5.39	6.35	3.87	0.60	+ 0.8	− 0.10	1.06	2.55	8.9	4.88	3.17	3.07
40	8.31	6.24	5.95	7.00	4.46	1.16	1.32	+ 0.34	0.61	2.09	8.4	5.56	3.86	3.63
50	9.09	6.77	6.61	7.74	5.14	1.85	1.61	0.92	− 0.12	1.56	7.95	6.31	4.57	4.18
60	9.65	7.36	7.35	8.49	5.89	2.64	2.17	1.60	+ 0.38	0.99	7.39	6.93	5.29	4.76
70	10.21	7.99	8.10	9.23	6.65	3.48	2.66	2.32	0.87	− 0.41	6.83	7.40	6.0	5.45
80	+ 10.9	+ 8.62	+ 8.84	+ 9.90	+ 7.38	+4.32	+ 3.62	+ 3.04	+ 1.31	+ 0.13	−6.28	+7.81	+6.8	+6.26
1885	....	+ 8.92	+ 9.19	+10.19	+ 7.73	+ 4.73	+ 3.88	+ 3.39	+ 1.51	+ 0.37	−6.0	+8.03	....	+6.70

TABLE IV—Continued.

Year.	Harrisburg, Pa.	Baltimore, Md.	Washington, D. C.	Cape Henry, Va.	Charleston, S. C.	Savannah, Ga.	Key West, Fla.	Havana, Cuba.	Kingston, Jamaica.	Panama, New Granada.	Rio Janeiro, Brazil.	Mobile, Ala.	New Orleans, La.	Vera Cruz, Mexico.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1600	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	....	....	....	....	....	....
70	....	+5.7	....	....	....	....	....	....	....	....	....	....	....	....
80	....	5.8	....	....	....	....	....	....	....	....	....	....	....	....
90	....	+5.7	....	....	....	....	....	....	....	....	....	....	....	....
1700	....	+5.4	....	....	....	....	....	....	....	....	....	....	....	....
10	....	5.0	....	....	....	....	....	....	....	....	....	....	....	....
20	....	4.5	....	+4.4	....	....	....	−4.0	....	....	....	....	−3.3	2.0
30	....	3.9	....	3.9	....	....	....	4.4	−6.2	....	....	....	3.6	2.9
40	....	3.2	....	+3.4	....	....	....	−4.9	−6.5	....	....	....	4.1	3.9
50	....	2.6	....	....	....	....	....	....	....	....	....	....	4.7	4.8
60	....	2.0	....	....	....	....	....	....	....	....	−7.86	....	5.3	5.8
70	....	1.46	....	....	−4.7	....	....	....	....	−8.4	7.39	....	5.9	6.7
80	....	1.04	....	....	4.9	....	....	....	....	8.3	6.81	....	6.5	7.5
90	−0.05	+0.76	+0.0	....	−4.9	....	....	....	−6.3	−8.1	−6.13	....	−7.0	−8.2
1800	+0.04	+0.64	+0.0	+0.3	−4.7	....	....	....	−6.1	−7.8	−5.33	−5.8	−7.52	−8.7
10	0.35	0.68	0.1	0.1	4.4	−4.9	....	−6.5	5.7	7.6	4.43	6.3	7.88	9.2
20	0.83	0.88	0.4	0.2	3.97	4.8	−6.7	6.3	5.3	7.3	3.41	6.73	8.11	9.4
30	1.45	1.23	0.8	0.35	3.44	4.5	6.48	6.1	4.9	7.04	2.30	6.99	8.18	9.4
40	2.17	1.70	1.29	0.68	2.84	4.14	6.06	5.8	4.5	6.76	−1.06	7.09	8.10	9.27
50	2.94	2.27	1.85	1.14	2.20	3.65	5.52	5.42	4.1	6.47	+0.28	7.01	7.88	8.95
60	3.71	2.90	2.45	1.70	1.56	3.08	4.88	4.99	3.7	6.20	1.73	6.77	7.52	8.46
70	4.43	3.55	3.04	2.31	0.95	2.48	4.18	4.54	3.3	5.9	3.28	6.38	7.05	7.82
80	+5.05	+4.17	+3.61	+2.94	−0.41	−1.89	−3.47	−4.09	−3.0	−5.7	+4.96	−5.86	−6.49	−7.05
1885	+5.30	+4.47	+3.87	+3.25	−0.17	−1.60	−3.12	−3.9	....	....	+5.83	−5.56	−6.18	−6.6

TABLE IV—Continued.

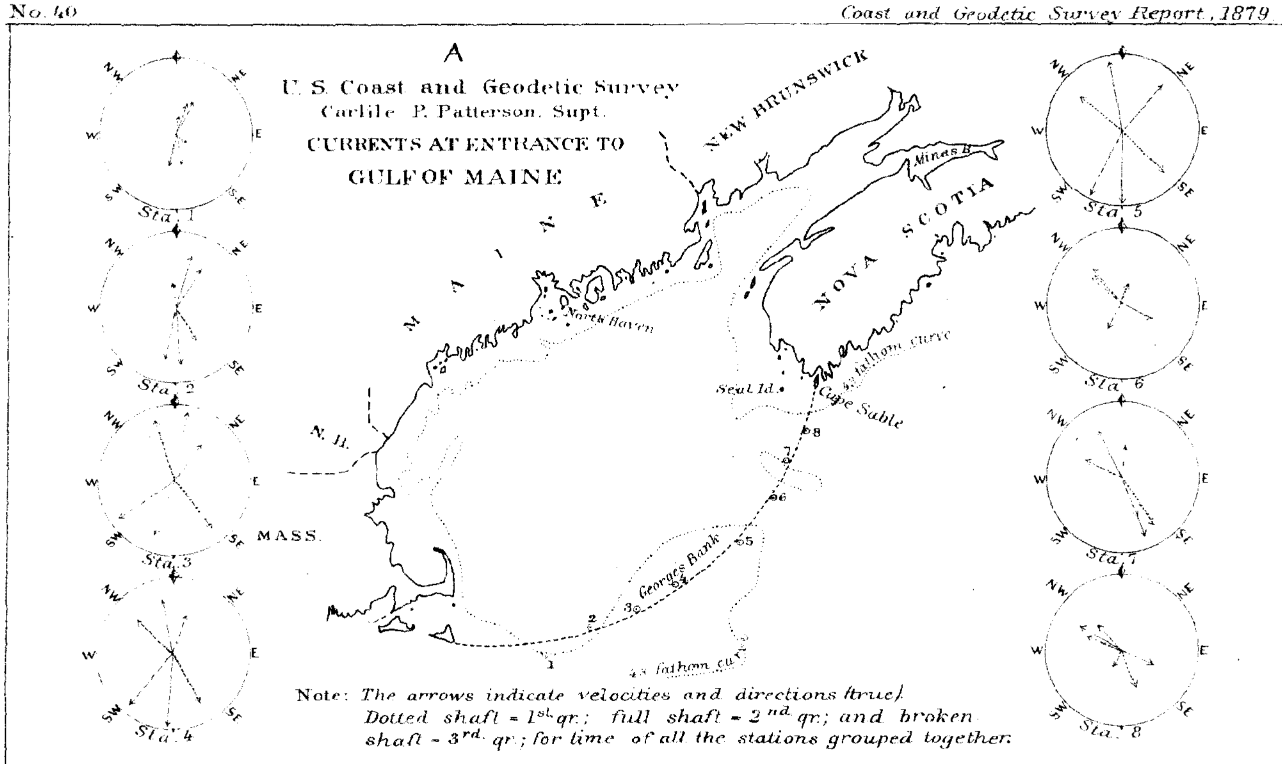
Year.	Mexico, Mexico.	Acapulco, Mexico.	San Blas, Mexico.	Magdalena Bay, Lower Cal.	San Diego, Cal.	Monterey, Cal.	San Francisco, Cal.	Cape Disappointment, Wash. Ter.	Kailua, Sandwich Islands.	Honolulu, Sandwich Islands.	Sitka, Alaska.	Unalashka, Alaska.	Petropavlovsk, Kamtchatka.
	°	°	°	°	°	°	°	°	°	°	°	°	°
1600	....	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....
40	....	....	....	....	....	....	....	....	....	....	....	....	....
50	....	....	....	....	....	....	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	....	....	....	....	....
70	....	....	....	....	....	....	....	....	....	....	....	....	....
80	....	....	....	....	....	....	....	....	....	....	....	....	....
90	....	....	....	....	....	....	....	....	....	....	....	....	....
1700	....	....	....	....	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	....	....
40	....	−3.1	....	....	....	....	....	....	....	....	....	....	....
50	....	3.9	....	....	....	....	....	....	....	....	....	....	....
60	−5.2	4.7	....	....	....	....	....	....	....	....	....	....	....
70	6.0	5.5	....	....	....	....	....	....	....	....	....	−18.3	−6.3
80	6.7	6.3	....	....	....	....	....	....	−7.8	....	−25.2	18.7	6.26
90	−7.4	−7.0	−7.3	....	−11.0	−11.4	−12.8	−18.0	−8.2	....	−25.8	−19.03	−6.06
1800	−7.90	−7.6	−7.8	....	−11.1	−12.0	−13.3	−18.1	−8.6	....	−26.4	−19.31	−5.72
10	8.34	8.1	8.2	....	11.3	12.6	13.9	18.4	8.8	−10.4	27.1	19.54	5.25
20	8.64	8.53	8.6	....	11.6	13.3	14.42	18.7	8.9	10.4	27.73	19.70	4.69
30	8.81	8.81	8.87	−8.1	11.9	13.9	14.93	19.2	9.0	10.3	28.30	19.78	4.06
40	8.83	8.95	9.06	8.87	12.20	14.44	15.40	19.72	8.9	10.2	28.74	19.77	3.39
50	8.71	8.96	9.15	9.59	12.54	14.95	15.80	20.29	8.8	10.0	29.02	19.68	2.72
60	8.44	8.81	9.14	10.20	12.88	15.42	16.13	20.88	8.5	9.7	29.13	19.51	2.08
70	8.05	8.55	9.03	10.66	13.20	15.79	16.37	21.46	8.2	9.4	29.05	19.27	1.51
80	−7.53	−8.2	−8.8	−10.98	−13.50	−16.08	−16.52	−22.00	−7.7	−9.0	−28.79	−18.97	−1.03
1885	−7.23	−7.9	−8.7	−11.1	−13.64	−16.19	−16.56	−22.26	−7.5	−8.8	−28.6	−18.8	−0.83

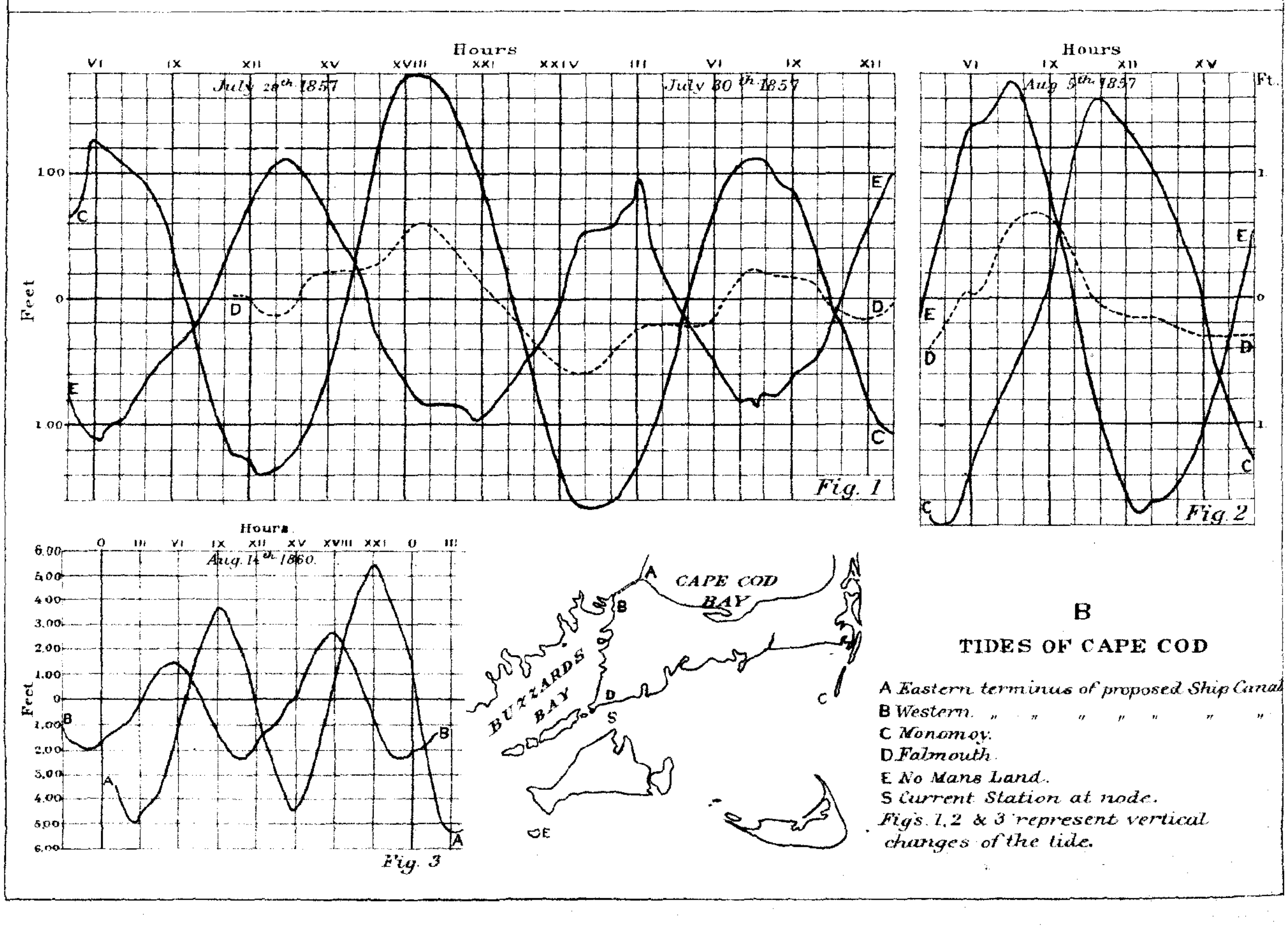
Although the writer has made some attempts to investigate the secular change of the magnetic dip,* and of the magnetic horizontal intensity,† neither of these subjects admits of such precision and range as could be given to the discussion of the declination, and for them in particular the use of a circular function in the place of an exponential function is as yet hopeless. The cause is sufficiently evident; with us, reliable observations for dip hardly date back to the year 1790 on the western coast, while on the eastern coast there are but few observations earlier than the year 1833. Respecting recorded horizontal intensities, there are but a few determinations made in the United States prior to 1830, these and other early observations are, of course, only of a differential character.‡

* See preliminary investigation in Coast Survey Report for 1856, Appendices Nos. 32 and 33.

† See preliminary investigation in Coast Survey Report for 1861, Appendix No. 22.

‡ In 1833, Gauss showed how the magnetic force could be expressed in absolute measure. In 1836, Professor Weber applied the principle to the small portable instruments, since in use; in 1838, he introduced the collimator magnet as proposed by Sir George B. Airy. For reference the English reader may consult vol. ii of R. Taylor's Scientific Memoirs, London, 1841.


A
U. S. Coast and Geodetic Survey
Carlile P. Patterson. Supt.
CURRENTS AT ENTRANCE TO
GULF OF MAINE
NEW BRUNSWICK
NOVA SCOTIA
MAINE
N. H.
MASS.
Minas B.
North Haven
Seal Id.
Cape Sable
Georges Bank
fathom curve
Sta. 1
Sta. 2
Sta. 3
Sta. 4
Sta. 5
Sta. 6
Sta. 7
Sta. 8
Note: The arrows indicate velocities and directions (true).
Dotted shaft = 1st qr.; full shaft = 2nd qr.; and broken shaft = 3rd qr.; for time of all the stations grouped together.


Hours
July 29th 1857
July 30th 1857
Feet
Fig. 1
Aug 5th 1857
Fig. 2
Hours
Aug. 14th 1860.
Feet
Fig. 3
CAPE COD BAY
BUZZARDS BAY
B
TIDES OF CAPE COD
A Eastern terminus of proposed Ship Canal
B Western " " " " " "
C Monomoy.
D Falmouth.
E No Mans Land.
S Current Station at node.
Figs. 1, 2 & 3 represent vertical changes of the tide.

APPENDIX No. 10.

PHYSICAL HYDROGRAPHY OF THE GULF OF MAINE, BY HENRY MITCHELL, ASSISTANT UNITED STATES COAST AND GEODETIC SURVEY.

BOSTON, *October* 10, 1878.

DEAR SIR: In accordance with your instructions, I have attempted a careful study of the data accumulated by the Coast Survey in the approaches to the New England coast, and the following pages are offered as the result, in part, of this study. Free to draw any inferences from the data that seemed warrantable, I have ventured upon some inductions, which, if they serve no other purpose than stepping-stones to wider and firmer conclusions, will justify themselves.

GENERAL DESCRIPTION.

The great bend of the coast between Nova Scotia and New England, which includes the Bay of Fundy, Massachusetts Bay, &c., as subsidiary features, has recently received the general designation *Gulf of Maine*. (See Diagram A.)

The seaward limit of this gulf is marked by a chain of shoals, forming, in effect, a submerged weir or barrier intersected by several channels which separate and distinguish shallow districts known as Nantucket Shoals, George's Bank, Brown Bank, and Seal Island Bank. The channels themselves have received no distinctive names upon the chart and none are known to be in general or uniform use. I have therefore adopted the following as perhaps the most ordinary titles: *Great South Channel*, lying between Nantucket Shoals and George's Bank; *Great Eastern Channel*, lying between the aforesaid bank and Brown Bank; and *Northern Channel*, lying between Brown Bank and Seal Island Bank.

Of the two isolated banks, George's is distinguished from Brown as a danger to navigation, the former presenting several spots shallow enough to fetch up vessels of ordinary draught, while the latter has nowhere less than 30 fathoms by chart.

After crossing the threshold and entering the gulf, the navigator finds himself "*off soundings*," in the ordinary use of the phrase; for between the chain of shoals at the entrance and the aproning of the coast within, a broad belt or basin of deep water is found. With a little stretch of the imagination one may conceive of the Gulf of Maine as a bowl with a break in its rim.

I shall use the word *sill* to designate specifically the line of least section along the chain of shoals from Nantucket to Cape Sable, because, as will presently be obvious, the words dam, weir, and bar, as we ordinarily use them, mean too much. I find the *sill*, then, lying on the arc of a circle of 167½ nautical miles radius, with nearly a quadrant of development convex toward the ocean. The length of this arc from Nantucket to Cape Sable is 259 nautical miles, and upon its site the mean depth is 43 fathoms, giving a section of 406,000,000 of square feet. Along the chord of this arc, *i. e.*, in a straight line from Nantucket to Cape Sable, we find the distance 235 miles and the average depth 76 fathoms, giving a section of 651,000,000 square feet, or about 50 per cent. more water way than is found over the sill.

The whole area of the gulf within the sill is 36,000 square miles, in round numbers, of which over 10,000 square miles have depths exceeding 100 fathoms. The greatest depth in the western portion of the gulf is 180 fathoms, about 46 miles eastward from Cape Ann, and the greatest depth in the eastern portion of the gulf is 184 fathoms, about 67 miles southwestward from Seal Island light. The general average for the entire gulf, including all its navigable bays and angles, may be set down at 75 fathoms at least.

Were the level of the sea to fall 43 fathoms, *i. e.*, to the present average level of the sill, the gulf would hardly lose one-third of its present area. It would still offer an expanse of 24,000 square miles; but instead of 259 miles width of entrance there would be but 50 miles, divided by

Brown Bank into two channels; in other words, the *sill* would emerge throughout some 200 miles of its whole development. There are indications of a state of things not unlike this, *in effect*, as having once existed. No general subsidence need be assumed, but simply the long continuance of familiar agencies, to assist the imagination to the conception of the Gulf of Maine as once a nearly inclosed sea. The dash of the waves and the scour of currents may accomplish as much as this, for "*nature doesn't lack time*," says the proverb, and here there is uninterrupted exposure in one direction half way round the globe, and great tidal movements.*

The coast of Nova Scotia, especially in the neighborhood of Cape Sable, is ragged with the wrecks of islands and headlands, which the people of the province call "*thrums*"—a word which is only provincial in this happy application. Cape Cod and Nantucket are thrums, and have crumbled into the sea to a considerable extent within my own experience as an observer. Mr. H. L. Marindin's comparison of the several plane-table surveys of the Chatham shore (page 106, Coast Survey Report, 1873) shows that the beach at this place had fallen back 700 feet since 1847, and Mr. D. Koppmann, engineer of the Massachusetts Harbor Commission, is my authority for the statement that "during the past year the crest of the glacial bluff on which the light-house stands has fallen back 46 feet before the dash of the sea. In the same way the southeastern portion of Nantucket Island, which is a glacial deposit of considerable elevation, has been encroached upon to such an extent that the site of a row of houses existing at the time of my father's survey, in 1838, at Siasconsett, is now beyond the breaker line, although a broad beach lies between the present cliff and the sea.

On the Cape Sable shore, *Chabert's* survey of 1750, compared with the recent survey of Captain Shortland, R. N., shows but little wear: the shores, strewn with rocks, resist the wear of the sea on this side, so that the enlargement of the gulf is almost entirely to the westward, and is not likely to be arrested by the uncovering of ledges till the meridian of 70° 30′ is reached, which passes within a mile of the Plymouth shore. When this is accomplished, the entrance to the gulf will be increased about 26 nautical miles, or over 10 per cent. of the present width.

St. George's Bank, the summit of which is called George's Shoal, is probably a wasted island. It is covered with pebbles and small stones, except in shallow portions and pot-holes, where the material ground down by the sea has accumulated. This may fairly be inferred from the official report of Captain Hull and the chart of Lieutenant Wilkes.

Capt. Isaac Hull, U. S. N., made note, in 1815 (?), of the assertion of Cape Cod fishermen that "part of the shoal has been seen quite dry, with gulls sitting upon it," and states that his own shoalest water was three feet after subtracting over seven feet for height of tide. There would seem to be no reason why the sands should not heap up occasionally so as to emerge at low tide; but the testimony is not direct, and I find much the same report mentioned with discredit in Hollingsworth's Nova Scotia, printed in 1786.

To what limiting depth the erosive action of waves extends has never been determined. We hear of sunken vessels broken up during violent gales that had lain previously in twenty fathoms; and Captain Tower, of the Boston Marine Society, is my authority for the statement that a diver of his, on the coast of Maine, having coiled a chain about his waist for extra weight, ventured down to the deck of a vessel twenty-three fathoms below the surface, and there noticed that ropes were swaying to and fro, and that the end of his chain was whipped about by the passing swell. In the case before us the tidal currents have been introduced as working forces as soon as the waves have removed the dry land; this has been noticed on the eastern shore of Nantucket particularly, where we find strong currents in localities only recently occupied by the sea; and in the great channels on either side of George's Bank the currents, although more feeble than those upon the shallow ground, have greater resultant power for the removal of material. There are strong flood and ebb streams over George's Bank, but these are nearly *in equilibrio* so that the shoal is no doubt maintained rather than reduced by their action. It was during the physical survey of New York Harbor in 1859 that it first occurred to me that I could treat the hourly current observations of a tidal day as simultaneous forces, where their influence upon a sandy bottom was in question,

* In a previous paper, entitled "Notes concerning the alleged changes in the relative elevations of land and sea," evidence is produced to show that the shores of the Gulf of Maine have undergone no vertical change since the voyage of Champlain in 1606.

and this mode of treatment soon revealed the causes of shoals of light sand in the midst of strong tides. It will be seen, from the tables that I shall presently refer to, that the currents over George's, worked up by *composition of forces*, give but a small and doubtful resultant. The summit of this shoal is a quicksand, never at rest but never escaping, and this condition of *unstable equilibrium* must continue till the unequal wear of the shores has materially altered the tidal fluxes.

The narrowest section at the entrance to the gulf is found between Cape Cod (just below Highland Lights) and Seal Island, Nova Scotia, where the distance is about 198 miles. Here the average depth is 90 fathoms (double the average depth upon the Sill), and the section is 650,000,000 square feet.

As compared with the chord of the circular Sill, before described, the variation of depth is found to be about in the inverse ratio of the width, and the section, therefore, very nearly constant. The agreement between these two sections, as regards area, or the slight decline which is in about the right proportion to tidal volume, might, in the absence of other facts, seem to indicate that the opening was the result of scour, in the same sense that we should speak of the section of an inlet through an alluvial coast; but when we come to the Sill and find the section more than 50 per cent. less, the semblance ceases. A bar at a river's mouth or at an inlet through the littoral cordon, presents, *in plan*, something very like what we have here, but not in *elevation*, for the bar cannot have less section than the river or inlet itself, under ordinary circumstances.

TIDES AND TIDAL CURRENTS.

The soundings over this region of our coast approaches were completed a few years ago, and made it possible to compute the area of entrance section and the average rate at which the currents should flow in order to fill and drain the great tides observed within. This computation did not enable us to determine the directions of the currents, except in a general way, and left us altogether in doubt as to the distribution of velocities. It was evident that the rate could not be uniform for the whole width of the entrance, or the time of turning from ebb to flood everywhere the same, but whether the current should flow more or less rapidly in deep than in shallow portions could not be foreseen. In rivers where the bed is alluvial, the thread of greatest velocity is coincident with the track of greatest depth, at least in straight sections; at the bars of tidal rivers and inlets the same is true, especially if we consider both flood and ebb as joint agents; but in the case before us we had from popular report and from such observations as had been made upon George's Shoal by Hull, Wilkes, and Howell, an intimation that the usual rules for bars would not apply, and this induced you to issue instructions to Master Robert Platt, of the Coast Survey schooner Drift, to make observations all along the line of least section.

These current observations, made with faithfulness and skill, have widened our knowledge of the peculiar tides of this section of the country and induced this report, which is designed to bring into accord and unite into one chain the various observations and studies that have been made in this section since 1854.

The tides of this region are peculiar in the respects that they present an abrupt departure from the general rule for the tide on this side of the Atlantic and are accompanied by strong tidal currents which often sweep vessels, especially those under sail, out of their reckoning. These peculiarities have been long known among seafaring men in a general way, but to Prof. A. D. Bache, our former Superintendent, belongs the credit of having first made them the subject of scientific inquiry, while it has remained for you to bring this inquiry to a practical focus by supplementing the coastwise observations of Professor Bache by others wide out at sea directly in the track of the mariner.

There is a popular rule among our coasters and fishermen which runs thus: "*To the southward of Nantucket southeast moon makes high water; to the northward of Nantucket south moon makes it.*"

It would be nearly as correct to say, *along the ocean frontage of the American coast, from the straits of Belle Isle to the straits of Flórida, southeast moon makes high water, except in the Gulf of Maine, where "south moon makes it:"* for leaving out the stations between Cape Sable and Nantucket, it will be seen from the tide tables that the characteristic lunar interval is seven and a half hours from York Point, Labrador, to Cape Canaveral, in Florida.*

* The Bermuda and Bahama outer islands fall under this rule nearly, while the Placentia district of Newfoundland presents, albeit in less degree, the anomalies found on the western shore of Cape Sable.

The objections to this rule, from a critical point of view, are obvious. There is no such phenomenon as *southeast moon* known to the almanac; and *south moon*, unless the magnetic meridian is used, occurs too late, except at the syzygies, to represent the approximate time of high water along the eastern shore of Massachusetts and upon the coast of Maine.

The entrance to the Gulf of Maine is the scene of a transition, which is practically the birth of a new and abnormal tide destined to become a monster in the Bay of Fundy.

In reviewing the early observations, some of which I had the honor to conduct under the superintendency of Professor Bache, his successor, Professor Peirce, suggested that we should try the hypothesis of a *node* in discussing the observations, and this has proved a valuable hint as new data have been procured.

Assuming that the existence of a node might be due, in some degree at least, to the configuration of the coast and ocean bed, I have premised that the nodal line is coincident with the arc of least section or the *Sill* of the gulf.

In the following table the times and heights of the tide are given at numerous points between Block Island, R. I., and Halifax, Nova Scotia:

TABLE I.

Station.	Establishment.	Range.	
Block Island	VII ½	2.8	
No-man's Land	VII ½	2.0	
Smith's Point	VII ¾	2.2	
Weweeder	Shifts.	1.5	Nantucket Island (outside).
Siasconsett	XI ¾	2.0	
Great Point	XII	3.4	
Monomoy	XII	3.8	Cape Cod.
Provincetown	XI ⅓	9.2	
Boston Light	XI ¼	9.3	
Portland	XI ¼	9.1	
North Haven	XI $\frac{1}{10}$	9.7	Entrance to Penobscot Bay.
Eastport	XI ⅓	18.2	
St. John	* XI ⅓	25.0	
Cumberland Basin	* XI ¾	41.6	Bay of Fundy.
Basin of Mines	XII	40.0	
Yarmouth	* X ¼	? 13.0	
Clark's Harbor (west side Cape Sable Island)	VIII ¾	7.6	Cape Sable.
Donald (east side of Cape Sable Island)	VIII ¼	5.5	
Halifax	* VII ¾	5.2	
St. George's Shoal	* XI	1.5	Des Barres—Atlantic Neptune, 1781.
	....	7.5	Capt. Isaac Hull, U. S. N., 1821.
	* X ½	7.0	Capt. Chs. Wilkes, U. S. N., 1837.

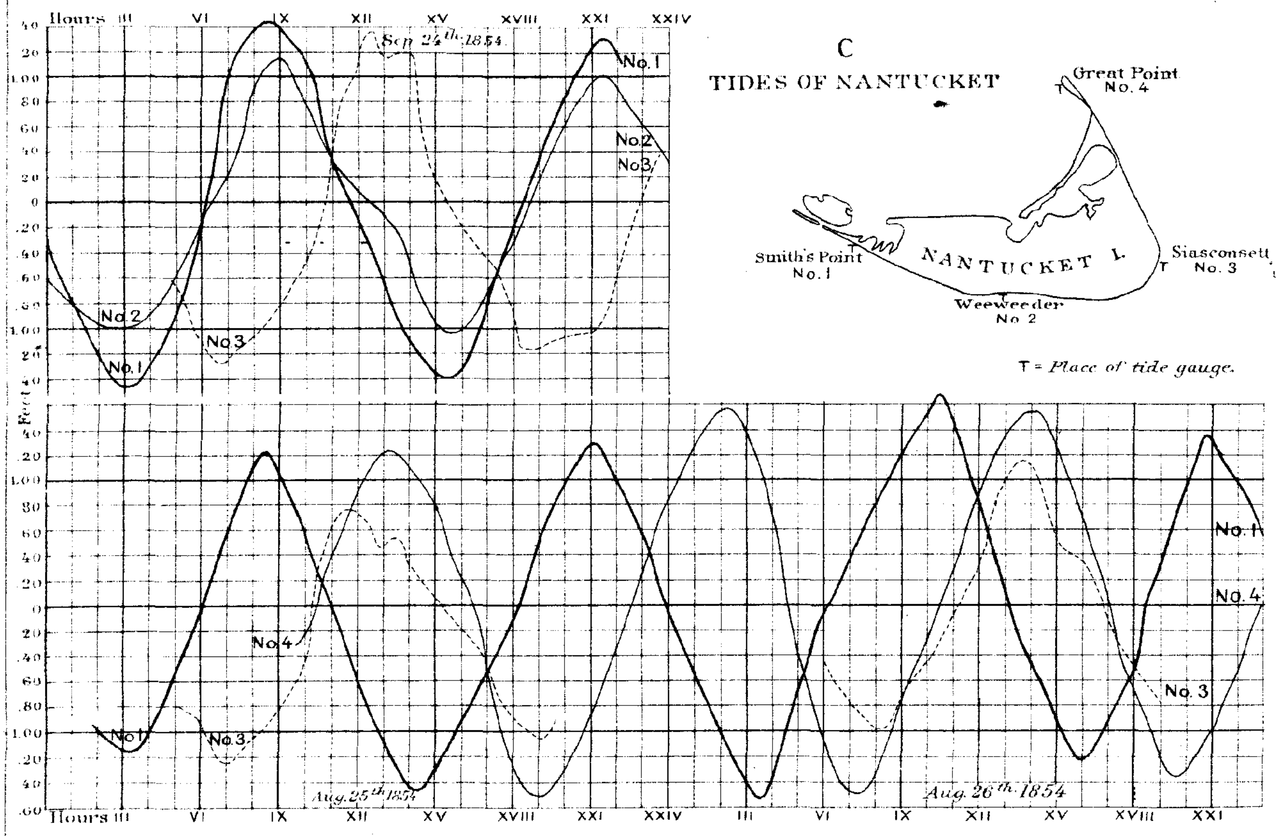
* Vulgar establishment from British Tide Tables, &c.

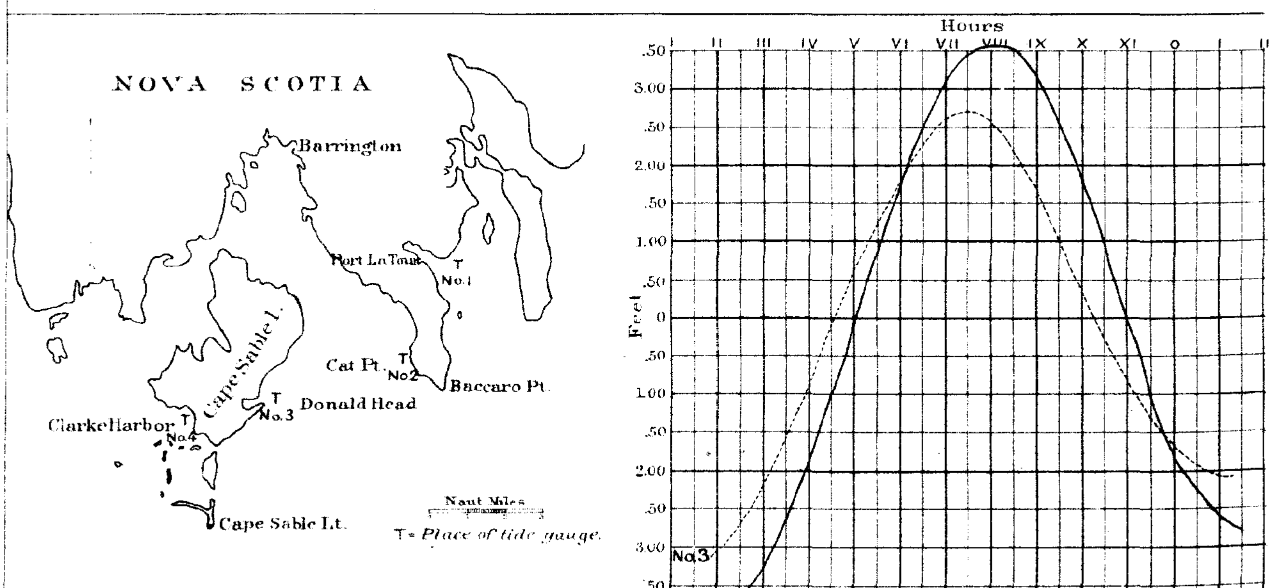
Perhaps I can best introduce the details of the nodal phenomena (adopting Professor Peirce's term) by referring first to the practical inquiries connected with the project for the construction of the Cape Cod Canal, which was designed to connect Buzzards' Bay (visited by the ocean tide) with Cape Cod Bay (visited by the gulf tide).

Fig. 3, Diagram B, is a plotting of the tidal curves of August 14, 1860, as actually observed at gauges separated by the seven miles of isthmus that lie between the two bays.† The tide of Cape Cod Bay, which is characteristic of the Gulf of Maine, has an average range of 9.17 feet, and its high water follows the moon's transit at an interval of $11^h\ 15^m$, or precedes the next transit by $1^h\ 9^m$; while the tide of Buzzards' Bay, representing the tide of our southern coast, has an average range of 4.11 feet, and follows the transit at an interval of $7^h\ 52^m$, or precedes the next transit $4^h\ 32^m$.

In the diagram offered here, a large diurnal inequality gives to the morning tide a range below, and to the afternoon tide a range above the average. It presents very well, however, the variations of slope likely to occur in the canal. At 3½ o'clock in the morning, for instance, Buz-

† Report of the Advisory Council of the Joint Committee of the Massachusetts Legislature on a Ship Canal, printed as an extra document by the Coast Survey.





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TIDES OF CAPE SABLE

Note *The time is that of North Haven expressed in lunar hours after transit of the moon. The tidal curves for Stations No 1 and No. 2 are omitted because so nearly coincident with No. 3.*

zards' Bay was nearly 5 feet above Cape Cod Bay, while six hours later a reverse slope of something over 5 feet obtained. We have no difficulty in conceiving of slopes like these in a canal, and as easily predict the currents they would engender under the local action of gravity, but the more difficult conception to which we now turn is that of slopes in the open ocean, the *effect* rather than the *cause* of horizontal movements.

Upon Diagram C are plotted tides observed upon the outside of Nantucket Island September 24, 1854. It will be observed that the Smith's Point and Great Point tidal curves are small but nearly symmetrical, and differ in time, like those at either end of the canal—only in greater degree, for here they are four or five hours apart. They represent, respectively, the ocean and gulf tides almost unaffected by each other. As we pass on to Siasconset and Weweeder we find the tides much reduced and distorted, but still distinguishable as belonging to different systems. The curves which the plotted times and heights reveal are still about four hours apart from center to center. In this short distance from Siasconset to Weweeder, less than 7 miles, we find differences of level of a foot and a half or two feet. A slope of three inches to the mile, which we have here in the open ocean, is double as great as that of the Mississippi River 400 miles above its mouth in great floods. The surface of the ocean is warped, not for a single instant, as in the passage of wind wave, but for hours together. Its surface slowly tilts up and down on either side of a nodal line every six hours.

The same two tides make a node in the Vineyard Sound along a line which runs across from Falmouth to West Chop. Here we find within half a mile tides of several hours' variation of time, and occasionally (precisely on the node) we have four distinct high waters in a day, so nearly equal that one cannot say within four hours at what time it is high-water or low-water. The coaster arriving from the South would claim that the swell which occurs with the moon in the southeast is really high-water, while the "Downeaster" would claim the swell occurring four hours later as the genuine tide.

Upon Diagram B, Figs. 1 and 2, will be found simultaneously observed tides of No-man's-land, Falmouth and Monomoy, the first and last representing, respectively, the ocean and gulf tides, while Falmouth represents the nodal fluctuation between them. Two sets are given to show how the two tidal systems affect each other, and how the fluctuations at the node alternately betray the presence of the greater tide, first on one side then on the other. It is evident that the two elementary tides are not subject to the same law of *inequalities*, but this may be due largely to the obstructions they individually meet. The diurnal and semi-diurnal tides, for instance, having different masses and moving at different rates, would give rise to different effects due to obstruction. I find in attempting to construct the tide near the node out of multiples of the other two superimposed that there is always a residual, regularly recurring but not to be accounted for. The very fact that the curves of rise and fall, as they near the node, lose their symmetry shows that each before merging into the other has lost its primal elliptical form, for no combination of elliptical figures would destroy the symmetry of the resultant. As the point of observation recedes from the node, the tidal curve shows less and less trace of transition, although the distortion of figure may sometimes be traced as far as Monomoy in one direction, and Block Island in the other.

Let us now turn from the phenomena exhibited at the western extremity of the nodal arc, and inquire what takes place at Cape Sable, to which this arc extends. In the table which follows (No. 2), and its illustrative diagram (D), the results of recent observations made by Mr. E. H. Lincoln and myself will be found. The object of our visit to Nova Scotia was to ascertain whether the point where the arc of least section runs upon the coast is the same at which the shift of establishment is initiated, and whether at this place the same warps of the ocean's surface occur that we had found at Nantucket. The inquiry involved much less difficulty than was anticipated, because remarkably quiet weather had so stilled the sea that we were able to place gauges in situations exposed to the ocean and beyond the suspicion of local influences. A fisherman, who had been cruising off the cape the day previous to our occupation of the stations at Cape Sable Island, told us that he had distinctly seen objects upon the bottom in 17 fathoms of water, the surface of the sea was so unruffled!

TABLE 2.

Lunar hours after transit.	Port La Tour, N. S.	Cat Point, N. S.	Donald Head, N. S.	Clark's Harbor, N. S.	Yarmouth, N. S.	Minas Basin, N. S.	North Haven, Me.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
0 00	....	....	....	—2.52	....	....	+2.79	The lunar hours count from the transit, and the time and moon are those of North Haven, Me. The common datum plane is *mean level.*
½	....	....	....	3.19	....	....	2.06	
I 00	....	....	....	3.80	....	....	+0.59	
½	....	....	—3.20	4.08	....	....	—0.82	
II 00	—2.92	—3.09	3.05	3.91	—5.38	— 3.30	2.34	
½	2.59	2.73	2.58	3.68	6.05	9.41	3.20	
III 00	2.07	2.20	2.12	3.18	6.50	13.22	4.45	
½	1 44	1.55	1.50	2.56	6.50	17.90	5.00	
IV 00	0.79	0.89	0.73	1.86	6.17	20.10	5.38	
½	—0.23	—0.28	—0.02	0.94	5.38	21.64	5.37	
V 00	+0.56	+0.51	+0.77	—0.04	4.33	21.59	5.10	
½	1.12	1.11	1.33	+0.98	2.76	20.51	4.45	
VI 00	1.72	1.78	1.80	1.81	—0.91	17.90	3.58	
½	2.12	2.22	2.38	2.53	+0.96	14.48	2.28	
VII 00	2.43	2.57	2.61	3.14	2.57	9.16	—0.75	
½	2.56	2.71	2.71	3.45	3.91	— 3.02	+0.79	
VIII 00	2.49	2.71	2.62	3.55	4.77	+ 3.18	2.12	
½	2.15	2.36	2.13	3.44	5.96	8.92	3.23	
IX 00	1.74	2.00	1.64	3.13	5.72	12.98	3.94	
½	1.40	1.55	0.99	2.56	5.76	15.84	4.43	
X 00	0.82	1.03	+0.40	1.84	5.37	17.81	4.73	
½	+0.27	+0.39	—0.15	+0.83	4.80	19.01	4.76	
XI 00	—0.45	—0.34	0.84	—0.05	3.74	19.13	4.44	
½	0.97	1.01	1.32	1.10	2.30	17.85	3.97	
0 00	1.53	1.56	1.74	1.79	+0.75	15.96	3.09	
½	1.85	1.94	1.90	2.23	—0.85	12.42	1.90	
I 00	—2.14	—2.15	2.02	2.63	—2.35	+7.64	+0.62	
½	....	....	—1.97	—2.70	....	— 2.49	—0.70	

NOTE.—The above observations are reduced to the elements of the tide of 5th of June, upon which date the transit occurred at 6^h 57^m a. m. North Haven tidal station has been continuously occupied so as to furnish simultaneous observations with each of the others. Port La Tour and Cat Point were occupied on the 8th, Donald and Clark's on the 5th, Yarmouth on the 2d, and Minas on the 17th.

It will be seen at once, on inspecting the table, that the heights observed at Port La Tour and Cat Point, to the eastward of Cape Sable, are almost identical, or correspond very nearly with Donald, on the east side of Cape Sable Island; but in passing the point of the cape a very decided increase of range and a sharp change of lunar interval present themselves. Simultaneous observations made every 15 minutes at Donald, on the eastern, and Clark, on the western side of Cape Sable Island, show a change in the position of the tidal curve of 36 minutes from center to center. This shift of time, which is effected in less than 3½ miles, measured coastwise, is greater than can be found going eastward the whole length of Nova Scotia bordering upon the ocean. The curve for Donald, given upon our Diagram D, will answer pretty well for every salient upon the coast for 300 miles to the eastward—in the same way that the similar tide of Smith's Point, Nantucket, will answer for the southern shores of Martha's Vineyard and Long Island.

The shift of time between Donald and Clark is 10 minutes to the mile, and the increase of range is 8 per cent. (compounding) to the mile. The new tide, rapidly evolving itself as it passes into the gulf, goes on shifting its time as it proceeds, but at a diminished rate. On reaching Seal Island it has fallen back 6 minutes to the mile, and increases its range 3 per cent.

Beyond this, although it becomes in the Bay of Fundy the highest tide in the world, it loses only 1 minute to the mile, and acquires its great range gradually. It never again warps the ocean's surface to the extent that it does at the place of its birth.

It will be seen from a little closer examination of the table (No. 2) that about the time of transit the ocean is level at Cape Sable, the heights being the same at Donald and Clark; but a half an hour later the warp amounts to 0.3, and goes on increasing till at the fourth hour the sea, which is nearly level in the approach from the eastward, makes a dip of over a foot between these two stations. After this the slope declines till at the sixth hour level is again restored. Still later the ocean tilts the other way, and the warp at the ninth hour amounts to a foot and a half, returning again to a level at the next transit.

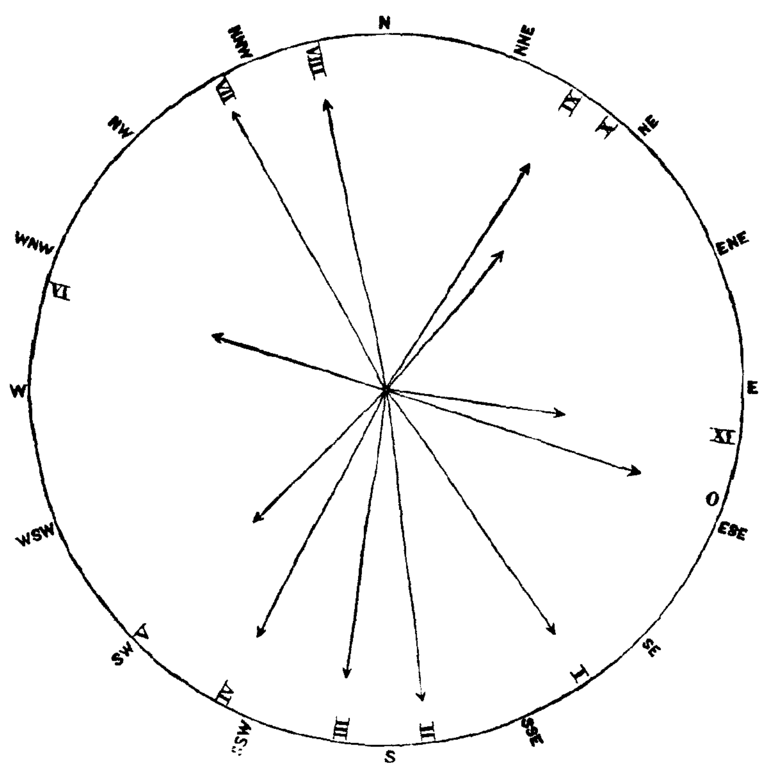
The surface level is restored at two periods 6 lunar hours apart at elevations of + 1.81 feet, and — 1.76 feet respectively as measured from the mean ocean level; but at the time of greatest warp the sea at Donald (where the break in the sea level first occurs) is at the ocean level or near it. Although the tidal curves are not distorted at the Cape Sable shifting point, they warp the ocean even more than at Nantucket. Three inches to the mile was stated as a fair maximum at Nantucket, but at Cape Sable it cannot be estimated at less than 5 inches, which is greater than the slope of the Mississippi River 1,000 miles from its mouth during floods.

These slopes are greater than will be found at the entrance to any of our commercial harbors, but they do not give rise to currents of the same order as those excited by the slopes in our harbor channels. In the entrances to our smaller harbors and inlets, we observe that flood current begins as soon as the surface of the ocean rises above that of the basin within, and ebb current begins under the reverse relations of surfaces, these movements being due to the *direct local action of gravity.* But in the ocean the horizontal motion is independent of the slope in the surface. Indeed, it is the slope which is dependent upon the pushing in or withdrawal of the water; as a matter of fact, both flood and ebb are running up hill at opposite ends of their courses, and there exchange names.

TABLE 3.

Lunar hours.	Velocity.	Azimuth.
	Knots.	°
0	1.45	288
½	1.55	316
I	1.63	326
½	1.75	340
II	1.73	353
½	1.60	361
III	1.58	8
½	1.65	14
IV	1.53	28
½	1.28	34
V	1.05	44
½	1.00	77
VI	1.03	108
½	1.10	128
VII	1.75	150
½	1.75	160
VIII	1.65	169
½	1.60	181
IX	1.45	212
½	1.25	214
X	0.98	219
½	0.98	235
XI	0.98	257
½	1.25	274

STATION 5, JULY, 1877.



NOTE.—This table is made from the actual observations of July 16 and 17, grouped according to lunar hours after transit, each hour being one-twelfth of the period elapsed between one transit and the next.

I confess to a very great surprise many years ago, when I conducted the tidal and current observations of the Vineyard Sound, to find that the horizontal motion was about as often opposed to the direction of the slope as in accord. Off West Chop, at the junction of Nantucket and Vineyard Sounds, it turned out that the currents were most rapid near the time of restoration of level between the two sounds, and slack-water occurred near the time of greatest difference of level. Over the great nodal arc, at the entrance to the Gulf of Maine, to which I have called your attention, the same appears to be true; the currents are most active when the sea is nearly level, and the water is running up hill for three hours of each tide. Slack-water occurs when the ocean is lying at or near its greatest slope—as when one swings a pendulum the greatest velocity is attained when the path of the bob is horizontal, and this bob comes to rest at the moment when at its highest point.

In Captain Platt's instructions, the geographical positions he was required to occupy were stated, and these were so nearly attained that his eight stations between Nantucket and Cape Sable fell very near the desirable points in the arc of least section as we have finally drawn it. There is considerable difference of merit among his observations, because of varying weather, and the Table 5, compiled from his work at station 5, on the eastern slope of George's Bank, is not offered as an average specimen, but as an illustration of the varying courses and velocities of the current under the best circumstances.

The currents prove to be simply *tidal*, there being no indication of any constant stream. Taking the whole series together, it appears probable that ebb and flood currents are exactly equal, although in applying factors derived from comparative ranges of the tide, to correct the velocities of different days or half days, an equality of the outflows and inflows is not actually reached.

By plotting the rise at North Haven for every half hour, with the velocity observed at the station of the same date, and determining the difference in time of the centers of the two curves, it has been possible to make use of every observation in determining the epochs of the current. In the following table (No. 4) these differences of time are furnished together with the consequent establishments given by applying these differences to the means of the whole tidal series at North Haven.

TABLE 4.

Station.	Position.		Difference of time of tide and current.	Current turns after moon's transit.		
	Latitude.	Longitude.		From flood to ebb.	From ebb to flood.	
	° ′	° ′	m			
1	41 10	68 55½	+ 52			The "Difference of time of tide and current" is the difference of time of the centers of the plotted curves.
2	41 20¾	68 23	+ 32			
3	41 31	67 52½	+ 12			
4	41 36½	67 24	— 04			
5	51 56½	66 38	+ 23			
6	42 24⅔	66 08	— 28			
7	42 50	55 56½	— 10			
8	43 04	65 40¾	— 24			The tide of North Haven is used, the establishment of which is XI h VII m for high water and XVII h XVIII m (or IV h LIV m) for low water, but the local time of each station is preserved.
Howell's Station, 1872	41 38	67 43½	+ 34			
Groups.						
				h. m.	h. m.	
1, 2, and 3	Southern Channel		+ 32	XI XXXVII	V XXIV	
3, 4, and 5	George's Bank		+ 10	XI XVII	V IV	
5, 6, and 7	Great Eastern Channel		— 05	XI II	IV XLIX	
7 and 8	Northern Channel		— 17	X XLVIII	IV XXXV	

Comparing this table (No. 4) with No. 1, it will be seen that the current runs into the gulf, over our great arc, until high water has occurred in every part of the basin. There are differences of time both among the tidal and the current stations, but these cannot be, in the main, attributed to delay in the transmission. The ocean at our arc is in motion from surface to bottom, and in the communication of this impulse through the deep gulf there is (and should be, I submit) no sensible loss of time. The whole scheme of cotidal lines devised for this section by Professor Bache, after the plan of Dr. Whewell, is open to the objection that the loss of time is too great at the shifting places for any possible effect of friction. It now appears that an impulse observed at one of our current stations on our nodal arc is almost immediately followed by a vertical change upon the most distant shore, as if the horizontal motion were the *force* and the vertical tide the immediate *mechanical effect* produced through an inelastic medium. The current observed is a proximate cause of the lift of water beyond, but only in the sense that an intermediate wheel in a train is the cause of motion beyond. Of course it is not denied that the horizontal motion is the effect of gravity in that wider sense that includes a wider region of unexplored ocean.

In Table No. 5, which follows, specimens of the tides at the western extremity of our nodal arc are furnished, while in Table No. 6 a generalization for characteristic stations in the gulf is attempted.

TABLE 5.

Lunar hours after transit.		September 24, 1854.			August 25 and 26, 1854.		
		Ordinates for Smith's Point.	Ordinates for Weweeder.	Ordinates for Siasconset.	Ordinates for Smith's Point.	Ordinates for Siasconset.	Ordinates for Great Point.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
0	00	−0.92	−0.85	....	....	....	....
	½	1.26	0.90	....	....	....	....
I	00	1.34	0.95	....	−1.05	....	....
	½	1.44	0.99	....	1.12	....	....
II	00	1.40	0.95	....	1.16	....	....
	½	1.22	0.88	....	0.96	....	....
III	00	1.00	0.69	−0.54	0.73	....	....
	½	0.80	0.52	0.72	0.52	....	....
IV	00	0.50	0.32	0.90	−0.30	−0.85	....
	½	−0.12	−0.14	1.09	+0.04	0.92	....
V	00	+0.40	+0.05	1.27	0.37	1.10	....
	½	1.01	0.25	1.21	0.63	1.22	....
VI	00	1.28	0.57	1.10	0.90	1.16	....
	½	1.38	1.01	1.00	1.11	1.05	....
VII	00	1.43	1.12	0.78	1.22	0.96	....
	½	1.37	1.11	0.69	1.08	0.83	....
VIII	00	1.25	1.00	0.57	0.88	0.62	....
	½	1.05	0.72	0.32	0.59	−0.46	−0.22
IX	00	0.55	0.50	−0.10	+0.28	+0.28	+0.08
	½	+0.22	0.27	+0.66	−0.07	0.54	0.38
X	00	−0.03	0.18	0.98	0.33	0.74	0.71
	½	0.25	+0.05	1.20	0.61	0.70	0.93
XI	00	0.50	−0.02	1.26	0.87	0.59	1.10
	½	0.75	0.13	1.15	1.06	0.46	1.20
0	00	1.00	0.35	1.20	1.24	0.50	1.19
	½	1.15	0.62	1.00	1.41	0.31	1.08
I	00	1.33	0.80	+0.23	1.46	0.18	0.92
	½	1.40	1.00	0.00	1.28	+0.07	0.77
II	00	1.31	1.06	−0.14	1.07	−0.08	0.50
	½	1.06	0.96	0.30	0.89	0.20	+0.22
III	00	0.80	0.75	0.47	0.69	0.35	−0.18
	½	0.50	0.58	0.63	0.48	0.60	0.54
IV	00	−0.21	0.28	0.90	0.27	0.87	1.04
	½	+0.15	−0.06	1.20	−0.02	1.00	1.32
V	00	0.40	+0.23	1.13	+0.30	1.05	1.47
	½	+0.78	0.52	1.08	0.68	1.04	1.48
VI	00	....	0.73	1.05	0.89	0.75	1.38
	½	....	0.90	1.04	1.11	....	1.25
VII	00	....	0.98	0.94	1.26	....	0.98
	½	....	0.92	0.63	1.23	....	0.69
VIII	00	....	0.77	0.29	1.08	....	0.45
	½	....	0.62	−0.09	0.87	....	−0.14
IX	00	....	+0.44	+0.28	0.60	....	+0.15
	½	....	....	....	0.37	....	0.42
X	00	....	....	....	+0.10	....	0.65
	½	....	....	....	−0.18	....	1.95
XI	00	....	....	....	−0.47	....	+1.16

TABLE 5—Continued.

Lunar hours after transit.	September 24, 1854.			August 25 and 26, 1854.		
	Ordinates for Smith's Point.	Ordinates for Weweeder.	Ordinates for Siasconset.	Ordinates for Smith's Point.	Ordinates for Siasconset.	Ordinates for Great Point.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
½				−0.72		+1.40
0 00				1.02		1.54
½				1.20		1.51
I 00				1.41		1.47
½				1.55		1.04
II 00				1.42		0.60
½				1.03		+0.02
III 00				0.68		−0.40
½				0.32		0.85
IV 00				−0.05	−0.48	1.11
½				+0.15	0.68	1.38
V 00				+0.33	0.82	1.50
½				0.62	0.95	1.46
VI 00				0.84	1.00	1.30
½				1.08	0.88	1.00
VII 00				1.22	0.68	0.72
½				1.43	0.52	0.44
VIII 00				1.62	0.42	−0.23
½				1.63	0.28	+0.04
IX 00				1.49	−0.08	0.32
½				1.17	+0.10	0.60
X 00				0.77	0.33	0.90
½				+0.20	0.87	1.15
XI 00				−0.04	1.08	1.40
½				0.38	1.13	1.51
0 00				0.63	1.00	1.52
½				0.86	0.55	1.28
I 00				1.10	0.38	1.05
½				1.23	0.32	0.72
II 00				1.12	+0.20	0.40
½				0.99	−0.10	+0.10
III 00				0.82	−0.31	−0.35
½				0.50	−0.50	0.70
IV 00				−0.03	−0.68	1.02
½				+0.37	−0.88	1.23
V 00				0.70	−1.04	1.38
½				1.03		1.27
VI 00				1.35		1.12
½				1.22		0.88
VII 00				1.08		0.60
½				0.87		0.39
VIII 00				0.62		−0.02
½				0.39		+0.31
IX 00				+0.10		0.61
½				−0.06		0.84
X 00						1.10
½						1.36
XI 00						1.65
½						1.77
0 00						+1.78

In the compilation of this table the actual observations are first plotted on profile paper, as in Diagram C, and then the ordinates for even lunar hours and half hours taken out. The datum plane is mean sea-level, the time local.

TABLE 6.

Lunar hours after transit.	Height of tide above and below ocean level.				
	Smith's Point, Nantucket, Mass.	North Haven, Me.	Minas Basin, N. S.	Donald Head, Cape Sable, N. S.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	
00	—0.80	+3.85	+19.6	—1.37	The time is that of North Haven, Me.; the datum plane mean-sea-level. At II^h L^m and at $VIII^h$ L^m the gulf is level with depression at Nantucket. At V^h L^m and XI^h L^m the greatest disturbance of level occurs.
½	0.97	2.97	18.0	1.95	
I 00	1.08	1.85	15.0	2.39	
½	1.12	+0.63	11.2	2.67	
II 00	1.08	—0.63	6.4	2.75	
½	0.98	1.85	+ 1.2	2.67	
III 00	0.80	2.97	— 3.9	2.39	
½	0.56	3.85	8.8	1.95	
IV 00	—0.29	4.48	13.4	—1.37	
½	+0.00	4.82	16.6	+0.71	
V 00	0.29	4.82	18.8	0.00	
½	0.56	4.48	19.9	0.71	
VI 00	0.80	3.85	19.6	1.37	
½	0.97	2.97	18.0	1.95	
VII 00	1.08	1.85	15.0	2.39	
½	1.12	—0.63	11.2	2.67	
VIII 00	1.08	+0.63	6.4	2.75	
½	0.97	1.85	— 1.2	2.67	
IX 00	0.80	2.97	+ 3.8	2.39	
½	0.56	3.85	8.8	1.95	
X 00	0.29	4.48	13.4	1.37	
½	+0.00	4.82	16.6	0.71	
XI 00	—0.29	4.82	18.8	+0.00	
½	—0.56	+4.48	+19.9	—0.71	

NOTE.—The above are generalized forms of tidal curves for the stations mentioned.

With the help of the foregoing tables, it is now proposed to describe the phenomena hour by hour, presuming that the agreement in the testimony gives the results for certain hours a degree of certainty, while the disagreements do not indicate errors of observation so much as the impossibility of reducing observations of different dates to the same terms. The Roman numerals will be used to indicate lunar hours after transit, and comments upon them will cover the half hour before and after each hour, and point out the distinctive features. In order to consider first the direct action of the flood stream, we shall begin our descriptions with the eighth hour after the transit of the moon when the gulf is nearly level, and when the ocean's surface is at the same height as that of the gulf.

$VIII^h$. This hour of general restoration of level corresponds nearly with that of greatest horizontal movement across the nodal arc. At all our stations the strength of the flood current now prevails, and a great mass of water is being pushed into the gulf through the deep channels and over the shoals.

IX^h. The effect of the great influx, which has scarcely abated, is observable in the rapid rise along the coast of Maine and in the Bay of Fundy, while at and beyond the nodal arc the tide of the ocean is falling. The dip of the entire Gulf is seaward except in the immediate neighborhood of Nantucket. The greatest slope is at Cape Sable, where it is 5 inches to the mile, although the general slope from the shore of Maine to the nodal arc is only 0.15 of an inch to the mile. This slope is very remarkably sustained, as we shall see, and it is difficult to conceive of a current steadily moving up hill, except we give it priority and make it the *cause* of the slope.

X^h. The conditions continue much the same as at IX^h. The Minas Basin is the highest place, and Nantucket the lowest, while North Haven, the intermediate station, has an intermediate height; but still the current runs up the great eastern and northern channels, although it is falling off in strength and a reaction is foreshadowed. The slope at Cape Sable is 4½ inches to the mile, as we approach Yarmouth 1¼, while in the Bay of Fundy it is less than 1 inch to the mile. At the other end of the nodal arc the slope at Nantucket is 1½ inches to the mile. From these slopes it would appear that the birth of the new tide is attended by a remarkable warp of the ocean at the node. There is probably no parallel instance in the rest of the ocean world.

XI^h. The Gulf of Maine lies at its greatest elevation. It is high tide along the entire shore of Maine and in the Bay of Fundy. The reaction takes place and the current along the nodal arc reverses. The slope from the Minas Basin to the ocean reaches 20 feet, which, following the line of greatest depth, represents 1 inch to the mile; but at Cape Sable we have still 1½ inches, and at Nantucket over 2 inches to the mile.

It may be concluded, then, that slack current occurs at the time when the final lift of the gulf has been accomplished.

0^h. As the moon crosses the meridian of North Haven the entire Gulf is falling, from the head of the Bay of Fundy, where the water stands at an elevation of 16 to 20 feet above the mean level of the ocean, to the nodal arc, where the surface is 1 foot below the mean level (at Nantucket), or 2 feet below at Cape Sable. The dip of the surface of the gulf is great and everywhere seaward, but not at a uniform slope. The current is ebb, however, along the entire length of the nodal arc.

I^h. It is low-water, or nearly so, in the ocean outside of the Gulf of Maine, and the surface of the sea at the nodal arc 1½ to 3 feet below mean sea level, while the Bay of Fundy is still much elevated, and the surface along the shore of Maine slightly above mean sea-level. The slope is still in the same direction (seaward), but is rapidly lessening, while the ebb current is fairly in train and everywhere augmenting.

II^h. The general level of the gulf is being restored, and the ebb current is at its greatest rate of flow nearly all along the nodal arc. The current is opposed to the slope of the ocean outside of the gulf, and we have a repetition, in the opposite sense, of the phenomena observed at $VIII^h$.

III^h. The tide is falling over the whole gulf, while the dip of the surface is toward the Bay of Fundy, at the head of which the greatest depression appears. The ebb current is losing strength in the eastern half of the gulf, where the slope having a reverse direction is greatest, but is still strong in the easternmost portion, which is approaching a level.

IV^h. The slope is northward over the entire gulf, and ebb everywhere prevails, although the general level of the open portion of the gulf is about 6 feet below that of the sea, and the Minas Basin at least 14 feet below. The maximum slope at Cape Sable is approaching, and the current of the northern channel is slacking up.

V^h. The gulf has sunk to its lowest average. It is low-water along the coast of Maine, and it is nearly low-water in the Bay of Fundy. The northward slope is approaching its maximum, and the current of the eastern section of the gulf turns from ebb to flood. At this moment the northward slope on the eastern shore of Nantucket is 2.3 inches to the mile, with a slight ebb current in the Great South Channel in a direction opposed to this slope—i. e., *up-hill*. At Cape Sable we have also a northward slope of 2.8 inches to the mile, but rapidly declining. But the general slope from the ocean to the coast of Maine is less than 0.5 inch to the mile, and in the open portion of the Bay of Fundy not above 1 inch. Here again we have a repetition of the conditions observed at XI^h. The outward movement due to the reaction of the tide is unable longer to sustain the slope, and a reversion takes place.

VI^h. The current is running flood all over our field of observation, in the direction of the slope generally, although the level is restored at Cape Sable and along the coast of Nova Scotia for some distance northward. In the Northern Channel the flood current has reached its first quarter, and is running nearly as fast along its level course as it is destined to do at its strength. The tide is everywhere rising, from the ocean to the head of the Bay of Fundy. On the eastern shore of Nantucket the slope northward has reached a maximum of nearly 3 inches to the mile, and the current in the Great South Channel has reversed its course from ebb to flood. It would appear that the epoch of greatest difference of level and that of slack-water correspond on either side of the entrance to the gulf. So that by careful tidal observations on shore the tables for mariners could be reduced to great accuracy.

VII^h. The ocean is rising very slowly and the Bay of Fundy rapidly. The slope is northward and toward the Bay of Fundy, except that Cape Sable is slightly above the stations on either side. The flood current is at its first quarter in the Southern Channel, and near its maximum in the Northern Channel.

To avoid confusion no comments have been made upon the tilt in an east and west direction, but such tilting goes on, as may be seen from comparing Nantucket and Cape Sable heights. The heights at these two extremities of the nodal arc are equal at about V and at X hours, and correspond with the mean ocean level very nearly. These times correspond with slack-water on George's Shoal, and with the greatest difference of level on a line transverse to the chord of the nodal arc. The hours of greatest difference of height between Cape Sable and Nantucket, VIII½ and II½, correspond nearly with a restoration of level in the transverse direction. From V to XI, during which the slope is westerly, the currents incline to draw round more easterly in direction, or to *run more up-hill.* From XI round to V, during which the slope is easterly, the ebb current inclines to flow more and more westerly. Here again we find the current disposed to take a course most opposed to the slope, as if the latter was the product of its push toward the shore.

I have referred to the pendulum as an illustration of the phenomena presented in the Gulf of Maine, because the horizontal motion at our Sill, like that of the pendulum at the lowest point of its course, is the proximate cause of the rise of the tide, first upon one side, then upon the other. Perhaps a happier illustration would be that of a bent tube or inverted siphon, whose arms are of very unequal size and of unequal inclination to the vertical. In such an instrument the oscillations of a fluid would be of very unequal range if we compared the results in the two arms. The great tide of the Bay of Fundy is the result of a movement of the ocean in this direction which forces a vast body of water into a contracting flume. Without going behind actual observations, however, for antecedent causes, I assume that our current observations represent the movement of the ocean just mentioned, which movement is probably a rocking motion primarily, as Professor Ferrel has ably represented.* Following up this idea, I have grouped together the observations at the three central stations on our great nodal arc, and then compared them, hour by hour, with the rates of rise or fall of tide on the coast of Maine. The first attempt was made with the velocities just as observed, ignoring the variations of direction, but this was evidently wrong. Next, the forces were decomposed, and those normal to the arc selected. These components should represent filling or draining over a sill, but the residual from the comparison with the tide was still too large. Lastly, a comparison was made between the squares of the velocities and the vertical changes on the shore, which seemed to answer very well, as will be seen from the table below (No. 7) in which the three trials are numerically stated. It would seem that the rise on the shore is the result of *impact*, in the most general sense, and the fall the reaction, if we can regard the observed velocities as increments of force; but if it were possible to determine the figure of the tidal prism from hour to hour in the gulf, the sum of the components of all the stations, according to the second trial mentioned above, would of course give the true measure for comparison, since it would represent actual filling or draining.

If it be granted that the horizontal movements of the deep sea are nearly synchronous, as our observations indicate, for many hundred miles, what explanation *within the limits of observation* can be offered for the sudden change of time in the vertical tide at the threshhold of the Gulf of Maine? Observations made by the British Admiralty eastward of Cape Sable, and those made by myself southward of Long Island, show that the flood movement for the tide of the outside coast is from northeast to southwest, and the ebb movement nearly the reverse of this. To this flood movement the Gulf of Maine is a *dead angle*, but for the return movement this gulf is a *pocket* into which the waters are crowded, and by virtue of their *vis viva* piled up in the Bay of Fundy. If we draw a chord line from a point near Cape Canaveral, in Florida, to Cape Hatteras, this line produced will be the chord of the great bend between Cape Hatteras and Nantucket, but beyond this the same straight line produced falls in with the major axis of the Gulf of Maine, excluding Nova Scotia as salient to the general bend of the coast, and making it an abrupt obstruction to any coastwise movement from the southward. This, I submit, as a possible solution of the problem of the peculiar tides of this section. The tide of the Bay of Fundy and the Gulf of Maine generally is a product of the reflex of obstruction in the path of the oceanic ebb tide. If the flux and reflux of the ocean causing the tide is a compound rocking motion, the heights would in a measure depend upon the angle of impact, so that the range would be small when the direction of the motion is diagonal to the trend of the coast, and greatest when most direct.

*Tidal Researches, by William Ferrel, United States Coast Survey.

TABLE 7.

Lunar hours.	Vertical change for each half hour.	Velocity of current at Stations 3, 4, and 5.	$-c\times.565.$ $+c\times.66.$	Residuals, $b-d.$	$c^2.$	$-c^2\times.36.$ $+c^2\times.47.$	Residuals, $b-g.$	Components of c: South, −. North, +.	$-i\times.68.$ $+i\times.81.$	$b-j.$
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
	Feet.	*Knots.*								
I	−1.17	−1.79	−1.01	+.16	−3.20	−1.15	+.02	−1.63	−1.10	−.07
½	−1.24	−1.82	−1.03	+.21	−3.31	−1.19	+.05	−1.81	−1.23	−.01
II	−1.24	−1.74	−0.98	+.26	−3.02	−1.09	+.15	−1.73	−1.17	−.07
½	−1.17	−1.67	−0.94	+.23	−2.78	−1.00	+.17	−1.65	−1.12	−.05
III	−1.00	−1.62	−0.92	+.08	−2.62	−0.94	+.06	−1.54	−1.05	+.05
½	−0.76	−1.50	−0.85	−.09	−2.25	−0.81	−.05	−1.35	−0.92	+.16
IV	−0.49	−1.28	−0.72	−.23	−1.63	−0.59	−.10	−1.10	−0.75	+.26
½	−0.17	−1.11	−0.63	−.46	−1.23	−0.44	−.27	−0.74	−0.50	+.33
V	+0.17	−0.09	−0.06	−.23	−0.08	−0.03	−.20	−0.18	−0.12	+.29
½	+0.49	+0.99	+0.65	+.16	+0.98	+0.46	−.03	+0.30	+0.24	+.25
VI	+0.76	+1.26	+0.83	+.07	+1.58	+0.74	−.02	+0.71	+0.58	+.18
½	+1.00	+1.52	+1.00	.00	+2.31	+1.09	+.09	+1.15	+0.93	+.07
VII	+1.17	+1.69	+1.12	−.05	+2.85	+1.34	+.17	+1.48	+1.20	−.03
½	+1.24	+1.73	+1.14	−.10	+2.99	+1.41	+.17	+1.64	+1.33	−.09
VIII	+1.24	+1.66	+1.10	−.14	+2.75	+1.29	+.05	+1.63	+1.32	−.08
½	+1.17	+1.54	+1.02	−.15	+2.37	+1.11	−.06	+1.52	+1.23	−.06
IX	+1.00	+1.38	+0.91	−.09	+1.90	+0.89	−.11	+1.32	+1.07	−.07
½	+0.76	+1.20	+0.79	+.03	+1.44	+0.67	−.09	+1.10	+0.89	−.13
X	+0.49	+1.01	+0.67	+.18	+1.02	+0.48	−.01	+0.81	+0.66	−.17
½	+0.17	+0.67	+0.44	+.27	+0.44	+0.21	+.04	+0.38	+0.31	−.14
XI	−0.17	−0.30	−0.17	−.00	−0.09	−0.03	+.14	−0.13	−0.09	−.08
½	−0.49	−1.17	−0.66	−.17	−1.36	−0.49	.00	−0.51	−0.35	−.14
XII	−0.76	−1.45	−0.82	−.06	−2.10	−0.76	.00	−0.83	−0.56	−.20
½	−1.00	−1.65	−0.93	+.07	−2.72	−0.98	+.02	−1.23	−0.84	−.16
Sums of residuals				3.49			2.07			3.14

NOTE.—In this table the signs + and − are used to distinguish flood from ebb, and the rising from the falling tide. The changes in the direction from hour to hour on ebb or flood have been ignored, except in computing the elements of column "**i**," where the components in the direction of the resultants of flood and ebb are given.

In the tides at the Placentia district of Newfoundland which juts out into the sea, traces are found of the same peculiarities that we have observed on the western coast of Cape Sable. I am not at all tenacious of this theory of the case, but I present it as the stepping-stone reached inductively from the data thus far collected, which, as before stated, I must regard as covering effects with their *proximate causes* only.

There is one important test which the above theory does not answer to, and this I can best represent in connection, if not in contrast, with the nodal hypothesis of Professor Peirce upon which my description of the tides has been based as stated at the outset.

It is premised in the nodal hypothesis that the depth and section in the North Atlantic is sufficient for the transmission of a body of water adequate to the creation of oscillations of very great extent, so that the tide of the oceanic basin is not broken up into numerous separate undulations; but where great bays or avenues extend into the continent nodes should occur; or if the pathway is shallow the tide becomes a progressive wave. In the case of the Gulf of Maine, its form, extent, and depth make a node necessary, and within it appears the reciprocal or complement of the ocean tide, speaking in the most general sense.

In the physical scheme proposed by myself, if the tide of the Gulf of Maine were due to the saliency of the Nova Scotian peninsula which arrests the recoil of the ocean tide, the duration of the rise in this gulf should correspond with the durations of the fall elsewhere, which I am satisfied is not the case in a majority of instances offered in the comparison I have instituted between our permanent stations at Old Point Comfort and North Haven. Of course it was not expected that the diurnal inequality of one tide would reverse that of the other, except in the most general way, because in my hypothesis the tide of the gulf was in a measure a mixture of the direct and the return, movement, and also because this inequality is prone to change in magnitude with obstructions which produce unlike effects upon waves of different duration and magnitude; but at periods when the diurnal inequalities of interval were large for both the ocean and the gulf tides, I found them of the same sign usually, instead of being reversed as my theory would demand. Presenting this objection also to Professor Peirce's explanation of the case, it was met by the statement that the diurnal and semi-diurnal tides being oscillations of different length could not make their nodes at the same point, so that the diurnal inequalities would not be reversed, but only greatly complicated, as they certainly are.

GEORGE'S BANK.

In a preceding portion of this report the condition of equilibrium under which George's Bank, or the shoal of sand which crowns it, is maintained has been briefly stated, and it remains to show from numerical data how this equilibrium obtains among the forces gauged at our several current stations in this vicinity.*

In the following tables (8 and 9) the resultants are given from a composition of the movements observed at each station precisely as if these represented simultaneous forces, the presumption being that the shoals of sand traverse the bottom of the sea like dunes upon the desert, at a rate bearing but a very small ratio to the forces, and therefore representing only the resultant of these forces for long periods.

TABLE 8.

Station No.	Soundings.	Locality.	Whole distance traversed by a water particle.	Resultant.		
				Distance.	Azimuth (true).	Course (true).
	Fathoms.		*Miles.*	*Miles.*	°	
1	60	Great South Channel	16.32	4.70	211	N. E. by N. ¼ N.
2	35	Western flank of George's Bank	23.51	5.93	257	E. by N.
3	15	George's Shoal	33.60	2.88	108	W. by N. ¾ N.
4	*42	George's Shoal	25.29	3.56	346	S. by E. ¼ E.
5	40	Eastern flank of George's Bank	33.57	3.84	318	S. E. ¼ S.
6_1	135	Great Eastern Channel	13.53	6.20	75	W. S. W. ¾ W.; doubtful.
6_2	125	Great Eastern Channel	18.77	11.03	129	N. W. ½ W.
7	52	Northern Channel, near Brown Bank	26.18	7.53	309	S. E. ½ E.
8	65	Northern Channel, near Seal Island Bank	19.62	4.81	58	S. W. by W. ¼ W.

*The characteristic sounding, upon the Coast-Survey Chart, for a circle of 2½ miles radius about Station 4 is 26 fathoms.

The above table is not corrected to mean rise and fall of tide, but the data is given as observed. In the following table (9), however, a tidal correction is attempted.

TABLE 9.

Station No.	Soundings.	Location.	Distance traversed by a water particle.	Resultant.		
				Distance.	Azimuth (true).	Course (true).
	Fathoms.		*Miles.*	*Miles.*	°	
1	60	Great South Channel	18.93	5.25	211	N. E. by N. ¼ N.
2	35	Western slope of George's Bank	24.70	6.42	263	E. ½ N.
3, 4, 5	*29	George's Shoal	33.00	†2.28	2	S. ¼ W.
6_2	125	Great Eastern Channel	18.77	11.03	129	N. W. ½ W.
7	52	Northern Channel near Brown Bank	21.00	5.21	310	S. E. ½ E.
8	65	Northern Channel near Seal Island Bank	20.40	5.00	58	S. W. by W. ¼ W.

* Average depth on a curved line passing through stations 3, 4, and 5 on Coast Survey chart.
† Mean of several groupings with different times for origins.

* Nantucket Shoals have formed the subject of a paper by Charles A. Schott, United States Coast Survey, which will be found in Appendix 48, Coast Survey Report of 1854. The shoal ground of Nantucket is connected by an sthmus (on which there is about 40 fathoms) with George's Bank.

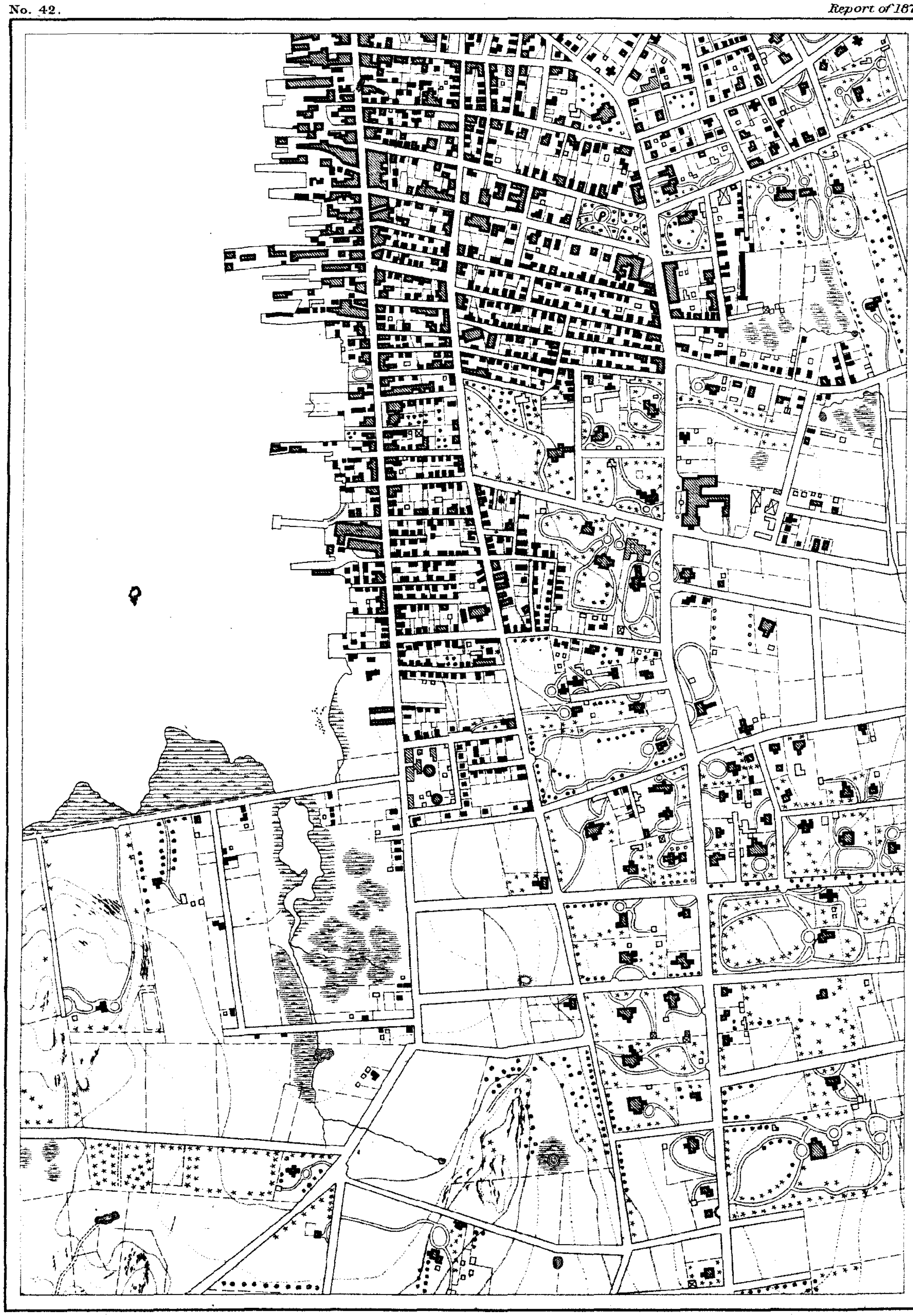
From the foregoing tables (8 and 9), it will be seen that the velocities increase from station to station as the depths diminish, but not in full ratio, while the resultants for a tidal day are less dependent upon velocity and depth than upon the relative directions of ebb and flood. The high velocity over George's Bank is the result of a diminution of section, but the presence of this bank as an antecedent obstruction is seen to be the cause of a retardation if we compare volumes. It is evident that the resultant at some point between the meridians passing through Stations 3 and 4 must be nearly zero. This point probably lies on the summit of George's Shoal, and would be a zero point if no bank or shoal existed, being simply that point in the common path of ebb and flood when these streams are equal and opposite. This shoal is probably prevented from rising to the surface by the variation of section induced by the rise and fall of the tides, which throw corresponding stages of ebb and flood out of balance above a certain plane, as we notice at the mouths of sandy harbors which would have no outlets if it were not that the volumes passing in and out with the tide follow a law at variance with that of the rise and fall, so that the maximum volume of outflow on the ebb (for instance) occurs at a lower stage (when there is less section) than that of the corresponding influx, and therefore has greater scouring powers.

The tendency of a shoal situated at the equilibrium point of converging currents to become steeper, may be likened to the disposition of a hill upon the land to become steeper under the reverse action of the rain, which abrades the sides more than the top. In the first case the shoal increases its slope twofold by adding to the top what is robbed from the flank; while in the other case the hill, although growing steeper, is declining in height, principally by the filling up of the valley. In the first case the ocean bed is being thrown out of level; in the other the surface of the continent is being planed down to uniformity.

Very respectfully submitted.

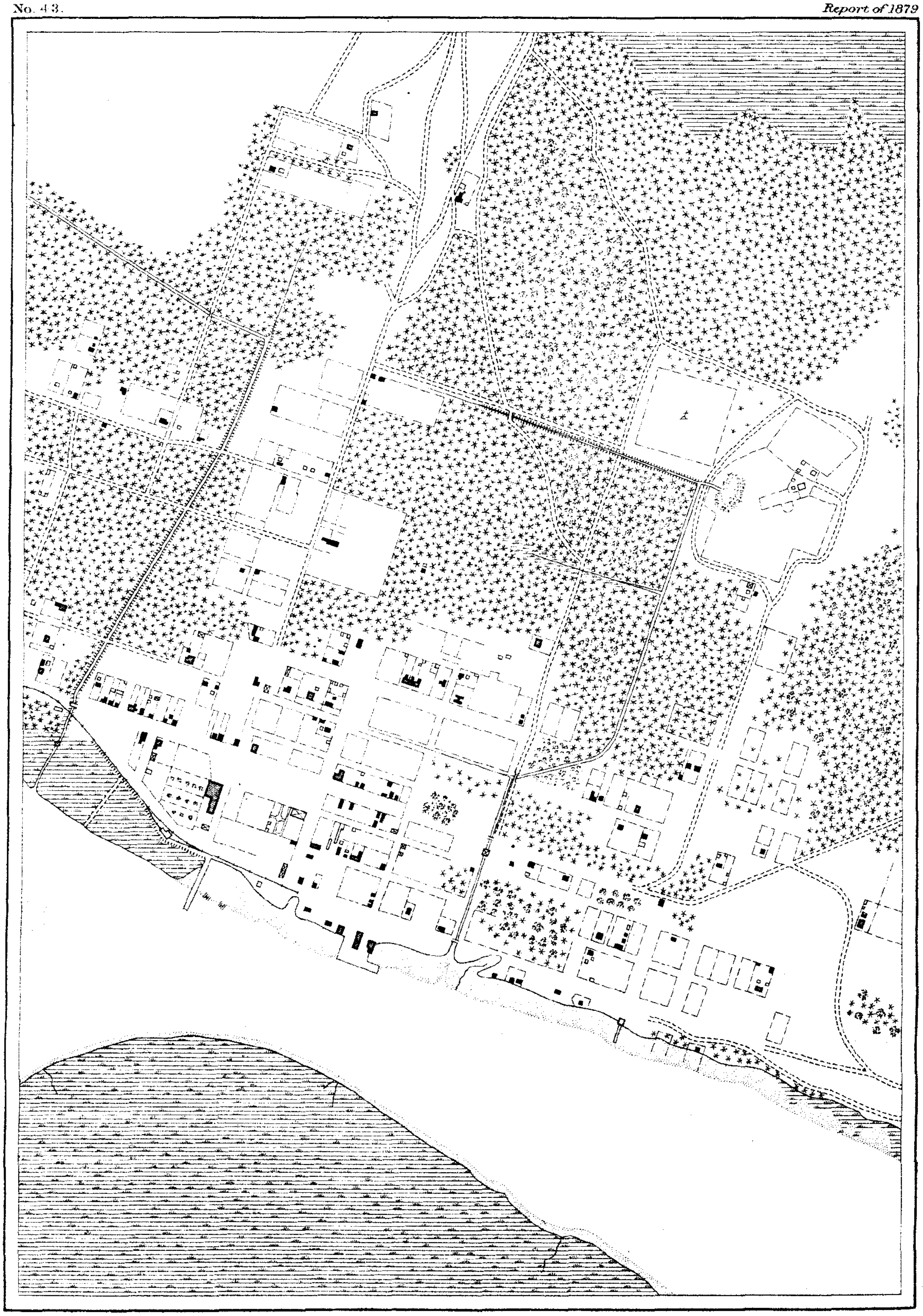
HENRY MITCHELL,
Assistant U. S. Coast and Geodetic Survey.

Dr. C. P. PATTERSON,
Superintendent U. S. Coast and Geodetic Survey.



TOPOGRAPHICAL DRAWING
Scale $\frac{1}{10000}$
By E. Hergesheimer Assistant

Blocking of Cities, Large Buildings, Suburban Villas and Grounds, Fresh Marsh (Newport R.I.)



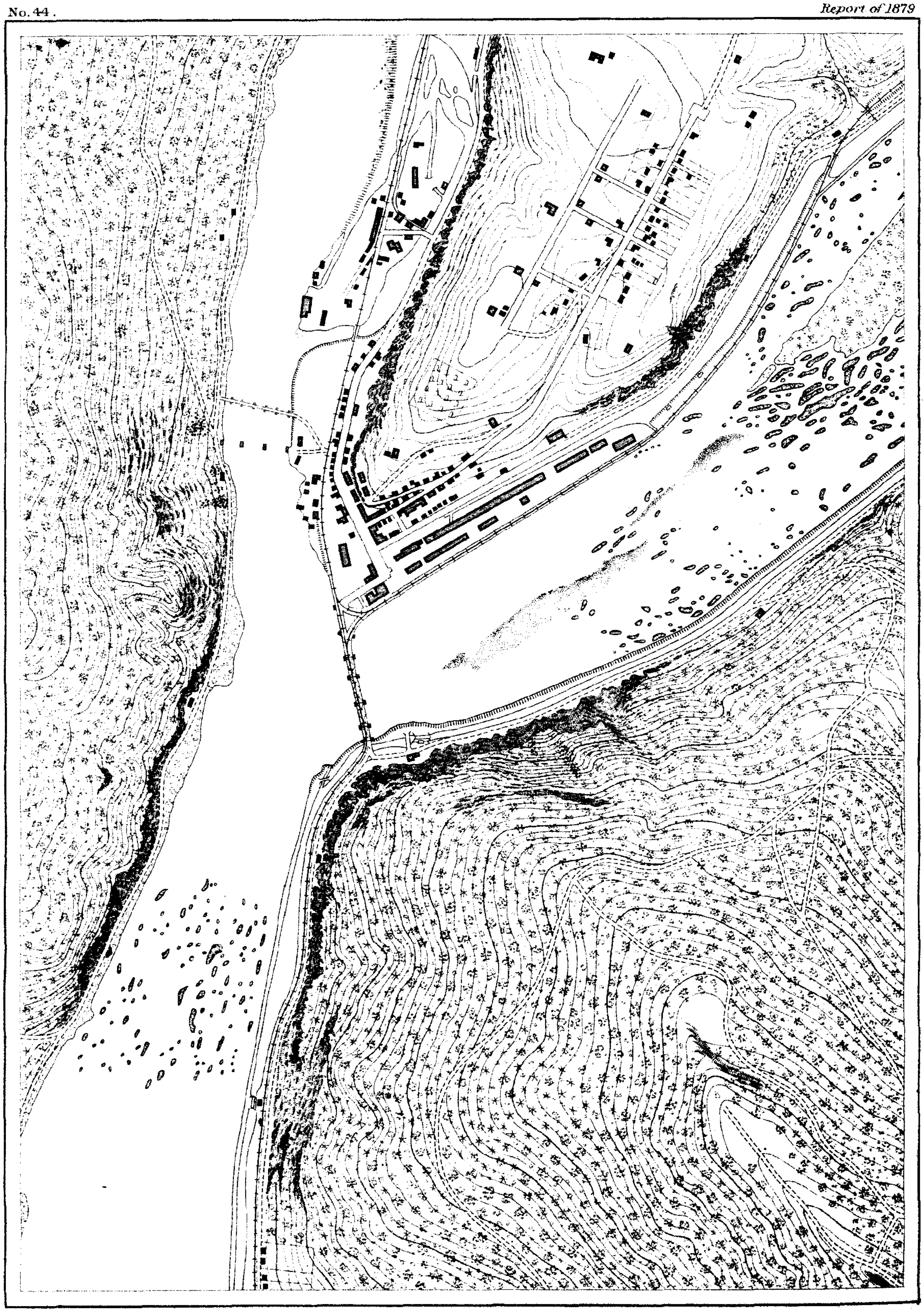
TOPOGRAPHICAL DRAWING
Scale $\frac{1}{10000}$
By E. Hergesheimer Assistant

Sparsely settled Town, Salt Marsh, Pine Woods, Ditches, Fences, and Undefined Roads (Brunswick Ga.)

U.S. COAST AND GEODETIC SURVEY

C. P. Patterson Superintendent

No. 44. Report of 1879

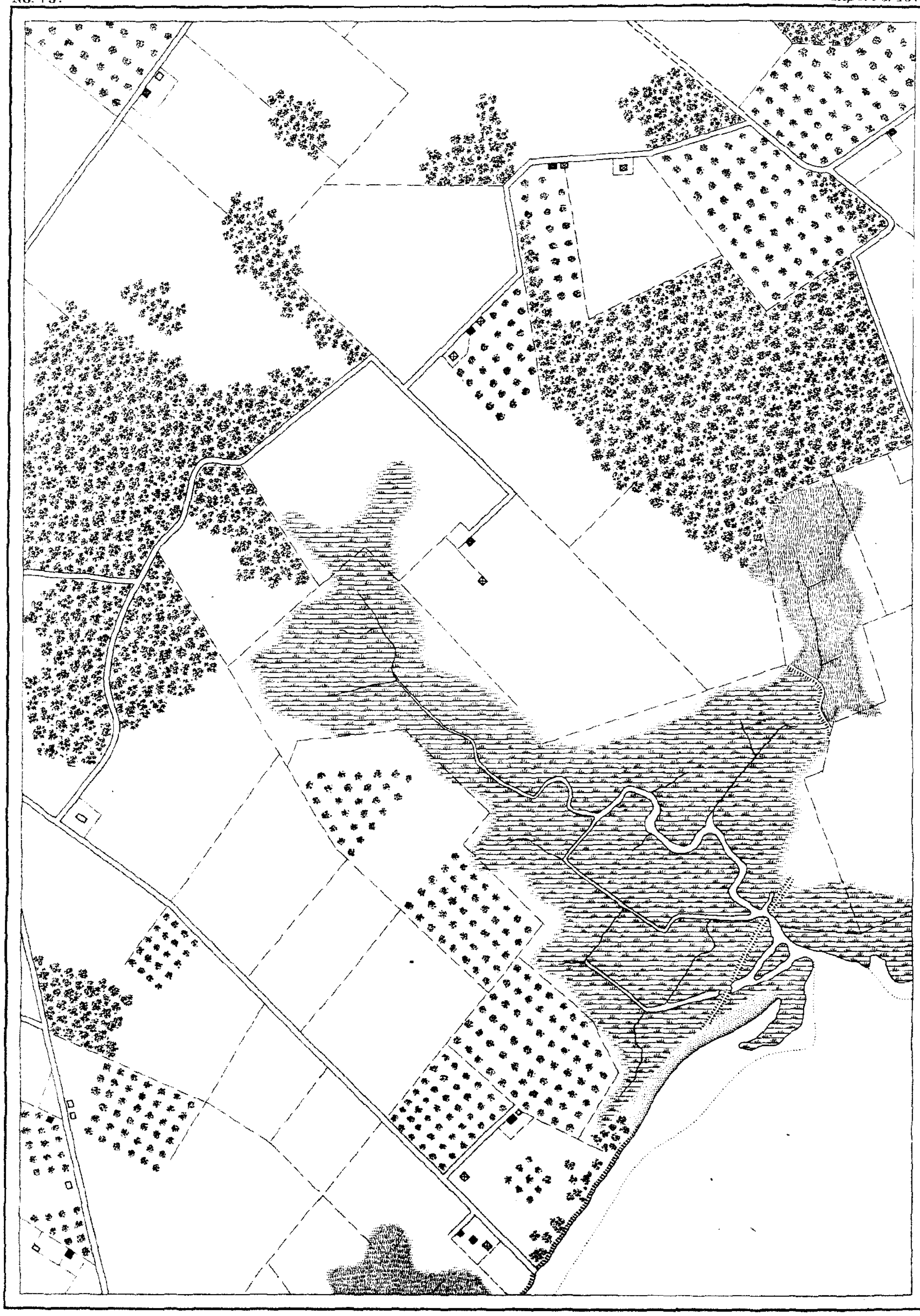


TOPOGRAPHICAL DRAWING

Scale $\frac{1}{10\,000}$

By E. Hergesheimer Assistant

Railroads, Canals, Iron Bridges, Rocky-cliffs, Mid-river drift, Water-worn Rocks, Mixed Woods over hill curves (Harper's Ferry)

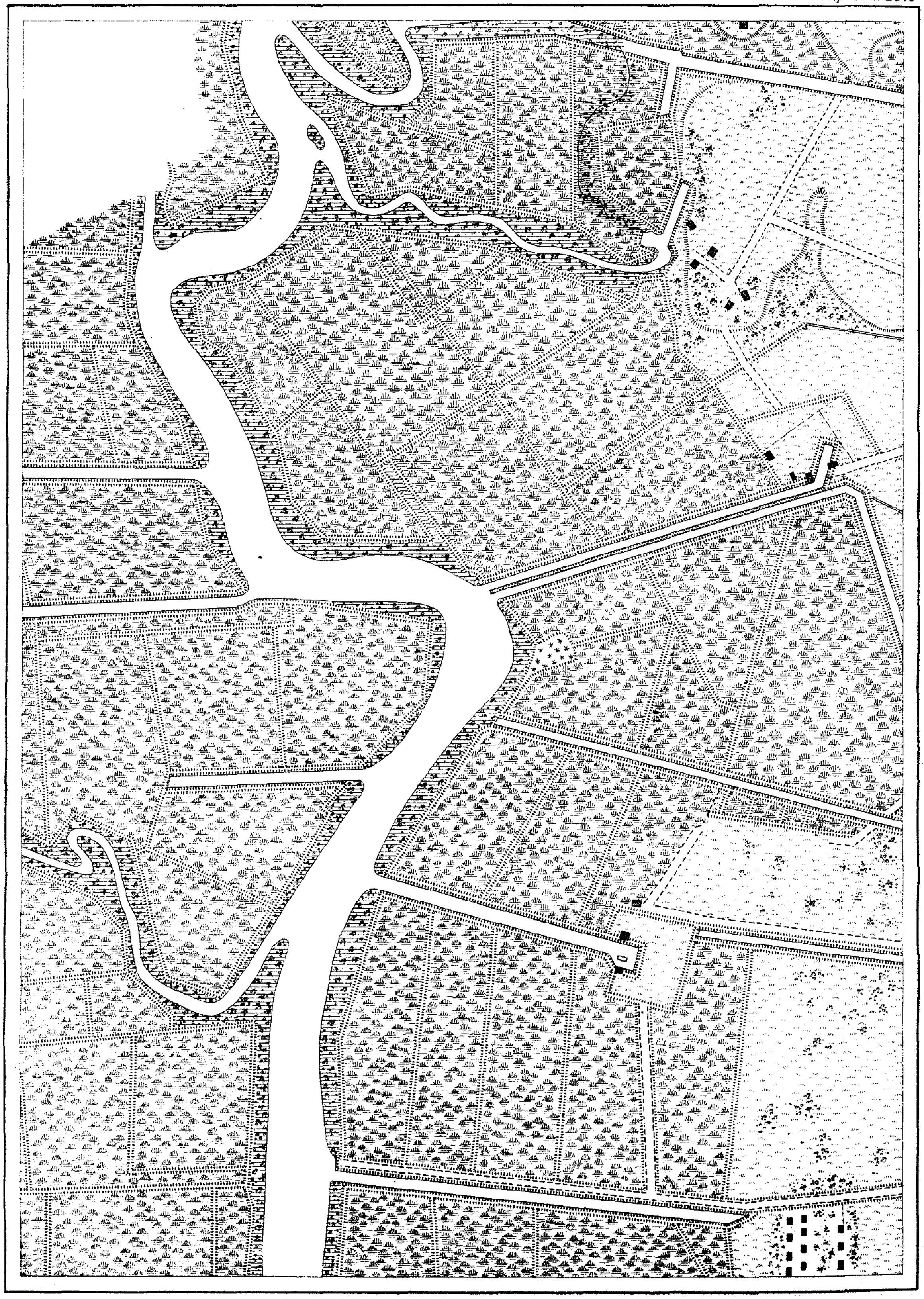


TOPOGRAPHICAL DRAWING

Scale $\frac{1}{10000}$

By E. Hergesheimer Assistant

Heavy Oak Woods, Reclaimed Marsh and Orchards (Delaware River)



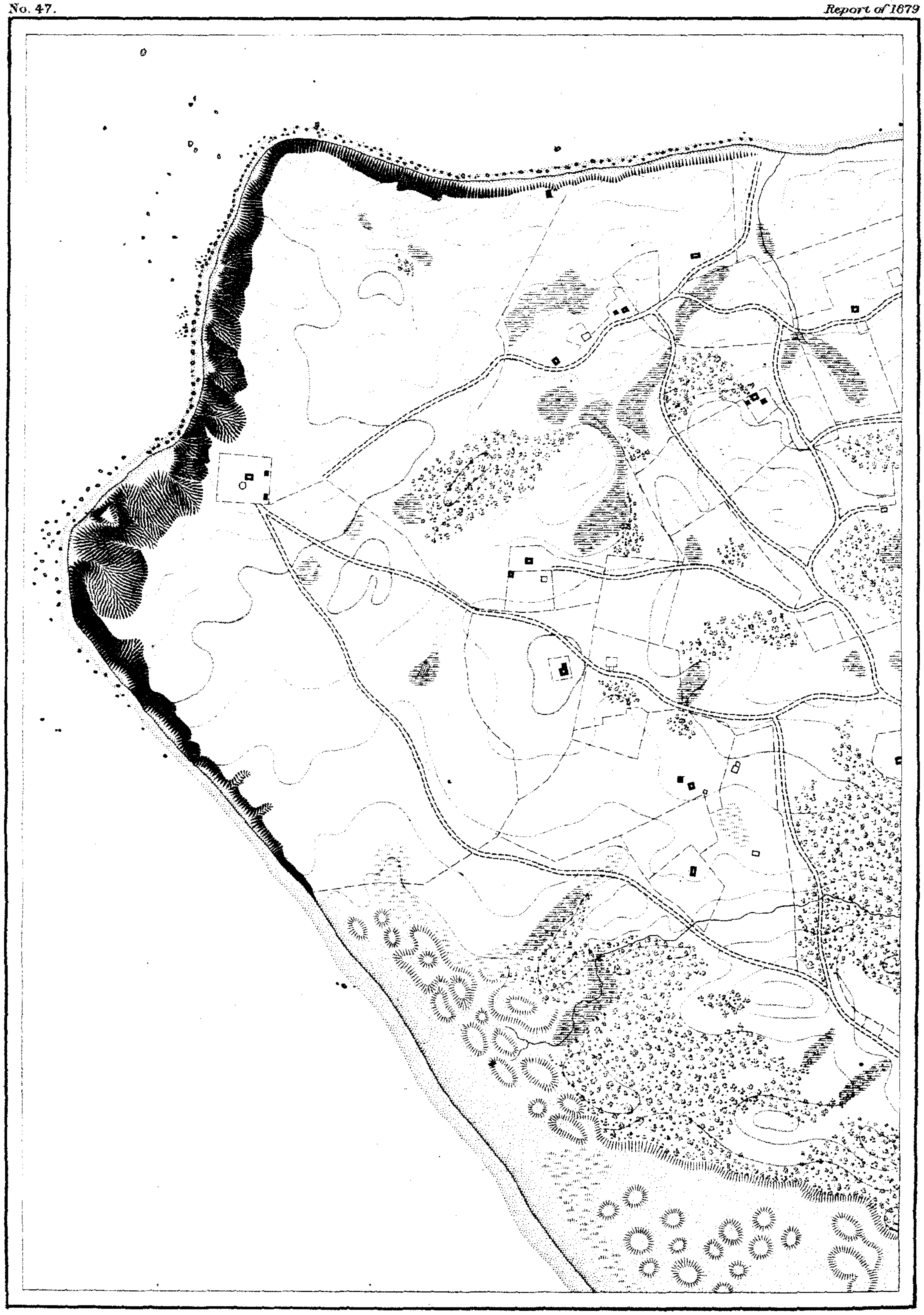
TOPOGRAPHICAL DRAWING
Scale $\frac{1}{10000}$
By E. Hergesheimer Assistant

Rice, Dykes and Ditches (Santee River)

U.S. COAST AND GEODETIC SURVEY

C.P. Patterson Superintendent

No. 47. Report of 1879



TOPOGRAPHICAL DRAWING

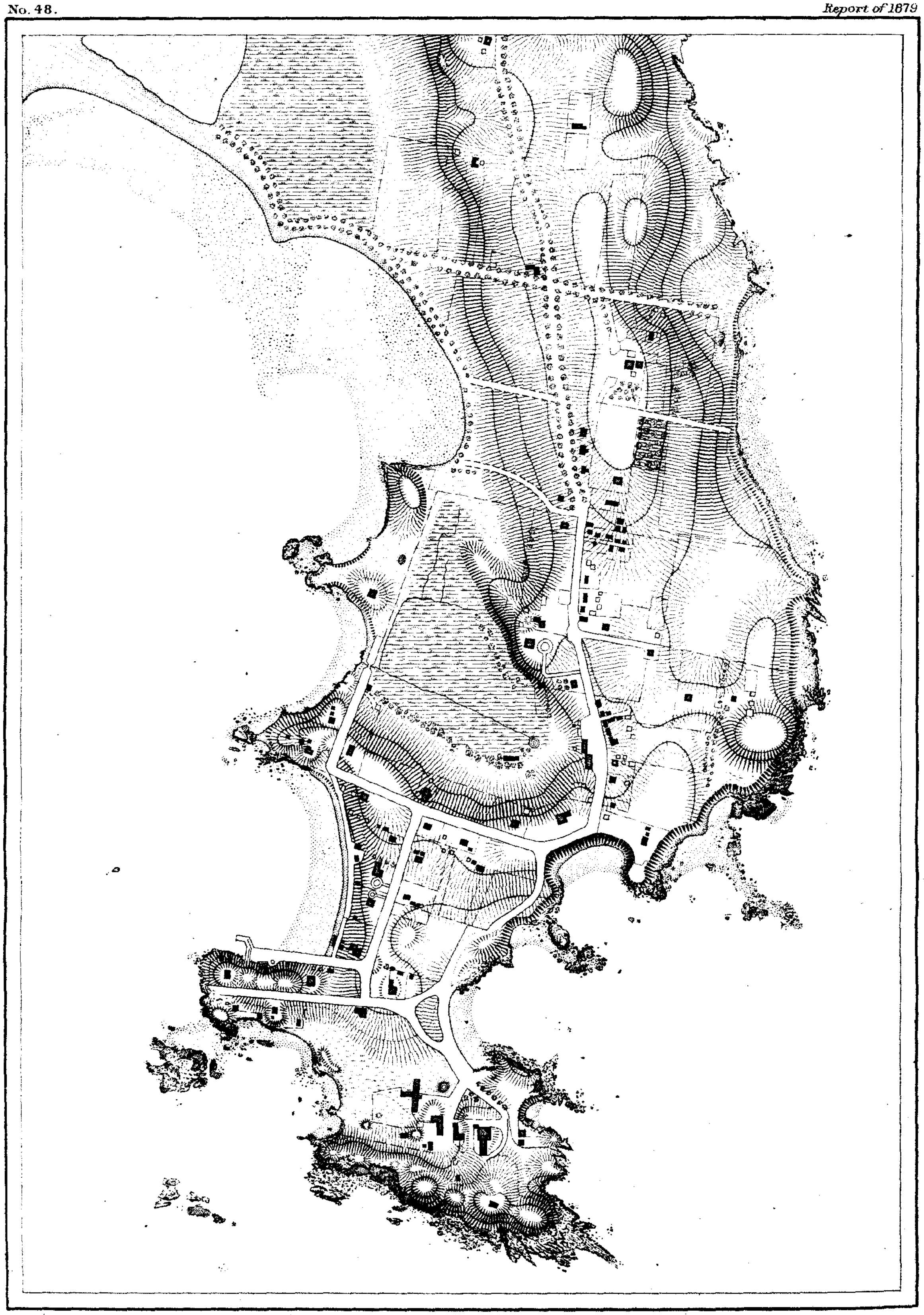
Scale $\frac{1}{10000}$

By E. Hergesheimer Assistant

Eroded drift banks, with boulders set free; and scrub deciduous woods (Gay Head)

U.S. COAST AND GEODETIC SURVEY
C.P. Patterson Superintendent

No. 48. | Report of 1879



TOPOGRAPHICAL DRAWING

Scale $\frac{1}{10\,000}$

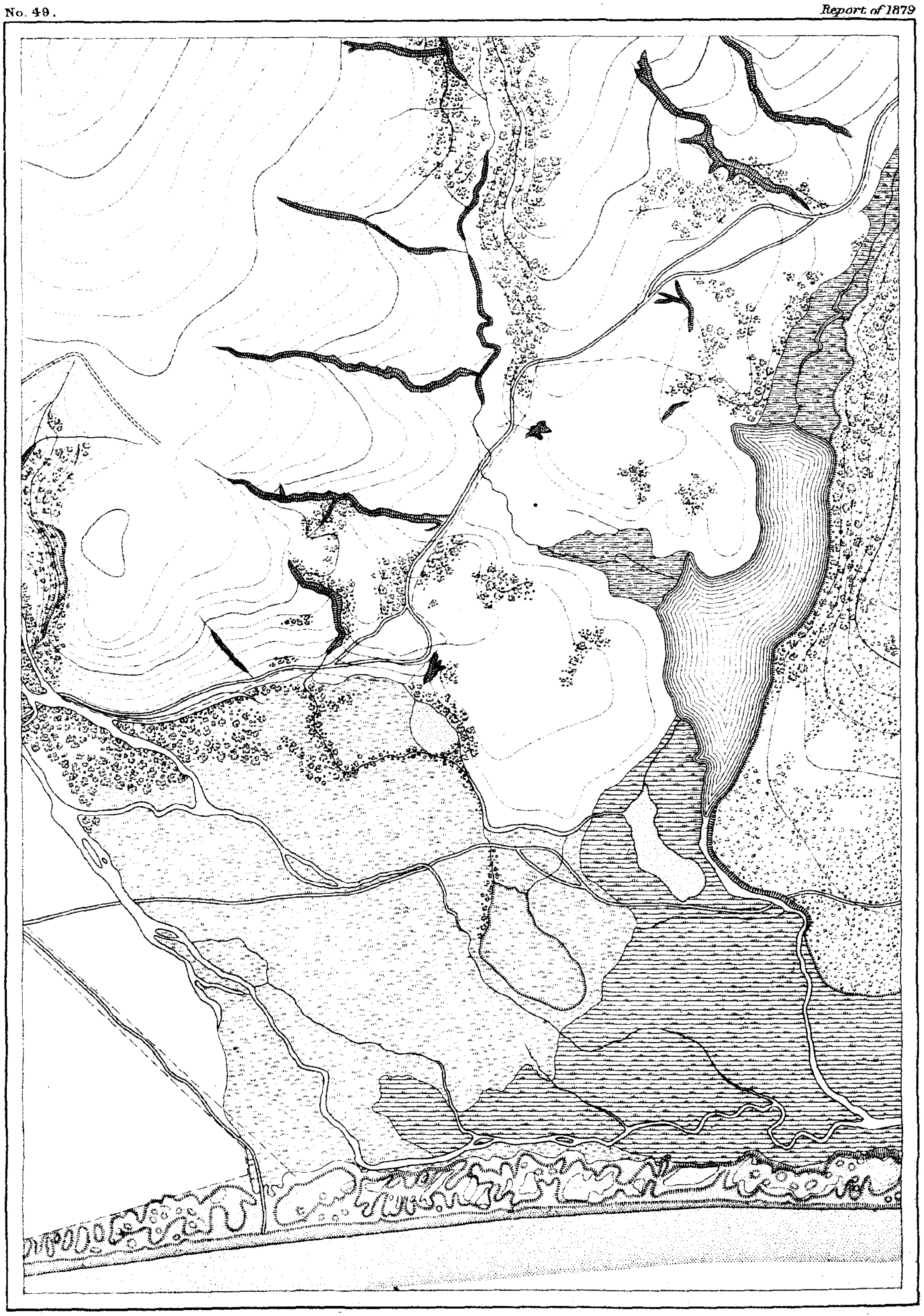
By E. Hergesheimer Assistant

Sand and Shingle Beaches, Eroded Earth Banks, Roads, Fences, Dwelling and Out-Houses, Shaded Road-sides, Hill-shading (Nahant)

U. S. COAST AND GEODETIC SURVEY

C. P. Patterson Superintendent.

No. 49. Report of 1879



TOPOGRAPHICAL DRAWING

Scale $\frac{1}{10\,000}$

By E. Hergesheimer Assistant

Sand Beach with Low Dunes, Fresh Water Pond, Meadow Grass, Sage Brush and Arroyos (S. Coast of California)

APPENDIX No. 11.

REPORT ON THE PREPARATION OF STANDARD TOPOGRAPHICAL DRAWINGS, BY EDWIN HERGESHEIMER, ASSISTANT COAST AND GEODETIC SURVEY.

(Refer to pp. 71 and 72 of this volume.)

OFFICE OF THE UNITED STATES COAST AND GEODETIC SURVEY,
Washington, July 1, 1879.

SIR: In the preparation of topographical drawings to be used as guides for inking the original plane-table sheets of the Coast and Geodetic Survey, selection was first made of such features, natural and artificial, as are most prevalent on our coasts.

The first subject was the representation of closely-built cities, comprising large public buildings, warehouses, &c., and suburban villas and grounds of the first class. Newport, R. I., was selected for this purpose, where it was found desirable to discontinue the inking of large buildings in full black, and to confine the black to the exterior, representing the outer walls, and to tint the interior by fine lines closely ruled. Carriage-ways and walks of villa or public grounds are here represented in full light line, instead of the broken line formerly used. Fresh marsh is also represented in a style different from that heretofore in use. Its representation had previously been by irregularly distributed tufts of grass, underlined by free hand with water lines, which, drawn with taste, is perhaps the most artistic representation of the feature; but which is seldom represented the same by any two persons. It was therefore thought best to introduce a style that could be definitely described and required. For this purpose, lines of the same strength and the same distance apart as those of the salt marsh are ruled and irregularly broken, then interlined and tufted by free hand with light short lines grouped irregularly, as shown in the first of the series of sketches accompanying this paper.

For the representation of a town sparsely settled, Brunswick, Ga., is given, on which salt marsh, pine woods, ditches, fences, undefined roads, and wagon tracks are shown.

For the represention of railroads, canals, iron bridges, bold faces of rock, mid-river drift, water-worn rocks, and distribution of mixed woods over close hill curves, the vicinity of Harper's Ferry is given. Here is illustrated the strengthening of the 100-feet hill curves for the more ready reading of the heights of hills.

For the representation of heavy oak timber, reclaimed marsh and orchards, a part of the New Jersey shore of the Delaware River is given.

For the representation of rice, and the dikes and ditches incident to its cultivation, a selection from Santee River is given.

For the representation of eroded drift banks with bowlders set free, and scrub deciduous woods, the western part of Martha's Vineyard, including Gay Head, is given.

For the representation of the rocky shores and intermediate sand and shingle beaches, beaches above high water and eroded earth banks, characteristic of the coast of New England, roads, fences, residences, outhouses, shade trees on the lines of roads, and the shading of low hills by normals, the extreme end of Nahant is given.

For the representation of a sandy beach, with low dunes, fresh-water ponds, meadow grass, sage-brush, fresh marsh, and eroded gulleys (arroyas), a selection from the vicinity of San Luis Obispo was made.

Samples not yet engraved have also been drawn for various characters of eroded and fractured granite rocks, as shown at Mount Desert Island; hard eruptive rocks, as shown at Cape Disappointment, Oregon, and eroded sedimentary forms at Arlington, Va.

Respectfully, &c.,

E. HERGESHEIMER,
Assistant.

CARLILE P. PATTERSON,
Superintendent.

APPENDIX No. 12.

(Report for 1879.)

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
November 1, 1880.

SIR: Herewith I transmit to you a report by the mechanician, on his reconstruction, under my direction, of the circle dividing engine, together with a tabular statement of the results of examinations of certain theodolites graduated by Mr. Saegmuller upon it, with the aid of his table of errors.

Yours, respectfully,

J. E. HILGARD,
Assistant in charge Coast and Geodetic Survey Office.

CARLILE P. PATTERSON, LL.D.,
Superintendent United States Coast and Geodetic Survey.

ON THE RECONSTRUCTION OF THE DIVIDING ENGINE OF THE COAST AND GEODETIC SURVEY. A REPORT TO THE ASSISTANT IN CHARGE OF THE OFFICE, BY G. N. SAEGMULLER, CHIEF MECHANICIAN.

(Appendix No. 12. Coast and Geodetic Survey Report for 1879.)

OCTOBER 20, 1880.

SIR: I have the honor to submit the following report on the present condition of the Coast survey dividing engine.

The character of the graduations produced by the engine before its reconstruction proved to be unsatisfactory, owing to several causes which I pointed out to you in a former report, which resulted in the old apparatus for tracing the lines being replaced by a new one of improved design and more substantial construction.

It was necessary, before attempting to correct the errors of the circle itself, to remove any possible errors arising from an instability of the tracing apparatus.

Although the performance of the engine was greatly improved after the new apparatus had been attached, yet large errors still existed, and, what was worse, they did not remain constant on the same parts of the circle, showing that the machine was not true to itself.

Unless the machine could be brought to do the same work over and over again, thus making the same corrections necessary, it was of no use to attempt to correct these errors.

A careful examination led to the belief that the unsteadiness of the machine was caused by the imperfection of the axis.

This axis, being a hollow truncated cone of soft brass, on the upper and lower ends of which two *steel rings*, forming the bearings, are shrunk, fits into a socket of red metal. The expansion of these metals being different, the axis could not be made to work in the same way at different temperatures. It was found that by an increase of temperature the axis would turn too easily. This had to be corrected by lowering the axis in its socket by means of a set-screw at the lower end. A decrease in temperature, again, would make it turn so hard that it could only be moved by exerting great pressure, therefore the axis had to be screwed up again to make it turn easier.

It is of the greatest importance that the axis should never be disturbed by means of the set-screw at the bottom, for when the circle is thus raised or lowered the screw will have a different bearing in the threads of the limb, thus requiring a re-examination of the table of errors.

The only remedy for this defect was to have the dividing room kept at an equal temperature.

I had also found that my presence for a considerable time at one side of the circle (the temperature of the room then being about 62° F.) caused it to expand, and by placing two micrometer microscopes at opposite parts of the circle, I actually measured that one semicircle exceeded the other by nearly four seconds, having become warmer by 2° F.

It was therefore decided to have the temperature kept steady at 98° F. As the room was small this was easily effected by two gas-burners. After this I found that the steadiness of the circle—or its axis—in relation to fixed microscopes left nothing to be desired. The examination of the circle could now be proceeded with, and it was decided first to examine the original graduation. If this had been found satisfactory, it would have been very easy to find the errors in the threads of the circle.

It was, however, soon apparent that the circle must have suffered a change, as the microscopes did not remain in focus when used on different parts of the circle. This defect could not be remedied, and an examination of the graduation under such conditions could have but little weight. I decided then to make an entirely new "original" graduation. Before doing this that part of the limb which was to receive the division was turned off by revolving the circle in its socket, which assured me that the plane of the graduation was at right angles to the axis. The definition of the microscopes now set to any part of the circle was equally good all around.

I long ago came to the conclusion that the surest and most expeditious way of producing an original graduation would be to make use of the method of continual bisection. It insures a uniformity in the system, which in dividing is of paramount importance, and, moreover, has the advantage of being very simple in principle.

If we have to bisect any arc, the correct place for the midway line is easily found by tracing a trial line as near as can be done in the middle. If it is in the right place, one-half of the arc as thus bisected must necessarily equal the other. Should one prove to be larger than the other, it is clear that one-half of this excess is to be taken from this arc to make it equal the other.

Unfortunately the division into 360 degrees does not allow a continual bisection. We can only go as far as to bisect the four quadrants again in two halves, viz, 45°. A further bisection would not bring us to an even degree. But rather than give up the method of bisection, and make use of trisection, and eventually of quini-section, I concluded to ignore the degrees altogether, and merely produce a division of equal parts, which ultimately could be converted into the proper degree division.

Two hundred and fifty-six is the highest bisectional number which it was thought convenient to use, and which would divide the circle into spaces, each of which would equal 1° 24′ 22″.5. It is perfectly easy and safe to deduce the proper 360° division from the 256 equal parts.

The first step in the process is to lay off by means of the screw 256 lines on the circle as nearly equidistant as the screw can do it. Great exactness is not essential, although it is desirable to have the errors of these 256 lines small.

It is evident that if the threads in the circle are all in their true places, these 256 parts would necessarily be equal; and, again, should it be found that they differed from each other, the amount of such difference would be the correction for the screw for that part.

Having laid off these 256 parts, the next step in the process is to examine them and compute their individual errors.

For this purpose two micrometer-microscopes, A and B, are placed diametrically opposite. Line 0 is under A; line 180 under B, with which latter coincidence is made. Without disturbing the microscopes the circle is turned until line 180 is under A, and coincidence is made by turning the circle by means of its own screw. Should microscope B now bisect line 0, it is evident that these lines have divided the circle into two equal parts. Should such not be the case, one-half of the difference found would be the error of the line.

Two methods can now be pursued: Either we can regard each line as being in its true place, and continue the examination, forming a table of apparent errors, from which the absolute errors can be afterwards computed, or else we can at once find the absolute error of the line under examination as we proceed, and correct it by tracing a new line. The field of the microscopes was large enough to include these new corrected lines.

The latter method seemed to me to be the best as being less liable to the introduction of error, and as it also saved the trouble of shifting the microscopes twice to the same place.

The method employed to correct erroneous lines is quite simple. Knowing the screw-reading when this line was cut—a table having of course been formed to lay off the 256 parts—it was only necessary to turn this screw to the amount of the errors and trace a new line. The errors as found by the observing microscope B were expressed in tenths of seconds; one division on the head being equal to that amount. The engine screw had a large head divided into single seconds; the tenths were here estimated, which could readily be done, as one second was represented by nearly one-tenth of an inch.

By observing the new line again under the microscope, we find whether the two arcs are now equal. No trouble was experienced in tracing a corrected line. Having thus divided the circle into two equal parts, one microscope is now removed and placed 90° from the other. Line 0 is again brought under A; line 90 is under B, with which coincidence is made. The circle is now turned 90° until line 90 comes under A, when line 180 will be under B. If it has been found that B bisects again, line 90 is in its true place. If not, one-half of the difference is applied and a new line traced. The same is done with line 270° on the other semicircle, after which microscope B is shifted one-half of the former amount, viz, 45°, and the examination of the eight 45° arcs is proceeded with, when we will get the corrected lines 0, 45, 90, 135, 180, 225, 270, and 315. This being done B is moved again a distance of 22° 30′, and 16 arcs are measured. Thus step by step we come down by repeated bisection to arcs corresponding to 11° 15′, 5° 37′ 30″, and 2° 48′ 45″. This latter quantity will now be too small to allow the microscopes to come any nearer; but the difficulty is overcome by skipping one line, and instead of taking one-half take one part and one-half, viz, 4° 13′ 7″.5.

We have thus obtained 256 equal parts. To deduce from these 360 equal parts is simple, as it is merely a matter of proportion. I proceeded in this manner:

Line 0 was brought under the microscope and the screw—by means of which the coincidence was made—read off; the circle was then turned by means of the screw until the next 256th line came under the same microscope when it had been moved 1° 24′ 22″.5, the screw index was again read, and from the number of whole turns and parts of turns which the screw had been turned in order to make the circle 1° 24′ 22″.5, the proportional part was taken and a degree line cut.

The readings of the engine screw, as thus found, give of course the corrections for each corresponding degree.

This final result is shown in the following table. By inspecting it, it will be found that the largest error to be corrected is 11″.5. To obviate the use of plus and minus signs, the screw index was placed at division 15.0 instead of 0.

Table of corrected screw readings for every degree.

Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.
0	15.0	22	15.5	44	16.3	66	17.0	88	18.4
1	15.1	23	15.3	45	16.0	67	16.9	89	18.6
2	15.2	24	15.2	46	16.4	68	16.8	90	18.8
3	15.3	25	15.1	47	16.6	69	16.7	91	19.0
4	15.4	26	15.2	48	16.9	70	16.6	92	19.3
5	15.5	27	15.4	49	17.1	71	16.7	93	19.7
6	15.6	28	15.5	50	17.5	72	16.9	94	20.1
7	15.7	29	15.7	51	17.8	73	17.0	95	20.4
8	15.8	30	15.8	52	18.1	74	17.1	96	20.5
9	15.9	31	16.1	53	18.3	75	17.3	97	20.7
10	16.0	32	16.5	54	18.5	76	17.1	98	20.8
11	15.8	33	17.1	55	18.8	77	16.9	99	20.9
12	15.6	34	17.6	56	18.9	78	16.8	100	21.0
13	15.5	35	18.0	57	19.0	79	16.7	101	20.7
14	15.4	36	17.9	58	19.1	80	16.6	102	20.2
15	15.2	37	17.8	59	19.2	81	16.9	103	19.6
16	15.3	38	17.7	60	19.3	82	17.2	104	19.0
17	15.5	39	17.6	61	18.9	83	17.4	105	18.5
18	15.6	40	17.5	62	18.4	84	17.6	106	18.1
19	15.7	41	17.2	63	18.0	85	17.8	107	17.8
20	15.8	42	16.9	64	17.5	86	18.0	108	17.4
21	15.7	43	16.6	65	17.0	87	18.2	109	17.1

Table of corrected screw readings for every degree—Continued.

Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.	Number of degree.	Screw reading.
110	16.8	160	12.3	210	15.4	260	11.9	310	10.7
111	17.1	161	12.8	211	15.4	261	12.1	311	11.2
112	17.4	162	13.3	212	15.4	262	12.4	312	11.7
113	17.6	163	13.8	213	15.4	263	12.6	313	12.2
114	17.7	164	14.3	214	15.4	264	12.9	314	12.8
115	17.9	165	14.8	215	15.4	265	13.1	315	13.5
116	17.4	166	15.3	216	15.4	266	12.6	316	13.9
117	16.9	167	15.8	217	15.3	267	12.1	317	14.4
118	16.5	168	16.3	218	15.2	268	11.6	318	14.8
119	16.1	169	16.8	219	15.1	269	11.1	319	15.2
120	15.8	170	17.2	220	15.0	270	10.6	320	15.7
121	15.8	171	17.1	221	15.0	271	10.9	321	15.7
122	15.8	172	17.0	222	15.0	272	11.2	322	15.6
123	15.9	173	16.9	223	15.0	273	11.4	323	15.5
124	15.9	174	16.7	224	15.0	274	11.7	324	15.4
125	15.9	175	16.6	225	15.0	275	12.0	325	15.3
126	16.1	176	16.3	226	14.4	276	12.1	326	15.2
127	16.3	177	16.1	227	13.8	277	12.2	327	15.1
128	16.4	178	15.8	228	13.2	278	12.4	328	15.0
129	16.5	179	15.5	229	12.6	279	12.6	329	14.9
130	16.7	180	15.3	230	12.0	280	12.7	330	14.8
131	16.7	181	15.1	231	11.7	281	12.6	331	14.6
132	16.7	182	14.9	232	11.4	282	12.5	332	14.4
133	16.7	183	14.8	233	11.1	283	12.4	333	14.2
134	16.7	184	14.6	234	10.8	284	12.4	334	14.0
135	16.7	185	14.5	235	10.5	285	12.3	335	13.7
136	16.9	186	14.3	236	10.8	286	11.7	336	14.0
137	17.0	187	14.1	237	11.1	287	11.1	337	14.3
138	17.2	188	13.9	238	11.4	288	10.5	338	14.7
139	17.4	189	13.7	239	11.7	289	10.0	339	15.1
140	17.5	190	13.5	240	11.9	290	9.5	340	15.4
141	17.3	191	13.6	241	11.7	291	9.6	341	15.4
142	17.2	192	13.8	242	11.4	292	9.8	342	15.4
143	17.0	193	13.9	243	11.3	293	10.0	343	15.3
144	16.9	194	14.1	244	11.0	294	10.1	344	15.3
145	16.7	195	14.3	245	10.8	295	10.3	345	15.3
146	16.3	196	14.5	246	10.7	296	10.4	346	15.4
147	16.0	197	14.6	247	10.6	297	10.5	347	15.5
148	15.7	198	14.7	248	10.4	298	10.6	348	15.6
149	15.5	199	14.8	249	10.3	299	10.7	349	15.8
150	15.2	200	14.9	250	10.2	300	10.8	350	16.0
151	15.1	201	15.1	251	10.2	301	10.7	351	16.0
152	15.0	202	15.2	252	10.2	302	10.6	352	15.9
153	14.9	203	15.4	253	10.3	303	10.5	353	15.8
154	14.8	204	15.5	254	10.3	304	10.4	354	15.7
155	14.7	205	15.6	255	10.3	305	10.3	355	15.6
156	14.3	206	15.6	256	10.6	306	10.4	356	15.4
157	13.8	207	15.5	257	11.0	307	10.5	357	15.2
158	13.3	208	15.5	258	11.3	308	10.6	358	15.1
159	12.8	209	15.4	259	11.6	309	10.7	359	15.1

The use of the foregoing table in graduating other circles is apparent. Although we have only 360 equal parts, yet the screw of the engine is of such excellence that we are fully justified in using it for the subdivision of each degree, especially as the errors differ so gradually. It may be mentioned here that the engine screw has by long usage so ground itself into the circle that it now takes hold of nearly 6°; that is, 71 threads. It would be almost impossible to make a screw like it, as the threads have now so adapted themselves to the circle that they are no longer parallel, but converge towards the center of the circle. The steel of which this screw is made is of such uniform texture that after all the wear it now runs perfectly true.

If we want to make use of the foregoing table to obtain a 5′ or 10′ division we must only apply the correction from degree to degree proportionally to each subdivision. As the correction for two successive degrees in no case exceeds 0″.6, it is evident that a subdivision into 5′ spaces will not have any appreciable error.

Several large circles, from 14 to 20 inches in diameter, have been graduated by means of this table. It had, of course, to be done by hand, as before drawing a line the screw had to be set to the required reading. This operation being tedious in the extreme, especially, it should be remembered, as the temperature had to be maintained at 98° F., and as at most 30° could be so divided in one day, thus requiring two weeks for each circle, it was desirable to make the machine automatic in correcting its own errors.

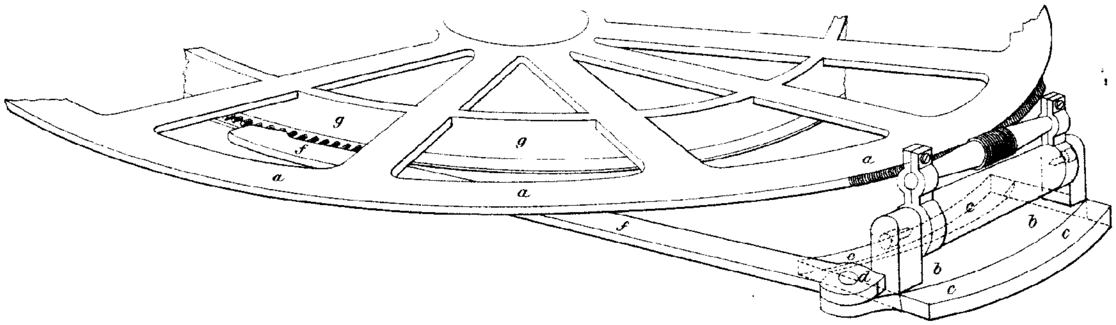
As this would have taken considerable time, and as a great many circles required graduation, I hit upon the following plan, which may be called half automatic, and which enabled me to graduate a circle in about eight hours. It was done in the following manner:

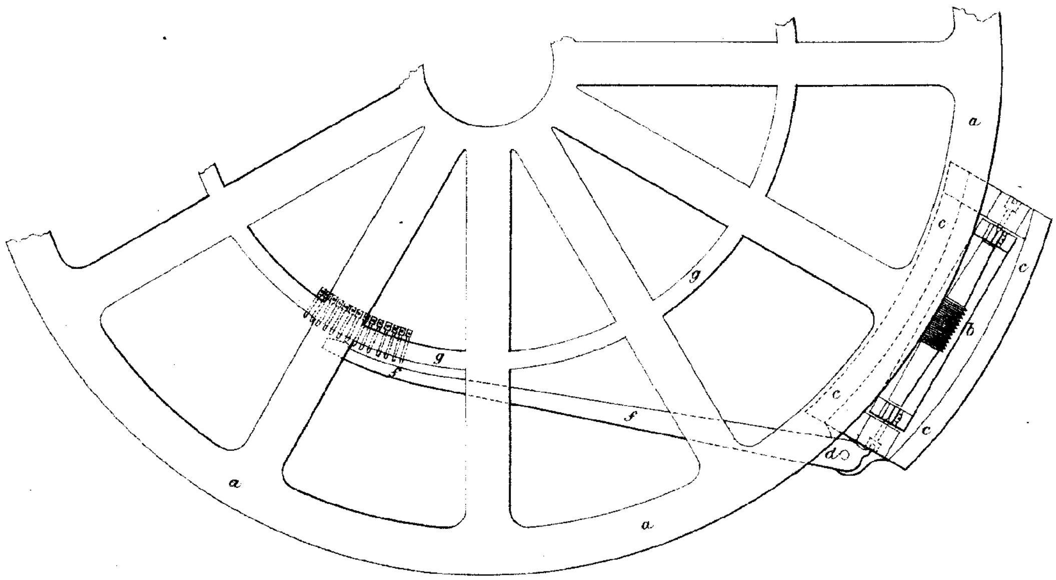
The screw giving the proper angular motion to the circle is propelled by means of a chain fastened to a crank-pin of a driving-wheel and wound around a cylinder, which in going forward turns the screw by means of clicks taking hold of the ratchet-wheel attached to one end of the screw. This operation takes place when the crank-pin of the driving-wheel is going down. Having reached the dead center, the chain with the cylinder is moved back by a weight attached to the other end of the chain, the clicks gliding now in an opposite direction over the ratchet-wheel of the screw. The amount of motion given to the circle depends, of course, on the motion of the screw, which is controlled by means of two stops on the cylinder acting between two blocks or anvils. These being set properly, the circle will, of course, be always moved forward the same angular distance. To move it more or less could be effected by moving the anvils confining the movement. My idea of thus correcting the errors was to have these anvils adjustable instead of having them fixed. I arranged them so that by turning a screw the anvil defining the forward movement could be raised or lowered. Being lowered, it had the effect of making the screw go more forward; being raised, it could not go so far. Both anvils were on the same piece; thus one was raised just as much as the other was lowered. This is very important, in order that the total amount the screw should turn would not differ. To allow the chain to go down when the anvils were at the lowest extremity a strong spring was inserted in the chain, which had enough action to insure a firm bearing of the stops whether the anvils were up or down. The screw by which this moving of the anvils was effected was so made that one-quarter turn made a correction of 0″.1. Dividing a circle into 5′ spaces this amount of correction from one line to another is never exceeded, and as it could be done without interfering with the automatic action of the engine, the circles were really all divided automatically by the machine, the correction merely, as the cylinder was turning back, being given by hand in moving the anvils the quantity the screw should read at each particular line.

Until the new arrangement for the automatic correction of errors, a plan of which I herewith submit, is attached, all circles will be divided by this method. Those already so divided show that the former existing errors in the machine have been successfully corrected.

In regard to an automatic correction of the errors, the idea which suggests itself first to the mind to gain this end is to make the "anvils," which define the motion of the screw, either movable, or to make the periphery of a wheel answer as the anvil. This wheel for every line to be cut could be made to move forward a sufficient quantity to present enough new surface upon which the stop would work; and it is evident that if this periphery is shaped to correspond to the errors of the machine, and if we had enough surface on the wheel, the desired end would be gained.

Practically, however, several difficulties are encountered. Unless the wheel were of such unwieldy proportion that each 5′ line could have its *corrected* anvil, *two* wheels would have to be used, one corresponding to the forward, the other to the backward anvil; for if we use a wheel of, say, 15 inches in diameter, which gives us for each degree an anvil of about $\frac{1}{10}$ inch, it is only the degree lines that would be corrected, and if, say, we had a correction for one degree, amounting to + 1″.0, this correction would be repeated with every line until the next "degree anvil" had come under the stop, unless the backward stop had *moved up* just as much as the forward one had been lowered; for it must not be forgotten that the screw must not make more than one full turn,





PLAN FOR AN AUTOMATIC CORRECTION TO THE GRADUATING ENGINE
OF THE
U.S. COAST AND GEODETIC SURVEY.

excepting at the place where a correction is desired. By making the wheel of very large size, in order to have enough periphery for every 5′ line, this difficulty could be overcome, but the wheel would have to have a diameter of at least 3 feet.

Nor is this the only difficulty. Another very serious one arises from the fact that the chain of the "driving-wheel" turning the stop-drum would be alternately tightened or slackened as the corrected places on the periphery were plus or minus.

This is a very serious objection, as the motion of the screw and the pressure of the stop against the anvil should be as uniform as possible.

These difficulties led me to consider another plan, in which the motion of the screw is left entirely undisturbed, and the correction of the errors is obtained by moving the whole screw "laterally" and in such a way as to correct the error while the screw is gearing into the circle.

In the annexed sketch *a a a* represents a portion of the engine circle; *g g* is a rib projecting below the circle, and into which I propose to insert 360 adjusting screws, each one to correspond to a degree of the graduation; *f f* represents a long lever, which has its fulcrum at *d*. The long arm of this lever presses against the adjusting screws; the short arm presses against the frame or plate carrying the screw; this plate slides in a dovetail slide laterally, and is pressed against the lever by means of a weight or spring.

Now it is evident if any of the screws project more than the others that the lever would be turned more, and consequently the circle shifted more to the left.

The long and short arms of the lever are as 50 × 1; and as 1″ corresponds to about $\frac{1}{9000}$ of an inch, to obtain such a correction the long arm would have to be moved about $\frac{1}{180}$ of an inch.

As the whole range of errors is about 13 seconds, the entire range of moving the frame of the screw required is about $\frac{1}{700}$ of an inch.

It is of the greatest moment that the screw shall not change its tangential relation to the circle. This is easily secured by making the bed-plate carrying the screw move in a circular slide concentric with the dividing engine circle. This is shown on the sketch by *b b*, the bed-plate moving between the slide-guides *cc*, *cc*.

It is a very simple matter to adjust these screws by taking one degree line as zero and bisecting it with a microscope; it is only necessary to turn the screw one degree (= 12 turns) to see whether the next line is bisected. If so, there is no error; if not, turn the screw in opposition to the lever until the circle has been moved the necessary quantity.

The long end of the lever is polished, hardened, and tapered off, in order to make the corrections from degree to degree gradual.

I think that this method will work very well; so far as my experiments have shown, it leaves nothing to be desired.

Nor will it require much alteration on the engine. Instead of having the screw-frame fixed we have it movable in a slide; we add a long lever and the necessary adjusting screws.

But I hope that before we undertake the automatical correction of the circle you will remember the plea for a good axis, without which all corrections and work done on the engine will only be partially successful. It is my firm opinion that the errors which we find in the graduated circles can be greatly reduced by having the present axis replaced by a better one. As it is, to arrive at such results in graduation as I have achieved, it is indispensable to have the temperature constant at 98°.

Respectfully submitted.

G. N. SAEGMULLER,
Chief Mechanician.

J. E. HILGARD,
Assistant in charge of Office.

A number of theodolites graduated by Mr. Saegmuller upon the dividing engine with the aid of his table of errors were examined at this office by the method explained in Appendix 11, Coast Survey Report of 1877.

It is there stated that "It should be borne in mind that it is not claimed for the method of bi- or tri-section that it is an absolute test of the accuracy of graduation. In every tri-section the three individual readings are referred each to the mean of the three, and the smallness of the resulting residuals is the criterion of the general accuracy." Yet as each tri-section is entirely independent of every other one, it is evident that we have no check upon the accuracy of the angular space between any two divisions not exactly 120° apart; and thus errors having a period of 120° will not appear by this method, the principal value of which consists in showing the probable value of accidental errors, or of errors having a period not commensurate with 120°.

If we determine the effect of the eccentricity upon any given reading and correct this reading for it, we will have left the residual error of graduation and pointing.

These residual errors are given below on Table I for every 5° for theodolites Nos. 5 and 118, and for every 10″ for theodolite No. 133, to illustrate the manner in which the probable errors of graduation given in Table II have been deduced for these and other theodolites.

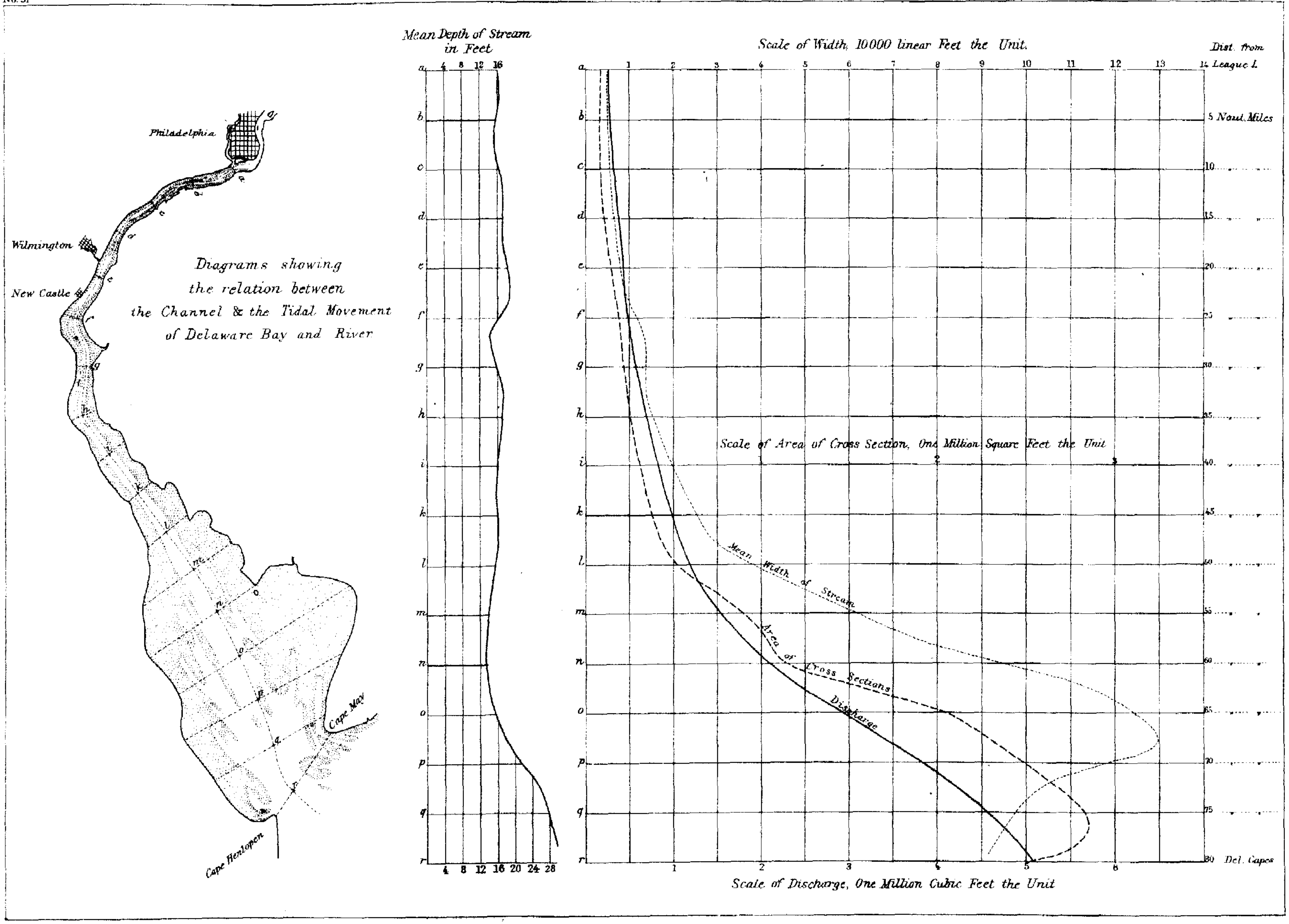
As the theodolites examined have different diameters, it is necessary for purposes of comparison to reduce the probable errors which are expressed in angular values to linear ones, as shown in columns 5 and 6.

TABLE I.—*Residual errors of graduation.*

Theod. No. 5, 20-inch, 3 micr.				Theod. No. 118, 12-inch, 3 micr.			Theod. No. 133, 8-inch, 2 micr.		
r	$r+0$	$r+120°$	$r+240°$	$r+0°$	$r+120°$	$r+240°$	r	$r+0°$	$r+180°$
°	″	″	″	″	″	″		″	″
0	+0.1	—0.1	+0.1	+0.9	+0.3	—1.3	0	+0.5	+1.0
5	—0.3	—0.5	+0.8	+1.0	+0.6	—1.5	10	0.0	—1.5
10	—0.8	—0.3	+1.1	+0.5	+1.4	—1.9	20	—1.5	—0.5
15	—0.5	+0.2	+0.3	+0.6	+0.9	—1.5	30	—2.5	—2.5
20	+0.1	—0.4	+0.3	+0.4	+0.3	—0.7	40	—2.5	—2.0
25	+0.7	—0.3	—0.4	—0.2	+0.4	—0.2	50	—2.0	—2.5
30	+0.5	—0.2	—0.3	—0.1	+1.2	—1.2	60	+1.0	—0.5
35	+1.0	—1.1	+0.1	—0.4	+1.0	—0.5	70	—0.5	+3.0
40	+1.4	—1.8	+0.3	—0.3	+1.0	—0.5	80	—2.0	+3.5
45	+1.3	—1.3	0.0	—0.8	+1.6	—0.8	90	—0.5	+2.5
50	+2.6	—0.6	—2.1	—0.7	+1.8	—1.0	100	—1.0	+1.0
55	+1.6	—1.3	—0.3	+0.3	+1.0	—1.3	110	—1.0	+1.0
60	+0.5	—1.7	+1.2	0.0	+1.9	—1.9	120	—0.5	+1.0
65	+0.2	—0.8	+0.6	—0.2	+1.6	—1.4	130	—2.0	+0.5
70	0.0	+0.2	—0.1	—1.3	—0.1	+1.3	140	—0.5	—2.0
75	+0.2	—0.5	+0.2	—1.2	—1.4	+2.6	150	0.0	—2.0
80	+0.1	—0.2	+0.1	—0.7	—1.1	+1.8	160	+3.5	—2.5
85	+0.1	+0.4	—0.6	—1.5	+0.9	+0.7	170	+2.5	—2.0
90	—0.8	+1.0	—0.3	—1.0	+0.8	+0.2	....	....	....
95	—0.1	+1.1	—1.0	—1.7	+0.6	+1.1	....	....	....
100	0.0	+1.6	—1.6	—1.7	+1.6	—0.1	....	....	....
105	+0.6	+1.7	—2.3	—1.3	—0.6	+1.8	....	....	....
110	+0.2	+1.5	—1.8	—2.1	—0.2	+2.2	....	....	....
115	+0.2	+1.1	—1.3	—1.3	—0.2	+1.5	....	....	....

TABLE II.

Number of Theod.	Diameter of circles.	Number of microscopes.	Number of examined divisions.	Probable error of one line of the graduation.	
	Inches.			″	*Inch.*
3	20	3	2	±0.39	±0.000019
5	20	3	3	0.60	.000029
118	12	3	2	0.83	.000024
131	12	3	3	0.83	.000024
108	12	2	2	1.02	.000030
132	8	2	3	1.63	.000032
133	8	2	3	1.30	.000025


Diagrams showing
the relation between
the Channel & the Tidal Movement
of Delaware Bay and River
Philadelphia
Wilmington
New Castle
Cape May
Cape Henlopen
Mean Depth of Stream
in Feet
4 8 12 16 20 24 28
Scale of Width, 10000 linear Feet the Unit.
Dist. from
League I.
5 Naut. Miles
Del. Capes
Scale of Area of Cross Section, One Million Square Feet the Unit
Mean Width of Stream
Area of Cross Sections
Discharge
Scale of Discharge, One Million Cubic Feet the Unit

APPENDIX No. 13.

ADDENDUM TO A REPORT ON A PHYSICAL SURVEY OF THE DELAWARE RIVER, BY HENRY MITCHELL, ASSISTANT UNITED STATES COAST AND GEODETIC SURVEY.

BOSTON, *March*, 1881.

DEAR SIR: In my report upon Delaware River, printed as Appendix No. 9 to the Report of the Coast and Geodetic Survey for 1878. I made the following statement:

"Other things equal, the size of a channel through alluviums may be said to vary directly as the amount of service which it is called upon to perform as a conduit."

In the extra copies of this Report, distributed among professional and interested parties, the word "*tidal*" was inserted before the word channel.

This statement, so widely at variance with all writers upon hydrodynamics, was a theoretical deduction from the laws of tides, and I confess that I did not expect that I could offer from the very scene of my labors the practical illustration which follows. Indeed, I was somewhat shaken in my own belief when I found, upon further reasoning from the theoretical standpoint, that two other conclusions were made necessary, still more at variance with preconceived ideas. I will state these three conclusions in their order, premising that *alluvial tidal channels* are in question.

1st. The transverse section is directly proportional to the discharge.

2d. The width is proportional to discharge.

3d. The mean depth is the same in all sections. In other words, a natural constant is found.

The table which follows was compiled by Henry L. Marindin from the Coast Survey Chart of Delaware Bay, and the diagram which he has made of the results I have placed after the table in order to display to the eye without effort the success of the experiment. Mr. Marindin used the planimeter for determining areas and mean widths, so that more than usual rigor was exercised in his computations.

You will observe that for the portion of the bay below artificial obstructions and above the counteraction of the waves of the ocean my three rules hold good in a remarkable manner. The width is affected by the wear of the waves upon the shore to a greater degree than the other elements, as might have been expected; but the mean depth for a distance of sixty-eight miles below League Island differs from the average (sixteen feet) only in one instance as much as three feet, and in eight out of the fourteen sections in this distance the variation does not exceed one foot. In this distance the width varies from a half mile to over twenty miles, and every conceivable form of shoal vexes the navigation. At a first glance at the chart one would think that mere chance disposed of channels, islands, and shoals, but our table brings order out of this chaos.

Yours, respectfully,

HENRY MITCHELL,
Assistant Coast and Geodetic Survey.

CARLILE P. PATTERSON, LL. D.,
Superintendent Coast and Geodetic Survey.

TIDAL MOVEMENT IN DELAWARE BAY AND RIVER.

Distance from League Island.	Locality.	Mean width of stream for 5 miles.	Mean depth.	Area of cross section.	Superficial area for 5 miles.	Contents of tidal prism in 5 miles.	Discharge. Total at cross section.	Discharge. Increase between cross sections.
Nautical miles.		Feet.	Feet.	Square feet (thousands)	Square feet (millions)	Cubic feet (millions)	Cubic feet per second (thousands)	Cubic feet per second (thousands)
0	Section No. 47 of 1878			93			245	
		5 190	16		158	947		38
5	Lazaretto			75			283	
		5 560	15		169	1 013		40
10	Marcus Hook			92			323	
		5 850	17		178	1 067		43
15	Old Man's Point			105			366	
		7 440	17		226	1 355		54
20	Deep-Water Point			151			420	
		8 810	19		268	1 605		64
25	Bulkhead Shoal			188			484	
		14 450	14		439	2 635		104
30	Elsingborough Point			214			588	
		13 800	17		419	2 515		100
35	Baker's Shoal			252			688	
		17 190	16½		522	3 133		124
40	Thoroughfare Neck			313			812	
		22 180	15½		674	4 043		161
45	Bombay Hook			374			973	
		28 470	16		865	5 189		206
50	Goose Point			516			1 179	
		49 520	14½		1 504	9 026		358
55	Mahon's River Light			920			1 537	
		74 430	13½		2 261	13 568		538
60	Egg Island Point			1 115			2 075	
		114 930	14		3 492	20 949		831
65	Mouth of West Creek			2 070			2 906	
		129 920	17½		3 947	23 682		940
70	Brandywine Shoal			2 485			3 846	
		102 570	26		3 116	18 695		742
75	Mummy Shoal			2 840			4 588	
		91 440'	29		2 207	13 240		525
80	Cape Henlopen to Cape May			2 495			5 113	

APPENDIX No. 14.

ON THE INTERNAL CONSTITUTION OF THE EARTH.

(Coast and Geodetic Survey Report for 1879.)

1. The law of the increase of density of the earth from the surface to the center has been well investigated by R. Lipschitz. His memoir is published in the 62d volume of Crelle's Mathematical Journal, and his formula is given on the 35th page. If x denotes the mean radius of any homogeneous stratum, referred to the mean radius of the earth as unity, the density k is

$$k = 9.453 - 6.953\, x^{2.39}$$

From this formula the density of the earth for different strata is given in the second column of the subjoined table. The first column contains the corresponding mean radius of the stratum.

2. From the above formula, the gravity (g) at the surface of a stratum, referred to the gravity of the whole earth at its surface as unity, neglecting the centrifugal force, is

$$g = \left(\frac{9.453}{3} - \frac{6.953}{5.39}\right)^{-1} \left(\frac{9.453}{3}\, x - \frac{6.953}{5.39}\, x^{3.39}\right) = 1.6936165\, x - 0.6936165 x^{3.39}$$

Its value is given in the third column of the table.

3. If the earth were liquid, the pressure p upon each square inch of every stratum, estimated in thousands of pounds, neglecting the centrifugal force of rotation and ellipticity, is given by the formula,

$$p = \int_x gk = 82422.80 - 145310.40x^2 + 75794.95x^{4.39} - 12907.34x^{6.78}$$

Its value is given in the fourth column of the table.

4. Were the earth's interior in convective equilibrium in conformity to the theory of Sir William Thomson, the increase of density should correspond to the increase of pressure. The immense incompressibility ρ which would thence result is exhibited in the fifth column of the table, which represents the incompressibility in terms of water as unity, in passing from the surface of one stratum to the next interior stratum of the table. This result does not affect the question of rigidity so ably discussed by Sir William Thomson.

x	k	g	p	ρ
1.0	2.50	1.	0	42.40
.9	4.0478	1.0389	6130	104.79
.8	5.3740	1.0295	15039	192.21
.7	6.4885	.9783	25906	299.83
.6	7.4021	.8932	37755	422.60
.5	8.1265	.7805	49593	557.07
.4	8.6748	.6462	60505	704.36
.3	9.0617	.4962	69725	876.08
.2	9.3045	.3357	76675	1116.67
.1	9.4247	.1690	80973	1610.50
0	9.453	0	82423	

CAMBRIDGE, *March* 27, 1878. BENJAMIN PEIRCE.

APPENDIX No. 15.

ON INSTRUMENTS AND METHODS USED FOR PRECISE LEVELING IN THE COAST AND GEODETIC SURVEY. REPORT BY O. H. TITTMANN, ASSISTANT.

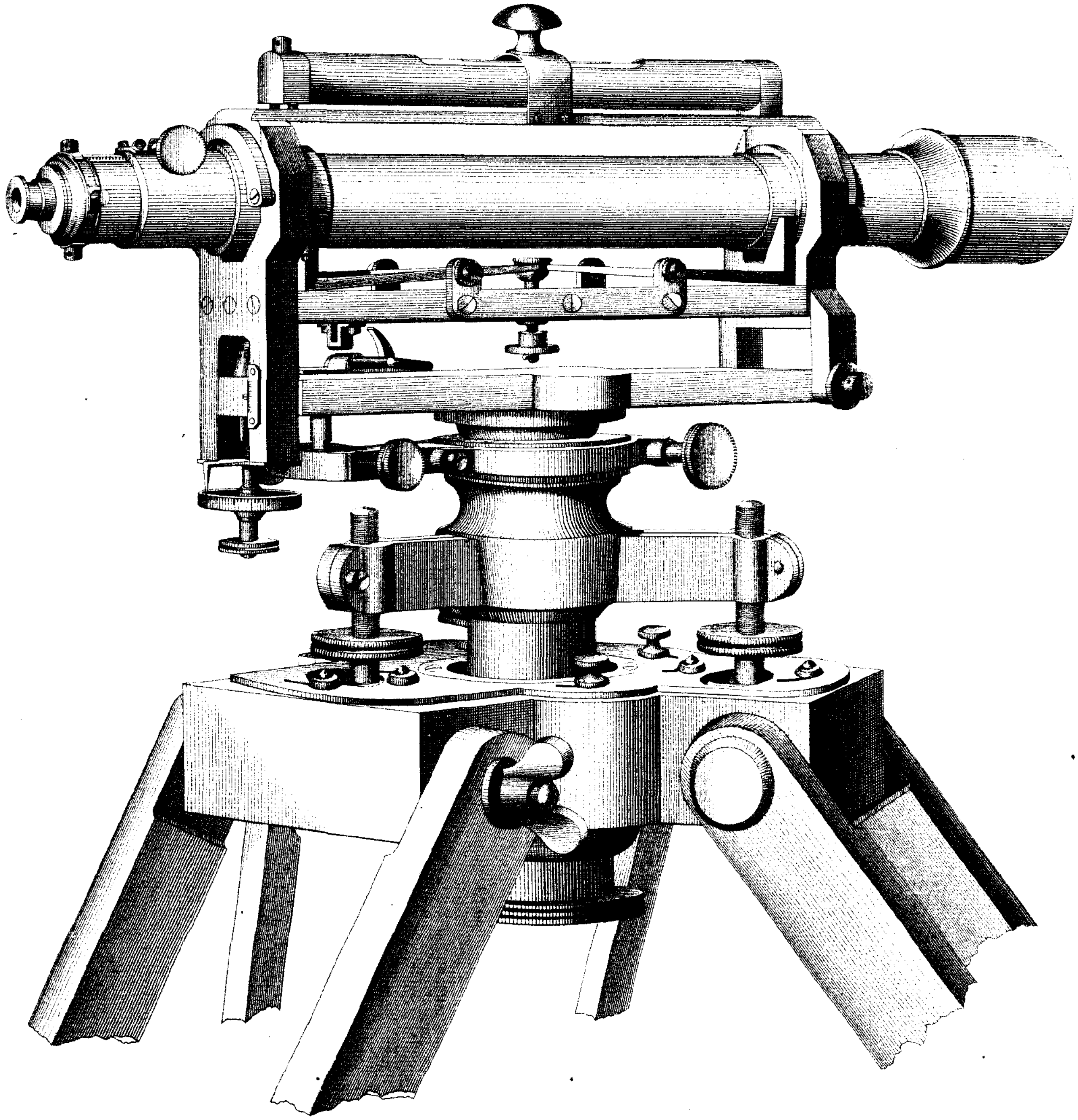
The leveling instruments adopted by the Superintendent for the precise work of the survey, are in principle the same as those known as the "Vienna" or "Stampfer" levels. Their introduction in 1877, with important additions in the accessory parts, and the manner of using them, is due to Assistant J. E. Hilgard.

The principle underlying the construction of these instruments is, that the telescope can be moved in a vertical plane about a horizontal axis by means of a micrometer screw. This construction is especially adapted to the object had in view, namely, of multiplying the pointings on a mark either in the horizon of the instrument or at an angle above or below it, even beyond the measuring range of the striding level. It was supposed that the accuracy of the striding level, where a large number of its divisions was involved, would be impaired by its exposure to the influences of the wind and of changing temperatures in the open air. It was therefore decided to use it only to define the horizontality of the telescope, but to measure any inclination of the latter by means of the micrometer screw. In using a target rod, therefore, it would only be necessary to bring the target approximately into the horizon, which effects a saving in time and an increase in accuracy over the usual attempt to bring the target exactly into the line of sight. The method is equally adapted to observing on rods without targets, and presents the obvious advantage of enabling the observer to attempt a *bisection* of any graduated space on the rod near the horizon.

These instruments are known in the survey as *geodesic levels.** In their present form they are constructed as follows (see accompanying illustration): A horizontal plate is fastened in the middle to the vertical axis of the instrument. One end of this plate carries the nut of a vertical micrometer-screw passing through it. This screw serves to raise or lower one end of the superstructure, which is pivoted to the other end of the fixed plate.

The superstructure consists of two uprights, joined somewhat below their middle by another horizontal plate. The upper portions of the uprights are fashioned into wyes, and carry the telescope and the sliding level; the lower portions are cut out so as to leave guide pieces passing outside the lower plate. A capstan-headed pivot-screw passes through each guide piece at one end into small sockets in the fixed plăte. Passing through the fixed plate the micrometer screw moves between the guide pieces at the other end and abuts against a small steel surface. The fixed plate carries an index, and one of the guide pieces a corresponding scale to register the whole turns of the micrometer, and also a pointer for reading the subdivisions on the micrometer head, of which there are 100. Near the micrometer end the fixed plate carries a cam-hook, which, on being turned, passes into a staple below the upper plate, raising it and everything above it off the micrometer screw during transportation. For the purpose of raising the telescope out of its wyes during transportation the upper plate carries two false wyes at the end of two arms, which are so pivoted and connected with a milled-head screw, passing through the middle of the plate, that by turning it the telescope may be raised on the false wyes and pressed securely against semicircular guards fastened across the true wyes; by the same means it may be lowered into its proper bearings for observation. The telescope rests in its wyes between two shoulders, on collars of bell-metal. Each shoulder carries a projecting pin, which, when it abuts against corresponding pins in the upright, defines two positions 180° apart, in which the observing thread is horizontal

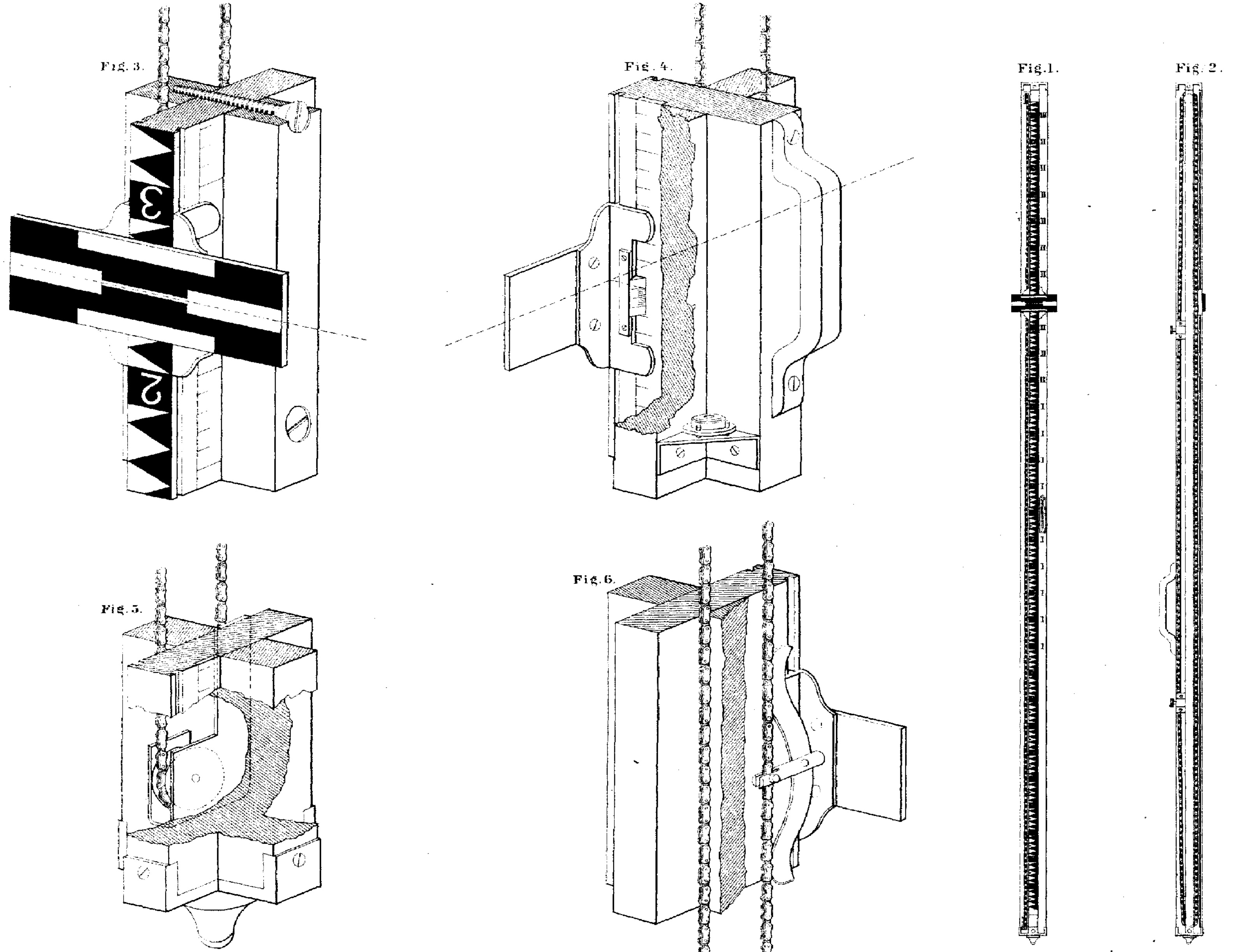
* The noun *geodesy* is common to the English, German, and French languages: the use of its derivatives, *geodetic—ical*, *geodesic—ical*, remains unsettled. We propose to use the hard form "*geodetic*" for the immediate adjective signifying things of the same kind and quality as the noun, and the softer form, *geodesic* (instead of *geodetical*), for the derived adjective, applicable to matters relating to or incidental to geodesy. Hence, *geodetic survey*, *geodesic level*.



GEODESIC LEVELING INSTRUMENT

U.S. COAST AND GEODETIC SURVEY.

(REPORT OF 1879.)



TARGET AND LEVELING ROD FOR GEODESIC LEVELING INSTRUMENT

Scale for Figs. 3, 4, 5 & 6.

10 9 8 7 6 5 4 3 2 1 0 1 2 3 dm.

Scale for Figs. 1 & 2.

10 9 8 7 6 5 4 3 2 1 0 1 2 3 m.

when the telescope is turned about its optical axis. The diaphragm in the telescope is of glass, and has two horizontal and one vertical line ruled upon it.

A clamp and tangent movement for accurate lateral pointing connects the vertical axis through the fixed plate with the external part of its socket. The vertical axis and socket pass downwards below the leveling screws, through the tripod head, to which the instrument is secured by means of a milled-head nut, threads for which are cut on the external part of the socket. A hemispherical washer of wood, fitting into a corresponding cavity in the tripod head between it and the nut, gives all the play required by the leveling screws.

The instrument is further secured by means of a brass plate, which may be clamped to the tripod head in such a manner as to fit over shoulders on the leveling screws, which are sunk into the tripod head to the necessary depth.

The level proper is a striding level, not fastened to the telescope.

The above description applies equally to the two forms of the instrument in use in the survey, with this exception, that geodesic level No. 1 has its vertical axis entirely above the tripod, and that it is much lighter than Nos. 2 and 3. Most of the precise leveling has been done so far with No. 1.

The smaller instrument, inclusive of tripod, weighs 23 pounds, while the weight of the larger is 45 pounds. The telescope of No. 1 has an aperture of about 35^{mm}, a focal length of 407^{mm}, and a magnifying power of 26. One millimeter of the level scale equals $3''.5$.

The telescopes of Nos. 2 and 3 have apertures of 43^{mm}, focal lengths of 410^{mm}, and magnifying powers of about 37. The value of one millimeter of the level scale equals $1''.5$.

Rod and target (see illustration).—The rods are made of well-seasoned white-pine wood, oiled and varnished, and are a little more than 3 meters long. Each rod consists of a main strip of wood 7.5^{cm} wide and 2.5^{cm} thick, along the center of each broad face of which is screwed and glued another strip of the same length, and 2.5^{cm} wide and 2.5^{cm} thick. A target, provided with guide pieces, and a friction spring, can be moved up and down one of the faces of the rod by means of an endless chain running over a fixed pulley at the bottom, and an adjustable one near the top of the rod. The chain passes through a clamp convenient to the rodman's hand. The target carries with it, at right angles to its face, a small ivory scale, graduated to millimeters, moving over a strip of brass let into the rod and extending its whole length. The brass is graduated to centimeters, and can be read to fractional parts of a millimeter by means of the ivory scale. The brass scale is fastened in the middle immovably to the rod, and is held in its groove by means of screws at the back passing through slots, so that the brass may freely expand towards the top and bottom, and it forms the scale proper on which all differences of heights are measured. The temperature is registered by means of a thermometer let into the rod. A handle screwed on that face of the rod opposite to the target, and a small circular level, enable the rodman to hold the rod vertical. That face of the rod which carries the target is graduated to centimeters, and serves the double purpose of a telemeter and of checking the reading of the brass scale, as will be explained further on. The foot of the rod is a rounded piece of brass, which is intended to rest in a corresponding depression in the foot plates.

The foot plates are circular disks of cast iron, about 15^{cm} in diameter, with depressions in the center for receiving the feet of the rods, and with prongs on the under side to secure immobility when properly pressed into the ground. Another support which has been used in thawing ground is a pin of wrought iron about 15^{cm} long, increasing from a point to a diameter of about 5^{cm} on top, which also contains a cavity for the reception of the foot of the rod. These pins must be driven into the ground with a maul.

The following adjustments of the instruments should be made and preserved:

1. *To adjust the sliding level for "wind,"* or to make it parallel with the axis of the collars.—Turn the lateral counter-screws on the level until the bubble remains between the same divisions of the scale when the level, while resting on the collars of the telescope, is revolved to one side or the other of the vertical plane passing through the axis of the collars.

2. *To make the axis of the level parallel to the plane of its supports.*—This is accomplished by noting the reading of the level in a direct and reversed position on the telescope and by correcting one half of the deviation of the bubble by means of the vertical adjusting screw of the level, and the other half by means of the micrometer screw under the telescope.

3. *To make the axis of the instrument vertical and perpendicular to that of the level.*—The previous adjustments having been made, the bubble is made to play and the vertical axis is turned 180°. One half of the deviation of the bubble is corrected by means of the foot screws and the other half by means of the micrometer screw. This adjustment having been perfected, the reading of the micrometer, which then corresponds to a horizontal pointing of the telescope, should be noted.

4. *To adjust the horizontality of the middle thread.*—When the instrument is leveled and the abutting pins intended to define the horizontality of the thread are in contact, and the telescope is pointed on a distant mark, the latter should remain bisected by the thread as long as it remains in the field of view, when the telescope is moved in azimuth. The adjustment is made by turning the diaphragm the requisite amount.

5. *To adjust the collimation.*—Point the telescope on a mark at a convenient distance, and then turn it 180° about its optical axis. If the intersection of the vertical and horizontal thread deviates from the pointing in the first position, correct one-half of the vertical deviation by means of the micrometer and one-half of the lateral deviation by means of the tangent screw, and the rest by means of the adjusting screws of the diaphragm. It is only necessary, however, that the horizontal thread should be put into the line of collimation as nearly as may be. When this adjustment has been made by pointing on a mark at a considerable distance, it should be tested on one so much nearer that the focus of the telescope requires changing. If the adjustment remains, the motion of the ocular is parallel to the geometrical and optical axis of the telescope, but, if not, a mechanician alone can make the required adjustment.

6. *To determine whether the telescope moves in a vertical plane.*—This is an adjustment depending on the construction of the instrument, and may be tested by pointing the telescope on a plumb-line and seeing whether the line of sight travels along it when it is raised or depressed by means of the micrometer screw. If it does not, a remedy may be sought for in a readjustment of the pivot screws of the superstructure.

7. *To determine the angular value of a revolution of the micrometer.*—This depends on the distance between the threads of the screw and the distance between the center of the screw and the pivots. Even though we assume the revolutions of the micrometer screw to be proportional to the arc through which the telescope moves, their angular value will vary on account of the eccentricity of the line of sight in reference to the pivots of the superstructure. As the reduction of the target to the horizon is generally less than 5^{mm}, which, at 100^{m}, corresponds to an angular value of only 10″, it is apparent that even in extreme cases the average value of a revolution derived by the following method will be amply sufficient for our purposes: Level the instrument, with the micrometer set at the horizontal reading of the telescope. At as great a distance, accurately measured, at which the scale-marks remain perfectly defined, set up a vertical scale or one of the rods. Measure the angular value between the divisions of the scale in terms of the micrometer to the amount of about two turns above, and as many below the horizontal reading of the micrometer.

Let D = the distance between the pivots of the superstructure and the rod;

Let d = the distance between the scale divisions of the rod, expressed in the same unit of measure as D;

Let m = the difference in reading of the micrometer, when the telescope points on the upper and lower scale divisions expressed in terms of the micrometer;

Then one turn, t, of the micrometer expressed in seconds of arc $= \frac{d}{D \sin 1'' \times m}$, and therefore the linear value, d, of t for any distance D is, $d = t\, D \sin 1''$, and this is tabulated for convenience of reduction.

It may here be remarked that it is not absolutely necessary to determine either the micrometer or level value or the inequalities of the collars in angular measure. The two latter may be expressed in micrometer divisions, and the linear value of these for any particular distance may be obtained as above described, and for intermediate distances it may be obtained by interpolation and tabulated.

8. *To determine the angular value of one division of the level scale.*—Mount the level on the telescope and observe the number of level-scale divisions through which the bubble moves when the telescope is raised or depressed through a given angle by means of the micrometer screw.

9. *To determine the inequality of the collars of the telescope.*—Mount the instrument firmly and level it carefully. Measure the inclination of the telescope in its wyes by reversals of the level. Carefully lift the telescope and, turning it end for end, replace it so that the object-end collar shall be in the wye in which the eye-end collar was before, and again measure the inclination of the telescope. This should be repeated with the telescope inverted or turned 180° about its optical axis until a satisfactory value has been obtained in both positions of the telescope.

Let I = the inclination of the telescope when direct. } Erect.
I_1 = the inclination of the telescope when reversed. }

Let i = the inclination of the telescope when direct. } Inverted.
i_1 = the inclination of the telescope when reversed. }

Then the inequality of collars,

$$h = \tfrac{1}{2}\left[\left(\frac{I - I'}{4}\right) + \left(\frac{i - i'}{4}\right)\right]$$

and the correction to be applied to an observed sight at the distance D, will equal D h sin 1″, and should be computed and tabulated.

If the object-end collar is too large the line of sight will be inclined downwards when the targent plane to the upper surface of the collars is horizontal. This constant should be determined at the beginning and end of each season's work.

10. *To determine the distance between the rod and instrument by means of the distance threads in the diaphragm.*—For the purpose of reducing the target reading to the horizon it is necessary to know the distance of the rod from the instrument. Although the angle between the distance threads changes with a change in the focus of the telescope, a table giving the distances corresponding to the difference of the readings of the threads on the rod, with sufficient precision, may be constructed as follows: Set up the rod at the measured distances of, say, 20 and 150 meters, and observe the space (which will form the "argument" of the table) intercepted by the distance threads on the painted graduation of the rod. Interpolate the table for intermediate distances and extend it proportionally. The extreme threads should be equidistant from the middle one for convenience of observing. If they are not, the distance should always be measured between the same two threads to avoid confusion in the record.

Verification and adjustment of the rods.—The brass scale should be compared with a standard for total length and uniformity of graduation.

Its coefficient of expansion must be known or be determined.

Its immobility, when attached to the rod, should be tested.

The graduation of the millimeter scale should be examined.

The thermometer should be compared with the standard.

The zero of the millimeter scale should correspond to the center of the target; if it does not, a correction must be applied whenever the rod reading is to be referred to a bench-mark on which the foot of the rod cannot be placed.

The target should be horizontal when the rod is vertical.

The level on the rod should be adjusted to indicate the verticality of the rod. This may be tested by suspending a plummet from the rod.

The chain, which is apt to stretch by usage, should not be allowed to become too slack; links may be taken out of it if the range of the movable pulley has been exhausted.

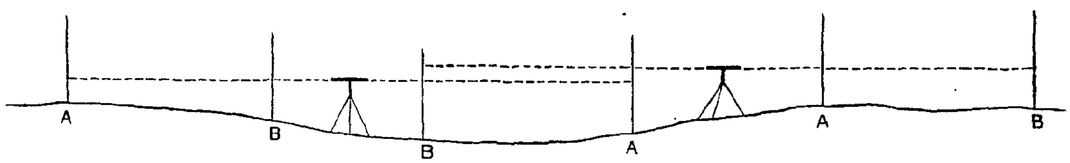
The distance of zero point of the graduation above the foot of the rod should be determined and the temperature noted. This distance is called the index error of the rod. Each rod should be designated by a letter or number.

METHOD.

The method of leveling adopted is that known as "leveling from the middle," or, more properly defined, that of equidistant back and fore sights. The manner of taking the sights is to bring the target of the rod nearly into the horizon of the telescope, and to measure with the micrometer the vertical angle between the horizon and the target by repeated pointings, so arranged as to eliminate errors of level and collimation. The target reading on the rod is then reduced to the horizon by computation. With this method, two systems have been in use hitherto:

1. *Simultaneous double levelling in one direction.*—By this the difference in height between two benches is determined by observing from the same station and with the same instrument, backsights on two different rods, set up at unequal distances from the instrument, and foresights on the same two rods, carried forward and placed at the same relative distances previously occupied. This method may be symbolically represented by two arrows, joined in the middle, pointing in the same direction, thus: ⇇.

The successive positions of the instrument and rods are shown on the diagram:



2. *Levelling in opposite directions.*—This consists in running a line between two benches in one direction, and relevelling it according to the same method in the opposite one, and may be symbolized by two arrows pointing in opposite directions: ⇄.

System 1 offers the advantage of a considerable saving in time over system 2, and affords a perfect check against errors of observation from station to station, since the difference in height between two rods, obtained in a foresight, should be equal to the difference obtained in the following backsight. If the rods are set up at unequal distances from the instrument, say the nearest at 25 meters and the farthest at 100, the foresights on the two rods will define the inclination of a plane to which, that defined by the backsights on the rods in the same position should be parallel This parallelism will be a test of the existence of any constant instrumental error. Such an error would produce a want of parallelism in the two planes equal to twice its effect in one direction.

System 2, on the other hand, offers the advantage of making the determinations in opposite directions under different conditions, and of exhibiting with greater certainty the existence of any cumulative errors. (See page 207.)

In India the direction of operation was alternated in consecutive sections for the purpose of compensating cumulative errors; and while the final result between two extremely distant stations may by such a process be freed from error, yet intermediate heights might be affected by considerable ones.

METHOD OF OBSERVING.

Plant the tripod firmly, either directly on the ground, or, if necessary, on iron pins driven into it, with the top of the tripod nearly horizontal, and with the legs so spread as to be least liable to disturbance by a movement of the observer. Loosen the clamp nut under the tripod head. Let the telescope down into its wyes by lowering the false ones in which it rests during transportation. Turn the cam-hook until the plate carrying the telescope rests on the micrometer screw, which is supposed to be set to its horizontal reading. Mount the striding level, and level the instrument approximately—that is, until the bubble remains in view, when the instrument is revolved in azimuth. Sight on the rod, and adjust the focus of the telescope and eye-piece.

A motion to the rodman to move the target until it is nearly bisected by the middle thread is followed by another to clamp it there, after which the rodman must give his sole attention to holding the rod vertical by watching the bubble of the attached level.

a. Next the observer, watching the striding level, turns the micrometer screw until the bubble is in some determinate position, for instance, until an equal length of it is on each side of the center of the level scale. It may be found advisable to select divisions at unequal distances from the center, which, being systematically adhered to, will always show whether the position of the level is direct or reversed. Care should be taken to avoid parallax in reading the level, particularly when an attached mirror is used.

Then the designating number or letter of the rod pointed on, the position of the telescope and level, and the reading of the micrometer corresponding to the adopted level reading, are recorded.

A pointing is next made on the target by turning the micrometer screw, the reading of which is again recorded when the horizontal thread bisects the target.

b. The level is reversed, and the micrometer is turned until the bubble of the level is between the same divisions as in the first reading, then the target is bisected, and the micrometer readings for level and target are recorded.

c. The telescope is inverted or turned 180° about its optical axis, the level remaining reversed as before. Again the micrometer is turned until the bubble is between the selected divisions, and then until the target is bisected, and the corresponding readings are recorded.

d. The level is shifted into its direct position, its bubble is brought between the selected divisions, and the micrometer is read. Lastly, another pointing is made on the target, and the micrometer readings are recorded.

Then the observer notes the readings of the upper and lower edges of the target and of the distance threads on the painted graduation of the rod. The rodman reads the scale and thermometer, and records them in a book which he carries for the purpose. His reading of the scale is verified by the recorder, and should correspond within a few millimeters to the mean obtained from the observer's reading of the upper and lower edge of the target.

If the system of simultaneous double levelling is followed, the observer will generally finish all the observations (*a*, *b*, *c*, *d*) on one rod before beginning on the next one, in order to give one of the rodmen time to advance while the observations on the other are being made. If system 2 is followed, the observations may be so arranged as to make the mean of the times of making the four observations on each rod the same, provided always that the rods are so nearly equidistant that the focus of the telescope does not require changing, as that might affect the collimation.

Such a sequence of observing is shown by the numerals in the following scheme:

Backsight.	Foresight.
Rod Y, 2, *b a*	Rod Z, 1, *a b*
3, *d c*	4, *c d*

During the observations the instrument should be screened from the sun by an umbrella. Before carrying the instrument forward it should be clamped to the tripod head by means of the nut. The false wyes should be screwed up to support the telescope, and the cam-hook should be urned to raise the superstructure off the micrometer screw.

The true distances of the rods from the instrument are obtained, as already stated, by means of the distance threads in the telescope, for purposes of reduction, but their position is selected at as nearly equal distances from the instrument as possible, by careful pacing of the rodmen. Where the slope of the ground is steep the distances may be taken as great as possible, and on comparatively level ground they may range from 50 to 150 meters, according to the condition of the weather and atmosphere. The rodmen should exercise great care to plant the foot supports firmly in the ground, and to keep clean the cavities in which the feet of the rods rest.

River crossing.—When a line of levels has to be carried across a wide river, and where, from the lowness of the banks, the line of sight would pass very near to the water, the instrument should be elevated so as to be above the vitiating influence of irregular refraction. If possible, two instruments should be mounted on opposite sides of the river, and simultaneous observations should be made on targets mounted near the respective instruments.

The elevation of each target above a bench-mark on its side of the river must be carefully determined, and each target and instrument should be as nearly as possible in the horizon of the other. The observations are made in the usual manner; if the distance across is not otherwise known with sufficient accuracy, the known value of the micrometer will serve to determine it sufficiently for purposes of reduction, by measuring across the river the length of a rod or other known length in terms of the micrometer. The inequality of collars being known in terms of the micrometer, the correction may be applied directly in that form.

If only one instrument is available, observations made in one direction should be repeated as soon as possible in the other, and several times alternately in opposite directions. By the observations in opposite directions the effect of refraction may be supposed to be eliminated, as is that of curvature.

It is shown, however, by observations made expressly for the purpose over a distance across the Potomac River of 650 meters, at different elevations, that it is necessary to elevate the instrument at least 10 feet above the water, in order to obtain results free from the effects of irregular *refraction.* Although more than twice as great as that usually admitted (being found about 0.27 against 0.12), the results obtained at elevations of 11 and 17 feet from observations in opposite directions show a satisfactory agreement, while observations made at a height of 4 feet above the water give a wide range in the results. The details of this experimental work are given in the paper immediately following the present one.

BENCH-MARKS.

The nature and location of the bench-marks will depend on the purposes they are intended to subserve, and are permanent or temporary. To the latter class belong those which are only intended to afford a check on the leveling operations and a test of their accuracy. They may consist of nails or spikes driven into trees, telegraph poles, or into pegs driven into the ground, while permanent ones are intended to secure the results of the work for all time. Public or private buildings, the piers of bridges, or outcropping ledges of rock will generally afford good points of reference, but where these do not exist, and yet permanent benches are required, cut stones, suitably marked, may be set into the ground for the purpose. When a mark is to be established on brick buildings a copper or brass bolt, about 10 centimeters long and 2 centimeters in diameter, should be set horizontally into a hole drilled into the center of a brick, and adjacent bricks should be marked with the letters U. S. B. M.

Bench-marks of cities and such as relate to water courses near which the line of levels passes should be connected with the latter, and when a railroad is crossed the elevation of the foot of the rail should be observed.

The frequency of permanent benches must depend in a measure upon the opportunities offered by the country through which the line passes, but cannot be too great. Permanent benches may again be subdivided into primary and secondary. The distance apart of temporary benches should be about 1 kilometer, both as a safeguard against errors and for the comparison of the relative accuracy of the work on different lines.

It should be remembered that whenever a bench-mark is to be connected, on which the foot of the rod cannot be placed, the distance between the foot of the rod and the zero of its graduation must be taken into account, and that of the other rod also, if the line does not end with same rod with which it was begun.

DEGREE OF PRECISION.

The rule, based on experience, adopted for the "Europäische Gradmessung" in 1867, is that the probable error of a difference in height of two points 1 kilometer apart should not, in general, exceed 3^{mm}, and never 5^{mm}.

The probable error deduced from the closure of polygons is, in general, however, smaller than the amounts above given, a circumstance which may be partly ascribed to the fact that greater accuracy is attainable, and partly to the compensation, in long lines, of cumulative errors, which experience has shown to exist at times, and the nature of which has not been satisfactorily explained.

As a guide, the observer may therefore accept for short distances a difference, d, between two levelings of the distance K, in kilometers, expressed by the formula $d = 5^{mm} \sqrt{2K}$.

RECORDS AND COMPUTATIONS.

A detailed description of every bench-mark and of its exact and general locality should be entered in a book kept for the purpose, and a general map, showing the line leveled and the location of the benches, must accompany the record of each season's work.

Explicit information in regard to everything having a bearing on the accuracy of the work, such as the times and manner of adjusting the instrument and rods, the strength of the wind, the condition of the ground, and the location of the instrument and rods while observing, whether on river or canal embankments, or on roads or fields, should be entered in the field book of observations either between stations or at the end of each day's work.

A specimen of the record of observations is appended. It shows also as much of the computation as is performed in the observing book. The means of the micrometer pointings on horizon and target and their difference, H – T, are computed and written down, as well as the difference between the distance wire and the mean of readings on the upper and lower edge of the target. A specimen of the computation and abstract is also appended.

In the form for computations the left-hand page refers to backsights, and the first column contains the number of the stations. The second column contains the argument, or space in centimeters, read off on the rod by the distance threads, and the next column the corresponding distance in meters. The fourth column contains the differences between the means of the micrometer readings on horizon and target. The three following columns, under the head of "corrections," contain the corrections there indicated, expressed in millimeters, which are summed up in the eighth column, and applied to the sum of the rod readings, the result forming the corrected rod readings. The same remarks apply to the right-hand page, which is devoted to foresights, and which, in addition, contains a column giving the difference between the sums of the back and the fore sights, or the difference in height of the benches. To this difference the temperature correction, derived from the mean of the recorded temperatures, is yet to be applied.

In order to facilitate the computations, tables are prepared for each instrument, giving for the argument derived from the distance threads, the inferred distances, the corresponding linear values of micrometer divisions, and the correction for inequality of pivots.

Curvature and refraction.—A table of corrections for curvature and refraction for different distances is appended. The curvature is computed by the formula $\frac{d^2}{2r}$, where d is the distance and r the radius of curvature of the earth for a line making an angle of 45° with the meridian in latitude 38°, equal to 6373 kilometers. The quantities are so small, however, that a mean radius of 6370 kilometers may equally well be used. The effect of refraction is at best a very variable quantity; it is taken here as the eighth part of the correction for curvature, corresponding very nearly to Gauss's coefficient.

The values in the table correspond, therefore, to the formula

$$\frac{d^2}{2r}(1-0.125) \text{ or } \frac{7}{8}\frac{d^2}{2r}=\frac{d^2}{14568000}.$$

As a convenient approximate rule we may take: correction $=\frac{11}{16}\cdot\frac{d^2}{10000}$, when the correction will be in millimeters, the distance being taken in meters. Thus, for $d=300$ meters, we have $\frac{11}{16}\cdot\frac{90000}{10000}=6.18^{mm}$ as in the table.

Temperature correction.—The form of computation neglects the correction for temperature of the rod, which is usually insignificant, and always more conveniently applied to aggregate results.

Table of curvature and refraction.

Distance.	Curvature and refraction.	Distance.	Curvature and refraction.
m.	*mm.*	*m.*	*mm.*
10	0.0	160	1.8
20	0.0	170	2.1
30	0.1	180	2.3
40	0.1	190	2.6
50	0.2	200	2.8
60	0.3	210	3.0
70	0.3	220	3.3
80	0.4	230	3.7
90	0.5	240	4.0
100	0.7	250	4.3
110	0.8	260	4.7
120	1.0	270	5.0
130	1.2	280	5.4
140	1.4	290	5.8
150	1.5	300	6.2

FORM OF RECORD.

BACK-SIGHT.								FORE-SIGHT.							
No. of station.	Telescope.	Level.	Micrometer. Horizon.	Micrometer. Target.	Dist. wire.	Upper and lower edge of target.	Rod reading and temp.	No. of station.	Telescope.	Level.	Micrometer. Horizon.	Micrometer. Target.	Dist. wire.	Upper and lower edge of target.	Rod reading and temp.
Running on road. Muddy. Foot of rod F on Bench No. 61.								Weather cloudy. Brisk wind. Rod E.							
	I	R	17.102	17.113	....	....	....		I	D	17.107	17.102	....	....	39°
9		D	126	117	....	....	....	9		R	097	102	....	....	....
	E	D	127	107	....	0.860	....		E	R	095	098	....	1.332	....
		R	117	111	2.240	0.810	0.8330			D	107	092	2.710	1.282	1.3072
			17.118	17.112	140.5	....	....				17.101	17.098	140.3	1.307	....
			−0.6								−0.3				
E.								Observed on a mark 0m.7685 above B. M. No. 62.							
	E	R	17.003	16.993	....	....	....		E	D	17.282	17.232	....	....	....
		D	034	992	....	....	....			R	262	240	....	....	....
10	I	D	16.963	918	....	1.248	39°	10	I	R	268	231	1.600	} Rod....	....
		R	16.927	920	1.530	1.200	1.2230			D	292	232	1.300		
			16.982	16.956	306	1.224	....				17.276	17.234	30	....	....
			−2.6								−4.2				

NOTE.—The general locality is stated in full at the beginning of each record book; the date, circumstances, weather, &c., on a separate page preceding the record of each day's work.

[FORM 23.—Computation of Geodesic leveling.]

FORM OF COMPUTATION.

U. S. Coast and Geodetic Survey. General locality: ——— ——— (Mississippi River).

BACK-SIGHTS.

Section, VIII; year, 1880; instrument, Geodesic level No. 8; rods, E and F.

No. of station.	Distance.		T-H.	Corrections.			Sum of corrs.	Rod readings.	Corrected rod readings.	B. M.
	Argument.	Meters.		T-H.	Inequality of collars.	Curvature and refraction.				
Forward measurement began with rod F and ended on a mark.										
						Index corr. rod F =		m. 0.0622	....	No. 61
9	141	144	−0.6	−1.1	+ 1.3	− 1.4	− 1.2	0.8330	....	to
10	32	32	−2.6	−1.0	+ 0.3	− 0.1	− 0.8	1.2230	....	No. 62
		176		−2.1	+ 1.6	− 1.5	− 2.0	2.1182	2.1162	

FORE-SIGHTS.

Observer, J. B. W.; Computer, T. P. B.

No. of station.	Distance.		T-H.	Corrections.			Sum of corrs.	Rod readings.	Corrected rod readings.	BS - FS.
	Argument.	Meters.		T-H.	Inequality of collars.	Curvature and refraction.				
March 16th.										
								m.		
9	140	143	−0.3	−0.5	+ 1.3	− 1.4	− 0.6	1.3072	....	....
10	30	31	−4.2	−1.6	+ 0.3	− 0.1	− 1.4	0.7685	....	....
		176		−2.1	+ 1.6	− 1.5	− 2.0	2.0757	2.0737	$+0^{m}.0425$

[FORM 25.—Abstract of Computation of Geodesic Leveling.]

FORM OF ABSTRACT OF RESULTS.

U. S. Coast and Geodetic Survey. General locality: ——— ——— (Mississippi River).

Section, VIII; year, 1880; instrument, Geodesic level No. 3; rods, E and F.

Observer, J. B. W.; Computer, T. P. B.

From B. M. to B. M.	Distance in kilometers. K.	Difference of height, in meters.			Diff. from mean v. mm.	$\frac{2vv}{K}$	No. of B. M	Distance from B. M. No. 1. Kilometers.	Height above B. M. No. 1. Meters.	Locality.
		Line ⟶	Line ⟵	Mean.						
56–57..................	1.094	+ 0.8616	— 0.8647	+ 0.8632	− 1.6	4.7	57	56.34	— 3.1173	
57–58..................	1.185	— 0.3066	+ 0.3029	— 0.3047	− 1.9	6.1	58	57.53	— 3.4220	
58–59..................	1.292	— 0.3137	+ 0.3135	— 0.3136	— 0.1	.0	59	58.82	— 3.7356	
59–60..................	1.042	— 0.2160	+ 0.2166	— 0.2163	+ 0.3	.2	60	59.86	— 3.9519	
60–61..................	1.039	+ 0.5884	— 0.5841	+ 0.5863	+ 2.1	8.5	61	60.90	— 3.3656	
61–62..................	350	+ 0.0425	— 0.0421	+ 0.0423	+ 0.2	0.2	62	61.25	— 3.3233	Worthington's Ho. "Maryland plantation."

APPENDIX No. 16.

OBSERVATIONS TO DETERMINE THE REFRACTION ON LINES PASSING NEAR A SURFACE OF WATER, MADE AT DIFFERENT ELEVATIONS ACROSS THE POTOMAC RIVER. REPORT BY ANDREW BRAID, ASSISTANT.

U. S. COAST AND GEODETIC SURVEY,
Washington, D. C., June 6, 1881.

SIR: In accordance with verbal instructions from yourself and the Assistant in Charge of the Office, a series of observations have been made by Mr. J. B. Weir and myself for the determination of the coefficient of refraction over water at different elevations.

The place selected for the observations was at Georgetown, D. C., the station on the north bank of the river being about 150 meters, and that on the south bank about 700 meters above the "Aqueduct Bridge." The length of the sights varies from 658 to 670 meters (distance determined by triangulation), and the elevations above the water from 4 to 17 feet.

The instruments used were geodesic micrometer levels Nos. 3 and 2, the former being used by Mr. Weir and the latter by me. Care was taken in every instance to have the two instruments at very nearly the same elevation above the surface of the water, and the sights in opposite directions observed simultaneously. After observing a series for each elevation the observers exchanged stations, but each retained his own instrument. Then a double series for each elevation was observed and stations again exchanged, &c.

In the reduction of the observations, corrections are applied for inclination, inequality of pivots, and earth's curvature, and half the remaining difference between any two simultaneous sights is assumed to be the error due to refraction. The errors due to inaccuracy of pointing are probably quite small, as the seeing was excellent, and the mean of a number of pointings (12 to 16) was taken in each case.

In the accompanying tabulation the results are arranged in three groups: for lower, middle, and upper elevation. It will be seen that the values for the coefficient derived are, as in our previous experience on the Mississippi River, large, and especially for the lower elevation; but, curiously enough, the upper-elevation observations give a larger value than that derived from the middle elevation.

Contrary to expectation also, the refraction seems to increase rapidly with the time, being less between 9 and 10.30 a. m. than at any subsequent period of the observations.

This peculiar circumstance, which may, perhaps, be due chiefly to increase of temperature, is more noticeable on the lower elevation, but is common to the others also, the only exceptions being found in stations 13, 21, 3, and 28. The mean value of the coefficient of refraction for the lower elevation is 0.378, for the middle elevation, 0.264, and for the upper elevation, 0,293. That but little error can be due to personal equation, or any difference in instruments, is shown by an examination of determined relative heights of the bench-marks on opposite sides of the river. Bench-marks "*a*" and "*b*" are on north side, and 1 and 2 on south side of river.

Middle and upper elevation observations give mean differences of height of bench-marks, 2 and *b* (2 being the higher), as $0^{m}.8029$ and $0^{m}.8034$, respectively, values which are almost identical. Now, if we select the observations of either observer (or, what is the same thing in this case, of either instrument), and compute them, *independently* of the simultaneous observations of the other observer, we get results differing only $0^{mm}.8$ from those above given.

Also the mean of all the lower elevations gives bench-mark 1 higher than bench-mark $a = 0^{m}.5276$, and either observer's observations computed *independently* gives result differing only $2^{mm}.3$ from this mean.

The lower-elevation results, however, give a difference of height of bench-marks 2 and *b* of

$0^m.7800$, or $0^m.0231$ less than derived from middle and upper elevations. This difference I cannot account for.

The inequality of pivots, being an important factor in these observations, has been redetermined for both instruments, and the present values used in this computation.

Yours, respectfully,

ANDREW BRAID,
Assistant.

CARLILE P. PATTERSON,
Superintendent.

Summary of results.

	No. of station.	Date.	Time.	Elevation over water.	Level No.	Just on north side of river sighting south.	Level No.	Just on south side of river sighting north.	Mean of north and south sights.	½ diff. = refrac.	Coefficient of refraction.
				Feet.		*m.*		*m.*	*m.*	*mm.*	
Lower elevation	1	May 7	10.30 a. m.	6	2	0.5606	3	0.5348	0.5477	12.9	0.186
	4	... do....	1.55 p. m.	4½	3	0.5468	2	0.4987	0.5227	24.1	0.351
	8	... do....	4.45 p. m.	4	3	0.5691	2	0.4746	0.5219	47.2	0.689
	9	May 9	9.40 a. m.	6	2	0.5325	3	0.5185	0.5255	7.0	0.100
	12	... do....	12.00 m.	5	3	0.5503	2	0.5028	0.5265	23.7	0.340
	16	... do....	1.40 p. m.	4½	3	0.5578	2	0.4995	0.5287	29.2	0.426
	17	... do....	2.15 p. m.	4	2	0.5646	3	0.4883	0.5264	38.2	0.562
	20	May 10	9.30 a. m.	6	2	0.5355	3	0.5080	0.5218	13.7	0.198
	23	... do....	11.35 a. m.	5½	3	0.5492	2	0.5015	0.5253	23.9	0.248
	27	... do....	1.00 p. m.	5½	3	0.5518	2	0.5013	0.5266	25.2	0.367
	30	... do....	3.40 p. m.	5	2	0.5717	3	0.4901	0.5309	40.8	0.597
	Mean time		12.46 p. m.			Mean B. M. 1 above B. M. a =			0.5276	....	0.378 = Mean.
						Which gives B. M. 2 above B. M. b =			0.7800		
Middle elevation	2	May 7	11.15 a. m.	13	2	0.8195	3	0.7896	0.8046	14.9	0.213
	5	... do....	3.15 p. m.	11	3	0.8172	2	0.7825	0.7999	17.4	0.249
	7	... do....	4.15 p. m.	11	3	0.8189	2	0.7800	0.7995	19.4	0.277
	10	May 9	10.15 a. m.	13	2	0.8147	3	0.7890	0.8018	12.9	0.184
	13	... do....	12.30 p. m.	11½	3	0.8206	2	0.7847	0.8027	17.9	0.256
	15	... do....	1.15 p. m.	11½	3	0.8189	2	0.7874	0.8032	15.8	0.226
	18	... do....	3.15 p. m.	11	2	0.8305	3	0.7807	0.8056	24.9	0.356
	21	May 10	10.05 a. m.	13	2	0.8304	3	0.7860	0.8082	22.2	0.317
	24	... do....	12.00 m.	12½	3	0.8183	2	0.7849	0.8016	16.7	0.239
	26	.. do....	12.50 p. m.	12½	3	0.8179	2	0.7821	0.8000	17.9	0.256
	29	... do....	2.50 p. m.	12	2	0.8284	3	0.7823	0.8053	23.1	0.330
	Mean time		1.04 p. m.			Mean B. M. 2 above B. M. b =			0.8029	....	0.264 = Mean.
Upper elevation	3	May 7	12.15 p. m.	17	2	0.8351	3	0.7866	0.8108	24.2	0.344
	6	... do....	3.50 p. m.	15	3	0.8145	2	0.7828	0.7987	15.9	0.226
	11	May 9	10.45 a. m.	17	2	0.8260	3	0.7841	0.8051	20.9	0.297
	14	... do....	12.50 p. m.	15½	3	0.8204	2	0.7780	0.7992	21.2	0.301
	19	... do...	3.45 p. m.	15	2	0.8294	3	0.7826	0.8060	23.4	0.333
	22	May 10	10.30 a. m.	17	2	0.8226	3	0.7878	0.8052	17.4	0.249
	25	... do....	12.25 p. m.	16½	3	0.8202	2	0.7780	0.7991	21.1	0.300
	28	... do....	2.30 p. m.	16	2	0.8242	3	0.7824	0.8033	20.9	0.297
	Mean time		1.04 p. m.			Mean B. M. 2 above B. M. b =			0.8034	....	0.293 = Mean.

LIST OF SKETCHES.

PROGRESS SKETCHES.

ILLUSTRATIONS.

NOTE.—Numbers 33 and 34 are superseded by No. 21.

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

Please Note:

This project currently includes the imaging of the full text of each volume up to the "List of Sketches" (maps) at the end. Future online links, by the National Ocean Service, located on the Historical Map and Chart Project webpage (http://historicals.ncd.noaa.gov/historicals/histmap.asp) will includes these images.

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