View on Wagon Road.
East of Nogales.

Vista en la Camino Carretero.
Al este de Nogales.

REPORT

OF THE

BOUNDARY COMMISSION

UPON THE

SURVEY AND RE-MARKING OF THE BOUNDARY BETWEEN THE UNITED STATES AND MEXICO WEST OF THE RIO GRANDE, 1891 TO 1896.

PARTS I AND II.

PART I.
REPORT OF THE INTERNATIONAL COMMISSION.

PART II.
REPORT OF THE UNITED STATES SECTION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE
1898.

MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES,

TRANSMITTING

A REPORT FROM THE SECRETARY OF STATE, ACCOMPANIED BY THE REPORT OF THE UNITED STATES BOUNDARY COMMISSION, PURSUANT TO THE CONVENTION BETWEEN THE UNITED STATES AND MEXICO OF JULY 29, 1882, TOUCHING THE RE-MARKING OF THE BOUNDARY LINE BETWEEN THOSE TWO COUNTRIES WEST OF THE RIO GRANDE.

To the Congress of the United States:

I transmit herewith a report from the Secretary of State, accompanied by the report of the United States Boundary Commission, pursuant to the convention between the United States and Mexico of July 29, 1882, touching the re-marking of the boundary line between those two countries west of the Rio Grande.

I urge that provision be made for the immediate printing of a sufficient supply of this valuable document.

WILLIAM McKINLEY.

EXECUTIVE MANSION,
Washington, April 26, 1897.

The PRESIDENT:

I transmit herewith the report of the United States Boundary Commission under the convention between the United States and Mexico, concluded July 29, 1882, which provided for an international boundary survey to relocate the existing frontier line between the two countries west of the Rio Grande.

The commissioners on the part of the United States were Col. J. W. Barlow, Corps of Engineers, U. S. A.; Capt. D. D. Gaillard, Corps of Engineers, U. S. A., and Mr. A. T. Mosman, of the United States Coast and Geodetic Survey, Treasury Department. They have discharged their work in a creditable and satisfactory manner, as will be further seen by the report and its several accompaniments.

Inclosing as a part of the record in the case a copy of a letter from the commissioners, dated November 25, 1896, the subject is respectfully submitted for your consideration.

Respectfully submitted.

JOHN SHERMAN.

DEPARTMENT OF STATE,
Washington, April 22, 1897.

List of accompaniments.

Report, 3 volumes.
Maps, 1 volume.
Engravings, 1 volume.
Letter of November 25, 1896, from the commissioners to the Secretary of State, with its accompaniments.

DEPARTMENT OF STATE,
INTERNATIONAL BOUNDARY COMMISSION,
UNITED STATES AND MEXICO,
Washington, D. C., November 25, 1896.

SIR: The commissioners on the part of the United States have the honor to submit herewith their final report on the survey and re marking of the boundary between the United States and Mexico west of the Rio Grande, pursuant to the convention between the United States and Mexico of July 29, 1882, revived by the convention of February 18, 1889, and continued until October 11, 1896, by that of April 24, 1894.

The report consists of the following:

First. The report of the joint commission (in triplicate, one copy being in the Spanish language), dated August 14, 1896.

An atlas, bound in leather, containing 19 sheets of the boundary map.

One volume, bound in leather, of 300 illustrations, showing views of the monuments and scenes adjacent to the boundary.

Second. The report of the United States section of the commission, consisting of 2 volumes (in duplicate) arranged in 10 chapters, including appendixes.

One atlas, bound in leather, containing 5 sheets of profile and 2 sheets, index map.

Two atlases (three retained by the commissioners), each containing 19 sheets of the boundary map, 5 sheets of profile, and 2 sheets, index map, showing the adjacent country.

Two volumes of illustrations (seventeen retained by the commission for distribution to the libraries of the War Department, the Military Academy at West Point, and the principal employees of the Survey.

Sixteen volumes (four sets) of the photographs and about 600 negatives were previously sent to the Department.

Inclosed herewith is a list of copperplates, electrotypes, original maps, survey records, etc., which are transmitted in connection with the report.

In presenting this report of the work upon which the commission has been engaged during the past four years we beg leave to express our appreciation of the uniform support and kind consideration received at all times from the Department, without which our labors would have been much more difficult.

We would also put on record the fact that throughout the many trying and often delicate conditions of an international character, which have of necessity arisen during the progress of the work, our associates of the Mexican commission have invariably shown a spirit of fairness and courtesy which has always rendered possible the satisfactory solution of every perplexing question.

To Señor Jacobo Blanco, engineer in chief of the Mexican section, who is a thorough English scholar, special thanks are due for valuable assistance in translating and interpreting, rendering the employment of a special translator unnecessary.

This report may now be laid before the President with a view to the transmission thereof to Congress.

With highest respect, your obedient servants,

J. W. BARLOW,
Colonel of Engineers, U. S. A.,
D. D. GAILLARD,
Captain of Engineers, U. S. A.,
A. T. MOSMAN,
Assistant, Coast and Geodetic Survey,
Commissioners.

The SECRETARY OF STATE, *Washington, D. C.*

List of boxes and rolls (with enumeration of contents) transmitted to the Department of State with the report of the International Boundary Commission, United States and Mexico, west of the Rio Grande.

Six boxes containing 300 half-tone copperplates of illustrations to accompany joint report.

One rack for copperplate holders.

Twelve boxes (copperplate holders) containing copperplates of map sheets Nos. 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 25, and 26, each box being marked "Mexican boundary west of the Rio Grande," with its plate number.

Ten boxes (electrotype-plate holders) containing electrotype plates of map sheets Nos. 2, 4, 6, 8, 10, 12, 14, 16, 18, and 19*a*, each box being marked "Mexican boundary west of the Rio Grande," with its plate number.

One roll containing 220 photolithographs, 44 sets, of the profile sheets, 90 illustrations for report of United States section, Chapter IV, and 5 atlas title sheets.

One roll containing 17 original maps, being sheets Nos. 1, 2, 5, 6, 7, 9, 11, 14, 18, 19, 20, 21, 22, 23, 24, 25, and 26.

One box, No. 1, containing astronomical records, as follows:

- 6 volumes 8vo., original latitude observations.
- 5 volumes 8vo., original azimuth observations.
- 9 volumes 8vo., original horizontal directions (triangulation).
- 2 volumes 8vo., original horizontal angles.
- 2 volumes 8vo., original magnetic observations.
- 8 volumes 8vo., original miscellaneous records.
- 1 volume 4to., original description of stations.
- 7 volumes 8vo., duplicate tangent record.
- 2 volumes 8vo., duplicate heliotrope experiments; also astronomical and geodetic computations and manuscript copies of Mr. J. F. Hayford's astronomical report and line report.

One box, No. 5, containing—

- 5 volumes original journal.
- 1 volume original tangent record, parallel 31° 47′ and meridian section.
- 1 volume original tangent record, parallel 31° 20′.
- 1 volume original tangent record, parallel 31° 20′ and California azimuth line.
- 7 volumes original tangent record, Sonora azimuth line.
- 2 volumes original heliotrope experiments.
- 4 volumes original tangent measurements, parallel 31° 47′.
- 1 volume original tangent measurements, meridian section.
- 1 volume original tangent measurements, meridian section and parallel 31° 20′.
- 7 volumes original tangent measurements, parallel 31° 20′.
- 6 volumes original tangent measurements, Sonora azimuth line.
- 4 volumes original tangent measurements, California.
- 1 volume original tangent remeasurements, meridian section and parallel 31° 20′.
- 2 volumes original level records, parallel 31° 47′.
- 1 volume original level records, parallel 31° 47′ and meridian section.
- 1 volume original level records, meridian section and parallel 31° 20′.
- 8 volumes original level records, parallel 31° 20′.
- 6 volumes original level records, Sonora azimuth line.
- 5 volumes original level records, California azimuth line.
- 1 volume original topographical sketches, parallel 31° 47′.
- 1 volume original topographical sketches, parallel 31° 47′ and meridian section.
- 3 volumes original topographical sketches, parallel 31° 20′.
- 3 volumes original topographical sketches, Sonora azimuth line.
- 1 volume original topographical sketches, California.
- 13 volumes original topographical records, parallel 31° 47′.
- 2 volumes original topographical records, parallel 31° 47′ and meridian section.
- 3 volumes original topographical records, meridian section.
- 45 volumes original topographical records, parallel 31° 20′.
- 41 volumes original topographical records, Sonora azimuth line.
- 19 volumes original topographical records, California.
- 6 volumes original record monument location.
- 2 volumes original record monument elevation.

One box, No. 24, containing correspondence of the United States section of the commission (letters received, letters sent).

PART I.

REPORT

OF THE

INTERNATIONAL BOUNDARY COMMISSION,

UNITED STATES AND MEXICO,

1891-1896.

CONTENTS OF REPORT OF THE JOINT COMMISSION.

LIST OF ILLUSTRATIONS. PART I.

REPORT OF THE JOINT COMMISSION.

SECTION 1.

The boundary between the Republics of the United States and Mexico was defined by the treaty of Guadalupe Hidalgo, and subsequently modified by that known as the Gadsden treaty, or treaty of La Mesilla.

The first of these was concluded and signed at the city of Guadalupe Hidalgo, on the 2d of February, 1848, by the duly authorized plenipotentiaries of the respective Governments. These were, on the part of the United States, Mr. Nicholas P. Trist, and on the part of Mexico, Señores Bernardo Couto, Miguel Atristain, and Luis G. Cuevas.

Following is a copy of Article V of the treaty of Guadalupe Hidalgo, which relates specially to the boundary between the two countries:

ARTICLE V. The boundary line between the two Republics shall commence in the Gulf of Mexico, three leagues from land, opposite the mouth of the Rio Grande, otherwise called Rio Bravo del Norte, or opposite the mouth of its deepest branch, if it should have more than one branch emptying directly into the sea; from thence up the middle of that river, following the deepest channel, where it has more than one, to the point where it strikes the southern boundary of New Mexico; thence westwardly along the whole southern boundary of New Mexico (which runs north of the town called *Paso*) to its western termination; thence northward along the western line of New Mexico, until it intersects the first branch of the river Gila (or if it should not intersect any branch of that river, then to the point on the said line nearest to such branch, and thence in a direct line to the same); thence down the middle of the said branch and of the said river until it empties into the Rio Colorado; thence across the Rio Colorado, following the division line between Upper and Lower California, to the Pacific Ocean.

The southern and western limits of New Mexico mentioned in this article are those laid down in the map entitled "*Map of the United Mexican States, as organized and defined by various acts of the Congress of said Republic, and constructed according to the best authorities. Revised edition. Published at New York in 1847 by J. Disturnell.*" Of which map a copy is added to this treaty, bearing the signatures and seals of the undersigned plenipotentiaries. And, in order to preclude all difficulty in tracing upon the ground the limit separating Upper from Lower California, it is agreed that the said limit shall consist of a straight line drawn from the middle of the Rio Gila, where it unites with the Colorado, to a point on the coast of the Pacific Ocean, distant one marine league due south of the southernmost point of the port of San Diego, according to the plan of said port made in the year 1782 by Don Juan Pantoja, second sailing master of the Spanish fleet, and published at Madrid in the year 1802, in the Atlas to the voyage of the schooners *Sutil* and *Mexicana*, of which plan a copy is hereunto added, signed and sealed by the respective plenipotentiaries.

In order to designate the boundary line with due precision, upon authoritative maps, and to establish upon the ground landmarks which shall show the limits of both Republics, as described in the present article, the two Governments shall each appoint a commissioner and a surveyor, who, before the expiration of one year from the date of the exchange of ratifications of this treaty, shall meet at the port of San Diego, and proceed to run and mark the said boundary in its whole course to the mouth of the Rio Bravo del Norte. They shall keep journals and make out plans of their operations; and the result agreed upon by them shall be deemed a part of this treaty, and shall have the same force as if it were inserted therein. The two Governments will amicably agree regarding what may be necessary to these persons, and also as to their respective escorts, should such be necessary.

The boundary line established by this article shall be religiously respected by each of the two Republics, and no change shall ever be made therein except by the express and free consent of both nations, lawfully given by the General Government of each, in conformity with its own Constitution.

For the purpose of carrying into effect the requirements contained in the above article, commissioners and surveyors were appointed by the two Governments. Those for the United States were Col. John B. Weller, commissioner, and Mr. Andrew B. Gray, surveyor. The Mexican Government appointed Gen. Pedro Garcia Conde, commissioner, and Señor José Salazar Illarregui, surveyor.

Under the direction of these commissioners the initial point of the boundary between Upper and Lower California was established on the Pacific coast and marked by a substantial monument.

A similar determination was made at the eastern extremity of this line, at the junction of the Gila and Colorado rivers, where another monument was placed. Between these the line was run and marked with five intermediate monuments. Astronomical observations were also made in the vicinity of Paso del Norte, which were afterwards used in establishing the initial point on the Rio Grande, in accordance with the treaty of December 30, 1853.

A more detailed account of the scientific work above referred to will be found in section 10 of this report.

SECTION 2.

By the treaty of December 30, 1853, that part of the boundary between the Rio Grande and the Rio Colorado, as previously defined, was materially changed, Article I of that treaty being as follows:

ARTICLE I. The Mexican Republic agrees to designate the following as her true limits with the United States for the future: Retaining the same dividing line between the two Californias as already defined and established, according to the fifth article of the treaty of Guadalupe Hidalgo, the limits between the two Republics shall be as follows: Beginning in the Gulf of Mexico, three leagues from land, opposite the mouth of the Rio Grande, as provided in the fifth article of the treaty of Guadalupe Hidalgo; thence as defined in the said article up the middle of that river to the point where the parallel of 31° 47′ north latitude crosses the same; thence due west 100 miles; thence south to the parallel of 31° 20′ north latitude; thence along the said parallel of 31° 20′ to the one hundred and eleventh meridian of longitude west of Greenwich; thence in a straight line to a point on the Colorado River 20 English miles below the junction of the Gila and Colorado rivers; thence up the middle of the said river Colorado until it intersects the present line between the United States and Mexico.

For the performance of this portion of the treaty, each of the two Governments shall nominate one commissioner, to the end that, by common consent, the two thus nominated, having met in the city of Paso del Norte, three months after the exchange of the ratifications of this treaty, may proceed to survey and mark out upon the land the dividing line stipulated by this article, where it shall not have already been surveyed and established by the mixed commission, according to the treaty of Guadalupe, keeping a journal and making proper plans of their operations. For this purpose, if they should judge it necessary, the contracting parties shall be at liberty each to unite to its respective commissioner scientific or other assistants, such as astronomers and surveyors, whose concurrence shall not be considered necessary for the settlement and ratification of a true line of division between the two Republics; that line shall be alone established upon which the commissioners may fix, their consent in this particular being considered decisive and an integral part of this treaty, without necessity of ulterior ratification or approval, and without room for interpretation of any kind by either of the parties contracting.

The dividing line thus established shall, in all time, be faithfully respected by the two Governments without any variation therein, unless of the express and free consent of the two, given in conformity to the principles of the law of nations, and in accordance with the constitution of each country, respectively.

In consequence, the stipulation in the 5th article of the treaty of Guadalupe upon the boundary line therein described is no longer of any force, wherein it may conflict with that here established, the said line being considered annulled and abolished wherever it may not coincide with the present, and in the same manner remaining in full force where in accordance with the same.

In compliance with the terms of the above article, the survey of the new line was carried on, and, after some changes in the personnel of the original commission, the whole boundary, including the part formed by the Rio Grande and the Rio Colorado, was duly established.

The direction of the California boundary was not changed, but its eastern terminus was fixed at the point where it crossed the channel of the Rio Colorado, about 6 miles (10 kilometers) west of the Gila. The monument previously erected near the junction now being unnecessary, was utilized to mark a point on the new Arizona and Sonora line near its western terminus.

In addition to the 6 monuments, which remained to mark the California boundary, the commissioners reported that 47 had been placed along the line from the Rio Grande to the Colorado. These were all shown upon the Mexican copy of the joint map, while upon the American copy but 46 were represented. Of these 53 boundary marks, alleged to have been placed along the entire line west of the Rio Grande, the majority were but rude piles of stone; a few only being of a durable character, and provided with proper inscriptions, while the intervals between them were found to be in some cases as great as 20 or 30 miles (32 or 48 kilometers), and in one instance 101 miles (163 kilometers). The durable monuments were, notably, Nos. 1, 2, and 3 on parallel 31° 47′, and those marking the extremities of the meridian section, the latter and No. 1 being of dressed stone laid in mortar.

A full account of the methods used in establishing the old monuments, and their character, will be found in section 10 of this report.

U. S. Custom-House, El Paso. Aduana de los E. U., El Paso.

SECTION 3.

In later years settlers entered upon the lands adjacent to the boundary, and mines were discovered in its immediate vicinity. Difficulties then arose regarding the exact location of the line, it being charged that some of the original marks had been destroyed or removed.

To put an end to these difficulties a convention between the two Governments was concluded at the city of Washington, July 29, 1882. Following is a copy of this convention:

The President of the United States of America on the one hand, and the President of the United States of Mexico on the other, being desirous of putting an end to whatever difficulties arise from the destruction or displacement of some of the monuments erected for the purpose of marking the boundary between the two countries, have thought proper to conclude a convention with the object of defining the manner in which the said monuments are to be restored to their proper places and new ones erected, if necessary; to which end they have appointed as their plenipotentiaries, to wit:

The President of the United States of America, Frederick T. Frelinghuysen, esquire, Secretary of State of the United States of America; and the President of the United States of Mexico, Señor Don Matias Romero, envoy extraordinary and minister plenipotentiary of the United States of Mexico, in Washington;

Who, after reciprocal exhibition of their full powers, found in good and due form, have agreed upon the following articles:

ARTICLE I. With the object of ascertaining the present condition of the monuments marking the boundary line between the United States of America and the United States of Mexico, established by the treaties of February 2, 1848, and December 30, 1853, and for determining generally what monuments, if any, have been destroyed or removed and may require to be rebuilt or replaced, a preliminary reconnoissance of the frontier line shall be made by each Government, within six months from the exchange of ratifications of this convention. These reconnoissances shall be made by parties under the control of officers of the regular army of the respective countries, and shall be effected in concert, in such manner as shall be agreed upon by the commanders of the respective parties. The expense of each reconnoitering party shall be borne by the government in whose behalf it operates.

These reconnoissance parties shall report to their respective Governments, within eight months from the exchange of the ratifications of this convention—

(*a*) The condition of the present boundary monuments.

(*b*) The number of destroyed or displaced monuments.

(*c*) The places settled or capable of eventual settlement, where it may be advisable to set the monuments closer together along the line than at present.

(*d*) The character of the new monuments required, whether of stone or iron, and their number, approximately, in each case.

ARTICLE II. Pending the conclusion of the preliminary reconnoissances provided in Article I, each Government shall appoint a surveying party, consisting of an engineer in chief, two associates, one of whom shall be a practical astronomer, and such number of assistant engineers and associates as it may deem proper. The two parties so appointed shall meet at El Paso del Norte, or at any other convenient place to be agreed upon, within six months from the exchange of the ratifications hereof, and shall form, when combined, an "International Boundary Commission."

ARTICLE III. The International Boundary Commission shall be required and have the power and authority to set in their proper places along the boundary line between the United States and Mexico, from the Pacific Ocean to the Rio Grande, the monuments heretofore placed there under existing treaties, whenever such monuments shall have become displaced; to erect new monuments on the site of former monuments when these shall have been destroyed, and to set new monuments at such points as may be necessary and be chosen by joint accord between the two commissioner engineers in chief. In rebuilding and replacing the old monuments and in providing for new ones the respective reports of the reconnoissance parties, provided by Article I, may be consulted: *Provided, however*, That the distance between two consecutive monuments shall never exceed 8,000 meters, and that this limit may be reduced on those parts of the line which are inhabited or capable of habitation.

ARTICLE IV. Where stone shall be found in sufficient abundance the monuments may be of stone, and in other localities shall be of iron, in the form of a simple tapering four sided shaft with pediment, rising above the ground to a height of 6 feet, and bearing suitable inscriptions on its sides. These monuments shall be at least two centimeters in thickness and weigh not less than 500 pounds each.

The approximate number thereof to be required may be determined from the reports of the preliminary reconnoissance parties, and the monuments, properly cast and finished, may be sent forward from time to time to such spots as the commission may select, to be set in place at the sites determined upon as the work progresses.

ARTICLE V. The engineers in chief of both sections shall determine, by common consent, what scientific processes are to be adopted for the resetting of the old monuments and the erection of the new ones, and they shall be responsible for the performance of the work.

On commencing operations, each section shall report to its Government the plan of operations upon which they shall have jointly agreed; and they shall from time to time submit reports of the progress made by them in the said operations; and finally they shall present a full report, accompanied by the necessary drawings, signed by the engineer in chief and the two associate engineers on each side as the official record of the International Boundary Commission.

ARTICLE VI. The expenses of each section shall be defrayed by the Government which appointed it; but the cost of the monuments and of their transportation shall be equally shared by both Governments.

ARTICLE VII. Whenever the number of the monuments to be set up shall be approximately known as the result of the labors of the preliminary reconnoissance parties, the engineers in chief shall prepare an estimate of their cost, conveyance, and setting up; and when such estimate shall have been approved by both Governments, the mode of making the payment of the part to be paid by Mexico shall be determined by a special arrangement between the two Governments.

ARTICLE VIII. The work of the International Boundary Commission shall be pushed forward with all expedition; and the two Governments hereby agree to regard the present convention as continuing in force until the conclusion of said work, provided that such time does not exceed four years and four months from the date of the exchange of the ratifications hereof.

ARTICLE IX. The destruction or displacement of any of the monuments described herein, after the line shall have been located by the International Boundary Commission as aforesaid, is hereby declared to be a misdemeanor, punishable according to the justice of the country of the offender's nationality, if he be a citizen of either the United States or Mexico; and if the offender be of other nationality, then the misdemeanor shall be punishable according to the justice of either country where he may be apprehended.

This convention shall be ratified on both sides and the rectifications exchanged at Washington as soon as possible.

In testimony whereof we have signed this convention in duplicate, in the English and Spanish languages, and affixed hereunto the seals of our arms.

Done in the city of Washington this 29th day of July, in the year of our Lord one thousand eight hundred and eighty-two.

FRED'K T. FRELINGHUYSEN. [SEAL.]
M. ROMERO. [SEAL.]

The reconnoissance provided for by this convention was made in 1883 independently by officers of the American and Mexican Governments respectively, and reports were duly submitted which verified the necessity of a more definite demarkation of the boundary.

SECTION 4.

The convention of 1882 in its further provisions was not carried into effect before the date of its expiration, and another convention to revive and continue the same was concluded February 18, 1889, between the two Governments. Following is a copy of this convention:

Convention between the United States of America and the United States of Mexico, to revive the provisions of the convention of July 29, 1882, to survey and relocate the existing boundary line between the two countries west of the Rio Grande, and to extend the time fixed in Article VIII of the said convention for the completion of the work in question.

Whereas the provisions of the convention between the United States of America and the United States of Mexico, signed at Washington on the twenty-ninth of July, one thousand eight hundred and eighty-two, to survey and relocate the existing boundary between the two countries west of the Rio Grande, so far as they relate to Article VIII of said convention, have not been carried out through delays in the appointment of the commission to undertake the work;

And whereas, by the additional article to the said convention, signed at Washington the fifth of December, one thousand eight hundred and eighty-five, the time fixed in Article VIII of the said convention of July 29, 1882, was extended for a period of eighteen months from the expiration of the term stipulated in said Article VIII.

And whereas, the said additional period of time, as so extended, has expired without the appointment of the commission in question, and the said convention has accordingly ceased to be in force pursuant to the provisions of Article VIII thereof;

And whereas, it is the wish and understanding of the United States and Mexico that the provisions of the said convention of July 29, 1882, shall be revived and continued in force and effect until the completion of the work for which it was originally negotiated, they have appointed for this purpose, their respective plenipotentiaries to wit:

The President of the United States of America, Thomas F. Bayard, Secretary of State of the United States of America, and

The President of the United States of Mexico, Matias Romero, envoy extraordinary and minister plenipotentiary of the United States of Mexico in Washington,

Who, after having communicated to each other their respective full powers, found in good and due form, have agreed upon and concluded the following articles:

ARTICLE I. In view of the fact that the original convention of July 29, 1882, between the United States and Mexico, providing for the resurvey of their boundary line, has lapsed by reason of the failure of the two Governments to provide for its further extension before the 3d day of January, 1889, as contemplated by the additional article to that convention, of December 5, 1885, it is hereby mutually agreed and expressly understood by and between the contracting parties hereto that the said convention of July 29, 1882, and every article and clause thereof, are hereby revived and renewed as they stood prior to January 3, 1889.

ARTICLE II. The time fixed in Article VIII of the convention concluded at Washington July 29, 1882, between the United States of America and the United States of Mexico, to establish an international boundary commission, for the purpose of resurveying and relocating the existing boundary line between the two countries west of the Rio Grande, as provided for in said convention, and which was extended for eighteen months from the expiration of the term fixed in Article VIII of the said convention of July 29, 1882, is hereby further extended for a period of five years from the date of the exchange of ratifications hereof.

This convention shall be ratified by the contracting parties in conformity with their respective constitutions and its ratifications shall be exchanged at Washington as soon as possible.

In faith whereof we, the undersigned, in virtue of our respective full powers, have signed the present convention in duplicate, and have thereunto affixed our respective seals.

Done at the city of Washington the 18th day of February, in the year of our Lord one thousand eight hundred and eighty-nine.

T. F. BAYARD. [SEAL.]
M. ROMERO. [SEAL.]

SECTION 5.

Pursuant to the above convention, and to carry its provisions into effect, officers on the part of the two Governments were selected as specified in the following letters of appointment:

DEPARTMENT OF STATE, *Washington, November 13, 1891.*

J. W. BARLOW, *Lieutenant-Colonel, Corps of Engineers, U. S. Army.*
DAVID DUB. GAILLARD, *Lieutenant, Corps of Engineers, U. S. Army.*
A. T. MOSMAN, Esq., *of the U. S. Coast and Geodetic Survey.*
El Paso, Texas.

GENTLEMEN: By designation of the President, you are to constitute the International Boundary Commission on the part of the United States, as provided by the treaty with Mexico of July 29, 1882, revived by that of February 18, 1889, to relocate, in conjunction with a similar commission appointed by the Government of Mexico, the monuments marking the boundary line between the two countries.

* * * * * * *

The Department has no instructions to give for the execution of your work beyond referring you to the provisions of the treaty upon the subject and enjoining upon you the desirability and the necessity of prosecuting your labors to completion as rapidly as circumstances will permit.

* * * * * * *

By the President's direction, Lieutenant-Colonel J. W. Barlow has been designated as special disbursing officer, and the Department's letter to him of the 6th instant, in so far as it relates to the expenditures on behalf of the Mexican Boundary Survey, is made a part of these general instructions.

I am, gentlemen, your obedient servant,

JAMES G. BLAINE.

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*DEPARTMENT OF FOMENTO, COLONIZATION, INDUSTRY, AND COMMERCE,
MEXICO, SECTION 1ST, NO. 1930.

In consideration of the capacity, patriotism, and other qualifications possessed by you, the President of the Republic has been pleased to appoint you engineer-in-chief of the commission, which, according to the respective treaties, will proceed to reestablish the monuments along the dividing line between Mexico and the United States of North America. And I communicate this for your satisfaction and give you a term of two months for the presentation of your credentials.

Liberty and constitution.

MEXICO, *October 14, 1891.*

M. FERNANDEZ, O. M.

To Engineer JACOBO BLANCO, *Present.*

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*DEPARTMENT OF FOMENTO, COLONIZATION, INDUSTRY, AND COMMERCE,
MEXICO, SECTION 1ST.

In consideration of the qualifications possessed by you, the President of the Republic has been pleased to appoint you adjunct astronomer of the commission to reestablish the monuments along the dividing line between Mexico and the United States of North America. And I communicate this for your information and give you a term of two months for the presentation of your credentials.

Liberty and constitution.

MEXICO, *October 19, 1891.*

M. FERNANDEZ, O. M.

To Engineer FELIPE VALLE, *Present.*

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*DEPARTMENT OF FORMENTO, COLONIZATION, INDUSTRY, AND COMMERCE,
MEXICO, SECTION 1ST.

In consideration of the qualifications possessed by you, the President of the Republic has been pleased to appoint you adjunct astronomer of the commission to reestablish the monuments along the dividing line between Mexico and the United States of North America. And I communicate this for your information and give you a term of two months for the presentation of your credentials.

Liberty and constitution.

MEXICO, *October 19, 1891.*

M. FERNADEZ, O. M.

To Engineer JOSÉ TAMBORREL, *Present.*

* Translations furnished by Señor Jacobo Blanco, Mexican Commission.

Señores Valle and Tamborrel subsequently withdrew, their places being finally filled by the appointment of Señores Valentin Gama and Guillermo B. y Puga, with similar commissions.

The instructions received from the Department of Fomento by the engineer in chief of the Mexican section, under date of November 3, 1891, were as follows:

*To fulfill the requirements of the commissions conferred upon you and the other engineers who have been placed under your orders to reestablish the monuments on the boundary line between Mexico and the United States of North America, you will observe the following instructions:

1. On your arrival at Paso del Norte you will, as soon as possible, put yourself in communication with the engineer-in-chief of the boundary commission of the United States, in order to form the International Boundary Commission, according to Article II of the treaty of July 29, 1882, installing it with the formalities that will be agreed upon, and having the corresponding act signed by the chiefs of both commissions, as well as by the adjunct astronomers.

2. You will observe exactly the clauses of that treaty in everything that relates to the fulfillment of the commission.

3. According to Article V of said treaty, you will determine by common agreement with the engineer in chief of the commission of the United States the scientific methods that must be adopted for the resetting of the old monuments and the erection of new ones, and you will report immediately to the Government the plan of operations upon which you shall have agreed.

4. You will also arrange with the engineer in chief of the United States commission the epochs at which the reports referred to in Article V of the treaty shall be rendered.

5. As soon as the plan of operations is settled you will proceed with the work with all possible activity, giving for that object precise and written instructions to each one of the engineers that form your commission.

6. All the data will be precisely recorded in field note books which will be delivered by each engineer to you as soon as they are filled up or the work is finished, with a duplicate copy, both signed by the same engineer.

7. In the instructions that you will give to every engineer, the form will be prescribed in which they will deliver their final results, not only for the general report referred to in Article V, but also with the object of proceeding without any delay to the publication of that report.

8. You will have corrected in the actual maps any error that may be found in the topographical configuration of the ground, and the new settlements that now exist upon the line or its vicinity will be accurately delineated.

9. Besides the reports referred to in the fourth of these instructions, you will communicate to the Government any matter that may occur in the course of operations of sufficient importance to require consultation.

In compliance with their instructions, the officers above appointed assembled at Paso del Norte on the 17th of November, 1891, when a joint meeting was held in the custom-house of that city, on which occasion the International Boundary Commission was duly organized as required by the convention.

The following declaration was drawn up, copies of which, in English and Spanish, were transmitted to the proper authorities at Washington and the City of Mexico:

In the principal hall of the custom-house of Ciudad Juarez (Paso del Norte) of the Mexican Republic the undersigned, engineers in chief and associates of the two sections named for the reestablishment of the boundary line between Mexico and the United States of North America, met on the 17th day of November, 1891, in virtue of the treaty concluded in Washington on the 29th day of July, 1882 (and renewed on the 18th day of February, 1889), and declared that from the date of meeting the "International Boundary Commission" was organized, for the purposes of the aforesaid convention, as expressed in Article II of the same.

In testimony of which we have signed the present document in both the Spanish and English languages, in duplicate.

J. W. Barlow,
Lieut. Col., Corps of Engineers.
Jacobo Blanco,
Ingo. en Jefe de la Com. Mex., Rúbrica.
A. T. Mosman,
Assistant, U. S. Coast and Geodetic Survey.
Felipe Valle,
Asto. Adjo. de la Com. Mex.
José Tamborrel,
Adjunto Astrónomo C. M. de L.
D. D. Gaillard,
First Lieut., Corps of Engineers.

*Translations furnished by Señor Jacobo Blanco, Mexican Commission.

SECTION 6.

A plan of operations, as required by the convention, was then prepared by the engineers in chief, with the assistance of the other members, and a copy as follows was submitted, in both languages, to each Government:

Plan of operations, including necessary surveys, adopted by the engineers in chief of the American and Mexican sections of the International Boundary Commission appointed by their respective Governments to relocate the old monuments and erect new ones along the frontier line west of the Rio Grande, pursuant to Article V of the treaty of July 29, 1882, revived by that of February 18, 1889.

I. All monuments whose position, after verification, are found to be as located by the International Boundary Commission of 1849–1856 shall be accepted as positive boundary marks. They may, however, be repaired or rebuilt if necessary.

II. Special astronomical determinations for latitude and longitude at the following points will be made:

(*a*) The initial monument near El Paso;

(*b*) The intersection of the one hundred and eleventh meridian with the parallel of 31° 20′ near Nogales;

(*c*) The terminal points, near San Diego and Yuma, respectively, of the azimuth line from the Pacific Ocean to the Colorado River.

III. The position of the boundary along the parallels of 31° 20′ and 31° 47′ will be verified by astronomical or geodetic determinations for latitude at certain points, which, with those established as above described, will fix the direction of these lines. The distances between such definite points may be about 20 miles.

The points of intersection of these parallels with the meridian section of the boundary may be verified, if deemed necessary, by astronomical determinations with the aid of the telegraph, if practicable.

IV. The monuments whose positions have been verified as above stated, and the new astronomical stations located as expressed in paragraph three, shall form the general line of the boundary between the Rio Grande and the one hundred and eleventh meridian.

V. The lines joining these several points on the parallels shall be run by the method known as "tangents and offsets;" the measurements on the ground along the tangents and offsets to be made as may be most convenient with tape, chain, or stadia, but in case these methods are impracticable, by triangulation.

VI. The two azimuth sections of the boundary between the one hundred and eleventh meridian and the Pacific Ocean were originally run as straight lines on the surface of the earth, and should be relocated as such; the same principles in regard to existing monuments and new stations to be observed as in locating the parallels.

VII. Capt. Thos. W. Symons's recommendations regarding the number and location of new monuments will be followed in general, subject to such modifications as the joint commission may find desirable.

VIII. In addition to the astronomical and geodetic work provided for, each section of the boundary survey party will make a map of the adjoining country on its own side for a distance of 2½ miles. The topography thus obtained should be supplemented by sketches and photographs, especially in the vicinity of the monuments, for the purpose of more exactly defining their positions.

IX. The western terminal of the azimuth line, from the one hundred and eleventh meridian to the Colorado, will be verified by astronomical or geodetic determinations from Monument No. VI, near Yuma.

X. The work will be commenced at El Paso and carried on to completion in the order deemed most advantageous by the engineers in chief.

In testimony whereof we have hereunto signed our respective names in Ciudad Juarez (Paso del Norte) this the 21st day of November, 1891.

J. W. BARLOW,
Lieut. Col. Corps of Engineers, U. S. A.
JACOBO BLANCO,
Ingo. en Jefe de la C. M.

It was found expedient, while the surveys were in progress, to depart from the plan of operations in the following particulars:

First. It was agreed at the joint meeting of August 10, 1892, to locate all new monuments on the geodetic arcs joining existing monuments for parallel 31° 47′ and the meridian section, omitting the results of any astronomical determinations for latitude on these lines.

Second. A similar agreement was made by the joint commission May 15, 1893, with respect to the location of new monuments on parallel 31° 20′.

Third. In consequence of the above agreements the results of astronomical determinations for latitude, taken at points between authentic monuments, were not used in locating the boundary, but were used in the later computations for the projection of the maps.

Fourth. No astronomical determinations for latitude were made along the azimuth lines of the boundary except at their extremities.

As fully explained in section 10 of this report, certain errors occurred in the original survey (1849–1856), unavoidable under the conditions existing at that time, and due chiefly to inaccurate determinations for longitude.

The present commission, by means of the telegraphic method for longitude and a careful measurement of the entire line, was able to determine the amount of these errors and the consequent loss or gain by each Government of certain areas of land. The loss fell most heavily upon Mexico, but the present commission, under the treaties, had no power to make any alterations in the boundary.

In compliance with Article VII of the convention of 1882, an agreement between the engineers in chief, accompanied by a drawing, was made March 1, 1892, in regard to the design and cost of the monuments. Following is a copy of said agreement:

The following agreement was entered into this 1st day of March, 1892, between the engineers in chief of the International Boundary Commission, respecting the design and inscription for the new monuments to be erected on the boundary west of the Rio Grande:

The monuments shall be cast either of steel or iron, as may be found most desirable;

The height 6 feet and thickness of metal 2 centimeters, as provided in the treaty;

The size at the base to be 12 inches square, and at top 9 inches square;

The pyramid at top to have a base 9 inches square and 6 inches in height;

The base of the monument will have a flange 4 centimeters in thickness, where it joins the sides, diminishing to 2 centimeters at the outer edge, and will be 6 inches wide; through this flange on each side will be a hole 1 inch in diameter; these holes are to receive the fastening bolts to secure the monument in place;

The monument will be filled either with concrete or sand well packed, as may be found most practicable, and to be fastened in place by four 1-inch bolts well secured to the natural rock foundation, where possible. Where no rock foundation is available a foundation of concrete, 3 feet square and 2 feet deep, will be prepared of Portland cement and sand in proportion of about one to three. In these cases the fastening bolts will extend through the foundation, and be secured below by suitable heads and washers; the upper ends of these bolts will be provided with a thread and nut, the latter round and put on with pipe tongs;

On the west side of each monument may be attached two socket rings for holding a flagstaff, for the purpose of more easily verifying the line between monuments remote from each other; these rings will be placed, one at the top of shaft, the other 12 inches below, and will be carefully located in the plane of the boundary;

The engineers in chief further agreed that the inscriptions to be placed on the new monuments should be as follows:

On north side: "Boundary of the United States, treaty of 1853, reestablished by treaties of 1882–1889."

On south side: "Limite de la Republica Mexicana, tratado de 1853, restablecido por tratados de 1882–1889."

It is at the present time impossible to prepare an accurate estimate of the cost of the monuments, including their conveyance and setting up, as required by Article VII of the treaty of 1882. An approximate estimate, however, can be given, based upon known difficulties attending the transportation of men and material in a desert country.

The weight of the monuments as designed is 710 pounds, which is 200 pounds greater than the weight suggested in the treaty. If made to weigh 500 pounds, with a height of 6 feet, of 2 centimeters thickness of metal, the monument would be more slender than the design now recommended; it would be a less conspicuous mark and, therefore, not deemed as desirable. Smaller dimensions than those given would seem inappropriate.

It is proposed to have as many of the monuments cast whole as can be transported to their locations on wagons, but for locations inaccessible for wagons the monuments will be cast in sections, for transportation on pack mules. These sections will be four side plates, two of which are 5 feet long, 12 inches wide at base, 9½ inches at top; two 10½ inches at base, 8 inches at top; the base plate 21 inches square; and top section, which will comprise the pyramid and 12 inches of the shaft. The weight of these pieces will be as follows:

	Pounds.
2 side plates, 135 pounds each	270
2 side plates, 110 pounds each	220
1 base plate, 110 pounds	110
1 top section, 110 pounds	110
Total	710

Estimate of cost of monuments, including concrete bases, transportation, and setting in place:

Castings, 710 pounds, at 4 cents	$28.40
Wrought bolts and nuts, 86 pounds, at 5 cents	4.30
Concrete, 18 cubic feet	15.00
Sockets for flagstaff	1.00
Transportation by wagon	15.00
Transportation by pack mules	10.00
Setting in place	15.00
Contingencies	11.30
Total for each monument	100.00

This is considered a fair probable average cost. In some instances transportation will greatly exceed the estimate, and in others it is hoped there will be a proportionate reduction.

J. W. Barlow,
Lieut. Col., Corps of Engineers, U. S. A., Engineer in Chief, American Section.
Jacobo Blanco,
Engineer in Chief, Mexican Section.

TYPE OF NEW MONUMENT, SHOWING BASE. MODELO DE UN MONUMENTO NUEVO, MOSTRANDO LA BASE.

SUPPLEMENTARY AGREEMENT UPON THE SAME SUBJECT.

The following additional agreement was entered into this 9th day of March, 1892, between the engineers in chief of the American and Mexican sections of the Boundary Commission:

I. All monuments, old and new, will be numbered consecutively, beginning at the initial monument near El Paso. The letters "NO" will be cast in the metal on the east side of each new monument, and proper figures afterwards attached by screws, bolts, or rivets.

II. It being understood that the new monuments would be procured in the United States, the estimates of cost—approximately $100 per monument—were based on the currency of that country.

III. When old monuments are retained the original inscriptions will be preserved, if possible, but when repairs are made the following inscription will be added:

On north side: "Repaired by the Boundary Commission created by treaties of 1882–1889."

On south side: "Renovado por la comision de limites creada por los tratados de 1882–1889."

IV. The better to preserve the monuments from injury by trespassers or animals, it is agreed that near cities the monuments shall be inclosed by an iron picket fence 4 feet high, and inclosing a space 4 feet wide on each side of the monument. In other localities barbed wire, surrounding the monuments at a distance of 2 feet, supported on wrought-iron posts attached to the foundation, will be sufficient protection.

V. It is estimated that the average cost per monument for the protection above mentioned will be about $10, United States currency.

J. W. BARLOW,
Lieut. Col., Corps of Engineers, U. S. A., Engineer in Chief, American Section.
JACOBO BLANCO,
Engineer in Chief, Mexican Section.

During the progress of operations it was found expedient to deviate in some minor particulars from the above agreements. By verbal understandings between the engineers in chief the following deviations were adopted:

First. The estimated cost was considerably exceeded, owing to the exigencies of transportation, and reached an average of $150 per monument.

Second. It was considered inexpedient to inclose all the monuments with fences, and but three were thus finally protected.

Third. The provision for filling the monuments with concrete or sand was not found to be desirable, after a few trials, and was discontinued.

Fourth. The weight of the castings exceeded the estimate, reaching an average of 800 pounds per monument.

Fifth. The letters "NO," in connection with the figures on the monuments, were considered unnecessary and were omitted.

Sixth. Beneath the inscriptions on the north and south sides, respectively, of each monument, was added the following penalty notice in English and Spanish: "The destruction or displacement of this monument is a misdemeanor, punishable by the United States or Mexico;" "La destruccion o dislocacion de este monumento es un delito punible por Mexico o los Estados Unidos."

Seventh. After a number of sectional monuments had been put up, the design was changed to meet the difficulties of pack transportation. The new design provided 7 pieces—a base, a cap, and 5 intermediate sections, the latter each 14 inches high, resting one above another, and all held in place by a vertical bolt connecting the base and top section, the cap being fastened with rivets.

The sectional monuments, when erected, were of the same appearance as those cast solid.

Agreement between the engineers in chief with respect to the destruction of Monument No. 255 and the adoption of a new site:

SAN DIEGO, CAL., *April 1, 1895.*

Monument No. 255, built of granite, near Tijuana, having been destroyed by the flood of January, 1895, the two engineers in chief made a careful examination of the locality, but were unable to discover any parts of the lost monument. It had evidently been buried many feet below the bed of the river, which had so changed its course as to flow over the original site. It being deemed inexpedient to attempt to erect another monument on the old site, it was agreed to abandon that location and adopt a new position for this monument on permanent ground. Accordingly, a survey was made in March, 1895, under the personal supervision and through the cooperation of the engineers in chief, and a site selected 1,080.62 meters to the eastward of the old location upon which to erect a duplicate of the lost monument.

J. W. BARLOW,
Lieut. Col. Engrs., U. S. A., Engineer in Chief American Section.
JACOBO BLANCO,
Ingo. en Jefe de la Com. Mex.

A granite monument, a duplicate of the one destroyed, including a protecting fence, was erected at the point determined, and the map and records changed to conform to the new location.

SECTION 7.

JOURNAL OF PROCEEDINGS OF JOINT COMMISSION.

EL PASO, TEX., *August 19, 1892.*

The joint commission met at 9.30 a. m. Present, Señor Jacobo Blanco, Col. J. W. Barlow, Señor Felipe Valle, and Lieut. D. D. Gaillard. (Mr. Mosman absent in camp at San Bernardino.)

The measured distances along parallel 31° 47′ and the meridian section of the boundary were compared and found to agree closely.

The tangents and meridian, as traced by each section, and the offsets to existing monuments were then compared and found to agree well.

It was agreed to accept all existing monuments on this portion of the boundary, and to locate all new monuments on the geodetic arcs joining existing monuments for the particular part of the boundary considered in the meeting to-day. (Parallel 31° 47′ and the meridian section.)

JACOBO BLANCO,
Engineer in Chief Mexican Section.
J. W. BARLOW,
Engineer in Chief American Section.
FELIPE VALLE,
Adjunto Astrónomo de la Sección Mexicana.
D. D. GAILLARD,
First Lieut. of Engineers, U. S. A.

YUMA, ARIZ., *May 15, 1893.*

The joint commission met at 10 a. m.

Present, Señor Jacobo Blanco, Col. J. W. Barlow, Mr. A. T. Mosman, Señor Valentin Gama, and Lieut. D. D. Gaillard. (Señor Felipe Valle absent in the City of Mexico.)

The measured distances along parallel 31° 20′ were compared and found to agree well with each other and with the astronomical determination of the total distance.

It was agreed to accept all existing monuments on this parallel except the one on the west side of the Pedregosa Mountains, which is to be further inspected by Col. J. W. Barlow and Señor Jacobo Blanco, and by them accepted or rejected.

It was agreed to locate all new monuments for parallel 31° 20′ on the geodetic arcs joining existing accepted monuments.

JACOBO BLANCO,
Ingo. Jefe de la Com. Mex.
J. W. BARLOW,
Lieut. Col., Corps of Engineers.
A. T. MOSMAN,
Assistant, U. S. Coast and Geodetic Survey.
VALENTIN GAMA,
Asto. Adjo. de la Com. Mex.
D. D. GAILLARD,
First Lieut., Corps of Engineers.

CAMP ON PARALLEL 31° 20′ WEST OF THE PEDREGOSA MOUNTAINS,
July 26, 1893.

Pursuant to an agreement made by the joint commission of the United States and Mexican boundary at Yuma, Ariz., on the 15th day of May last, the engineers in chief of the two sections of the commission, viz, Señor Jacobo Blanco and Lieut. Col. J. W. Barlow, have on this day carefully inspected the monument at the point mentioned, and decided to accept it as one of the original monuments of the boundary.

JACOBO BLANCO,
Ingo. en Jefe de la Sección Mexicana.
J. W. BARLOW,
Engineer in Chief of the American Section.

Camp No. 1, of U. S. Section.
On Rio Grande.

Campamento No. 1, de la Sección de los E. U.
En el Río Grande.

SAN DIEGO, CAL., *December 28, 1894.*

It is hereby agreed between the engineers in chief of the United States and Mexican Boundary Commission that the monument referred to in agreement dated May 15, 1893, and its supplement of July 26, 1893, is understood to be the monument near the Gallardo Mountain which was found and located by the American surveying party.

JACOBO BLANCO,
Ingo. en Jefe Sección Mexicana.
J. W. BARLOW,
Lieut. Col. Engrs., U. S. A., Engineer in Chief American Section.

In the village of Nogales, State of Sonora, on the 15th day of November, 1893, there were present Mr. B. A. Wood, of the American section, and Capt. Gaspar Martinez Ceballos, of the Mexican section, of the International Boundary Commission, who compared, in the presence of Señor Jacobo Blanco, engineer in chief of the Mexican section, the data and results obtained, by both sections, along the azimuth line, from the extremity of parallel 31° 20′ to the Colorado River, as far as Monument IX.

The comparison of said data and results showed clearly that the monuments as far as No. IX were well identified, with the exception of No. XIX. No. XI was not found.

It was agreed, consequently, to accept the monuments from the extremity of the parallel to No. IX, inclusive, with aforesaid exceptions, and interpolate between them the new monuments in a straight line, admitting, in case of discrepancy, a difference not exceeding 2 meters, which will be equally divided, it being understood, however, that should the difference be considerable, though within the limit, the line shall be checked and the discrepancy be reduced as much as possible.

B. A. WOOD,
Assistant Engineer, American Section.
GASPAR MARTINEZ CEBALLOS,
Cap. 2, Ingo. Ayudte. de la Sección Mex.
JACOBO BLANCO,
Ingo. en Jefe d ela Sección Mex.

YUMA, ARIZ., *December 14, 1893.*

A joint meeting of the International Boundary Commission was held in the office of Señor Jacobo Blanco, engineer in chief of the Mexican section, at Yuma, at 9 a. m. to day.

Present: Señor Jacobo Blanco, engineer in chief of the Mexican section; Mr. A. T. Mosman, assistant, United States Coast and Geodetic Survey, and Lieut. D. D. Gaillard, United States Corps of Engineers. Absent: Col. J. W. Barlow, United States Corps of Engineers, suffering from a broken arm; Señor Valentin Gama, absent in the field, and Don Francisco Diaz Rivero, recently appointed, en route from the City of Mexico.

It was agreed:

First. That the astronomical length of parallel 31° 47′, the meridian section, and parallel 31° 20′, as determined by the United States section,* will be accepted as the standard of length for this portion of the boundary.

Second. In deciding the measured distances between monuments on this part of the boundary equal weight will be given to the United States and Mexican results and a mean of these taken. These means shall then be adjusted to conform to the astronomical lengths of the portions considered.

JACOBO BLANCO,
Engineer in Chief, Mexican Section.
A. T. MOSMAN,
Assistant, Coast and Geodetic Survey.
D. D. GAILLARD,
First Lieut. of Engineers, U. S. A.

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*NOTE.—The Mexican section did not observe for longitude at the western extremity of the line on parallel 31° 47′.

A meeting of the International Boundary Commission was held at Yuma, Ariz., on March 20, 1894, in the office of Señor Jacobo Blanco, engineer in chief of the Mexican section of the commission, at 9 o'clock a. m.

Present: Señor Jacobo Blanco, engineer in chief of the Mexican section; Mr. A. T. Mosman, assistant, Coast and Geodetic Survey, and Lieut. D. D. Gaillard, Corps of Engineers, United States Army. Absent: Col. J. W. Barlow, United States Corps of Engineers, at Washington, D. C., and Señor Valentin Gama, in the field. There were also present at this meeting Capt. G. Martinez Ceballos, of the Estado Mayor Especial of the Mexican Army, assistant engineer of the Mexican section of the International Boundary Commission, and Mr. E. L. Ingram, assistant engineer of the American section.

The direction and distances along the boundary line between the Colorado River and Monument IV were compared and found to agree closely, and it was agreed to accept Monuments VI, V, and IV as authentic.

JACOBO BLANCO,
Engineer in Chief of the Mexican Section.
A. T. MOSMAN,
Assistant, U. S. Coast and Geodetic Survey.
D. D. GAILLARD,
First Lieut., Corps of Engineers.
E. L. INGRAM,
Assistant Engineer of American Section.
GASPAR MARTINEZ CEBALLOS,
Capitain de E. M. E., Ingeniero Ayudante de la Sec. Mex.

SAN DIEGO, CAL.

On the 19th day of June, 1894, in the office of the American section of the International Boundary Commission. Present: Col. J. W. Barlow, Mr. A. T. Mosman, and Lieut. D. D. Gaillard, United States Commissioners; Señor Jacobo Blanco, engineer in chief of the Mexican section of the aforesaid International Commission, and Señor Valentin Gama, engineer and assistant astronomer of the same. Was discussed—

The actual condition of the work of the two sections, which was summed up as follows:

1. The tracing of the lines from the Rio Grande to the Pacific is finished, with agreement between the two sections.

2. In general the distances along these lines have been measured or determined, with the exception of some partial remeasurements, which perhaps it may be necessary to make and which do not affect in any practical manner at present the international boundary already established.

3. The replacing of old monuments and the interpolation of other new ones has proceeded up to monument 248, and will be entirely concluded from the Rio Grande to the Pacific in July.

4. The topographical fieldwork in the agreed zone of 2½ miles on each side of the line is finished on the part of the American section in their territory, and the field maps of their whole work will be finished before the expiration of the present convention (October 12, 1894), but the final maps to accompany the report can not be made till the Mexican section has finished their topography and made their field maps of the same.

The Mexican section, due to its smaller resources and force, principally during the first part of the work, lacks still the topography along the two azimuth lines. In that of Sonora the work is now actually progressing with all activity, and another topographical section will be organized in that of California about the end of July.

For what each section respectively lacks for camp and office work and for the common work of both on maps and detailed reports an extension for two years, reckoned from the expiration of the time granted by the convention of October, 1889, is considered necessary, and such an extension is respectfully requested from each one of the two Governments by the respective sections of the

International Commission, with the understanding that the work will be prosecuted with all activity in order to finish, if possible, before the limit requested.

J. W. BARLOW,
Lieut. Col. of Engineers.

A. T. MOSMAN,
Assistant, Coast and Geodetic Survey.

D. D. GAILLARD,
First Lieut. of Engineers.

JACOBO BLANCO,
Engineer in Chief of the Mexican Section.

VALENTIN GAMA,
Engineer and Assistant Astronomer.

SAN DIEGO, CAL., *October 1, 1894.*

At a meeting of the joint commission, held at the residence of Col. J. W. Barlow, at 3 p. m., at which were present all of the members, it was unanimously agreed that, subject to the approval of the proper departments of our respective Governments, the commission hereby adjourns, to meet next on October 11, 1895, at Washington, D. C., there to adopt a plan of work for the completion of the final maps of the boundary line and to prepare the report.

J. W. BARLOW,
Lieut. Col. of Engineers, U. S. A.

D. D. GAILLARD.
First Lieut. of Engineers, U. S. A.

A. T. MOSMAN,
Assistant, U. S. Coast and Geodetic Survey.

JACOBO BLANCO,
Engineer in Chief, Mexican Section.

VALENTIN GAMA,
Assistant Astronomer.

SECTION 8.

ASTRONOMICAL DETERMINATIONS.

The original plan agreed on by the joint commission for running the boundary was to determine both the latitude and longitude of the extremities and turning points of the boundary, at or near which points the monuments erected by the original commission were reported as still standing, and to observe for latitude and azimuth on the parallels at points about 20 miles apart.

Longitude.—The method used for longitude by the United States section was exchange of signals by telegraph. Usually ten nights' exchanges were obtained, five with one observer at eastern station and the other at western, then five more with the positions of the observers reversed. The same stars were observed at both stations for time and instrumental corrections to eliminate errors in the right ascensions of the stars used.

The method used by the Mexican section was to refer the points of observation (stations) to the meridians of Tacubaya and Mexico by exchange of telegraphic signals. The corrections and rates of chronometers employed were obtained by observations of meridian transits registered by the ear in Ciudad Juarez, and with chronograph at Nogales and Yuma.

The longitude of Monument 1, where the parallel of 31° 47′ leaves the Rio Grande, was fixed by a triangulation by the United States section, connecting the monument with the longitude station at El Paso, and by signals by the Mexican section to the longitude station at Juarez. The longitude of Monument 40, at the intersection of parallel 31° 47′ with meridian, was obtained directly by the United States section using a temporary field telegraph line, erected by direction of General Greeley, Chief Signal Officer, United States Army, connecting with the Western Union telegraph line at Separ, on the Southern Pacific Railway. General Greeley also furnished operators at both ends.

The longitude of Nogales was transferred to Monument 127, at the intersection of parallel 31° 20′ with the one hundred and eleventh meridian, as determined by the original commission, by a triangulation by United States section connecting the monument with the longitude station at Nogales. This triangulation was repeated by the Mexican section. The longitude of Monument 204, 20 miles below Yuma, on the line connecting Monument 127 with the initial point in the Colorado, was obtained from the observed longitude at Yuma by triangulation by the United

States section, repeated by the Mexican section. The longitude of Monument 207, where the line from the junction of the Gila and Colorado leaves the river, was obtained from the same triangulation. The longitude of Monument 258, on the Pacific, was furnished by the Coast and Geodetic Survey based on observations for longitude made at San Diego in 1892, connecting this point with the main chain of longitude stations on the Pacific coast and reduced to the monument by Coast and Geodetic Survey triangulation.

The details of these triangulations will be found in another part of this report, under section No. 9.

Latitudes.—It was arranged by the joint commission that the parallel of 31° 47′ should be determined by occupation of alternate stations by the United States and Mexican astronomers along the parallel, about 20 miles apart, for latitude and azimuth.

In pursuance of this plan, observations were made by the astronomers of both sections at Monument No. 1, on the Rio Grande, and at Monument No. 40, at the western extremity of this parallel. The United States section occupied two intermediate stations and the Mexican section two.

Along the parallel of 31° 20′ a different plan was adopted. Along this parallel each section of the commission observed independently of the other. Both sections observed at the eastern end, and at Nogales near the western end; the Americans at six intermediate stations and the Mexicans at four. The stations were not identical, as the Mexican section observed only at monuments, and as these monuments were very unequally distributed as to distance, in some places being over 40 miles apart, the United States section had two stations where no old monuments existed, so as to divide the line as nearly as possible into sections of 20 miles each. By a vote of the joint commission no account was taken of the resulting latitudes at stations between old monuments in fixing the final line. Observations were also made at Yuma and at Monument No. 204, 20 miles below Yuma, on the Colorado River, and at Monument No. 258, on the Pacific.

Azimuths.—At each latitude station observations for azimuth were made by the United States section, usually on three nights, on Polaris near elongation, and the direction of the new tangent started from each azimuth station, fixed by repeated measures of the angle between the azimuth mark and the most distant point of the tangent visible from the station.

The azimuth of the old tangent ending at the station was checked in the same manner.

The method used by the Mexican section was to measure the angle between Polaris and a mark two or three times in both positions of the instrument; the group formed in this way is called a series in the following table.

The azimuth of each tangent was corroborated at its extremity by the observation of the back azimuth.

Longitude results by United States section.

DIFFERENCE OF LONGITUDE BY TELEGRAPH.

[Observers, C. H. Sinclair and G. R. Putnam.]

Stations.	Number nights.	Difference of longitude.	Probable error.
		m. s.	s.
San Diego, Cal.-Yuma, Ariz	10	10 9.114	± 0.005
Yuma, Ariz.-Nogales, Ariz	10	14 43.690	± 0.007
Nogales, Ariz.-El Paso, Tex	10	17 48.520	± 0.009
Corner near Monument No. 40-El Paso, Tex	4	6 52.626	± 0.013

LONGITUDES FROM GREENWICH.

Station.	Time.	Longitude.
	h. m. s.	° ′ ″
El Paso, transit of 1892	7 05 57.350	106 29 20.25
Boundary corner	7 12 49.976	108 12 29.64
Nogales	7 23 45.870	110 56 28.05
Yuma	7 38 29.560	114 37 23.40
San Diego	7 48 38 674	117 09 40.11

Longitude results by United States section—Continued.

LONGITUDE OF PROMINENT POINTS ON BOUNDARY.

Points.	Longitude.		
	°	′	″
Court-house, El Paso	106	28	55.11
Cathedral, Juarez, Mexico	106	29	4.72
Federal building, El Paso	106	29	9.58
Monument No. 1, Rio Grande	106	31	39 03
Monument No. 40, upper corner	108	12	29.67
Monument No. 53, lower corner	108	12	29.67
Monument No. 122, Nogales	110	56	34.53
Monument No. 127, corner	111	4	34.45
Monument No. 204, east bank Colorado	114	46	48.64
Monument No. 207, west bank Colorado	114	43	54.31
Monument No. 258, Pacific	117	7	31.89

UNITED STATES LATITUDE OBSERVATIONS.

All the latitude observations were made with the Würdemann zenith telescope No. 20. The principal dimensions of this instrument are: Clear diameter of objective, 67 mm.; focal length, 826 mm.; diameter of vertical circle, 144 mm. The eyepiece magnifies about 70 diameters. The vertical circle is graduated to fifteen-minute spaces, and its vernier reads to half minutes. The latitude level carries a 2 mm. graduation of 70 divisions, *numbered continuously from one end to the other.*

The time was computed from sextant observations of the sun's altitude.

The instrument was usually mounted on a wooden pier, similar to that used for the azimuth instrument, but larger and heavier, and covered by a portable tent. At Nogales and at Yuma the zenith telescope was mounted upon the brick pier which had previously been used as a latitude pier by the Coast and Geodetic Survey longitude party.

The mean places of the stars observed for latitude were furnished in advance by Prof. T. H. Safford, of Williams College, Williamstown, Mass. (See catalogue in report of United States section.)

The value of micrometer was determined at every station except at No. 14 by transits across the thread of polaris near elongation, the thread being set at each half turn in succession for the twenty turns near the middle of the field of the telescope, and the time of transit observed by eye and ear.

The following table gives the results for latitude by the United States section:

Latitude results of United States section.

No. of United States station.	Number of monument.	Number of nights.	Instrument used.	Number of observations.	Results for latitude.			Probable error.	Observer.
					°	′	″	″	
1	1	4	Zenith telescope	67	31	46	59.40	±0.06	J. F. Hayford.
2	15	3	do	39			60.34	± .07	Do.
3	26	4	do	46			58.08	± .05	Do.
4	40	7	do	130			59.72	± .04	Do.
5	53	5	do	99	31	19	61.79	± .04	Do.
6		3	do	102			57.94	± .04	Do.
7	67	7	do	99			56.86	± .04	Do.
8	77	4	do	100			58.99	± .03	Do.
9		4	do	101			66.07	± .03	Do.
10	98	7	do	106			64.67	± .04	Do.
11	111	4	do	126			57.58	± .03	Do.
12	122	5	do	121			60.73	± .04	Do.
13		4	do	105	32	43	34.69	± .03	Do.
14	204	2	do	25	32	29	.91	± .08	Do.
15	258	4	do	96	32	32	1.34	± .04	Do.

UNITED STATES AZIMUTH OBSERVATIONS.

All the azimuth observations were made with Fauth repeating theodolite No. 725. The horizontal circle, 25 cm. (10 inches) in diameter, is graduated to 5′ spaces, and is read by two opposite verniers to 5″. It is furnished, on the horizontal motions, with axis clamps and tangent screws working against spiral springs. The telescope has a focal length of 41 cm. and an objective 45 mm. in diameter. The eyepiece used magnifies about 30 diameters, and is furnished with a micrometer with which the azimuth observations were made, except at Monument 53, where the azimuth was measured on the horizontal circle by repetitions.

The theodolite was mounted on a wooden pier in the large observatory tent. The pier was a hollow, triangular column, built of 3-inch pine, put together with screws and banded at top and bottom with heavy hoop iron. The pier was set as a fence post at each station, about 45 cm. of its length being below ground. The earth was tamped solidly around it, and its hollow interior was also filled with earth to give it greater rigidity.

The mark used for azimuth work was an ordinary bull's-eye lantern showing through a hole an inch in diameter in front of the small box which served to protect it from the wind. This light was placed from 1 to 3 miles from the theodolite at each station. The time was obtained with sufficient accuracy for the azimuth work by sextant observations of the sun's altitude.

With the exception of one station all the azimuth observations were taken with the eyepiece micrometer by the method described in Bulletin No. 21, December 12, 1890, of the Coast and Geodetic Survey.

All the observations were taken near elongation, usually within one hour, and polaris was used at each station.

The azimuth light having been previously placed nearly in the vertical plane of the star, the observations consisted simply of the measurement with the eyepiece micrometer of the small horizontal angle between the star and mark, the chronometer time of each star pointing being noted.

Each set of observations consisted of five pointings on the mark, followed by five on the star, with telescope direct; five more pointing on the star, followed by five on the mark with telescope reversed, completed the set. The level was read at the beginning, middle, and end of each set in both positions of the telescope.

Having determined the azimuth of the mark we need next to determine the exact location of a point to the westward (or eastward), on the prime vertical of the station, said point serving with the station to fix the direction of the "tangent" to be continued forward to the next station.

A point was first placed as nearly in azimuth 90° as could be done by a single pointing and reading of the horizontal circle, usually within ten seconds. The distance to this point from the station was measured by chain or stadia, and the angle between the point and the azimuth mark was measured with the theodolite used as a repeater, each set of observations consisting of six repetitions of the angle and six of the explement (360 angle). The linear correction at right angles to the line of sight necessary to place the point in the prime vertical of the station was then computed and the final point set by linear measurement from the approximate point.

Azimuth results by United States section.

No. of United States station.	Locality.	Number of nights.	Method used.	Number of sets.	Results for azimuth.	Probable error.	Observer.
					° ′ ″	″	
1	Monument No. 1	2	Micrometer	5	178 30 40.11	±0.21	J. F. Hayford.
2	Monument No. 15	1	do	5	37.46	± .25	Do.
3	Monument No. 26	1	do	5	178 31 47.46	± .23	Do.
4	Monument No. 40	2	do	6	1 26 16.16	± .34	Do.
5	Monument No. 53	2	Theodolite	7	89 57 27.40	± .70	Do.
6	San Luis	2	Micrometer	13	1 23 12.93	± .23	Do.
7	Monument No. 67	3	do	12	181 27 55.52	± .14	Do.
8	Monument No. 77	3	do	10	181 28 31.84	± .19	Do.
9	Dutch Charley's	3	do	12	181 28 12.96	± .16	Do.
10	Monument No. 98	3	do	27	181 27 56.39	± .14	Do.
11	Monument No. 111	3	do	9	178 31 29.03	± .20	Do.
12	Nogales	3	do	9	178 33 39.19	± .26	Do.
13	Yuma	3	do	9	178 32 1.12	± .14	Do.
14	Monument No. 204	3	do	9	178 31 21.01	± .21	Do.
15	Monument No. 258	3	do	9	181 28 39.30	± .27	Do.

ASTRONOMICAL RESULTS BY MEXICAN SECTION.

Longitude.—The points determined by the Mexican section were: Juarez, Monument No. 1, Nogales, and Yuma.

The first and the last two were determined by reference to the meridians of Tacubaya and Mexico by exchange of signals by telegraph. The chronometer corrections and rates employed were obtained by observations of the transits of stars with a transit instrument, made by Troughton and Sims, of about 30 inches focal length, and registered by eye and ear at Juarez and by chronograph at Nogales and Yuma.

The longitude of Monument No. 1 was obtained from the station at Juarez by exchanges of flashes of light.

The following table gives the results obtained for longitude of the different points from Greenwich:

Table of longitude results by Mexican section.

No. of astronomical station.	Locality.	Number of nights.	Method.	Number of observations.	Results.			Probable error.	Observer.
					h.	m.	s.	s.	
	Juarez (church)	2	Telegraph	12	7	5	55.98	±0.24	V. Gama.
1	Monument No. 1	3	Light flashes	6	7	6	6.54	± .25	F. Valle.
10	Nogales	6	Telegraph	35	7	23	45.61	± .03	Do.
11	Yuma	3	do	12	7	38	30.03	± .31	G. B. y Puga.

Latitudes.—Twelve astronomical stations were established at various points on the line for the determination of latitude. At four of these—see the following table—an altazimuth of 12 inches diameter of limb was used, and difference of zenith distance of pairs of stars selected so as to be reduced by the "Talcott method" were observed, except at Monument No. 1, where the latitude was determined by circum-meridian zenith distances. At the eight remaining points the latitude was determined by the "Talcott method," using a zenith telescope of about 30 inches focal length.

The results given in the following table are reduced to the center of the monument named by measurement, except those given for Station No. 7 and Yuma, where the latitudes correspond to the points of observation:

Latitude results by Mexican section.

No. of Mexican station.	Locality.	Number of nights.	Instrument used.	Number of observations.	Results for latitude.			Probable error.	Observer.
					°	′	″	″	
1	Monument No. 1	1	Altazimuth	28	31	46	59.47	±0.47	F. Valle.
2		9	do	26	31	47	0.87	± .10	Do.
3	Monument No. 21	3	Zenith telescope	63	31	46	58.85	± .10	Do.
4	Monument No. 40	3	do	34	31	46	59.66	± .06	Do.
5	Monument No. 53	3	Altazimuth	24	31	20	1.83	± .19	Do.
6	Monument No. 64	3	Zenith telescope	44	31	20	2.60	± .14	Do.
7		3	do	41	*31	19	59.65	± .05	Do.
8	Monument No. 98	3	Altazimuth	69	31	20	3.02	± .18	Do.
9	Monument No. 111	4	Zenith telescope	76	31	19	58.27	± .18	Do.
10	Nogales—Monument No. 122	3	do	98	31	20	0.97	± .11	Do.
11	Yuma	3	do	28	32	43	34.22	± .26	G. B. y Puga.
12	Monument No. II at Tijuana	6	do	31	32	32	25.26	± .19	Do.

*This latitude is not exactly that of the astronomical station, but is that of the pile of stones that Sr. Valle mistook for Monument No. XX.

Azimuths.—At nine of the latitude stations there were made observations for azimuth also, and at seven other points observations for azimuth alone were made, making 16 points at which azimuth was observed to be used in tracing the tangents to the parallels and to obtain the azimuth of the oblique lines.

The instrument usually employed was an altazimuth of 12 inches, except at Monuments Nos. 204 and 207, where one of 8 inches was used.

The method followed was to measure the angle between Polaris and a signal two or three times in both positions of the instrument, the group thus formed being called a series in the following table:

Table of azimuth results by Mexican section.

No. of astronomical station.	Locality.	Series.	Nights.	Method used.	Results for azimuth.	Probable error.	Observer.
					° ′ ″	″	
1	Monument No. 1	5	3	Altazimuth	191 31 31.2	0.13	F. Valle.
	Monument No. 2	4	3	do	233 33 23.2	.42	C. A. Gonzalez.
2		5	2	do	188 34 50.1	.71	F. Valle.
	Monument No. 15	6	2	do	178 30 45.5	.59	C. A. Gonzalez.
3	Monument No. 21	3	2	do	269 56 37.8	.46	F. Valle.
4	Monument No. 40	4	2	do	0 0 2.7	.96	Do.
5	Monument No. 53	5	3	do	89 59 57.5	.96	Do.
6	Monument No. 64	3	3	do	90 0 6.3	.22	Do.
7	Monument No. 83	4	4	do	89 59 28.7	.77	Do.
8	Monument No. 98	5	3	do	3 36 18.6	.50	Do.
9	Monument No. 111	5	2	do	179 35 59.2	.37	Do.
	Monument No. XIX	8	4	do	179 30 31.3	± .20	V. Gama.
	Quitobaquita	7	3	do	181 19 57.6	± .73	Do.
	Monument No. 204	8	3	do	109 33 49.5	± .39	Do.
	Monument No. 207	4	4	do	179 0 39.8	± .46	Do.
	Monument No. 221	8	3	do	85 4 44.7	± .51	Do.

The azimuths in this table are counted from the south by the west.

FINAL ASTRONOMICAL RESULTS.

The results for longitude as given by the United States section were adopted by the Mexican section. The reason for this was that the United States section determined differences of longitudes, exchanging observers to ascertain and eliminate their personal equation, and observed the same stars at both stations. The Mexican section determined differences of longitudes with Tacubaya without exchange of observers, and different stars were observed at the two stations.

The results for latitude are given in the following table. The adopted results are (when both sections observed at the same station) the mean, by weight, of the United States and Mexican results from their respective observations.

Final results for latitude.

Monument. Old No.	Monument. New No.	United States results.	Probable error.	Mexican results.	Probable error.	Latitude.	Remarks.
		° ′ ″	″	° ′ ″	″	° ′ ″	
1	1	31 46 59.40	±0.06	31 46 59.47	±0.47	31 46 59.40	
Mexican Station No. 2				31 47 0.87	± .15	31 46 60.88	No monument.
5	15	31 47 0.34	± .07			31 46 60.34	
6	21			31 46 58.85	± .10	31 46 58.85	
7	26	31 46 58.08	± .05			31 46 58.08	
9	40	31 46 59.72	± .04	31 46 59.66	± .06	31 46 59.70	
11	53	31 19 61.79	± .94	31 19 61.83	± .19	31 19 61.79	
United States Station No. 6		31 19 57.94	± .04			31 19 57.94	Do.
13	64			31 19 62.60	± .14	31 19 62.60	
16	67	31 19 56.86	± .03			31 19 56.86	
19	77	31 19 58.99	± .03			31 19 58.99	
Mexican Station No. 7				31 19 59.65	± .05	31 19 59.65	Do.
United States Station No. 9		31 19 66.07	± .03			31 19 66.07	Do.
21	98	31 19 64.67	± .04	31 19 63.02	± .17	31 19 63.02	
24	111	31 19 57.58	± .03	31 19 58.27	± .18	31 19 57.58	
27	122	31 19 60.73	± .04	31 19 60.97	± .11	31 19 60.75	
II	204	32 29 1.00	± .07			32 29 1.00	Arizona-Sonora.
Yuma		32 43 34.69	± .03	32 43 34.22	± .26	32 43 34.69	No monument.
II				32 32 25.26	± .19		California.
I	258	32 32 1.34	± .04			32 32 1.34	Do.

Mexican observations made at *Monument No. 98*; United States observations made at Salazar's old monument, on *east* side of San Pedro River, and reduced to Monument No. 98 by triangulation; hence Mexican result used.

Observatory at Monument No. 204.

Observatorio en el Monumento No. 204.

SECTION 9.

GEODESY.

In order to identify the existing old monuments, as well as to obtain the necessary elements for locating the new monuments on the lines forming the boundary, the following geodetic operations were executed:

I. Tracing the parallels according to the method of tangents and offsets.

II. Tracing the meridian section by simple alignment, its direction having been previously verified.

III. Tracing the azimuth lines, either by straight lines connecting consecutive existing old monuments directly, or by the aid of auxiliary lines starting at one of these monuments and passing as closely as possible to the next monument.

IV. Triangulation made in the vicinity of the initial monument on the Rio Grande by the United States section to refer the initial monument to its astronomical observatory, and the reference of the longitude of the initial monument to the astronomical station at Juarez made by the Mexican section by flash signals at night.

V. Triangulation made in Nogales by the United States section and repeated by the Mexican section to refer Monument No. 127, at the west end of the line on parallel 31° 20′, to the astronomical observatory occupied successively by both sections of the commission.

VI. Triangulation made in the vicinity of Yuma, Ariz., by the United States section, and repeated by the Mexican section, to refer Monuments No. 204 and No. 207 to the astronomical observatory at Yuma, Ariz., occupied successively by both sections of the commission.

All the preceding operations were executed independently and at different epochs by the two sections of the commission, the results being compared as soon as practicable after reduction.

On parallels 31° 47′ and 31° 20′ new monuments intervening between two consecutive existing old monuments were located upon a curved line joining the latter, the curvature of this line being as nearly that of the corresponding parallel as possible.

On the meridian section and on the azimuth lines the new monuments were located upon the straight lines joining consecutive existing old monuments.

In tracing straight lines, as well as in triangulation, heliotropes were generally used for distant signals.

In the following tables are given the lines run by the two sections, respectively, and the measured offsets to existing monuments from those lines on parallels 31° 47′ and 31° 20′, and on the azimuth lines:

Parallel 31° 47′.

No. of monument. On original survey. United States.	No. of monument. On original survey. Mexican.	No. of monument. New No.	United States tangent. No.	United States tangent. Begins.	United States tangent. Ends.	United States tangent. Measured offset.	Mexican tangent. No.	Mexican tangent. Begins.	Mexican tangent. Ends.	Mexican tangent. Measured offset.
						Meters.				*Meters.*
1	1	1	1	Monument No. 2.	Monument No. 15.	1.02	1	Monument No. 2.	Monument No. 15.	15.19
2	2	2	1	.....do	.....do	1.00	1	.....do	.....do	15.00
3	3	3	1	.....do	.....do	2.00	1	.....do	.....do	16.20
Mexican astronomical station No. 2.		.....	1	.....do	.....do	24.77	1	.....do	.....do	40.60
Not shown.	4	11	1	.....do	.....do	122.46	1	.....do	.....do	157.10
Not found.	5	15	1	.....do	.....do	240.10	1	.....do	.....do	296.10
Not shown	4	11	2	United States astronomical station No. 2.	Monument No. 11.	22.91	.....	.....	.....	.....
Not found.	5	15	2	.....do	.....do	4.14	.....	.....	.....	.....
United States astronomical station No. 2		.....	2	.....do	.....do	0.00	.....	.....	.....	.....
Not found.	5	15	3	.....do	Monument No. 26.	4.14	2	Monument No. 15.	Monument No. 21.	10.50
United States astronomical station No. 2		.....	3	.....do	.....do	0.00	.....	.....	.....	.....
5	6	21	3	.....do	.....do	27.05	2	Monument No. 15.	Monument No. 21.	35.70

+ = To N. — = To S. (United States tangent)

+ = To N. — = To S. (Mexican tangent)

Parallel 31° 47′—**Continued.**

No. of monument: On original survey: United States.	Mexican.	New No.	United States tangent: No.	Begins.	Ends.	Measured offset.	Mexican tangent: No.	Begins.	Ends.	Measured offset.
						Meters.				*Meters.*
United States astronomical station No. 3.		.....	3	United States astronomical station No. 2.	Monument No. 26	58.40	...			
6	7	26	3	.....do	.....do	60.84	...			
5	6	21	4	United States astronomical station No. 3.	Monument No. 21	10.78	3	Monument No. 21	Monument No. 40	0.95
United States astronomical station No. 3		.....	4	.....do	.....do	0.00	...			
United States astronomical station No. 3.			5	.....do	United States astronomical station No. 4.	0.60	...			
6	7	26	5	.....do	.....do	2.44	3	Monument No. 21	Monument No. 40	9.87
7	8	33	5	.....do	.....do	25.20	3	.....do	.....do	60.72
8	9	40	5	.....do	.....do	98.97	3	.....do	.....do	163.32
United States astronomical station No. 4		.....	5	.....do	.....do	63.11	...			

A check tangent was run from United States astronomical station No. 2 between Monuments Nos. 15 and 21, giving offsets of 4.14 and 29.30 meters, respectively. Offsets to above points on parallel 31° 47′ are all measured to the north.

Meridian section.

The line traced by both sections on the meridian section of the boundary was the straight line joining Monuments Nos. 40, 46, and 53, which had been found to lie exactly in the meridian.

Parallel 31° 20′.

No. of monument: On original survey: United States.	Mexican.	New No.	United States tangent: No.	Begins.	Ends.	Measured offset.	Mexican tangent: No.	Begins.	Ends.	Measured offset.
						Meters.				*Meters.*
10	11	53	8	United States astronomical station No. 5.	United States astronomical station No. 6.	— 6.49	1	Monument No. 53	Monument No. 64	0.00
United States astronomical station No. 5		.....	8	.....do	.....do	0.00	...			
11	12	.....	8	.....do	.....do	.....	...			
United States astronomical station No. 6		.....	8	.....do	.....do	60.00	...			
Do		.....	9	United States astronomical station No. 6.	United States astronomical station No. 7.	0.00	...			
12	13	64	9	.....do	.....do	5.75	1	Monument No. 53	Monument No. 64	98.64
Mexican astronomical station No. 6.			...	.....	.....	.....	2	Mexican astronomical station No. 6.	Mexican astronomical station No. 7.	0.00
12	13	64	...	.....	.....	.....	2	.....do	.....do	— .57
13	14	65	9	United States astronomical station No. 6.	United States astronomical station No. 7.	—118.59	2	.....do	.....do	—129.29
14	15	66	9	.....do	.....do	104.01	2	.....do	.....do	—118.80
15	16	67	9	.....do	.....do	— 90.20	2	.....do	.....do	—108.56
United States astronomical station No. 7		.....	9	.....do	.....do	— 94.24	...			
15	16	67	10	United States astronomical station No. 7.	United States astronomical station No. 8.	4.05	...			

+ = To N. — = To S. (United States tangent)

+ = To N. — = To S. (Mexican tangent)

Parallel 31° 20′—Continued.

No. of monument. On original survey. United States.	Mexican.	New No.	No.	United States tangent. Begins.	Ends.	Measured offset.	No.	Mexican tangent. Begins.	Ends.	Measured offset.
						Meters.				*Meters.*
United States astronomical station No. 7.			10	United States astronomical station No. 7.	United States astronomical station No. 8.	0.00				
16	17	73	10	do	do	37.51	2	Mexican astronomical station No. 6.	Mexican astronomical station No. 7.	— 44.54
17	18	.....	10	do	do	256.58	2	do	do	196.50
18	19	77	10	do	do	257.32	2	do	do	198.17
United States astronomical station No. 8			10	do	do	258.13				
18	19	77	11	United States astronomical station No. 8.	United States astronomical station No. 9.	— 0.73				
United States astronomical station No. 8			11	do	do	0.00				
19	20	82	11	do	do	15.80				
Mexican astronomical station No. 7.							2	Mexican astronomical station No. 6.	Mexican astronomical station No. 7.	143.80
19	20	82					3	Mexican astronomical station No. 7.	Monument No. 98	157.14
Mexican astronomical station No. 7							3	do	do	0.00
United States astronomical station No. 9			11			138.58				
Do			12	United States astronomical station No. 9.	Monument No. 98	0.00				
Station A, tangent No. 13			12	do	do	59.06				
20	21	98	12	do	do	51.47	3	Mexican astronomical station No. 7.	Monument No. 98	379.78
Station A, tangent No. 13			13	Station A, tangent No. 13.	Monument No. 111	0.00				
Mexican astronomical station No. 8.							4	Mexican station No. 8.	Monument No. 111	0.00
20	21	98	13	Station A, tangent No. 13.	Monument No. 111	— 7.62	4	do	do	.33
21	22	106	13	do	do	—110.33	4	do	do	— 97.04
22	23	108	13	do	do	—103.05	4	do	do	— 89.19
United States astronomical station No. 11			13	do	do	— 66.18	4	do	do	
23	24	111	13	do	do	— 59.97	4	do	do	— 43.91
United States astronomical station No. 11.			14	United States astronomical station No. 11.	United States astronomical station No. 12.	0.00				
23	24	111	14	do	do	6.20*	5	Mexican station No. 9.	Monument No. 127	3.43
Mexican astronomical station No. 9			14	do	do		5	do	do	0.00
24	25	.....	14	do	do		5	do	do	
25	26	118	14	do	do	118.56	5	do	do	117.66
United States astronomical station No. 12			14	do	do	17.17				
Do			15	United States astronomical station No. 12.	Monument No. 127	0.00				
26	27	122	15	do	do	12.33	5	Mexican station No. 9.	Monument No. 127	29.70
27	....	127	15	do	do	— 24.63	5	do	do	32.86

+ = To N.
— = To S.

+ = To N.
— = To S.

On parallels 31° 47′ and 31° 20′ offsets are measured in the meridian.

Sonora azimuth line.

LINES TRACED BY UNITED STATES SECTION.

The lines traced were practically the straight lines joining the twelve accepted existing original monuments, the greatest offsets to any monuments on the boundary line as now marked being —1.81 meters at Monument No. 128 and —0.82 meters at Monument No. 184.

LINES TRACED BY MEXICAN SECTION.

[— = To S.]

No. of monument on original survey. United States.	No. of monument on original survey. Mexican.	New No.	Begins.	Ends.	Measured offset.
					Meters.
27	....	127	127	141	0.00
XVIII	XVIII	129	....	....	0.00
XVII	XVII	136	....	....	—29.49
XVI	XVI	137	....	....	—34.20
XV	XV	141	...	....	—50.20
XV	XV	141	141	146	—6.00
XIV	XIV	146	....	....	0.00

From Monument No. 146 to Monument No. 204 the lines traced were practically the straight lines joining the accepted existing monuments.

California azimuth line.

No. of monument. On original survey.	No. of monument. New No.	United States line. No.	United States line. Begins.	United States line. Ends.	United States line. Measured offset.	Mexican line. No.	Mexican line. Begins.	Mexican line. Ends.	Mexican line. Measured offset.
					Meters.				*Meters.*
VII....	(¹)	1	Boundary post....	Between monuments Nos. 230 and 231	.00	.....	....	....	....
VI....	207	1	.....do	.....do	.00	1	Monument No. 207.	Monument No. 221.	.00
V.....	220	1	.....do	.....do	32.55	1	.....do	.....do	+34.30
IV.....	221	1	.....do	.....do	+30.46	1	.....do	.....do	+32.11
IV.....	221	.....	....	....	....	2	Monument No. 221.	Between monuments Nos. 230 and 231.	+32.11
	230	1	.....do	.....do	—18.53	2	.....do	.....do	—18.32
	231	2	Between monuments Nos. 230 and 231.	Monument No. 247.	—25.80	3	Between monuments Nos. 230 and 231.	Monument No. 247.	—25.80
	247	2	.... do	.....do	+62.14	3	.....do	.....do	+62.20
	247	3	Monument No. 247.	Monument No. 252.	+62.14	4	Monument No 247	Monument No. 252.	+62.20
III	252	3	.....do	.....do	.00	4	.....do	.....do	.00
III	252	4	Monument No. 252.	Monument No. II.	.00	.....	....	....	....
	251	.....	....	....	....	5	Monument No. 251.	Monument No. 258.	+11.91
II	....	4	Monument No. 252.	Monument No. II.	.00	5	.....do	.....do	+ 1.69
	257	.....	....	....	....	5	.....do	.....do	.00
II	....	5	Monument No. II.	Monument No. 258.	.00	.....	....	....	....
I.......	258	5	.....do	.....do	.00	5	Monument No. 251	Monument No. 258.	— .57

+ = To N.
— = To S.

¹ Boundary post.

On the Sonora and California azimuth lines offsets are measured at right angles to the line as run.

OPERATIONS OF THE MEXICAN SECTION.

With the exception of some distances which, on account of the character of the country, were measured directly by steel tape or by means of small triangles, the measurements along the boundary line were made by stadia.

The offsets for points in the parallel were measured with a steel tape in the corresponding meridian which had been previously laid off with a small theodolite.

Mexican Consulate, Nogales, Arizona. Consulado Mexicano en Nogales, Arizona.

View of Yuma.

Vista de Yuma.

OPERATIONS OF THE UNITED STATES SECTION.

On parallel 31° 47′ distances along tangents were measured by both chain and stadia. All other distances along the boundary line were measured by stadia.

The meridians in which were measured offsets to points in the parallels were obtained by turning off from the tangents angles dependent on the azimuth of the corrected tangent at the point.

Offsets were measured with a steel tape in the meridian so obtained. All distances were reduced to mean sea level of San Diego Bay by means of a line of levels carried by the United States section from the Rio Grande to the Pacific.

JOINT OPERATIONS.

The triangulations made by the United States section and checked by the Mexican section at Monument No. 1, on the Rio Grande, Nogales, and Yuma, are as follows:

DETERMINATION OF LONGITUDE OF MONUMENT NO. 1, UNITED STATES TRIANGULATION.

A base was measured on the railroad near Astronomical Station No. 1, and a triangulation laid out by the United States section from this base, connecting Astronomical Station No. 1 with Monuments Nos. 1, 2, and 3, the magnetic station near Monument No. 1, the longitude station at El Paso; also with the public buildings in El Paso and Juarez.

By this triangulation the difference of longitude of Monument No. 1 from the longitude station at El Paso is + 2′ 18.78″, making the longitude of Monument No. 1, 106° 31′ 39.03″.

MEXICAN DETERMINATION BY FLASHES.

The longitude of observatory at Juarez was transferred to Monument No. 1 by the Mexican section by flashes, the difference between those points being + 2′ 45.75″, making the longitude of Monument No. 1, 106° 31′ 38.10″.

TRIANGULATION AT NOGALES.

A base line of 724.96 meters was carefully measured at night on the railroad at Nogales, Mexico, and a triangulation made connecting the astronomical station at Nogales, Ariz., with the azimuth station and monuments Nos. 122 and 127. This triangulation was repeated by the Mexican section.

Results of triangulation.

	Latitude.			Longitude.		
	°	′	″	°	′	″
Astronomical station, Nogales, Ariz	31	20	4.70	110	56	28.05
Monument No. 122	31	20	0.75	110	56	34.33
Monument No. 127	31	19	59.30	111	4	34.46

TRIANGULATION NEAR YUMA, ARIZ.

A base of 2,203 meters was measured by the United States section, checked by the Mexican section afterwards, and an extensive system of triangulation made connecting the astronomical station in the corral of the United States Quartermaster's Department, occupied by both the United States and Mexican astronomical parties for latitude and longitude, with the azimuth station of both sections, with Monument No. 207 on west side of the Colorado River, and with Monument No. 204 on the east side of the same river 20 miles below the junction of the Gila and Colorado. This triangulation was repeated by the Mexican section.

The results of this triangulation are:

	Latitude.	Longitude.
	° ′ ″	° ′ ″
Yuma astronomical station	32 43 34.69	114 37 23.40
Azimuth station	32 42 39.54	114 37 7.44
Boundary post	32 43 29.54	114 36 56.61
Monument No. 204	32 29 1.03	114 46 48.64
Monument No. 207	32 43 1.86	114 43 54.31

Previous to commencing the erection of monuments it had been agreed that when the meridian of the site had been selected in the field the corresponding distances from the next preceding monument site to this meridian would be compared, and if found to differ more than one three-hundredths on parallel 31° 47′, the meridian section, parallel 31° 20′, and the Sonora azimuth line, or more than one five-hundredths on the California azimuth line, they would be remeasured.

Each section would then, from its own tangent or auxiliary line, lay off on the ground in this meridian the computed position of the monument. If the meridian distances of the points so located differed less than 2 meters it was agreed that the mean position would be taken as the true position. Should this difference exceed 2 meters the corresponding tangents or auxiliary lines were to be retraced.

The agreed limits as to distances and offsets were strictly adhered to except in one case each—the discrepancy between the United States and Mexican measurements of the distance between Monuments 185 and 186 being one two-hundred-and-seventieth, and in their offsets at Monument 191 being 2.04 meters.

As both of these cases occurred on the desert, where water was difficult to obtain, and where remeasurements would have caused serious delay, and as they exceeded the limit but slightly, it was considered best, in the interests of the work, to accept these discrepancies rather than to attempt remeasurements under such adverse conditions.

The distances between monuments obtained by each section separately were compared, and the mean of the measurements of the two sections taken as the true measurement. This result was then reduced to mean sea level of San Diego Bay, California, by the usual geodetic formula, employing the elevations given by the line of levels of the United States section.

The distances thus obtained (with the exception of those on the meridian section) were adjusted—in the parallels to the astronomical longitudes of their extremities, and on the Sonora and California oblique lines to the astronomical longitudes of their extremities and the observed azimuths.

The results of these reductions are shown in the following tables, and in addition are shown the difference, in a north and south direction, between the United States and Mexican locations of the monument site, and also the character of the monument erected.

Final distances, in meters, between monuments on parallel 31° 47′.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Reduced distances.		Mex. from U. S. pt. (+N. −S).	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
1								Masonry.
2	711.67	712.1	711.89	−0.14	711.75	713.4		Do.
3	4,262.76	4,258.9	4,260.83	− .81	4,260.02	4,270.3		Do.
4	7,568.61	7,563.5	7,566.05	−1.48	7,564.57	7,582.7	+0.36	Solid iron.
5	7,527.66	7,533.7	7,530.68	−1.47	7,529.21	7,547.3	+1.36	Do.
6	7,930.11	7,931.6	7,930.86	−1.55	7,929.31	7,948.3	+1.04	Do.
7	7,703.02	7,704.3	7,703.66	−1.51	7,702.15	7,702.7	+ .94	Do.
8	7,876.59	7,870.1	7,873.34	−1.54	7,871.80	7,890.7	+ .03	Do.
9	1,400.39	1,400.3	1,400.35	− .28	1,400.07	1,403.4	− .82	Do.
10	7,012.36	7,010.9	7,011.63	1.37	7,010.26	7,027.1	−1.39	Do.
11	7,797.80	7,791.5	7,794.65	−1.53	7,793.12	7,811.8		Masonry.

Final distances, in meters, between monuments on parallel 31° 47′—Continued.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Reduced distance.		Mex. from U. S. pt. (+N., −S).	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
12	5,094.78	5,094.8	5,094.79	− .99	5,093.80	5,106.0	− .18	Solid iron.
13	6,920.12	6,906.2	6,913.16	− 1.34	6,911.82	6,928.4	+ .65	Do.
14	4,671.24	4,675.2	4,673.22	− .91	4,672.31	4,683.5	− .31	Do.
15	3,281.42	3,284.1	3,282.76	− .65	3,282.11	3,290.0	....	Masonry.
16	1,657.06	1,656.7	1,656.88	− .32	1,656.56	1,660.5	.00	Solid iron.
17	4,333.13	4,346.7	4,339.92	− .83	4,339.09	4,349.5	− .38	Do.
18	3,872.51	3,877.6	3,875.05	− .74	3,874.31	3,883.6	.28	Do.
19	4,209.52	4,210.0	4,209.76	− .80	4,208.96	4,219.1	+ .81	Do.
20	3,970.52	3,969.2	3,969.86	− .75	3,969.11	3,978.6	+ .62	Do.
21	3,430.65	3,431.2	3,430.93	− .65	3,430.28	3,438.5	....	Masonry.
22	1,991.14	1,993.7	1,992.42	− .39	1,992.03	1,996.8	+ .08	Solid iron.
23	1,609.44	1,610.2	1,609.82	− .31	1,609.51	1,613.4	− .14	Do.
24	4,437.34	4,434.4	4,435.87	− .88	4,434.99	4,445.6	.01	Do.
25	3,815.76	3,820.9	3,818.33	− .76	3,817.57	3,826.7	− .04	Do.
26	1,328.39	1,328.7	1,328.54	− .26	1,328.28	1,331.5	....	Masonry.
27	3,094.45	3,092.1	3,093.28	− .63	3,092.65	3,100.1	+ .03	Solid iron.
28	3,523.44	3,531.3	3,527.37	− .72	3,526.65	3,535.1	+ .28	Do.
29	3,676.90	3,675.7	3,676.30	− .75	3,675.55	3,684.4	+ .56	Do.
30	4,300.20	4,305.0	4,302.60	− .88	4,301.72	4,312.1	− .40	Do.
31	3,430.16	3,427.0	3,428.58	− .70	3,427.88	3,436.1	− .33	Do.
32	2,433.47	2,440.4	2,436.93	− .50	2,436.43	2,442.3	....	Masonry.
33	1,142.99	1,144.3	1,143.65	− .23	1,143.42	1,146.2	....	Do.
34	4,149.30	4,160.2	4,154.75	− .90	4,153.85	4,163.8	+ .14	Solid iron.
35	4,541.29	4,535.0	4,538.15	− 1.00	4,537.15	4,548.1	+ .48	Do.
36	3,700.68	3,702.0	3,701.34	− .81	3,700.53	3,709.4	+ .66	Do.
37	3,000.55	2,999.0	2,999.77	− .65	2,999.12	3,006.4	+ .02	Do.
38	2,592.28	2,592.2	2,592.24	− .56	2,591.68	2,597.9	+ .07	Do.
39	2,775.39	2,780.7	2,778.04	− .60	2,777.44	2,784.1	.67	Do.
40	2,053.88	2,057.4	2,055.64	− .45	2,055.19	2,060.1	....	Masonry.
Total	158,828.97	158,858.8	158,843.89	−31.64	158,812.25	159,193.5		

Final distances, in meters, between monuments on the Meridian section.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Distance reduced to mean sea level.	Mex. from U. S. pt. (+N, −S).	Kind of monument.
	United States.	Mexican.	Mean.				
40	....	....	....	....	....	....	Masonry.
41	3,327.58	3,329.1	3,328.34	− 0.71	3,327.63	0.0	Solid iron.
42	4,449.05	4,448.4	4,448.73	− .95	4,447.78	.0	Do.
43	3,564.70	3,560.2	3,562.45	− .76	3,561.69	.0	Do.
44	3,689.32	3,690.96	3,690.14	− .79	3,689.35	.0	Do.
45	4,747.35	4,752.59	4,749.97	− .98	4,748.99	.0	Do.
46	4,765.65	4,751.5	4,758.57	− 1.02	4,757.55	....	Masonry.
47	4,773.77	4,774.05	4,773.91	− 1.00	4,772.91	.0	Solid iron.
48	3,894.98	3,882.4	3,888.69	− .82	3,887.87	.0	Do.
49	4,442.75	4,443.58	4,443.17	− .92	4,442.25	.0	Do.
50	4,381.53	4,382.88	4,382.20	− .92	4,381.28	.0	Do.
51	4,043.01	4,055.2	4,049.11	− .85	4,048.26	.0	Do.
52	3,321.38	3,321.2	3,321.29	− .69	3,320.60	.0	Do.
53	542.20	542.0	542.10	− .10	542.00	....	Masonry.
Total	49,943.27	49,934.06	49 938.67	−10.51	49,928.16		

Final distances, in meters, between monuments on parallel 31° 20'.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Reduced distances.		Mex. from U. S. pt. (+N., —S.)	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
53	....	....	....	....	....	....	....	Masonry.
54	3, 985. 48	3, 976. 70	3, 981. 09	— 0. 96	3, 980. 13	3, 981. 7	+0. 26	Solid iron.
55	6, 773. 09	6, 763. 40	6, 768. 25	— 1. 62	6, 766. 63	6, 769. 3	+ . 43	Do.
56	2, 137. 85	2. 138. 40	2, 138. 12	— . 51	2, 137. 61	2, 138. 4	+ . 16	Do.
57	3, 620. 93	3, 613. 50	3, 617. 22	— . 87	3, 616. 35	3, 617. 8	+ . 07	Sectional iron.
58	5, 614. 12	5, 605. 20	5, 609. 66	— 1. 34	5, 608. 32	5, 610. 6	+ . 30	Solid iron.
59	2, 096. 09	2, 089. 70	2. 092. 89	— . 50	2, 092. 39	2, 093. 2	- . 33	Do.
60	6, 483. 40	6, 469. 70	6, 476. 55	— 1. 55	6, 475. 00	6, 477. 6	— . 09	Do.
61	5, 775. 44	5, 774. 46	5, 774. 95	1. 39	5, 773. 56	5, 775. 9	— . 19	Do.
62	2, 192. 33	2, 188. 43	2. 190. 38	— . 52	2, 189. 86	2, 190. 7	+1. 14	Do.
63	3, 334. 25	3, 333. 79	3, 334. 02	— 83	3, 333. 19	3, 334. 5	+ . 22	Do.
64	4, 011. 83	4, 011. 83	4. 011. 83	— . 94	4 010. 89	4, 012. 5	....	Masonry.
65	6, 183. 46	6, 168. 40	6, 175. 93	— 1. 48	6, 174. 45	6, 176. 9	....	Do.
66	5, 405. 71	5, 401. 90	5, 403. 80	— 1. 29	5, 402. 51	5, 404. 7	....	Do.
67	4, 813. 46	4, 803. 00	4. 808. 23	— 1. 15	4, 807. 08	4, 809. 0	....	Do.
68	3, 313. 58	3. 313. 60	3, 313. 59	— . 79	3, 312. 80	3, 314. 1	— . 06	Solid iron.
69	4, 987. 87	4. 979. 80	4, 983. 84	— 1. 20	4, 982. 64	4, 984. 6	— . 45	Do.
70	3, 324. 08	3. 324. 29	3, 324. 18	— . 80	3, 323. 38	3, 324. 7	+ . 11	Sectional iron.
71	6, 096. 10	6, 084. 35	0, 090. 22	— 1. 46	6, 088. 76	6, 091. 2	— . 12	Do.
72	1, 125. 31	1, 128. 98	1, 127. 15	— . 27	1, 126. 88	1, 127. 3	— . 11	Do.
73	2, 529. 39	2, 533. 60	2, 531. 49	. 61	2, 530. 88	2, 531. 9	....	Masonry.
74	3, 794. 68	3, 790. 80	3, 792. 74	— . 82	3, 791. 92	3, 793. 4	+1. 31	Solid iron.
75	5, 679. 31	5, 677. 70	5, 678. 51	— 1. 22	5, 677. 29	5, 679. 6	+1. 00	Do.
76	4, 036. 72	4, 031. 20	4, 033. 96	— . 87	4, 033. 09	4, 034 7	— . 37	Do.
77	3, 487. 51	3, 478. 60	3, 483. 05	— . 75	3, 482. 30	3, 483. 7	....	Masonry.
78	1. 967. 75	1, 965. 88	1, 966. 82	— . 42	1, 966. 40	1, 967. 2	— . 43	Solid iron.
79	5 987. 34	5, 987. 71	5, 987. 53	— 1. 29	5, 986. 24	5, 988. 6	— . 22	Do.
80	4, 675. 14	4, 681. 49	4, 678. 31	1. 01	4, 677. 30	4, 679. 2	—1. 60	Sectional iron.
81	1, 326. 86	1, 329. 46	1, 328. 16	— . 29	1, 327. 87	1, 328. 4	— . 19	Do.
82	1, 797. 34	1, 795. 05	1, 796. 20	— . 39	1, 795. 81	1, 796. 5	....	Masonry.
83	1. 871. 46	1, 869. 22	1, 870. 34	— . 40	1, 869. 94	1, 870. 7	— . 44	Solid iron.
84	6, 060. 61	6, 060. 23	6, 060 42	— 1. 31	6, 059. 11	6. 061. 5	— . 87	Do.
85	3, 983. 66	3, 982. 49	3, 983. 07	. 86	3, 982. 21	3, 983. 8	. 77	Do.
86	4, 449. 98	4. 437. 85	4, 443. 92	— . 95	4. 442. 97	4, 444. 7	— . 12	Do.
87	6, 319. 34	6, 331. 68	6, 325. 51	— 1. 36	6, 324. 15	6, 326. 7	— . 67	Do.
88	6, 685. 44	6, 684. 92	6, 685. 18	— 1. 44	6, 683. 74	6, 686. 4	— . 61	Do.
89	3, 467. 42	3, 458 70	3, 463. 06	— . 75	3, 462. 31	3, 463. 7	— . 62	Do.
90	3, 991. 16	3, 990. 00	3, 990. 58	. 86	3, 989. 72	3, 991. 3	—1. 15	Do.
91	5, 153. 64	5. 143. 30	5. 148. 47	— 1. 11	5, 147. 36	5, 149. 4	+ . 28	Do.
92	5, 693. 59	5, 693. 10	5, 693. 35	— 1. 23	5, 692. 12	5, 694. 4	— . 84	Do.
93	4, 460. 52	4. 464. 65	4, 462. 58	. 96	4, 461. 62	4, 463. 4	. 74	Do.
94	3, 308 49	3, 309. 24	3, 308. 87	. 71	3, 308. 16	3, 309. 5	— . 98	Do.
95	3, 474. 68	3, 475. 46	3, 475. 07	— . 75	3. 474. 32	3, 475. 7	— . 58	Do.
96	3, 074. 18	3, 073. 04	3, 073. 61	— . 66	3, 072. 95	3, 074. 2	— . 67	Do.
97	3, 623. 74	3, 624. 14	3, 623. 94	— . 78	3, 623. 16	3, 624. 6	+ . 11	Do.
98	3, 345. 53	3, 344. 71	3, 345. 12	— . 72	3, 344. 40	3, 345. 7	....	Masonry.
99	4, 995. 32	4, 990. 13	4, 992. 72	— 1. 08	4, 991. 64	4, 993. 6	— . 27	Solid iron.
100	4, 862. 07	4, 853. 93	4, 858. 00	— 1. 05	4, 856. 95	4, 858. 9	— . 89	Sectional iron.
101	442. 92	441. 92	442. 42	— . 10	442. 32	442. 5	— . 59	Do.
102	1 727. 08	1, 731. 65	1, 729. 37	— . 37	1, 729. 00	1, 729. 7	—1. 00	Do.
103	5, 114. 18	5, 115. 09	5, 114. 63	— 1. 10	5, 113. 53	5, 115. 6	+ . 91	Solid iron.
104	2, 355. 49	2, 349. 64	2. 352. 57	— . 51	2, 352. 06	2, 353. 0	— . 45	Do.
105	2, 787. 47	2, 790. 62	2, 789. 04	— . 60	2, 788. 44	2, 789. 6	— . 93	Do.
106	6, 492. 22	6, 470. 68	6. 481. 45	— 1. 40	6, 480. 05	6, 482. 6	....	Masonry.
107	2, 930. 34	2. 925. 70	2, 928. 02	. 63	2, 927. 39	2, 928. 6	— . 42	Solid iron.
108	1, 527. 71	1, 526. 96	1, 527. 33	. 32	1, 527. 01	1, 527. 6	....	Masonry.
109	3, 559. 15	3. 554. 85	3, 557. 00	— . 77	3, 556. 23	3, 557. 6	— . 87	Solid iron.
110	3. 330. 01	3, 326. 10	3. 328. 05	— . 72	3, 327. 33	3, 328. 7	+ . 12	Do.
111	2. 018. 42	2, 021. 40	2, 019. 91	— . 43	2, 019. 48	2, 020. 3	....	Masonry.
112	2. 682. 37	2. 675. 87	2, 679. 12	— . 58	2, 678. 54	2, 679. 6	+ . 13	Solid iron.
113	6, 120. 64	6, 106. 53	6, 113. 59	— 1. 32	6, 112. 27	6. 114. 7	. 32	Do.

Final distances, in meters, between monuments on parallel 31° 20′—Continued.

No. of monument.	Distance between monuments.			Reduction to mean sea level	Reduced distances.		Mex. from U.S. pt., (+N., —S.)	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
114	1,994.22	1,990.28	1,992.25	— .43	1,991.82	1,992.6	— .31	Sectional iron.
115	3,044.31	3,046.91	3,045.61	— .66	3,044.95	3,046.2	+ .48	Do.
116	3,862.46	3,862.43	3,862.44	— .83	3,861.61	3,863.2	+ .35	Do.
117	4,145.24	4,141.65	4,143.45	— .89	4,142.56	4,144.2	+1.03	Solid iron.
118	1,865.96	1,864.60	1,865.28	— .40	1,864.88	1,865.6	....	Masonry.
119	5,149.38	5,135.23	5,142.30	— 1.11	5,141.19	5,143.2	+ .63	Solid iron.
120	2,471.31	2,471.31	2,471.31	.54	2,470.77	2,471.8	+ .04	Do.
121	1,075.72	1,075.73	1,075.73	— .24	1,075.49	1,075.9	— .48	Do.
122	256.70	256.70	256.70	— .05	256.65	256.8	....	Do.
123	*1,922.09	1,917.29	1,919.69	— .40	1,919.49	1,920.2	— .65	Do.
124	*3,062.83	3,063.24	3,063.03	— .64	3,062.71	3,063.9	+ .76	Do.
125	*3,067.06	3,065.84	3,066.45	— .64	3,066.13	3,067.4	+ .31	Sectional iron.
126	*4,403.16	4,404.65	4,403.91	— .92	4,403.45	4,405.2	.31	Do.
127	231.82	231.72	231.77	.05	231.72	231.8	....	Masonry.
Total	273,017.51	272,792.30	272,904.90	—60.77	272,845.43	272,954.2		

* Distances marked as above were determined by triangulation.

Final distances, in meters, between monuments on the Sonora azimuth line.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Reduced distances.		Mex. from U.S. pt. (+N., —S.)	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
127	....	....	....	....	....	....	....	Masonry.
128	394.11	393.51	393.81	— 0.10	393.71	393.5	....	Sectional iron.
129	5,647.28	5,637.35	5,642.32	— 1.33	5,640.99	5,638.0	....	Masonry.
130	3,665.60	3,660.18	3,662.89	— .70	3,662.19	3,660.2	+0.01	Sectional iron.
131	5,688.13	5,696.30	5,692.21	— 1.11	5,691.10	5,688.1	+ .18	Do.
132	5,341.67	5,354.61	5,348.14	— 1.04	5,347.10	5,344.3	+ .06	Do.
133	2,528.45	2,534.23	2,531.34	— .49	2,530.85	2,529.5	.04	Do.
134	3,053.65	3,045.46	3,049.55	— .59	3,048.96	3,047.3	+ .01	Solid iron.
135	6,173.87	6,184.13	6,179.00	— 1.21	6,177.79	6,174.5	.00	Do.
136	2,529.90	2,533.84	2,531.87	— .49	2,531.38	2,530.0	....	Masonry.
137	4,236.79	4,240.52	4,238.66	— .77	4,237.89	4,235.6	....	Do.
138	4,569.35	4,565.38	4,567.36	— .81	4,566.55	4,564.1	.00	Solid iron.
139	3,592.49	3,591.21	3,591.85	— .63	3,591.22	3,589.3	.00	Do.
140	4,568.86	4,569.25	4,569.06	— .81	4,568.25	4,565.8	.00	Do.
141	2,028.56	2,028.87	2,028.72	— .36	2,028.36	2,027.3	....	Masonry.
142	5,518.10	5,524.90	5,521.50	— .75	5,520.75	5,517.8	.06	Solid iron.
143	5,632.46	5,631.96	5,632.21	— .77	5,631.44	5,628.4	— .09	Do.
144	4,535.78	4,531.78	4,533.78	— .61	4,533.17	4,530.8	— .15	Do.
145	5,523.13	5,529.98	5,526.55	— .75	5,525.80	5,522.8	.00	Do.
146	6,370.76	6,369.38	6,370.07	— .88	6,369.19	6,365.8	....	Masonry.
147	7,270.59	7,290.63	7,280.61	— .94	7,279.67	7,275.8	.00	Solid iron.
148	3,884.47	3,892.10	3,888.28	— .50	3,887.78	3,885.7	— .09	Do.
149	4,663.77	4,658.48	4,661.12	— .60	4,660.52	4,658.0	.00	Do.
150	4,062.76	4,053.55	4,058.15	— .52	4,057.63	4,055.5	....	Masonry.
151	3,606.87	3,604.20	3,605.54	— .34	3,605.20	3,603.3	.00	Solid iron.
152	5,236.91	5,237.71	5,237.31	— .49	5,236.82	5,234.0	.00	Do.
153	4,557.97	4,569.21	4,563.59	— .43	4,563.16	4,560.7	.00	Sectional iron.
154	5,989.55	5,977.44	5,983.50	— .56	5,982.94	5,979.7	+ .07	Solid iron.
155	5,294.19	5,293.77	5,293.98	— .50	5,293.48	5,290.7	+ .05	Do.
156	5,387.32	5,379.85	5,383.58	— .51	5,383.07	5,380.2	+ .07	Do.
157	4,668.84	4,662.30	4,665.57	— .44	4,665.13	4,662.6	+ .18	Do.
158	3,953.42	3,952.35	3,952.88	— .37	3,952.51	3,950.4	— .05	Do.
159	3,840.63	3,839.24	3,839.93	— .36	3,839.57	3,837.5	— .06	Sectional iron.
160	4,069.36	4,061.88	4,065.62	— .38	4,065.24	4,063.1	....	Masonry.
161	1,989.95	1,988.10	1,989.02	— .19	1,988.83	1,987.8	+ .02	Solid iron.
162	5,295.83	5,281.81	5,288.82	— .50	5,288.32	5,285.5	....	Masonry.

Final distances, in meters, between monuments on the Sonora azimuth line—Continued.

No. of monument.	Distance between monuments. United States.	Mexican.	Mean.	Reduction to mean sea level.	Reduced distances. To mean sea level.	To agree with astronomical distance.	Mex. from U. S. pt. (+N., —S.)	Kind of monument.
163	1,968.40	1,967.52	1,967.96	.15	1,967.81	1,966.8	.04	Sectional iron.
164	5,197.76	5,205.03	5,201.40	— .39	5,201.01	5,198.2	— .06	Solid iron.
165	6,084.31	6,085.08	6,084.69	— .45	6,084.24	6,081.0	— .04	Do.
166	2,945.70	2,941.98	2,943.84	— .21	2,943.63	2,942.1	— .04	Do.
167	4,758.30	4,747.01	4,752.65	— .35	4,752.30	4,749.7	+ .01	Do.
168	2,480.73	2,477.05	2,478.89	.18	2,478.71	2,477.4	....	Masonry.
169	5,055.51	5,046.68	5,051.10	— .28	5,050.82	5,048.1	+ .08	Solid iron.
170	4,467.84	4,461.05	4,464.44	— .25	4,464.19	4,461.8	+ .00	Do.
171	3,365.58	3,370.33	3,367.95	— .19	3,367.76	3,366.0	+ .06	Do.
172	4,475.34	4,467.08	4,471.21	— .25	4,470.96	4,468.6	+ .16	Do.
173	5,781.93	5,773.39	5,777.66	— .33	5,777.33	5,774.2	+ .19	Do.
174	3,275.28	3,268.57	3,271.93	— .19	3,271.74	3,270.0	+ .09	Do.
175	4,931.43	4,925.12	4,928.27	.28	4,927.99	4,925.4	....	Masonry.
176	4,286.88	4,284.38	4,285.63	— .20	4,285.43	4,283.1	.00	Solid iron.
177	6,014.37	6,007.58	6,010.98	— .28	6,010.70	6,007.5	— .01	Do.
178	7,695.93	7,688.09	7,692.01	— .35	7,691.66	7,687.6	+ .10	Do.
179	4,697.74	4,698.41	4,698.07	— .22	4,697.85	4,695.3	+ .28	Do.
180	5,705.80	5,696.27	5,701.04	.26	5,700.78	5,697.7	+ .45	Do.
181	7,713.33	7,709.49	7,711.41	— .36	7,711.05	7,706.9	+ .04	Do.
182	7,298.47	7,293.36	7,295.91	— .34	7,295.57	7,291.7	.13	Do.
183	7,907.79	7,897.35	7,902.57	.36	7,902.21	7,898.0	.21	Do.
184	4,215.93	4,209.08	4,212.50	— .19	4,212.31	4,210.1	.30	Sectional iron.
185	4,496.87	4,495.45	4,496.16	— .21	4,495.95	4,493.5	+ .78	Do.
186	4,496.74	4,513.41	4,505.07	— .21	4,504.86	4,502.5	+ .80	Do.
187	4,007.18	4,003.62	4,005.40	— .19	4,005.21	4,003.1	+ .77	Solid iron.
188	7,830.22	7,816.14	7,823.18	— .36	7,822.82	7,818.6	+1.08	Do.
189	6,278.96	6,264.56	6,271.76	— .29	6,271.47	6,268.1	+1.45	Sectional iron.
190	3,554.76	3,547.80	3,551.28	— .16	3,551.12	3,549.2	+1.24	Solid iron.
191	3,259.00	3,250.39	3,254.70	— .16	3,254.54	3,252.8	+2.04	Sectional iron.
192	3,139.33	3,139.33	3,139.33	— .14	3,139.19	3,142.4	+1.96	Do.
193	5,381.94	5,375.01	5,378.48	— .23	5,378.25	5,383.8	1.85	Solid iron.
194	5,726.85	5,722.94	5,724.89	— .23	5,724.66	5,730.6	1.67	Do.
195	3,124.26	3,127.16	3,125.71	— .12	3,125.59	3,128.8	+1.54	Do.
196	5,938.12	5,938.15	5,938.13	— .21	5,937.92	5,944.0	+1.39	Do.
197	7,240.19	7,228.81	7,234.50	— .23	7,234.27	7,241.7	+1.21	Do.
198	7,776.79	7,773.80	7,775.30	— .22	7,775.08	7,783.1	+ .98	Do.
199	7,597.09	7,593.77	7,595.43	— .18	7,595.25	7,603.1	+ .83	Do.
200	7,555.07	7,567.29	7,561.18	— .16	7,561.02	7,568.8	+ .54	Do.
201	6,409.00	6,396.94	6,402.97	— .10	6,402.87	6,409.5	+ .51	Do.
202	4,734.12	4,725.07	4,729.60	— .07	4,729.53	4,734.4	+ .35	Do.
203	4,667.87	4,658.10	4,662.98	— .06	4,662.92	4,667.7	+ .16	Do.
204	4,189.56	4,183.50	4,186.53	— .04	4,186.49	4,190.8	....	Sectional iron.
205	3,000.00	3,000.00	3,000.00	— .00	3,000.00	3,000.0	+ .00	Solid iron.
Total	376,099.6	375,906.6	376,003.1	—31.46	375,971.6	375,887.3		

Final distances, in meters, between monuments on the California azimuth line.

No. of monument.	Distance between monuments. United States.	Mexican.	Mean.	Reduction to mean sea level.	Reduced distance. To mean sea level.	To agree with astronomical distance.	Mex. from U. S. pt. (+N. —S.)	Kind of monument.
206	....	....	....	....	....	....	0.00	Solid iron.
207	809.04	809.73	809.38	0.00	809.38	809.4	....	Masonry.
208	3,348.02	3,352.41	3,350.22	— .02	3,350.20	3,356.0	+ .92	Solid iron.
209	6,364.66	6,353.99	6,359.32	— .08	6,359.24	6,370.2	+ .40	Do.
210	7,048.50	7,050.29	7,049.40	— .07	7,049.33	7,061.5	+ .50	Do.
211	4,309.53	4,317.98	4,313.76	— .03	4,313.73	4,321.2	+1.48	Do.
212	4,241.70	4,236.75	4,239.22	— .02	4,239.20	4,246.6	+1.14	Do.
213	4,718.03	4,725.28	4,721.66	— .03	4,721.63	4,729.8	+ .38	Do.

Final distances, in meters, between monuments on the California azimuth line—Continued.

No. of monument.	Distance between monuments.			Reduction to mean sea level.	Reduced distance.		Mex. from U. S. pt. (+N., —S.)	Kind of monument.
	United States.	Mexican.	Mean.		To mean sea level.	To agree with astronomical distance.		
214	6,175.85	6,181.82	6,178.83	— .04	6,178.79	6,189.5	.28	Solid iron.
215	5,379.43	5,382.96	5,381.20	— .01	5,381.19	5,390.5	+ .22	Do.
216	6,588.48	6,584.64	6,586.56	— .01	6,586.55	6,598.0	.32	Do.
217	6,461.52	6,467.22	6,464.37	— .01	6,464.36	6,475.6	.44	Do.
218	5,215.11	5,214.71	5,214.91	— .01	5,214.90	5,223.9	+ .36	Do.
219	4,713.20	4,721.84	4,717.52	.00	4,717.52	4,725.7	+ .26	Do.
220	5,414.83	5,407.42	5,411.12	.00	5,411.12	5,420.5	....	Sectional iron.
221	2,777.00	2,774.16	2,775, 58	.00	2,775.58	2,780.4	....	Do.
222	7,074.85	7,080.72	7,077.79	.00	7,077.79	7,090.1	.04	Solid iron.
223	5,178.35	5,169.00	5,173.67	.00	5,173.67	5 182.6	— .30	Do.
224	6,557.87	6,558.38	6,558.13	.00	6,558.13	6,569.5	— .44	Do.
225	1,877.03	1,877.03	1,877.03	— .02	1,877.01	1,880.3	— .52	Do.
226	4,359.80	4,355.10	4,357.45	— .06	4,357.39	4,364.9	— .66	Do.
227	4,292.76	4,285.70	4,289.23	— .06	4,289.17	4,296.6	— .26	Do.
228	5,868.36	5,861.63	5,865.00	— .08	5,864.92	5,875.1	.52	Do.
229	5,007.86	5,005.03	5,006.44	.15	5,006.29	5,015.0	— .80	Sectional iron.
230	7,524.35	7,516.71	7,520.53	— .44	7,520.09	7,533.1	— .98	Do.
231	7,486.58	7,472.60	7,479.59	— 1.11	7,478.48	7,491.4	—1.24	Do.
232	4,924.38	4,933.40	4,928.89	— .83	4,928.06	4,936.6	—1.18	Solid iron.
233	4,555.62	4,555.99	4,555.80	— .66	4,555.14	4,563.0	—1.04	Do.
234	4,097.08	4,104.50	4,100.79	— .59	4,100.20	4,107.3	— .98	Sectional iron.
235	4,099.58	5,009.59	5,004.59	— .80	5,003.79	5,012.5	— .90	Do.
236	3,620.45	3,620.84	3,620.64	— .61	3,620.03	3,626.3	— .98	Solid iron.
237	4,154.26	4,151.62	4,152.94	— .69	4,152.25	4,159.4	— .76	Do.
238	2,856.08	2,858.91	2,857.50	— .48	2,857.02	2,862.0	— .70	Do.
239	4,177.97	4,179.99	4,178.98	— .69	4,178.29	4 185.5	.66	Do.
240	3,055.94	3,055.94	3,055.94	— .41	3,055.53	3,060.8	— .50	Do.
241	1,859.92	1,861.68	1,860.80	— .24	1,860.56	1,863.7	— .58	Sectional iron.
242	4,713.90	4,710.30	4,712.10	— .64	4,711.46	4,719.6	— .12	Do.
243	5,122.38	5,120.51	5,121.45	— .46	5,120.99	5,129.9	.48	Solid iron.
244	1,641.46	1,641.49	1,641.47	— .16	1,641.31	1,644.2	— .48	Do.
245	3,649.83	3,654.90	3,652.37	— .34	3,652.03	3,658.4	— .42	Do.
246	3,025.12	3,031.58	3,028.35	— .37	3,027.98	3,033.2	— .26	Sectional iron.
247	864.54	864.54	864.54	— .10	864.44	865.9	— .20	Do.
248	3,665.12	3,665.12	3,665.12	.32	3,664.80	3,671.2	— .20	Do.
249	3,103.51	3,106.16	3,104.83	— .10	3,104.73	3,110.1	— .22	Solid iron.
250	2,625.36	2,625.36	2,625.36	— .08	2,625.28	2,629.8	— .18	Sectional iron.
251	6,247.04	6,240.75	6,243.90	— .26	6,243.64	6,254.4	— .04	Do.
252	3,681.64	3,681.64	3,681.64	— .15	3,681.49	3,687.9	....	Masonry.
253	5,498.50	5,492.52	5,495.51	— .14	5,495.37	5,504.9	.00	Solid iron.
254	3,555.48	3,558.65	3,557.06	— .08	3,556.98	3,563.1	.00	Do.
255	2,461.78	2,461.78	2,461.78	— .03	2,461.75	2,466.0	....	Granite.
256	4,932.79	4,932.79	4,932.79	— .03	4,932.76	4,941.2	.00	Solid iron.
257	2,350.58	2,350.58	2,350.58	— .02	2,350.56	2,354.6	.00	Do.
258	1,768.52	1,766.80	1,767.66	— .02	1,767.64	1,770.7	....	Marble.
Total	226,004.79	225,997.79	226,001.29	—11.55	225,989.74	226,379.6		

SECTION 10.

METHODS USED FOR FIXING THE BOUNDARY IN THE ORIGINAL SURVEY, 1849–1856.

Astronomical determinations of the original survey.—In the first survey of the boundary line, in 1849–1856, there were established twelve stations for latitude and azimuth between the Rio Grande near El Paso and the Pacific near San Diego, and six of these—Paso del Norte, Carrizalillo Springs, Nogales, Quitobaquita, Yuma, and Camp Riley—were longitude stations.

The results for longitude were obtained by observations of the transit of the moon and moon-culminating stars with telescopes of as large size as are usually used in field observations.

In all cases where it was necessary to disclose the results on the spot—as at those stations at the extremities of the azimuth lines, and at stations such as the one hundred and eleventh meridian of longitude, which formed turning points in the boundary—the longitude was deduced from computations based on the data afforded by the Greenwich Ephemeris before receiving corresponding observations.

Owing to the fact that the final values of these longitudes when computed, using corresponding observations at Greenwich and other observatories, differed from that first obtained by the predicted place of the moon as much as nineteen seconds of time, the difference of longitude between stations computed from different data was also affected by a considerable error.

THE METHOD OF RUNNING THE LINES ON THE GROUND.

The parallel of 31° 47′, the meridian section, and parallel 31° 20′.—The initial point of parallel 31° 47′ was determined by observations made by both sections of the original commission, and it was ascertained that the difference between the determinations of the parallel of 31° 47′ made by the two sections was 0.84″. It was mutually agreed to take the mean of the two results, and the point was ascertained and marked in the presence of both commissioners as the point where the parallel 31° 47′ strikes the river; that is to say, the point where the boundary under the treaty of December 30, 1853, leaves the river to run westward. A tangent to the parallel 31° 47′ was laid off and prolonged westward, and Monuments Nos. 2 and 3 were set by offsets from the same, using the Bessel spheroid to compute said offsets.

An astronomical station was then established at Carrizalillo Spring, the water nearest to the end of the required 100 miles, and its latitude and longitude determined. "A monument was then established on the road due south of the observatory, and the parallel extended in both directions—east, until it met, in the sand hills, the line produced from the Rio Bravo; west, it was extended to the end of the 100 miles, and the parallel was obtained by measuring offsets from the tangent." (P. 30, Emory's report.)

In regard to the determination of the length of the line along parallel 31° 47′, the result can not now be verified from the records. According to agreement of both sections, stated in Major Emory's report of the boundary, "the 100 miles was obtained by combining the observed longitude at Carrizalillo and the distance actually measured. (P. 30, Emory's report.)

Later, the Mexican section made a new survey of the parallel 31° 47′, starting a tangent at Carrizalillo and extending it in both directions, east and west, and, not finding the monuments numbered 6, 5, and 4 by Emory, they constructed four new ones. Two of these were near the locations of Nos. 6 and 5 (Emory), but the other two were erected instead of Monument 4 (Emory). This explains the discordance in the numbers on the United States and Mexican maps; the former showing eight monuments on parallel 31° 47′, and the latter nine.

For the purpose of measuring the distance between the monuments, a triangulation was made by Señores Molina and Contreras, extending the chain of triangles executed by Señores Fernandez Leal and Herrera along the meridian section to Monument No. 4 (Mexican) only; consequently, the distance between Nos. 3 and 4 (Mexican) was never measured by either section of the original commission, and the whole distance from the initial monument on the Rio Grande to Monument No. 9, at the extremity of the line on parallel 31° 47′, was never directly measured. This is not surprising when the difficulties are considered under which that survey was conducted—the principal being the hostility of the Indians and the lack of water and other supplies in this desert region.

The distances as shown by the United States and Mexican maps, compared with the measured distances made by the present commission, are shown in the following tables:

COMPARISON OF DISTANCES BETWEEN MONUMENTS, AS OBTAINED FROM THE DATA PUBLISHED BY THE COMMISSION OF 1849–1856 WITH THOSE OBTAINED BY THE PRESENT COMMISSION.

Comparative distances on parallel 31° 47′.

Monuments.	Distances, 1849-1856.		Distances, 1892.	Difference from—	
	United States.	Mexican.		United States.	Mexican.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
I. (1E.) to II. (2E.)	697	713	713	+ 16	0
II. (2E.) to III. (3E.)	4, 217	4, 278	4, 270	+ 53	— 8
III. (3E.) to IV		56, 745	54, 932		—1, 813
IV. to V		19, 971	20, 007		+ 36
V. to VI. (5E.)		21, 500	21, 530		+ 30
VI. (5E.) to VII. (6E.)	12, 647	13, 192	13, 214	+ 567	+ 22
VII. (6E.) to VIII. (7E.)	21, 971	21. 628	21, 656	— 315	+ 28
VIII. (7E.) to IX (8E.)	22, 627	22, 820	22, 870	+ 243	+ 50
3E. to 5E	98, 499	98, 216	96, 469	—2, 030	—1, 747

	Meters.
(1) Length of line according to United States maps, 1849–1856	160, 658
(2) Length of line according to Mexican maps, 1849–1856	160, 847
(3) Length of line according to present commission	159, 193
Difference between (1) and (3)	—1, 465
Difference between (2) and (3)	—1, 654

Meridian section.

	Meters.
(1) Length of line according to United States maps, 1849–1856	49, 927
(2) Length of line according to Mexican triangulation, 1855	49, 881
(3) Length of line according to commission, 1892	49, 928
Difference between (1) and (3)	— 1
Difference between (2) and (3)	—47

PARALLEL 31° 20′.

A tangent to parallel 31° 20′ was started from Espia and carried to Ojo del Perro. From Ojo del Perro a new tangent was run in both directions; east to the meridian, which checked the one run west from Espia, and west to the San Luis Mountains. At San Luis Springs, about 30 miles west of the initial point of the boundary on parallel 31° 20′, observations were again made for latitude and azimuth, and a new tangent was started in both directions; east to meet the one from Ojo del Perro, and west across the San Luis Valley and the Guadalupe Pass.

The next astronomical station was established at San Bernardino Springs, and the third tangent produced east and west; east to check and connect with tangent No. 2, and west as far as the hills west of San Pedro River. The fourth astronomical station was on the Santa Cruz River, in latitude 31° 17′ 56.33″, and from here a point on the parallel of 31° 20′ was obtained by direct measurement, and a tangent started in both directions. The next station was at Nogales, in latitude 31° 21′ 00.48″ and longitude 110° 51′ 2.10″ west of Greenwich. From observations at this observatory a fifth tangent was deduced, and extended by a separate party in both directions, running west until the one hundred and eleventh meridian of longitude was reached. Owing to the difficulties of the country the longitude was transferred by direct measurement and by triangulation. (See Emory's report, p. 31.)

"The monuments erected on the line were of two classes: First, of dressed stone, laid without mortar; second, of round stones, undressed, forming simply mounds.

"Of the first, one was erected at the point south of the Carrizalillo, another at the intersection of meridian 108° 09′ 41.85″ and parallel 31° 20′, one at San Luis Springs, two at San Bernardino, one at San Pedro, one north of Santa Cruz, one where the line crosses (second time) Santa Cruz River, one at Los Nogales, and one at intersection of 111° and 31° 20′. Many mounds of the second class were erected, always at points where the line crosses a road or trail. Mr. Salazar stated that he had erected, of dressed stone, in a permanent and durable manner, a monument at the initial point on the Rio Bravo, and two monuments west of that point." (See Emory's Report, p. 32.)

The following are excerpts from the journal of the joint commission, meeting of June 24, 1856, page 37 of the report:

Señor Salazar stated that after he separated from Mr. Emory, on the 20th of August, 1855, he reviewed with his parties the different lines of the boundary; that is to say, the parallel 31° 47′, the meridian, and the parallel 31° 20′, on which lines the Mexican commission executed the following work:

From the point south of El Carrizalillo, on which was erected a monument, he observed minutely on Polaris to determine the prime vertical on both sides, east and west. The prime vertical and the parallel 31° 47′ were connected by a triangulation, on the east side with that which had been made at the initial point and on the west side with the intersection of meridian. By this triangulation five points to the east were fixed, at which points he caused to be erected monuments of stone, with mortar, because he found not one established by the United States commission in said direction.

The monument at the road was reconstructed of stone, with mortar. Upon all of them was inscribed the abridged inscription agreed upon. This line was then marked with ten monuments. That at the west end he caused to be erected of dressed stone, with mortar, and inscribed with the complete inscription agreed upon, similar to that which was erected at the initial point on the Rio Bravo.

Mr. Salazar stated that he observed at the south end of the meridian for latitude and longitude, his results differing very little from those of the United States commission; that from this point was carried north a triangulation which was connected at the north end with that made on the parallel 31° 47′, and was used to determine the position of said end on the parallel and on the meridian; that these two extreme points were left where the United States commission established them; that having found no monument between them, he caused one to be erected intermediate, in sight of the Ojo de los Mosquitos, of dressed stone laid in mortar, with the usual inscriptions; that the monument at the south end was erected of dressed stone and mortar, with inscriptions similar in all respects to those at the north end and at the initial point. On the parallel 31° 20′, besides the observations he made at the intersection, he observed for latitude at San Luis Springs, at San Bernardino, and San Pedro River. He found monuments at the two first-named points, but none at the last; that his observations proved that the points were on the parallel 31° 20′, and he caused monuments to be erected at these points with mortar, having the usual inscriptions upon them, and that he thought it proper to erect a monument of the same kind in Guadalupe Pass.

Mr. Emory stated his entire satisfaction with what had been done by Mr. Salazar, and gave his assent thereto, except with regard to the monument at San Pedro River. He desired to call in Mr. Weyss, who was with Mr. Von Hippel when the monument was erected on the San Pedro. His own recollection was, that a very substantial monument had been erected at the San Pedro by the United States commission.

Mr. Weyss was brought before the commissioners, and stated that a monument of dressed stone, with the usual inscription, was erected on the parallel 31° 20′, three thousand eight hundred and twenty-five feet west of the San Pedro River. The maps and views were exhibited showing the exact locality of this monument. Mr. Emory stated, if the Indians had destroyed that monument it was all very well; but if it was still standing, there might be some discrepancy, amounting, possibly, to 1 inch of arc, or 100 feet between the latitude of the monument erected by Mr. Salazar and that erected under his orders. If so, it might hereafter, when the country was settled, produce confusion.

Mr. Salazar stated, that in case both existed he would take the monument erected by Mr. Von Hippel as the true boundary. Assented to by Major Emory.

For a complete list of all the monuments of every description found, see table at end of this section.

The monument erected by Major Emory on the west side of the San Pedro River, and that erected by Señor Salazar on the east, were both found in 1892, and their latitudes, by astronomical observations, were as follows: Señor Salazar's monument, 31° 19′ 35″ (United States); Major Emory's monument, 31° 20′ 3.02″ (Mexican), and the latter was used to retrace and mark the line in 1893.

Comparative distances on parallel 31° 20′.

Monuments.	Distances, 1849–1856.		Distances, 1893.	Difference from—	
	United States.	Mexican.		United States.	Mexican.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
XI (10E)					
XIII (12E)	44,390	44,358	46,002	+1,612	+1,644
XIV (13E)	5,885	5,861	6,176	+ 291	+ 315
XV (14E)	4,875	4,935	5,405	+ 530	+ 470
XVI (15E)	4,404	4,331	4,809	+ 405	+ 478
XVII (16E)	20,156	20,192	21,374	+1,218	+1,182
XIX (18E)	18,127	18,087	16,991	—1,136	—1,096
XX (19E)	17,085	17,002	15,760	—1,325	—1,242
XXI (20E)	67,729	67,446	68,967	+1,238	1,521
XXII (21E)	23,710	23,617	28,765	+5,055	+5,148
XXIII (22E)	4,192	4,179	4,456	+ 264	277
XXIV (23E)	8,082	8,157	8,907	+ 825	+ 750
XXVI (25E)	24,623	24,473	23,706	— 917	— 767
XXVII (26E)	8,686	9,611	8,948	262	663
XXVIII (27E)	12,916	12,893	12,688	— 228	— 205

	Meters.
(1) Length of line according to United States maps, 1849–1856	264,860
(2) Length of line according to Mexican maps, 1849–1856	265,142
(3) Length of line according to present commission	272,954
Difference between (1) and (3)	+8,094
Difference between (2) and (3)	+7,812

The line from 111° longitude and 31° 20′ latitude to a point in the Colorado River, 20 miles below the junction of the Gila and Colorado.—By agreement between the two commissioners the western end of this line was located in the Colorado River, 20 miles below the junction of the Gila and Colorado. No monument could be placed here, but in the direction of the line, 4,135.74 meters from the initial point, Monument No. II, of iron, was erected.

The position of this monument is given as latitude 32° 29′ 1.48″, longitude 114° 46′ 14.43″, and the azimuth of the boundary line at this point as 71° 19′ 23.18″ southeast to the monument at the junction of 31° 20′ with the one hundred and eleventh meridian, as determined by the original commission.

As this longitude was found by the present commission to be 111° 4′ 34.45″ and the longitude of Monument II, 114° 46′ 48.64″, the computed azimuth of the line became 289° 1′ 14.96″=70° 58′ 45.04″ southeast, a difference of 20′ 38″. The length computed by the original commission was 382,844.87 meters−4,135.74 meters=378,709.13 meters. The computed length in 1893 was 372,887.3, a difference of 5,821.8 meters.

After running the line for a short distance to the eastward the work was given up for want of water, and it was agreed that both parties cease work at the west end and proceed to the east end by the road along the Gila, the only available one at this season of the year, there to fix the point of intersection of the parallel of 31° 20′ with the 111th meridian, as determined by the observed longitude of Nogales carried westward by triangulation and direct measurement. In the latter part of August the instrument was placed in position and the azimuth (computed) of the new line (69° 19′ 45.9″ northwest) laid off, and the line was run by both United States and Mexican parties conjointly from peak to peak, marking these points by Monuments XIX, XVIII, XVII, XVI, XV, XIV, XIII, XII, XI, X, and IX. Monument IX stands on the Sierra de Sonoyta 14.5 miles from No. X, and about 1½ miles north from the village of Sonoyta. The distance between monuments was determined by a rough triangulation consisting of intersections on prominent peaks, north and south of the line, measuring only the angles at the location of the different monuments and concluding all others.

On the plain near Sonoyta a base was measured by the Mexican section and a connection made from this measured base with the line—Monuments IX to X—by four triangles with concluded angles, and from this line the distances between the other monuments to the eastward were computed. This triangulation was also carried westward to include Monuments VII and VIII, near the astronomical station at Quitobaquita, and afterwards still farther west to Monuments VI and V. The distances obtained by triangulation from the measured base were then adjusted to sum up equal to the distance from Monument VII to the eastern extremity of the line, as obtained by computing this length from the astronomical positions of the two ends, viz, Quitobaquita and the 111th meridian.

The distance between Monuments VII and V, obtained from the triangulation from the measured base, was used uncorrected for the final adopted distance of Monument V from Monument VII.

The distance from Monument II to Monument IV was assumed to be that determined by the triangulation at Yuma. The sum of these distances, viz, Monument VII to V plus Monument II to IV, was then subtracted from the whole distance, Monument VII to Monument II, as obtained from the longitudes of Monuments II and VII, for the distance between Monuments V and IV.

In 1893 neither Monument IV, on the Tinajas, nor Monument V, on the Tules, nor Monument III, on the desert, said to have been built a short distance east of Monument II, could be found, nor could anyone be found who had ever seen or heard of these monuments.

The line of 1893 was therefore run by the United States section from Monument II to Monument VI, and afterwards carried eastward, from monument to monument, to its eastern extremity, now Monument No. 127. The Mexican section ran this line from the eastern end, and the location of points on the line between existing monuments where new monuments were erected in 1893–94 was determined by the data furnished by both surveys. The differences in the distances between the original monuments on this line, as determined by the first survey in 1855, and those obtained by actual measurement in 1893, reduced to sea level and adjusted to sum up equal to the astronomical distance from Monument No. 204, on the Colorado River, to Monument No. 127, at the end of the line on parallel 31° 20′, are given in the following table.

The measured distance of stadia and triangulation reduced to sea level is 372,971.62 meters; the computed distance on broken line from the astronomical positions of the two ends, 372,887.3 meters; the difference being 83.8 meters, or 1 in 4,550.

Comparative distances on Sonora line.

Monument.	Distance determined in— 1849–1853.	Distance determined in— 1892–1894.	Difference.
	Meters.	*Meters.*	*Meters.*
II			
VI	175,026	162,894	— 12,132
IX	31,379	31,314	— 65
X	23,405	23,415	10
XII	6,974	7,273	+ 299
XIII	44,699	46,562	+ 1,863
XIV	18,986	19,875	+ 889
XV	26,494	27,565	+ 1,071
XVI	14,593	14,746	+ 154
XVII	3,519	4,236	+ 717
XVIII	27,963	28,974	+ 1,012
XIX	5,262	5,638	+ 376
Parallel 31° 20′	409	394	— 15

	Meters.
Distance from Monument II to extremity of line on parallel 31° 20′, according to United States maps, 1849–1856	378,709
Distance according to present commission	372,887
Difference	5,822

OLD MISSION, SAN JOSÉ DE TUMACACORI.

ANTIGUA MISIÓN DE SAN JOSÉ DE TUMACACORI.

Measurements of the 20 miles from junction of the Gila and Colorado to initial point in Colorado.—We have by report of original commission the data to reduce to the junction of the Gila and Colorado, as then existing, the point selected by the commission in 1849 on the azimuth line joining the junction of the Gila and Colorado rivers with Monument I, on the Pacific. By the measurements then made this point was found to be 73.5 feet south and 1,070 feet west of the junction. It was originally marked by an iron monument, subsequently transferred to a point near the Colorado River on the new Arizona-Sonora line, and called Monument II.

If we admit that the post found in 1893 marks the point established in 1849, as all the testimony obtainable from old residents of Yuma seems to prove, we have the latitude and longitude of the junction of the Gila and Colorado 0.73″ north and 12.53″ east of the boundary post of 1893. Its latitude will therefore be 32° 43′ 30.27″ and longitude 114° 36′ 44.08.″ Computing from Monument II to initial point in the Colorado River by data of the original commission, giving the distance from Monument II to initial point as 4,135.71 meters and azimuth 108° 40′ 36.82″, we have latitude of initial point = 32° 29′ 43.97″, longitude = 114° 49′ 18.71″. The positions of both junction and initial point are here given as derived from the observed latitude and longitude in 1893 at Yuma, transferred by triangulation to boundary post and Monument II. Computing the distance and direction of line from initial point in the Colorado to junction of Gila and Colorado, from latitude and longitude given above, we get the distance 32,171.4 meters, or 15 meters less than 20 miles. Its azimuth is 217° 38′ 53.06″.

The difference of latitude of the two points is, by original commission, 13′ 47.85″; by present commission, 13′ 46.30″; of longitude by original commission, 12′ 34.78″; by present commission, 12′ 34.63″.

THE CALIFORNIA LINE FROM THE INITIAL POINT ON THE PACIFIC TO THE JUNCTION OF THE GILA AND COLORADO RIVERS.

Emory's report, page 5, says:

> At the various conferences of the joint commission, the mode of conducting the survey was discussed; and it was agreed to determine the line by astronomical methods, as the only mode by which we could do so correctly and within our means.

On page 144 the report says:

> The following is the order in which are arranged the subjects embraced in the determination of the line:
> 1. The longitude of Camp Riley, near the initial point.
> 2. The longitude of camp near the junction of the Gila and Colorado.
> 3. The latitude of Camp Riley, near the initial point.
> 4. The latitude of camp near the junction of the Gila and Colorado.
> 5. Transfer of the latitude and longitude of Camp Riley, by triangulation, to the initial point.
> 6. Azimuth of straight line from initial point, on Pacific, to junction of Gila and Colorado.

The computations are given on pages 162–166, and on page 165 we find—

	°	′	″
Latitude of initial point on the Pacific	32	31	59.63
Latitude of junction of Gila and Colorado	32	43	32. 2
Difference of longitude	2	32	24. 9

From our results for latitude and longitude in 1892 and 1893 we have—

	°	′	″
Latitude of initial point on the Pacific	32	32	1.34
Latitude of junction of Gila and Colorado	32	43	30.27
Difference of longitude	2	30	47. 9

The difference in the results for difference of longitude by original commission in 1849 and present commission in 1892 = 1′ 37″.

	°	′	″
Resulting azimuth at initial point on the Pacific by original commission	264	12	2.95
Azimuth of line Monument I to Monument VI, 1893	264	10	50.33

The line was run by the original commission from both ends toward the desert, and Monuments I, II, and III were erected near the west end and Monuments VI, V, and IV near the east end. The space between Monuments III and IV (82 miles) was unmarked.

Comparative distances on California line.

Monuments.	Distance, 1849.		Distance, 1893.	Difference from—	
	United States.	Mexican.		United States.	Mexican.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
I					
III	19,247	19,810	20,600	+1,353	+ 790
IV	145,823	144,109	132,080	—13,743	—12,029
V	2,831	2,783	2,780	— 51	— 3
VI	57,418	54,931	70,918	+13,500	+15,987

	Meters.
(1) Distance between Monuments I and VI, according to United States maps, 1849	225,319
(2) Distance according to Mexican maps, 1849	221,633
(3) Distance according to present commission	226,380
Difference between (1) and (3)	1,061
Difference between (2) and (3)	4,797

The United States distances shown in preceding tables, of parallels 31° 47′, 31° 20′, and the California line, were deduced graphically from the United States maps of the original survey.

The distances on the Sonora line were copied from the report of Major Emory, and agree with those given in the manuscript report of Señor Jimenez.

The Mexican distances along parallel 31° 47′ were obtained from the triangulation made in 1855 by Señores Contreras and Molina, with the exception of those between Monuments I, II, III, and IV, that were taken graphically from the Mexican maps. The distances along parallel 31° 20′ and California line were taken graphically from the same maps.

The meridian section was obtained from the triangulation made in 1855 by Señores Fernandez Leal and Herrera.

DIFFERENCES BETWEEN DETERMINATIONS OF LONGITUDE BY ORIGINAL COMMISSION AND THOSE OF THE PRESENT SURVEY.

The following table gives the latitudes and longitudes of the principal points along the boundary, and shows also the difference between the determinations of the original commission and those of 1892. Two of these longitude differences have a material bearing on the location of the boundary as regards the area of territory lost or gained by either country in consequence of errors in the first survey.

According to the treaty of 1853, the parallel of 31° 47′ north latitude shall be the boundary from the initial point on the Rio Grande where the parallel crosses the river; "thence due west 100 miles; thence south to the parallel of 31° 20′ north latitude; thence along said parallel of 31° 20′ to the 111th meridian of longitude west of Greenwich; thence in a straight line to a point on the Colorado River 20 English miles below the junction of the Gila and Colorado rivers; thence up the middle of said river Colorado until it intersects the present line between the United States and Mexico."

The length of parallel 31° 47′ was made by the original commission, from the initial point in the Rio Grande to Monument 40, to be 1° 41′ 57.55″ (see p. 190, Emory's Report), which is equal on Clark's Spheroid to 160,953.9 meters. The present survey made the length of parallel between the channel of 1853—distant 71.04 meters from Monument 1—and Monument 40, 159,264.4 meters. The survey of 1892 showed the channel of the Rio Grande to be 172.06 meters east of Monument 1, so that the length of parallel 31° 47′ in 1892 was 159,365.5 meters. One hundred miles on parallel 31° 47′ equals 160,933 meters, so the parallel now is 1,567 meters short of 100 miles; and at the time of original survey the parallel was 1,668 meters short of 100 miles.

Monument No. 127 was placed at the intersection of parallel 31° 20′ with the 111th meridian of longitude, as determined by the original commission.

Our longitude of Monument No. 127, is 111° 4′ 34.4″, or 4′ 34.4″ too far west—equal to 7,254.2 meters, or 4.5 miles.

The difference of longitude between the boundary post at Yuma, and Monument 1 on the Pacific, was 2° 32′ 24.9″, as determined by the original commission in 1849. (Page 165, Emory's Report.) By determination of 1892 it was 2° 30′ 47.9″.

The distance from the junction of the Gila and Colorado to Monument I on Pacific, is 2,534 meters less than that by the original commission.

Comparison of latitudes and longitudes observed in 1892–93 with those of the original survey in 1849–1856.

	Latitudes.				Longitudes.					
	1892–93.			1849–1856.	1892–93.			1849–1856.		
	°	′	″	″	°	′	″	°	′	″
Cathedral, Juarez, Mexico	31	44	15.90	15.70	106	29	4.72	106	29	0.00
Monument 1, Rio Grande	31	46	59.40	60.00	106	31	39.03	106	31	23.50
Monument 40, upper corner	31	46	59.70	60.00	108	12	29.67	108	13	24.05
Monument 53, lower corner	31	20	1.79	0.00	108	3	29.67	108	13	24.05
Monument 127, west end of parallel 31° 20′	31	19	59.30	60.00	111	4	34.45	111	0	0.00
Monument 204, east bank Colorado River	32	29	1.00	1.48	114	46	48.64	114	46	11.43
Boundary post, Yuma	32	43	29.54	31.60	114	36	56.67	114	36	22.20
Monument 258, Pacific coast	32	31	61.34	59.63	117	7	31.89	117	8	29.70

The differences in the results for longitude are due to improved methods of observation and the use of the telegraph by the present commission.

Original monuments.

PARALLEL 31 47′.

No. of monument on original survey. United States.	No. of monument on original survey. Mexican.	No. when repaired or rebuilt in 1892.	Distance apart.	Description of monuments when survey was made.
			Miles.	
1	1	1	....	Cut stone; pyramidal form; square base; inscriptions; fair preservation
2	2	2	0.4	Roughly dressed stone; pyramidal form; square base; no inscriptions; poor preservation.
3	3	3	2.6	Roughly dressed stone; pyramidal form; square base; no inscriptions· good preservation.
	4	11	34.3	Rough stones; mud mortar; pyramidal form, square base; inscriptions; tumbling to pieces.
	5	15	12.4	Do.
5	6	21	13.4	Do.
6	7	26	8.2	Do.
7	8	33	13.5	Do.
8	9	40	14.2	Cut stone; pyramidal form; square base; inscriptions; good preservation.
			99.0	

MERIDIAN SECTION.

8	9	40	....	Cut stone; pyramidal form; square base; inscriptions; good preservation.
9	10	46	15.2	Rough stones; mud mortar; pyramidal form; square base; inscriptions; poor preservation.
10	11	53	15.8	Cut stone; pyramidal form; square base; inscriptions; excellent preservation.
			31.0	

Original monuments—Continued.

PARALLEL 31° 20'.

No. of monument on original survey. United States.	No. of monument on original survey. Mexican.	No. when repaired or rebuilt in 1892.	Distance apart.	Description of monuments when survey was made.
			Miles.	
10	11	53	0.0	Cut stone; pyramidal form; square base; inscriptions; excellent preservation.
11	12	....	....	No trace remaining.
12	13	64	28.7	Mound of loose stones; circular base; height 4 feet; no inscriptions.
13	14	65	3.9	Mound of loose stones; badly scattered; circular base; no inscriptions.
14	15	66	3.4	Rough stones; mud mortar; pyramidal form; square base; inscriptions; tumbling to pieces.
15	16	67	3.0	Mound loose stones; badly scattered; square base; no inscriptions.
16	17	73	13.4	Loose stones; pyramidal form; square base; inscriptions; tumbling to pieces.
17	18	....	10.5	Loose stones; pyramidal form; square base; no inscriptions; tumbling to pieces.
18	19	77	.1	Loose stones; pyramidal form; square base; inscriptions; tumbling to pieces.
19	20	82	9.9	Pulled down; apparently pile of loose stones; round base; no inscriptions.
20	21	98	43.1	Loose stones; pyramidal form; square base; no inscriptions; tumbling to pieces.
21	22	106	18.0	Loose stones; almost entirely demolished; no inscriptions.
22	23	108	2.8	Loose stones; pyramidal form; square base; no inscriptions; tumbling to pieces.
23	24	111	5.5	Do.
24	25	....	....	No trace remaining.
25	26	118	14.8	Loose stones; pyramidal form; square base; no inscriptions; tumbling to pieces.
26	27	122	5.6	Loose stones; pyramidal form; square base; inscriptions; tumbling to pieces.
27		127	7.9	Do.
			170.6	

LINE FROM WEST END PARALLEL 31° 20' TO COLORADO RIVER.

No. of monument on original survey.	No. when repaired or rebuilt in 1893-94.	Distance apart.	Description of monuments when survey was made.
		Miles.	
....	127	....	Loose stones; pyramidal form; square base; inscriptions; tumbling to pieces.
XIX*	128	0.3	Mound loose stones; round base, 3 feet high; no inscriptions.
XVIII	129	3.5	Loose stones; square base; 2½ feet high, no inscriptions.
XVII	136	18.1	Mound loose stones; round base; 2½ feet high; no inscriptions.
XVI	137	2.6	Do.
XV	141	9.2	Mound loose stones; round base; 4 feet high; no inscriptions.
XIV	146	17.2	Mound loose stones; round base; 5 feet high; no inscriptions.
XIII	150	12.4	Mound loose stones; round base; 4 feet high; no inscriptions.
XII	160	29.1	Mound broken lava; round base; 3 feet high; no inscriptions.
XI	....	....	No trace remaining.
X	162	4.5	Mound broken lava; square base; 4 feet high; no inscriptions.
IX	168	14.7	Mound loose stones; round base; 4 feet high; no inscriptions.
VIII	....	....	No trace remaining.
VII	....	....	Do.
VI	175	19.6	Mound loose stones; round base; 3 feet high; no inscriptions.
V	....	....	No trace remaining; probably never erected.
IV	....	....	Do.
III	....	....	No trace remaining.
II	204	101.8	Cast iron; pyramidal form; inscriptions; rivets loose and foundation undermined.
I	....	....	No trace remaining.
	Initial Point Col. River.	2.7	
		235.7	

*It was decided by the engineers in chief of the two sections that this monument was not sufficiently authentic, and it was not accepted. Monument 128, however, was erected on the line joining Monuments 127 and 129, and but 1.81 meters south of the center of this mound.

Original monuments—Continued.

LINE FROM THE COLORADO RIVER TO THE PACIFIC OCEAN.

No. of monument on original survey.	No. when repaired or rebuilt in 1894.	Distance apart.	Description of monuments when survey was made.
	Initial Pt. Col. River.	*Miles.*	
VI	207	0.6	Entirely demolished; was of cast iron; part of iron base alone remains.
V	220	43.8	Cast iron; pyramidal form; square base 6 feet high; inscriptions.
IV	221	1.7	Do.
III	252	82.6	Entirely demolished; base alone remains; was of cast iron.
II	(*)	7.9	Do.
I	258	5.0	Ornamental marble monument; 16 feet high, with inscriptions; badly defaced by visitors.
Pacific Ocean..	....	.2	
		141.8	

* A monument, No. 255, erected here in 1894 was destroyed by a flood in January, 1895, and another similar to it was placed on a more permanent site to the east of the old monument.

SECTION 11.

TOPOGRAPHY OF UNITED STATES SECTION.

By agreement between the engineers in chief of the two sections of the joint commission, each section was to map the topographic features of a belt 2½ miles in width on its own side of the boundary line, in such detail as would be necessary to plot the locations on field maps of a scale of 1 ÷ 30,000.

To do this the measured distances along the boundary were used as bases, and stadia lines were run from the boundary, in a general northerly direction, to near the outer limit of the topographic belt, turning near this limit so as to cover most conveniently the principal topographic features in the vicinity, and then returning and closing on a located point on the boundary line. From these closed lines "spur lines" were run as needed, and from both the closed and spur lines numerous secondary sights, giving azimuth, distance, and vertical angle, were taken.

On both the closed and spur lines backsights and foresights were always taken, and at each of these sights the azimuth, the distance and vertical angle were read. The maximum error in distance allowed on closing was one three-hundredth, and in elevation one decimeter per kilometer per degree of average vertical angle of the courses of the line.

In some cases locations were made by intersections, and occasionally the topography was "filled in" from located points by aid of the prismatic compass, hand level, and sketching.

Between the Pozo Verde Mountains and the Colorado River, a distance of more than 323 kilometers, the region bordering the boundary line is difficult of access, remote from railroads, is practically uninhabited, and is a true desert, containing but five badly spaced permanent watering places in the entire distance.

Owing to these causes, and in order to expedite the work in this inhospitable region, it was decided that between the west end of parallel 31° 20′ and the Colorado River a topographic belt, 1 kilometer in width, adjacent to the boundary line would be surveyed and plotted in the usual manner, but that the remainder of the 2½ mile belt of topography would be taken by placing flags on all of the prominent peaks, ridges, and other natural objects, to be located by the transit man engaged in measuring the boundary line. Another transit man would then occupy these positions and from them locate all flags in sight. Other important topographical features were then to be located, either by stadia or by resection, and contoured sketches of the immediate vicinity made.

Datum points for elevations were given by a line of levels carried along the boundary from the Rio Grande to the Pacific, and connected at El Paso, Tex., and Yuma, Ariz., with bench marks of the Southern Pacific Railway and at San Diego, Cal., with a bench mark established by the United States Coast and Geodetic Survey.

The datum plane was that of mean sea level of San Diego Bay, California.

Great care was taken in running the line of levels. The rods were held on iron pins driven firmly in the ground. Equal foresights and backsights were taken, and at each setting of the instrument both of these sights were read until two values of each were obtained which did not differ more than 1 millimeter, the rod being unclamped and reset after each reading. The mean of the two values thus obtained was taken as the true reading.

Most of the topographic notes were reduced in the field by the observers who took them, and about half of the field sheets were plotted there; the rest were plotted in the office either by the assistant engineers in charge of topographic work in the particular region or by an assistant engineer personally familiar with it.

TOPOGRAPHY OF THE MEXICAN SECTION.

From the initial monument on the Rio Grande to Monument 111 (XXIV) the method employed was to determine, by intersections from different points on the tangents, the most prominent points of the ground, the lines joining these points then constituting bases from which other points were fixed by intersections. At some of these points conveniently selected, sketches of the ground were made to complete the configuration. In some places polygons were run with bearings and distances, having as bases points on the tangents or referred to said tangents, measuring the distances with tape or stadia. The heights were determined by vertical angles.

From Monument 111 to 258 on the Pacific Ocean the method of detail employed was a series of polygons, run by bearings and distances by means of a field compass and odometer on wheels run by hand, said polygons having as a base two consecutive monuments of the boundary. From several points of these polygons sights were taken to the most prominent points of the ground to fix them by intersections, and a sketch of the ground was carried of 1 kilometer in width on each side of the line of the polygon.

The heights were determined with aneroids and vertical angles. Each polygon was run so that it would take in the most important details of the ground, and was selected to obtain the best points of view for the sketches.

At the Colorado River a special survey was made by a chain of triangles along its banks and 180 vertices were located exactly on the banks of the river. Of these vertices one-half were on the American side and the other half on the Mexican side.

The angles of the triangulation were measured with two theodolites reading to 1 minute, repeating each angle twice in both positions of the instrument.

The first base for the triangulation was measured on the line out from Monument 206 to Monument 207, and its azimuth obtained from the line of said monuments. The triangulation was carried on to Monument 205. Four bases of verification were measured at about every 45 triangles, and every section of the chain was computed from its own measured base.

The islands were surveyed by polygons lying on the vertices, measuring the distances with metric tape, when the polygons were small, or with odometers upon handwheels, when they were large. By the same method the main estuaries were surveyed and other polygons were run in the valley of the river so as to take in the detail of the Mexican side and make sure that no detail was hidden by the vegetation.

The final results of the triangulation were computed with the differences of geographical coordinates, between Monuments 205 and 207, and were compared with those obtained for the same points by the geodetical work of the commission. The following differences were found:

	′	″
Difference of latitude by Mexican triangulation in 1894	13	29.9
Difference of latitude by boundary survey triangulation in 1893	13	29.6
Discrepancy	0	0.3
Difference of longitude by Mexican triangulation in 1894	4	42.3
Difference of longitude by boundary survey triangulation in 1893	4	43.3
Discrepancy	0	1.0

The projection of the map was adjusted to the positions of the boundary survey.

Old Mission, San Xavier del Bac.

Antigua Misión de San Javier del Bac.

SECTION 12.

As provided at the meeting of the joint commission held in San Diego June 19, 1894, the two Governments were informed of the necessity for an extension in the time of the last convention to enable the commission to fully complete its labors, including the preparation of the final maps and reports. In compliance with this request a convention between the United States and Mexico was signed at Washington on August 24, 1894, and duly ratified by the respective Governments.

Following is a copy of this convention:

Whereas the United States of America and the United States of Mexico desire to comply fully with the provisions of the convention concluded and signed at Washington July 29, 1882, providing for an international boundary survey to relocate the existing frontier line between the two countries west of the Rio Grande; and

Whereas the time fixed by Article VIII of that convention for the termination of the labors of the International Boundary Commission, as extended by Article II of the convention, concluded and signed between the two high contracting parties February 18, 1889, will expire October 11, 1894; and

Whereas the two high contracting parties deem it expedient to agree upon a further extension of the time stipulated in Article II of the convention aforesaid, to the end that the International Boundary Commission may be enabled to finish all its work and so render a report, accompanied by a final map of the topography on both sides of the line, they have appointed for this purpose their respective plenipotentiaries, to wit:

The President of the United States of America, Walter Q. Gresham, Secretary of State of the United States of America, and

The President of the United States of Mexico, Matias Romero, envoy extraordinary and minister plenipotentiary of the United States of Mexico in Washington,

Who, after having communicated to each other their respective full powers, found in good and due form, have agreed upon and concluded the following article:

ARTICLE I.

The period fixed by Article VIII of the aforesaid convention of July 29, 1882, between the United States of America and the United States of Mexico, which was extended for five years from the date of the exchange of the ratifications of the convention of February 18, 1889, between the same high contracting parties and which will terminate October 11, 1894, is hereby further extended for a period of two years from that date.

This convention shall be ratified by the high contracting parties in conformity with their respective constitutions, and its ratifications shall be exchanged in Washington as soon as possible.

In faith whereof, we, the undersigned, in virtue of our respective full powers, have signed this convention, in duplicate, in the English and Spanish languages, and have thereunto affixed our respective seals.

Done at the city of Washington, the 24th day of August, in the year 1894.

WALTER Q. GRESHAM. [SEAL.]
M. ROMERO. [SEAL.]

JOURNAL OF THE JOINT COMMISSION (CONTINUED).

In accordance with the resolution adopted at the last previous meeting in San Diego, Cal., October 8, 1894, the International Boundary Commission, United States and Mexico, met at the State Department, Washington, D. C., at 11 a. m., October 11, 1895, and, after being presented to the Secretary of State, adjourned to meet again on October 15, 1895. Present: Col. J. W. Barlow, United States Corps of Engineers; Señor Jacobo Blanco, engineer in chief of the Mexican section; Mr. A. T. Mosman, assistant, United States Coast and Geodetic Survey; Señor Valentin Gama, assistant astronomer, and Lieut. D. D. Gaillard, United States Corps of Engineers. Absent: Señor Guillermo B. y Puga, probably en route from Mexico.

JACOBO BLANCO,
Ingo. en Jefe, de la Sección Mexico.
VALENTIN GAMA,
Adjunto Astronomo.

J. W. BARLOW,
Colonel of Engineers, U. S. A.
D. D. GAILLARD,
First Lieutenant of Engineers.
A. T. MOSMAN,
Assistant, Coast and Geodetic Survey.

At a meeting of the International Boundary Commission held in the offices of the commission in Washington, D. C., October 23, 1895, there were present all of the members. The proposed meeting of October 15 had been informally postponed by mutual consent while office rooms were being prepared.

It was agreed that the scale of the final maps of the joint commission shall be one 1÷60,000; that the distance between contours shall be 20 meters; that the projection used shall be the polyconic; that the interval between meridians and parallels shall be five minutes of arc, and that the center meridians shall be perpendicular to the lower edges of the sheets, which shall be 1 meter in length. Natural features of the country shall be designated by their local names. As a basis for plotting the maps the horizontal distances between monuments already agreed upon will be used. Elevations will be determined by the level line run by the United States section between the Rio Grande and the Pacific. The title on each sheet shall be both in English and Spanish.

It was also agreed to adopt the changed distances between Monuments 254–255 and 255–256, and to modify the tables to conform to the new position of Monument 255, as relocated by the two engineers in chief after its destruction in January, 1895.

J. W. Barlow, *Colonel of Engineers, Commissioner.*	Jacobo Blanco, *Ingo. en Jefe, de la Sección Mex.*
D. D. Gaillard, *First Lieut. of Engineers.*	Valentin Gama, *Adjunto Astronomo.*
A. T. Mosman, *Assistant, Coa t and Geodetic Survey.*	Guillermo B. y Puga, *Adjunto Astronomo.*

At a meeting of the commission held January 10, 1896, a general form for the joint report was agreed upon, which has been substantially followed in writing the report.

At a meeting of the International Boundary Commission, between the United States and Mexico, held in Washington, D. C., on January 23, 1896, all the members being present, it was agreed, subject to the approval of the two Governments, to have the 20 sheets of the joint map of the survey of the United States and Mexican boundary, from the Rio Grande to the Pacific, engraved upon copper, the expense, approximately $8,000, United States currency, to be equally divided.

Jacobo Blanco, *Ingo. en Jefe, de la Sección Mex.*	J. W. Barlow, *Colonel of Engineers, U. S. A.*
Valentin Gama, *Adjunto Astronomo.*	D. D. Gaillard, *Captain of Engineers, U. S. A.*
Guillermo B. y Puga, *Adjunto Astronomo.*	A. T. Mosman, *Assistant, Coast and Geodetic Survey.*

Washington, D. C., *February 24, 1896.*

At a meeting of the joint commission held this day, at which were present all of the members, it was agreed that the part of the joint report relating to astronomical observations (latitude, longitude, and azimuth) should consist of:

First. A table containing the final results of the determinations made by the Mexican section of the commission with their probable errors; the method of observations; the number of nights on which observations were taken; the number of observations, and the name of the observer.

Second. A similar table, giving the corresponding results obtained by the American section of the commission.

Third. A table of means and final values adopted by the International Commission.

Jacobo Blanco, *Ingo. en Jefe, de la Sección Mex.*	J. W. Barlow, *Colonel of Engineers,* *Engineer in Chief of the American Section.*
Valentin Gama, *Adjunto Astronomo.*	D. D. Gaillard, *Captain of Engineers, U. S. A.*
Guillermo B. y Puga, *Adjunto Astronomo.*	A. T. Mosman, *Assistant, U. S. Coast and Geodetic Survey.*

SECTION 13.

CONSTRUCTION OF THE MAPS OF THE BOUNDARY.

The field maps of the topography were made, as described in section 11, on a scale of 1÷30,000, the part on the north of the boundary of a width of 2½ miles by the United States section, and the part south, of the same width, by the Mexican section; the width of the entire belt plotted being 5 miles.

At a meeting of the joint commission on October 23, 1895 (see section 12), it was agreed that the scale of the final maps shall be 1÷60,000; that the contour intervals shall be 20 meters; that the projection used shall be polyconic; that the intervals between meridians and parallels shall be five minutes of arc, and that the center meridians shall be perpendicular to the lower edges of the sheets, which shall be 1 meter in length.

As a basis for plotting the maps the horizontal distances between monuments shall be used. Elevations will be determined by the level line run by the United States section.

Before beginning the maps it was agreed that a mean parallel of latitude should be adopted, which should be the mean of all the observed latitudes along the boundary, and that the horizontal distances between monuments given in the tables of section 9, together with the mean latitude, should govern their location.

The topography of the 2½ miles to the north of the line was then drawn in pencil, reduced from the field maps of the United States section, by the United States draftsmen. The topography of the 2½ miles south of the line was also drawn in pencil, reduced from the field maps of the Mexican section, by the Mexican draftsmen. The maps in pencil were then carefully compared before inking.

The land boundary between the Rio Grande and the Pacific was contained in 18 sheets. A sheet (numbered 19) was then drawn for the Colorado River section. As the river and the eastern side had been surveyed by the United States section in March, 1893, and the river and the western side by the Mexican section in February and March, 1894, the two representations of the river do not correspond,* so both are shown on sheet No. 19 in different colors.

In the following table column 4 shows the observed latitudes at nineteen stations along the boundary called A, and column 3 the mean geodetic latitudes resulting called G; column 5 shows the difference G—A, or the derived "station errors" in latitude of all these nineteen stations.

Mean geodetic latitudes, reduced to mean of United States and Mexican observed latitudes on whole line.

Monuments.		Mean geodetic δ — G.			Observed δ = A.			G — A.	Locality.
Old No.	New No.	°	′	″	°	′	″	″	
1	1	31	46	61.35	31	46	59.40	+1.95	On Rio Grande.
				60.95			60.88	+ .07	Mex. Station No. 2, on desert.
5	15			60.54			60.34	+ .20	Near Wragg's Ranch.
6	21			60.62			58.85	+1.77	Near Columbus.
7	26			60.56			58.08	+2.48	Near Carizalillo Springs.
9	40			60.59			59.70	+ .89	Upper corner.
11	53	31	19	59.48	31	19	61.79	—2.31	Lower corner.
				59.27			57.94	+1.33	U.S. Sta. No. 6, near Whitewater.
13	64			59.29			62.60	—3.21	Mexican Station No. 6.
16	67			55.52			56.86	—1.34	Near Lang's Ranch.
19	77			61.51			58.99	+2.52	San Bernardino.
				60.85			59.65	+1.20	Mex. Station No. 7, Niggerhead.
				62.89			66.07	—3.18	U. S. Sta. No. 9, Dutch Charley's.
21	98			62.13			63.02	— .89	San Pedro.
24	111			57.83			57.58	+ .25	Lanoria.
27	122			57.03			60.75	—3.73	Nogales.
11	204	32	29	2.16	32	29	1.00	+1.16	East bank Colorado River.
		32	43	35.85	32	43	34.69	+1.16	U. S. Station No. 13, Yuma
I	258	32	32	1.01	32	32	1.34	—0.33	On Pacific coast.

* The difference in the two representations of the river arises from the fact that the bed of the river changed between the time of the United States survey in 1893 and that of the Mexican survey in 1894.

Mean latitudes and longitudes of monuments on parallel 31° 47′.

No. Old.	No. New.	Mean latitude. °	′	″	Longitude. °	′	″	No. Old.	No. New.	Mean latitude. °	′	″	Longitude. °	′	″
1	1	31	46	61.35	106	31	39.03	6	21	31	46	60.62	107	35	55.08
2	2			61.35		32	6.15		22			60.61		37	10.98
3	3			61.35		34	48.46		23			60.60		38	12.30
	4			61.23		39	36.66		24			60.58		41	1.27
	5			61.11		44	23.51		25			60.57		43	26.71
	6			60.98		49	25.61	7	26			60.56		44	17.32
	7			60.85		54	19.06		27			60.56		46	15.15
	8			60.72		59	18.97		28			60.56		48	29.51
	9			60.70	107	0	12.31		29			60.57		50	49.55
	10			60.59		4	39.40		30			60.58		53	33.44
4	11			60.46		9	36.31		31			60.58		55	44.64
	12			60.48		12	50.38		32			60.58		57	16.87
	13			60.51		17	13.71	8	33			60.58		58	0.44
	14			60.53		20	11.73		34			60.58	108	0	38.69
5	15			60.54		22	16.77		35			60.59		3	31.56
	16			60.55		23	19.88		36			60.59		5	52.55
	17			60.57		26	5.20		37			60.59		7	46.81
	18			60.58		28	32.80		38			60.59		9	25.56
	19			60.60		31	13.16		39			60.59		11	11.37
	20			60.61		33	44.39	9	40	31	46	60.59	108	12	29.67

Mean latitudes and longitudes of monuments on parallel 31° 20′.

No. Old.	No. New.	Mean latitude. °	′	″	Longitude. °	′	″	No. Old.	No. New.	Mean latitude. °	′	″	Longitude. °	′	″
11	53	31	19	59.48	108	12	29.67		91	31	19	61.95	109	52	24.96
	54			59.47		15	0.28		92			61.98		56	0.35
	55			59.46		19	16.34		93			62.02		58	49.19
	56			59.46		20	37.23		94			62.04	110	0	54.37
	57			59.45		22	54.07		95			62.06		3	5.84
	58			59.44		26	26.30		96			62.08		5	2.13
	59			59.44		27	45.48		97			62.11		7	19.22
	60			59.43		31	50.50	21	98			62.13		9	25.78
	61			59.42		35	28.98		99			61.35		12	34.66
	62			59.41		36	51.84		100			60.59		15	38.45
	63			59.40		38	57.98		101			60.52		15	55.19
13	64			59.39		41	29.75		102			60.25		17	0.62
14	65			55.16		45	23.40		103			59.44		20	14.13
15	66			55.37		48	47.84		104			59.08		21	43.13
16	67			55.52		51	49.75		105			58.65		23	28.25
	68			55.58		53	55.10	22	106			57.63		27	33.86
	69			55.67		57	3.65		107			57.51		29	24.64
	70			55.73		59	9.41	23	108			57.45		30	22.43
	71			55.85	109	2	59.82		109			57.60		32	36.99
	72			55.87		3	42.46		110			57.75		34	42.90
17	73			55.92		5	18.23	24	111			57.83		35	59.32
	74			57.17		7	41.72		112			58.15		37	40.68
	75			59.04		11	16.56		113			58.88		41	31.98
	76			60.37		13	49.17		114			59.11		42	47.35
19	77			61.51		16	0.95		115			59.48		44	42.58
	78			61.53		17	15.36		116			59.94		47	8.71
	79			61.58		21	1.88		117			60.43		49	45.47
	80			61.62		23	58.88	26	118			60.65		50	56.03
	81			61.63		24	49.13		119			58.57		54	10.58
20	82			61.65		25	57.08		120			57.57		55	44.08
	83			61.66		27	7.84		121			57.13		56	24.78
	84			61.70		30	57.13	27	122			57.03		56	34.49
	85			61.72		33	27.82		123			56.81		57	47.12
	86			61.75		36	15.94		124			56.46		59	43.02
	87			61.80		40	15.26		125			56.11	111	1	39.05
	88			61.84		44	28.18		126			55.60		4	25.68
	89			61.88		46	39.20	28	127			55.58		4	34.45
	90			61.91		49	10.17								

Mean latitudes, longitudes, and azimuths along the Sonora line from Monument No. 127 to Monument No. [illegible] on Colorado River.

Monuments.		Mean latitude.			Longitude.			Azimuths.						To monument.	Distance.
Old No.	New No.							Forward.			Back.				
		°	′	″	°	′	″	°	′	″	°	′	″		*Meters.*
27	127	31	19	55.5	111	4	34.4	110	40	12	290	38	22	129	6,031.5
XVIII	129	31	21	4.6	111	8	7.8	110	34	54	290	25	59	136	28,973.8
XVII	136	31	26	34.2	111	25	15.1	110	26	12	290	24	53	137	4,235.7
XVI	137	31	27	22.2	111	27	45.4	110	24	26	290	19	53	141	14,746.5
XV	141	31	30	8.9	111	36	29.1	110	20	49	290	12	17	146	27,565.6
XIV	146	31	35	19.1	111	52	49.4	110	14	37	290	8	26	150	19,875.1
XIII	150	31	39	1.8	112	4	37.2	110	5	18	289	50	44	160	46,562.1
XII	160	31	47	38.1	112	32	19.5	109	51	13	289	48	56	162	7,273.3
X	162	31	48	58.2	112	36	39.6	109	48	22	289	41	00	168	23,415.2
IX	168	31	53	15.0	112	50	37.9	109	39	14	289	29	20	175	31,314.0
VI	175	31	58	55.6	113	9	21.2	110	24	22	289	32	23	204	162,894.5
II	204	32	29	2.2	114	46	48.6	108	40	37	288	39	38	205	3,000.0
	205	32	29	33.4	114	48	37.5	....			....			127	375,887.3

Mean latitudes, longitudes, and azimuths along the California line from Monument No. 206 to Monument No. 258 on Pacific.

Monuments.		Mean latitude.			Longitude.			Azimuths.						To monument.	Distance.
Old No.	New No.							Forward.			Back.				
		°	′	″	°	′	″	°	′	″	°	′	″		*Meters.*
	206	32	43	5.0	114	43	23.2	85	31	9	265	30	52	207	809.4
VI	207	32	43	3.0	114	43	54.3	85	30	52	265	6	43	220	70,109.0
V	220	32	39	57.0	115	28	36.7	85	2	17	265	1	20	221	2,780.4
IV	221	32	39	49.2	115	30	23.0	85	0	33	264	15	15	252	132,080.3
III	252	32	33	8.0	116	54	26.4	84	17	57	264	14	51	254	9,068.0
	254	32	32	38.6	117	0	12.2	84	14	43	264	13	52	255	2,466.0
	255	32	32	30.6	117	1	46.2	84	14	34	264	12	53	256	4,941.2
	256	32	32	14.4	117	4	54.6	84	12	57	264	11	32	258	4,125.3
I	258	32	31	1.0	117	7	31.9	....			....			206	226,379.6

The foregoing report is hereby attested by the signatures of all the members of the International Boundary Commission.

Done at the office of the commission in the city of Washington, D. C., this the 14th day of August, 1896.

J. W. BARLOW,
Colonel of Engineers,
Engineer in Chief of the American Section.
A. T. MOSMAN,
Assistant,
United States Coast and Geodetic Survey.
D. D. GAILLARD,
Captain of Engineers, U. S. A.

JACOBO BLANCO,
Ingeniero en Jefe de la Sección Mexicana.
VALENTIN GAMA,
Adjunto Astrónomo.
GUILLERMO B. Y PUGA,
Adjunto Astrónomo.

At a meeting of the International Boundary Commission held at the office of the commission, in Washington, D. C., August 14, 1896, present all members, the following resolutions were unanimously adopted:

1. That the full report of the joint commission prescribed in Article V of the convention of July 29, 1882, shall consist of the accompanying manuscripts, written in the English and Spanish languages, both in duplicate, comprising, in the English copies, 100 pages, and in the Spanish copies, 94 pages, of type-written text, including tables. These copies have this day been signed by all the members of the commission, and one copy in each language will be retained by each

section of the commission for transmittal to the proper department of its government; also, copies, each in duplicate, one for each section of the commission, of the joint map of the survey, comprising nineteen engraved sheets, on a scale of 1 ÷ 60,000, covering the boundary from the Rio Grande to the Pacific Ocean and showing the topography of a belt of territory 5 miles wide.

2. The report and map above specified are now complete and have been duly attested by the signatures of all the members of the commission.

3. In addition to these will soon be completed a set of illustrations, 300 in number, prepared from photographs taken in the field, showing views of the 258 monuments marking the boundary and special characteristic scenes.

4. It is further agreed that the engraved plates and electrotypes of the map, twenty of each, shall be equally divided between the two sections of the commission. These plates and electrotypes are numbered from the Rio Grande westward; the United States section will receive the engraved plates having odd numbers and the electrotypes having even numbers; the Mexican section to receive the others, the object being that each section shall have a complete set (engraved and electrotype plates) of the entire map. The manuscript drawings of the map will also be divided equally, each section retaining the sheets inked by its own draftsmen.

5. The half-tone plates, prepared from photographs, being in duplicate, each section will retain one complete set. These will be completed under the supervision of the engineers-in-chief and by them forwarded to their respective governments.

6. The International Commission, having no further business to transact, adjourns *sine die.*

JACOBO BLANCO,
Yngo. en Jefe, Sec. Mex.;
VALENTIN GAMA,
Adjunto Astrónomo;
GUILLERMO B. Y PUGA,
Adjunto Astrónomo;
Commissioners.

J. W. BARLOW,
Colonel of Engineers, U. S. A.,
Engineer in Chief, American Section;
A. T. MOSMAN,
Assist. U. S. Coast and Geod. Survey;
D. D. GAILLARD,
Captain of Engineers, U. S. A.,
Commissioners.

PART II.

REPORT

OF THE

UNITED STATES SECTION

OF THE

INTERNATIONAL BOUNDARY COMMISSION, UNITED STATES AND MEXICO.

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Parish Church at Juarez.

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REPORT OF THE UNITED STATES SECTION OF THE COMMISSION.

CHAPTER 1.

ORGANIZATION AND TRANSPORTATION.

Under the provisions of the convention of July 29, 1882, revived by that of February 18, 1889, between the United States and Mexico, providing for an international boundary survey to relocate the existing frontier line between the two countries west of the Rio Grande, the President of the United States directed the appointment of Lieut. Col. J. W. Barlow, Corps of Engineers; First Lieut. D. D. Gaillard, Corps of Engineers; and Mr. A. T. Mosman, assistant, United States Coast and Geodetic Survey, members of a commission, who, with corresponding appointees of the Mexican Government, would form an International Boundary Commission to carry into effect the provisions of those conventions.

These officers were notified of their appointment early in November, 1891, and were directed to proceed to El Paso, Tex., for consultation with the Mexican members who were expected to reach that point on the 7th of the month.

Lieutenant-Colonel Barlow and Mr. Mosman were instructed to visit Washington for conference with the Secretary of State before proceeding to El Paso, at which place they arrived on the 14th; Lieutenant Gaillard having preceded them by a few days.

Señor Don Jacobo Blanco, engineer in chief, and Señores Felipe Valle and Jose Tamborrel, associate engineers, appointees on the part of Mexico, were already on the ground; and after the usual official and personal civilities had been observed, a meeting of all the members was held at the Mexican custom-house in Juarez on the 17th of November, 1891, when the International Boundary Commission was duly installed.

The proceedings at this meeting were somewhat formal in character, and resulted in the preparation and signing of a document declaring the fact of the organization of the commission; copies in both English and Spanish were then made and transmitted to the proper departments in Washington and Mexico.

The preparation of a plan of operations was now given careful consideration by the two engineers in chief with the assistance of the associate engineers, and was adopted on the 21st of the month. Its provisions related entirely to the methods to be pursued in making the surveys. A copy of this agreement will be found in the report of the joint commission.

The Mexican section of the commission at this time was prepared to take the field in prosecution of their surveys, having already been provided with instruments, camp equipage, and an escort of troops. The American commission, on the contrary, had made no provision whatever, and there being no further duty to be performed by them until the necessary men and material could be assembled for field operations, the joint commission separated on the 22d of November, the Mexicans to begin their survey, the Americans returning to the Eastern States to procure instruments and skilled assistants, preparatory to entering upon their part of the required work.

The months of December, 1891, and January, 1892, were spent by the American commissioners in procuring instruments, engaging assistant engineers and other necessary employees, considering and devising plans for organizing the field parties and supplying them while engaged in the desert and mountain regions to be crossed during the progress of the work.

The American members reassembled at El Paso on February 2, 1892, and at once began the work of organizing the field parties and collecting the necessary transportation.

A general division of the work of the commission was decided upon, as follows: The senior commissioner, who, by designation of the President of the United States, was also the disbursing officer, to have charge, as engineer in chief, of all duty pertaining to the location, construction, and erection of monuments; the disbursement of the funds, including the payment of employees and purchase of property and supplies. The second member to have general supervision over the running of the line in the field and the topography. The third commissioner to have general charge of the astronomical work. This division of labor was substantially adhered to throughout the continuance of operations.

Following is the organization of the American commission on taking the field at El Paso in February, 1892:

J. W. Barlow, lieutenant-colonel of Engineers, commissioner, and engineer in chief; D. D. Gaillard, first lieutenant of Engineers, commissioner; A. T. Mosman, assistant, Coast and Geodetic Survey, commissioner; L. Seward Terry, secretary and disbursing clerk; J. F. Hayford, assistant astronomer; J. L. Van Ornum, assistant engineer and topographer; E. L. Ingram, assistant engineer; B. A. Wood, assistant engineer; T. H. Logan, transportation clerk; J. T. Amos, field clerk; James Page, computer; P. D. Cunningham, levelman; J. H. Wright, photographer; L. S. Smith, transitman; A. F. Woolley, jr., transitman; H. B. Finley, recorder; N. G. Ellerbe, recorder; Thomas Evans, rodman; Joe H. Wheeler, rodman; D. L. Ledbetter, rodman; C. W. Speiermann, rodman; Henry Griffin, rodman; Edmund Davis, rodman; A. J. Sampson, rodman; A. Van Ornum, chainman; W. T. Simpson, chainman; Luke O'Reilly, targetman; F. G. Malloy, targetman; Albert Lang, targetman; E. Frye, targetman; J. S. Bilby, carpenter; W. J. Tucker, blacksmith; L. C. Chriss, wagon master (temporary); James Groves, chief packer.

Besides these, about twenty men were employed as teamsters, packers, cooks, and helpers; the aggregate number of employees of all classes being about sixty.

In addition to the above, Capt. W. L. Finley, Ninth United States Cavalry, was detailed by the War Department to act as quartermaster and commissary of subsistence for the commission; and Capt. and Asst. Surg. E. A. Mearns, United States Army, as medical officer.

By an arrangement with the Superintendent of the United States Coast and Geodetic Survey, a longitude party, consisting of C. H. Sinclair and G. R. Putnam, observers, and O. B. French, recorder, was detailed to determine the longitude, by telegraph from Los Angeles, of San Diego, Yuma, Nogales, and El Paso. A point on the boundary 100 miles west of El Paso was also included in the work of this party.

The personnel of the organization was not entirely permanent; some changes among the subordinates of the engineering force occurred from time to time as contingencies arose; while among the teamsters, cooks, and laborers, the changes were quite frequent. In the higher departments the men employed continued, without exception, until the close of the work for which they were engaged.

The transportation and camp equipage was purchased for the expedition, and proved to be of excellent quality, well adapted to the service required. It was at first as follows: 7 four-mule baggage wagons, 3 six-mule water-tank wagons, 3 two-mule light spring wagons, 1 two-mule buckboard, 1 four-mule ambulance, 25 mules for packing, 83 mules in all, and 14 saddle ponies.

The tentage consisted of 5 officers' wall tents, 12 conical wall tents, 20 small wall tents.

It was found unnecessary to materially increase the number of animals during the entire progress of operations; but experience taught us that a special pack train was a very expensive method of transportation, and not an absolute necessity. In May, 1892, another baggage wagon was purchased, and in the following October the pack train was greatly reduced, and later on discontinued; the animals being put in harness and employed in hauling additional wagons, which were much needed. These animals were, however, frequently used for packing on parts of the line where wagons could not be taken, and restored to the teams when the emergency had passed.

Captain Finley served but a short time with the commission. His services were valuable and appreciated in procuring and organizing the transportation, but after a few days of camp experience the Captain, at his own request, was relieved on the 25th of March, 1892, and his duties transferred to Maj. T. H. Logan, formerly of the Fifth United States Infantry, who ably and zealously performed them for a period of twenty months, when physical incapacity—the result of an old wound—compelled his resignation.

Assistant Surgeon Mearns continued with the surveying expedition, being a most efficient and careful medical officer, as well as an enthusiastic and energetic collector of specimens of natural history, until relieved by request of the medical department, in November, 1892. Dr. Mearns was restored to the commission in July following, and remained until the close of its field work in September, 1894. On leaving the field Dr. Mearns was assigned to professional duty at Fort Myer, Va., and, with the permission of the War Department, continued the preparation of his biological report with his usual zeal and industry.

The commission, on commencing operations at El Paso, was provided, by direction of the War Department, with a military escort to accompany the expedition as a protection against Indians or other marauders. This force consisted of 20 enlisted men of the Tenth Cavalry, Lieuts. P. E. Trippe and R. G. Paxton commanding, and a detachment of 30 enlisted men of the Twenty-fourth Infantry, under Lieut. A. C. Ducat, jr. The latter officer was relieved at his own request before taking the field, the detachment going out under the command of Lieut. J. R. Seyburn, Twenty-fourth Infantry, who was also the acting quartermaster and commissary of subsistence for the escort.

Many changes occurred in the personnel of the escort, the troops being relieved and others substituted as the exigencies of the military service required. A complete list of the several officers and detachments serving with the commission will be given in another place.

The commissioners are pleased to express their appreciation of the assistance rendered by the several officers who served with the escorts, and of the high soldierly qualities displayed by them in many difficult and laborious situations. They would also testify to the general good conduct of the enlisted men, and their usual cheerful performance of duty.

During the first season's operations it was deemed advisable to keep the entire organization as nearly intact as possible, and under the constant personal supervision of the commissioners. It was also expected to work in concert with the Mexican expedition, and possibly on alternate sections of the line, which would have greatly lessened the labors of each party. Owing, however, to various causes, among which was the fact that the Americans were able, with their better organization and more practical methods, to make more rapid progress than the Mexicans, this plan could not be carried out, and it was finally determined that both parties should run the entire line, each selecting such points for astronomical determinations as might be thought proper, and afterwards compare the results. Under all the existing conditions this was the only practical method of proceeding.

To carry out the work of the American commission conveniently the whole force was subdivided into detachments as follows, the general camp moving as often as necessary to keep within touch of all sections:

1. Astronomical party for determining latitude and azimuth: J. F. Hayford, assistant astronomer and observer; James Page, computer; H. B. Finley, recorder; J. S. Bilby, general helper; a cook and 2 teamsters; 1 spring wagon, 1 baggage wagon, and, when necessary, 1 water-tank wagon.

2. Tangent party for running the tangents: E. L. Ingram, assistant engineer and observer, in charge; N. G. Ellerbe, recorder (temporary); 2 chain men; 4 target men; 1 cook and 1 helper; 2 teamsters; 1 spring wagon, 1 baggage wagon, and 1 water-tank wagon.

3. Topographical party: J. L. van Ornum, assistant engineer, in charge; P. D. Cunningham, level man; L. S. Smith, transit man; A. F. Woolley, jr., transit man; 6 rod men; 1 cook and 1 helper; 3 teamsters.

The main supply camp, with the commissioners and field office, frequently included one or more of the other parties, and for convenience and economy combined the messing outfits. This was especially so in the beginning. Afterwards it was found expedient to separate the parties more completely.

Besides the parties above enumerated there were employed with the supply camp: B. A. Wood, assistant engineer, draftsman; T. H. Logan, quartermaster and commissary; J. T. Amos, field clerk and assistant; J. H. Wright, photographer; 1 blacksmith, 1 wheelright and carpenter, 1 cook and 1 helper, several teamsters and laborers.

Of the cooks and teamsters but few remained permanently, and it was only after numerous trials and changes that a satisfactory complement of these indispensable employees could be obtained. A plan which worked very well was finally adopted with the teamsters of giving a monthly increase of wages for satisfactory and continuous service.

The photographic work was first undertaken by J. H. Wright. He was soon found to be ill adapted to field service, and his place was supplied by M. J. Lemmon for a short period. He was also unsatisfactory, and Mr. D. R. Payne was employed in August, 1892, and continued to the close of the entire work, rendering most faithful and efficient service in his profession as photographer, and also as overseer in the erection of monuments.

In conducting the survey across the desert west of the Rio Grande the expedition encountered severe difficulties. The absence of water in the vicinity of the line for the first 50 miles, and the soft, sandy nature of the soil, which retarded the progress of wagons, being among the most serious. Men and animals were new and unseasoned to hardship, but in a few days the majority became accustomed to field life, and the work soon progressed rapidly and satisfactorily.

The main camp and supply train reached Old Monument No. 4, 50 miles west of the Rio Grande, on the 20th of March, 1892. To this point all supplies were hauled across the desert from El Paso. After leaving the vicinity of the river, water was obtained from Strauss and Lanark, stations on the Southern Pacific Railway, by hauling from 10 to 15 miles.

While camped at Old Monument No. 4, and its vicinity, water was obtained from a well 3 miles north of this monument. This well is 100 feet deep, the water raised by windmill and horsepower for supplying a large herd of cattle owned by a Mrs. Wragg. The quantity was quite abundant but the quality bad, being strongly alkaline. Beyond, in New Mexico and southeastern Arizona, water was obtained with less difficulty, several natural springs and a number of ranchmen's wells having been found available.

From this point (Monument No. 4) westward advantage was taken of the Southern Pacific Railway in the transportation of supplies from the most convenient point of purchase to the stations nearest the field of operations, which method greatly relieved the strain upon the animals of the expedition.

The survey continued without serious inconvenience, reaching the "corner" at the western extremity of the boundary on parallel 31° 47′ in the latter part of April. The main camp remained here from the 22d of April until the 18th of May. At the latter date the astronomical observations had been completed, including an exchange of telegraphic signals between this station and El Paso.

For the latter purpose a field telegraph line was erected to this point from the railroad at Separ, about 35 miles distant. The material for the line was loaned by authority of Gen. A. W. Greeley, Chief of the Signal Service of the War Department, and put up under the direction of Lieut. Frank Greene, United States Signal Service, by a company of the Twenty-fourth United States Infantry, Bvt. Maj. James N. Morgan, commanding. The wagon transportation was supplied from the boundary train. This work was performed with remarkable expedition. The line was in working order on the evening of the fifth day after the material arrived. It was used four nights for exchange of signals, and immediately removed.

Before moving this camp the tangent and topographical parties carried their work well along the meridian southward, and were able to obtain water from Mosquito Springs, 15 miles distant and near the line, on the Mexican side. The water in the vicinity of camp at the "corner" was scarce and of poor quality, a moderate supply being obtained from a well owned by Mr. Doyle, 3 miles west of camp.

From the wells of Mr. Rector, several miles south, some water was obtained, and also from the Carrizalillo Springs, 15 miles eastward. Wood in abundance and of excellent quality was always available, being generally the roots of dead mesquite, which were obtained with little labor and made the best of fuel for cooking. For evening campfires grease wood, yucca, and the branches and roots of mesquite served a good purpose.

For a time a supply station was established on the railroad at Separ, whence stores were hauled by the commission teams to the camps along the parallel of 31° 20′ as far as San Bernardino,

San Bernardino Springs. Manantiales de San Bernardino.

some miles west of the Guadalupe Mountains. From the latter point, until within reach of Nogales, a supply station was established near Bisbee, on the Arizona and Southeastern Railroad, which point was easily accessible by the wagons of the expedition for a distance of 100 miles along the boundary.

The main camp reached San Bernardino on the 26th of July, and all the work of the survey was completed in that vicinity during the month of August.

On August 6 a detachment of men and teams, under T. H. Logan, was sent overland 240 miles to El Paso to take up the work of monument erection on the parallel of 31° 47′.

This transportation consisted of 4 baggage wagons, 1 water-tank wagon, 1 spring wagon, 1 buckboard, and 2 saddle ponies. At El Paso another spring wagon with 2 horses was purchased for this party, and later on a water-tank wagon and 1 baggage wagon were added, the animals being supplied from the 15 pack mules which had been sent from the main camp for duty with the monument party.

This party when fully organized consisted of the following men and transportation: One commissioner, Lieut. Col. J. W. Barlow, in general charge; E. L. Ingram, assistant engineer, in charge of location party; T. H. Logan, quartermaster, and in charge of working party; D. R. Payne, photographer and general assistant; 1 stone mason, 1 blacksmith, 1 rodman, 7 teamsters, 4 laborers, 1 cook, and 2 helpers—a total of 21 persons.

A Mexican party, consisting of one commissioner, an assistant engineer with helpers, and appropriate transportation, accompanied this party and assisted in the location of monuments. The work of construction and erection was done wholly by the American section.

A detachment of 12 enlisted men from the Twenty-fourth Infantry and 2 troopers from the First Cavalry were attached as an escort for this party, and were provided with a baggage wagon and 4 mules for transportation.

This monument party continued work until the close of November, erecting monuments along the parallel of 31° 47′ and the meridian section to the parallel of 31° 20′. It then moved overland and joined the main survey camp near La Noria, Ariz.

The entire force was now engaged in completing the survey of the line along parallel 31° 20′ to the angle at the one hundred and eleventh meridian, where the boundary changes its direction.

The weather in this elevated mountain region having become very trying upon the men in the field, and it being very important that the desert country adjoining the Colorado River be surveyed before the heat of summer should make that work impracticable, it was decided to transfer the entire expedition to Yuma and carry on the survey from the Colorado River across the deserts on either side during the winter and early spring months.

The expense of shipping by rail was found to be so great that it was decided to move overland, and to accomplish this with the least possible delay in prosecuting the fieldwork, the transportation was divided. About one-half was started via Tucson and along the wagon road near the Southern Pacific Railway on the 15th of December, 1892. This detachment safely reached Yuma on the 31st of the month. The other half remained with the parties which were completing the survey in the vicinity of Nogales and followed early in January, 1893.

The engineers and others engaged upon the survey, with their instruments and personal baggage, were sent by rail to Yuma, reaching that point in time to commence work at once, with the aid of the first section of the transportation previously sent over.

Two survey parties were here organized from the whole force to push the surveys both east and west from the Colorado River, with a view to completing the work on the Yuma and Colorado deserts before the advent of hot weather.

After finishing at Yuma the astronomical determinations for latitude and azimuth, and connecting the observatory with old Monument No. VI, on the west side of the river, and old Monument No. II, on the east side, by triangulation, the astronomical party was discontinued as a separate organization and its members assigned to duty with the two line parties.

The entire organization was now divided as follows:

1. Survey party for tangent work and topography from the Colorado to the Pacific: E. L. Ingram, assistant engineer in charge, running theodolite; P. D. Cunningham, transitman; H. B. Finley, transitman; C. W. Spiermann, levelman; A. Lang, in charge of heliotrope; 9 rodmen, 1 cook and 1 helper, 4 teamsters, 2 packers, and 1 guide—a total of 23 persons.

The transportation of this party consisted of 2 baggage wagons, a water-tank wagon, a light spring wagon, 16 draft mules, and 2 riding horses.

2. Survey party for operations east of the Colorado to the one hundred and eleventh meridian: J. L. Van Ornum, assistant engineer, in charge of topography; J. F. Hayford, assistant engineer, in charge of the azimuth line; L. S. Smith, transitman; James Page, transitman; Ernst Franké, levelman; J. T. Amos, clerk and assistant quartermaster; 3 heliotropers, 9 rodmen, 1 mechanic, 1 packer, 4 teamsters, 2 cooks, and 3 laborers—a total of 29 persons.

The transportation for this party consisted of 4 baggage wagons, 2 water-tank wagons, 2 spring wagons, 6 pack and 5 riding animals—a total of 41 animals.

To supply these parties with rations and forage, the remainder of the transportation was kept busy hauling from Yuma to the respective camps until the distance became too great for economical service from this point.

When the party working toward the coast had crossed the desert and entered the region of the Coast Range of mountains its base of supplies was changed to San Diego, and to supply the the party working eastward, after getting beyond convenient wagon communication with Yuma, stores were shipped by rail to points on the Southern Pacific Railway and hauled thence to the line by wagons.

At Yuma the commission office, including the draftsman and photographer, was retained until late in May, when that camp was abandoned.

The senior commissioner then took charge of the monument party just organized for work on parallel 31° 20′, proceeding to Nogales for this purpose. The second commissioner went to Buenos Ayres, near the boundary, south of Tucson, to take charge of the survey party approaching that point from the west, and the third commissioner went to San Diego to supervise the party working in that direction through the Coast Range of mountains.

The monument party was made up from the men and transportation which had been engaged in hauling between Yuma and the survey camps, with some necessary additions and modifications. Its organization was as follows: One commissioner, Lieut. Col. J. W. Barlow; B. A. Wood, assistant engineer; T. H. Logan, quartermaster and overseer; D. R. Payne, photographer and painter; 2 rodmen, 1 blacksmith, 1 stone mason, 5 teamsters, 5 laborers, 1 cook, and 2 helpers; a total of 21 persons.

The transportation consisted of 3 baggage wagons, 1 truck wagon, 2 water-tank wagons, 2 spring wagons, 5 horses, and 24 mules.

This party as above organized assembled at Nogales in May, 1893, and took up the work of locating and erecting monuments on parallel 31° 20′, eastward from the one hundred and eleventh meridian.

These three organizations were continued, with some changes, until the completion of their duties. During this season the aggregate force employed reached the maximum, being 80 men and 22 wagons of all classes.

The party working westward completed the survey to the Pacific September 23, 1893, and, with the exception of those retained for special office work, the members were discharged and the transportation sold.

The other party was engaged on its work in the field until the 20th of October, when, having reached the one hundred and eleventh meridian, it was transferred to Tucson, where the disbursing office had been previously established, and there disbanded. The majority of the men were discharged, and such transportation as was no longer required for the monument party was sold. The assistant engineers and instrument men were transferred to the office in San Diego for temporary service reducing notes and preparing field maps of their work.

After the survey parties were disbanded, the only field force retained was the monument party, which, having finished its work on parallel 31° 20′ and the meridian section, in November, 1893, took up the work of locating and erecting monuments westward from the one hundred and eleventh meridian.

On taking the field again, after its reorganization at Tucson, this party was considerably strengthened to meet the increased difficulties on this part of the boundary, and consisted of the following men and transportation: One commissioner, Lieut. Col. J. W. Barlow; B. A. Wood, assistant engineer, in special charge of location; D. R. Payne, photographer and overseer; J. T.

Amos, quartermaster and clerk; M. E. Cunningham, wagon master; John Duncan, foreman of laborers; Joe H. Wheeler, rodman; 1 blacksmith, 1 stone mason, 9 laborers, 9 teamsters, 2 cooks, and 2 helpers—a total of 31 men; 2 spring wagons, 1 buckboard, 3 water-tank wagons, 5 baggage wagons, 1 truck wagon, 5 horses, and 36 mules.

The commissioner met with a severe accident early in December which compelled him to leave the field for several months. General charge of operations was then given to B. A. Wood, assistant engineer, whose zeal, energy, and intelligence are worthy of special mention in connection with this part of his service.

The above organization of the monument party was continued while operating between the one hundred and eleventh meridian and the Colorado River. On reaching Yuma the question of supply became much simplified, and the force was considerably reduced. The supply camp, hitherto a necessity, was discontinued, and the surplus transportation sent overland under charge of Mr. Amos, to San Diego, where it was subsequently sold. Mr. Wood's services being required in the office at San Diego, Mr. Ingram relieved him at this point.

The following organization was that employed in monument location and erection from the Colorado River to the Pacific: E. L. Ingram, assistant engineer, in charge; D. R. Payne, overseer and photographer; M. E. Cunningham, wagon master; 1 blacksmith, 1 cook, 1 helper, 2 packers, 3 teamsters, 5 laborers; a total of 16 persons.

The transportation consisted of 1 spring wagon, 1 buckboard, 2 baggage wagons, 2 water-tank wagons, 1 truck wagon, 3 horses, and 26 mules.

There were employed in the office at San Diego at this time upon clerical and preliminary map work: L. Seward Terry, secretary and disbursing clerk; J. L. Van Ornum, assistant engineer; J. F. Hayford, assistant engineer; B. A. Wood, assistant engineer; James Page, computer; P. D. Cunningham, computer; P. A. Mosman, computer; Joseph Thompson, assistant clerk.

This office force was reduced as rapidly as the services of these assistants could be spared.

The monument party completed the erection of monuments to the Pacific in June, 1894, when the party was disbanded and the transportation and camp equipage sold. The assistant engineer and the photographer joined the office force in San Diego, and were engaged in preparing the records of their work until the fall, when the entire commission adjourned to meet again in Washington in October, 1895, to complete the reports and maps of the expedition.

It has been previously stated that the principal assistants, who were engaged at the beginning of operations, continued with the expedition until the close of the work for which they were employed. It is proper to add in the case of each of these gentlemen, viz, Messrs. Van Ornum, Hayford, Ingram, and Wood, that they all brought to bear upon their duties rare intelligence and excellent previous training, and throughout the difficult and arduous work devolving upon them were ever willing and prompt to further the interests of the commission. To them is due large credit for the successful completion of the survey and the erection of the monuments.

The same might be said of Mr. L. S. Smith, who, holding the position of transitman from the beginning, was advanced in pay and responsibility, and is especially deserving of commendation for efficiency in investigating the causes of stadia error.

The services of Mr. A. F. Woolley, jr., transitman, were also valuable and appreciated during the several months that he remained with the expedition.

It is also proper to mention, in this connection, the services of Mr. James Page, computer and transitman, for thorough efficiency, and those of Mr. P. D. Cunningham, a most zealous and conscientious young engineer, who rose from the position of levelman to that of assistant engineer.

Messrs. C. W. Speiermann, Ernst Franké, and H. B. Finley were faithful, industrious, and thoroughly conscientious assistants, who rose from subordinate positions to places of higher responsibility and pay during the progress of their work.

Maj. T. H. Logan deserves especial mention for rare skill, zeal, and industry in managing men and transportation in the field, and would have undoubtedly continued to the end except for physical disability.

Mr. L. Seward Terry, secretary and disbursing clerk, performed his delicate and responsible duties from the beginning to the close of operations with entire satisfaction, combining in his methods clerical ability of high order with rapidity of execution and extreme accuracy of detail.

Mr. J. T. Amos, assistant clerk and assistant quartermaster, was a man of ability and sterling integrity, conscientiously performing the duties assigned to him.

Among the more subordinate members of the expedition were several whose good conduct and pluck under adverse conditions were conspicuous, serving in great measure to prevent accidents and delays in the field. In this list should be mentioned M. E. Cunningham, hired as teamster, and afterwards promoted to wagon master; John Duncan, also a teamster, and promoted to master laborer upon monument work.

Among the most deserving rodmen were Joe H. Wheeler, Thomas Evans, Albert Lang, W. T. Simpson, Albert Davis, and Eugene Gill.

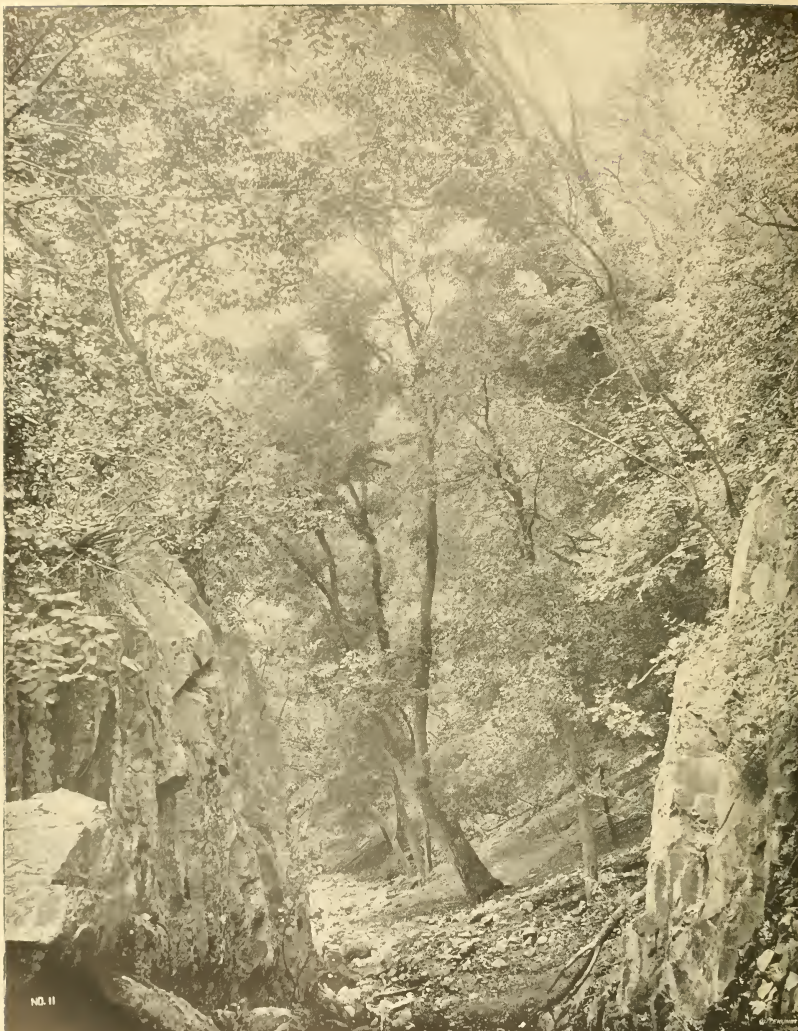
Of the teamsters and packers whose services were specially praiseworthy were W. P. Blair, W. F. Mallory, Jack Nimo, Andrew Linder, John Groves, Charles Rohrer, and Robert Lynch.

Officers of escort with International Boundary Commission.

Name.	Rank.	Regiment.	Date of joining.	Date of relief.
A. C. Ducat, jr	First lieutenant	Twenty-fourth Infantry	Jan. 23, 1892	Feb. 9, 1892
P. E. Trippe	do	Tenth Cavalry	Jan. 29, 1892	Feb. 20, 1892
J. R. Seyburn	Second lieutenant	Twenty-fourth Infantry	Feb. 9, 1892	Aug. 10, 1892
E. A. Mearns	Captain	Medical Department	Feb. 10, 1892	Nov. 1, 1892
R. G. Paxton	Second lieutenant	Tenth Cavalry	Feb. 20, 1892	Mar. 29, 1892
T. G. Irvin, jr	First lieutenant	Second Cavalry	Apr. 12, 1892	Aug. 10, 1892
F. N. Kingsbury	Captain	do	July 3, 1892	do
W. P. Jackson	Second lieutenant	Twenty-fourth Infantry	Aug. 10, 1892	Oct. 10, 1893
W. C. Rawolle	Captain	Second Cavalry	do	Aug. 20, 1892
R. B. Bryan	First lieutenant	do	do	do
J. R. Seyburn	Second lieutenant	Twenty-fourth Infantry	Sept. 1, 1892	Apr. —, 1893
I. C. Jenks	do	do	Sept. 14, 1892	Nov. 9, 1892
M. C. Wessells	Captain	do	Nov. —, 1892	Dec. 6, 1892
H. E. McVay	First lieutenant	Medical Department	do	Apr. 17, 1893
F. A. Winter	do	do	Apr. 17, 1893	Nov. —, 1893
G. H. McMaster	Second lieutenant	Twenty-fourth Infantry	June —, 1893	Oct. —, 1893
E. A. Mearns	Captain	Medical Department	July 22, 1893	Sept. 8, 1894
S. V. Ham	Second lieutenant	Twenty-fourth Infantry	Oct. 10, 1893	Nov. 5, 1893
B. W. Leavell	First lieutenant	do	Oct. 19, 1893	Dec. 20, 1893
W. H. Bean	do	Second Cavalry	Dec. 29, 1893	Aug. 4, 1894
Do	do	do	Aug. 19, 1894	Oct. 2, 1894

Number of enlisted men in escort, International Boundary Commission.

Date.	Number of men.	Date.	Number of men.
1892.		1893.	
January	50	June	64
February	50	July	65
March	50	August	62
April	88	September	61
May	87	October	50
June	85	November	30
July	86	December	30
August	87	1894.	
September	87	January	30
October	87	February	30
November	88	March	29
December	35	April	29
1893.		May	29
January	35	June	29
February	35	July	23
March	45	August	13
April	43	September	15
May	43		



Turkey Cañon, near Monument No. 66.   Cañón cerca del Monumento No. 66.

CHAPTER II.

GENERAL DESCRIPTION OF THE COUNTRY ADJACENT TO THE INTERNATIONAL BOUNDARY LINE.

Any general description of the country adjacent to the international boundary line between the Rio Grande and the Pacific must of necessity give an incomplete idea of its appearance to one unfamiliar with the arid regions and the peculiar character of its fauna and flora, for probably in no section of the United States of equal extent is the rainfall so small and the summer heat so intense. The average annual precipitation along the entire boundary is but about 8 inches, and on the Yuma and Colorado deserts but 2 or 3 inches, a deficiency which will be made more significant to the ordinary reader when it is stated that the boundary line, although having a total length of about 700 miles, crosses but five permanent running streams between the Rio Grande and the Pacific and this, too, although crossing most valleys and mountain ranges nearly at right angles, the direction most favorable for encountering all existing streams.

From the summer of 1890 to that of 1893 the entire country between the Rio Grande and the Colorado suffered from a drought of unprecedented duration and severity, the effects of which were intensified by the overstocked condition of the ranges. This state of affairs added greatly to the difficulties and expense of the survey. Vegetation was parched, water holes dried up, and scarcely any grass was left by the famishing cattle. This long drought was broken by abundant rains in July and August, 1893, but not until the stock-raising interests had suffered severely.

The small rainfall of this region generally occurs at two periods of the year—midwinter and midsummer—the latter rainfall the greater and by far the most important; consequently this period is known as the "rainy season." The summer rains generally commence about the 1st of July and cease sometime between the 1st and 20th of September. It is soon after the first of these rains that vegetation in this region begins to assume a spring-like character. Leaves burst forth, the hills and valleys are covered with grass, and a bewildering profusion of wild flowers covers the entire country. As if conscious of the short duration of the rainy season, these grow with great rapidity, and their seeds mature ere the rains cease. In a month or so thereafter they have again assumed the somber colors typical of fall and winter. Thus in the short space of three or four months vegetation here enjoys its spring, its summer, and its autumn.

Before going more into details it may be well to note certain general characteristics of this region which at once strike the ordinary traveler.

These are the bare, jagged mountains rising out of the plains "like islands from the sea;" the abundance of the evidences of volcanic action in times geologically recent; the parallelism of the mountain ranges with one another, and with the Pacific Coast; the general absence of trees; the preponderance of evergreen vegetation, and its dull, leaden-green hue; the prevalence of thorns in nearly all vegetation; the general absence of fragrance in flowers; the resinous character of the odor of the most common trees and shrubs, and the abundance and large size of the cactus.

The entire country along the boundary is thinly settled, the principal settlements within 20 miles of the boundary on either side being at Lake Palomas, Hachita, the Sulphur Spring Valley, La Morita, the San Pedro Valley, the Huachuca Mountains, the Santa Cruz Valley, Oro Blanco, Arivaca, the Baboquivari Valley, the Papago rancherías of Pozo Verde, Cobota, and Pozo de Luis, the Sonoyta Valley, the Colorado River Valley, and the country between the summit of the Coast Range and the Pacific. The only towns within the limits above mentioned are Bisbee, Santa Cruz, Nogales, Yuma, and San Diego. With the exception of these towns and settlements the rest of this zone of about 24,000 square miles contains less than 100 permanent inhabitants.

Mining and stock raising comprise the principal occupations of the settlers, but at the time of the survey both of these were in a very depressed condition, owing in the one case to the low price of silver, and in the other to the long drought of three years' duration and to the overstocked condition of the ranges. An exception to this depression, however, was found at Bisbee, Ariz., where are located the mines and reducing works of the Copper Queen Company, which are reported as returning excellent profits to the owners.

Although the soil in many places is very fertile, yet the great scarcity of water renders it impossible for the inhabitants to carry on agriculture, except to a very limited extent.

But for sandy stretches on the deserts many miles in length, and rough passes through the mountains, the natural roads along the boundary are very good. With the exception of the Colorado River section, there exists, however, no practicable wagon road along any one of the six sections of the boundary line and within a reasonable distance of it, which lies either entirely in the United States or in Mexico, a fact which even now, in spite of the small number of inhabitants along the boundary is the cause of considerable unavoidable inconvenience to travelers when customs officials are encountered.

It is rather remarkable that an arbitrarily chosen boundary line like the one under discussion, should, between the Rio Grande and the Colorado River, follow almost exactly the summit of the divide which separates the waters flowing north into the United States from those flowing south into Mexico.

Having given the foregoing general description of the boundary line, the different sections, beginning at the Rio Grande, will be briefly described in turn.

Section 1, parallel 31° 47′.—The Rio Grande in the vicinity of El Paso, Tex., is a variable stream with turbid waters carrying an immense amount of sediment, and as a consequence it is bordered by alluvial bottoms, through which by erosion, it is continually changing its bed. Floods generally occur in June and July, but during the greater part of the year the volume of flow is comparatively small and the river can readily be forded. In dry seasons it ceases entirely to flow for weeks at a time. In the immediate vicinity of the Initial Point of the boundary the mountains on either side encroach on the river, and as a consequence its banks there are more stable and its changes of bed smaller in extent.

Leaving the Rio Grande the boundary line crosses the Muleros Mountains, a rugged, broken mass, almost destitute of vegetation, composed of a curious and bewildering intermixture of stratified limestone and igneous rocks. Between 2 and 3 miles west of the summit of the Muleros Mountains the line reaches, by a rather abrupt ascent, the surface of a wide, sandy mesa, about 4,000 feet above sea level, over which it continues for a distance of about 48 miles. Mile after mile this mesa stretches in an endless monotony of flat, rolling ridges and shallow valleys, with not a tree to relieve the dreary aspect of the landscape. The earth is covered with a coarse, brownish-yellow sand, which supports, in places, an excellent growth of black grama grass, and a stunted growth of greasewood, mesquite, yucca, and "ochetilla" (Fouquieria splendens).

On the edge of this mesa lies the Sierra del Potrillo, a cluster of bare, rounded mountains, giving evidence, by extinct craters and the extent of the "mal pais" in its vicinity, of considerable volcanic activity in the past. Toward its western edge the mesa becomes more rolling, and rocky hills covered with broken lava are scattered at intervals over its surface.

Descending from the mesa by a well-marked and rather abrupt descent, the line passes for a distance of about 17 miles over a broad, level valley, bare of vegetation, and having a soil composed of a stiff clay sediment, which becomes almost impassable when wet. This valley lies between the Floridas and the Tres Hermanas mountains, and extends in a north and south direction.

Down this valley, and connecting at Deming, N. Mex., with the Southern Pacific Railway, a railroad had been located a year or two previously, and the grading extended from Deming to a point several miles below the boundary, when work was suspended on account of financial difficulties. Anticipating the completion of this railroad a town site was laid out where it crossed the boundary line; lots were sold, and a small settlement, bearing the name of Columbus, was started.

A mile or two south of this settlement commences a chain of shallow, marshy lakes, whose waters are strongly impregnated with alkali, and which are connected with one another by a small running stream. This chain, called Lake Palomas, terminates in a broad, shallow lake, several square miles in area, with no visible outlet. When the water in this lake is low its shores are covered with an alkaline deposit, 2 or 3 inches in depth, resembling snow.

About 5 miles south of the boundary, on the western edge of the chain of lakes, and near some fine, bold springs, was located the Mexican custom-house, which had been recently moved there from Ascencion as a punishment for an outbreak against the Government at that place. One troop of cavalry was quartered there at the time, giving to the place an unexpected appearance of life and activity. The peculiar chain of lakes constituting Lake Palomas is supposed to be due to the reappearance of the waters of the Mimbres River after their long underground

Mosquito Spring. Aguaje del Mosquito.

Camp of U. S. Section.
At Dog Spring, New Mexico.

Campamento de la Sección de los E. U.
En el Ojo del Perro, Nuevo México.

journey. Beyond these lakes they reappear no more. Lake Palomas is the first natural water encountered near the boundary after leaving the Rio Grande, distant 75 miles by road. Water had been obtained, however, before reaching Columbus, from a well at a ranch on the edge of the valley about 3 miles northwest of Monument 15.

An excellent road leads from Deming, via Columbus, to the Mormon settlements in Chihuahua, but the road to El Paso, after leaving the Mimbres Valley, is sandy, very heavy, entirely without water, and practically impassable unless an abundant supply of water is carried along.

After leaving the valley of the Mimbres the line passes for several miles over the rolling, grass-covered ridges lying south of the Tres Hermanas Mountains, a region marked by abundant evidences of past volcanic activity.

Beyond these ridges a wide, flat valley is crossed, and the line then passes over the Carrizalillo Mountains, a spur of the Sierra Boca Grande to the southwest. On these mountains were seen the first trees encountered since leaving the Rio Grande; a few stunted cedars, which found a precarious growth amid the broken basalt which everywhere covers the surface of the mountains.

A little over 4 miles north of Monument 33 lies Carrizalillo Spring, the first water after leaving Lake Palomas. This spring furnishes an abundant supply of good water, most of which is utilized in supplying the needs of a cattle ranch located in the immediate vicinity.

Beyond the Carrizalillo Mountains the line crosses a broad, grass-covered valley, 10 or 12 miles wide; then it enters the Apache Mountains, where it terminates at Monument 40, a fine, cut-stone monument, with suitable inscriptions. These mountains contain an abundance of low-grade silver ore, from which but little profit is derived, owing to the scarcity of water and the cost of transportation. A good road leads from this vicinity, via Carrizalillo Spring, to Deming, N. Mex., and another, via Hachita, to Separ, a station on the Southern Pacific Railway.

Section 2, the meridian section.—Commencing at Monument 40 the lines passes, for a distance of about 5 miles, over the Apache Mountains and then over a broad, fertile valley, covered with a thick growth of mesquite, greasewood, etc., on its northern and western border, and with excellent grass in other places. This valley is bounded on the northwest by the majestic Sierra de la Hacheta (locally known as the Big Hatchet Mountain), and stretches away to the south and east to unite with the valley of the Corralitos River.

A little over a mile east of Monument 46 are situated the "Ojos de los Mosquitos," yielding a plentiful supply of water, impregnated with alkali. From this point good roads lead to Carrizalillo Spring, Dog Spring, Ascencion, and the settlements along the Corralitos River. From Monument 46 the portion of the valley over which the line passes rises with a gentle slope toward the south, until the foothills of the Dog Mountains are reached, when the section terminates at an elevation of about 4,900 feet above sea level. This point is marked by Monument 53, a fine, cut-stone monument, identical in appearance with that marking the beginning of the section.

Section 3, parallel 31° 20′.—From Monument 53 the line passes for several miles over the rough hills south of the Dog Mountains, thence across the east branch of the Playas Valley, the Whitewater Hills, the west branch of the Playas Valley, and the San Luis Mountains, all in a distance of about 35 miles. A little over a mile north of Monument 55 is Dog Spring (Ojo del Perro), at which is located a cattle ranch, and which furnishes a supply of excellent water sufficient for several thousand head of animals. The country along this part of the boundary is covered with excellent grass, which affords pasturage for numerous cattle and horses.

A little over 6 miles north of Monument 58 is Alamo Hueco Spring, where the supply of water is both excellent and abundant. At the south end of the Whitewater Hills water can generally be found, but in very dry seasons the quality is poor and the supply very limited. In such cases, however, a plentiful supply can be obtained about 6 miles southwest of this point, at "San Francisco Water." This entire region abounds in game, and is a veritable hunter's paradise. Hundreds of antelope roam over the valleys, and deer, bear, and turkeys are plentiful in the mountains.

On the summit of the San Luis range, which here forms the "continental divide," the boundary line attains its greatest elevation, about 6,600 feet above the sea. About 4½ miles north of the boundary the road from Dog Spring crosses the mountains by an excellent pass known as San Luis Pass. Two miles north of the line is another pass less traveled than the former, but shortening the distance considerably.

To the north of San Luis Pass the range gradually rises in height to Animas Peak, which practically marks its northern extremity. To the south of the pass the mountains become higher and more rugged, and the range stretches south into Mexico as far as the eye can see, forming here the axis of the Sierra Madre, and presenting a wild and picturesque beauty singularly fascinating. On the foothills and lower slopes the prevailing rock is red basalt, while on the summit and upper slopes it is apparently an igneous rock of volcanic origin resembling granite. The valleys at the base and lower slopes are dotted with evergreen oaks, the acorns affording food for thousands of wild pigeons, while on the upper slopes are dense forests of juniper, pine, fir, and Arizona cypress.

A few hundred yards northeast of Monument 66 is situated San Luis Spring, which affords a moderate supply of fair water, and from which good roads lead to Lordsburg and Separ, on the Southern Pacific Railway. No settlements are now found in this vicinity, those at one time existing having been abandoned during the raid of the noted Apache chief, Geronimo. Prospective settlers are now deterred through fear of a small band of renegade Chir-i-ca-hua Apaches, who, under the leadership of the redoubtable "Kid," still continue their murderous raids in the vicinity, and as yet have succeeded in escaping the pursuit of the numerous detachments of troops sent against them.

Leaving the San Luis Mountains the line passes over the Animas Valley and the Guadalupe Mountains and descends into the San Bernardino Valley. The Guadalupe Mountains where crossed by the boundary line are in reality but the broken, jagged edge of a terrace, marking a descent of about 1,400 feet from the Animas Valley to the San Bernardino Valley. For the most part bare of trees, they present to the eye a confused mass of peaks, crags, ridges, and cañons. Through these the old emigrant road makes its way by sudden turns and steep descents until it enters the Guadalupe Cañon, which gradually widens, improving the character of the road thereby. This rough and difficult passage, called Guadalupe Pass, is the only route through the mountains within many miles north or south of the boundary.

Monument 71 in these mountains marks the intersection of the boundary line between Arizona and New Mexico with the international boundary line.

By local repute the boundary line between Sonora and Chihuahua is said to intersect the international boundary line at the same spot; but as this boundary line is generally shown as the axis of the Sierra Madre, it would seem that the intersection should occur at Monument 65, on the San Luis Mountains. Water was found at a small spring in Guadalupe Cañon, and also in wells near the point where the boundary line crosses the cañon.

In San Bernardino Valley the line crossed the first running water since leaving the Rio Grande, over 192 miles distant. In this valley, a few miles north of the boundary line, rises San Bernardino Creek, the most northerly tributary of the Yaqui River. Numerous springs are found in the valley, and thousands of cattle seek pasture on its marshy surface. A large ranch is established at some fine springs just north of the line, while a short distance south of the line are found the ruins of a bastioned adobe fort and numerous outbuildings, marking the site of a flourishing presidio established during the Spanish rule. Good roads lead from San Bernardino to Tombstone and Bisbee.

Crossing the gravelly mesa west of the San Bernardino Valley the line passes over the Perrilla Mountains, which, with the Swisshelm Mountains to the north, form a spur of the Chir-i-ca-hua Mountains, and divide the San Bernardino Valley from the Sulphur Spring Valley. A short distance south of the line is a very prominent, flat-crested peak, Cerro Gallardo, locally known also as "Niggerhead," which forms a prominent landmark. About 2 miles southeast of Monument 81 was located a "vinateria," where a supply of good water was obtained from a shallow well.

From the Perrilla Mountains the land slopes gradually and uniformly down to the middle of the valley, and by a similarly long and tedious slope the foothills of the Mule Mountains are reached. Several settlements are located in this valley, as water can always be obtained by sinking wells to a moderate depth.

Crossing this valley the boundary line passes through a gap near the southeastern extremity of the Mule Mountains, thence along the north slope of the valley lying between the Mule Mountains and the Sierra San José until the valley of the San Pedro River is reached.

About 10 miles north of the boundary line, in the Mule Mountains, is located the prosperous mining town of Bisbee, a place of about 2,000 inhabitants. About 20 miles to the northwest of

Camp of Mexican Section.
At San Bernardino, Arizona.

Campamento de la Sección Mexicana.
En San Bernardino, Arizona.

Mexican Custom-House, La Morita. Aduana Mexicana en la Morita.

Bisbee is Tombstone, once one of the great mining camps of the world, but now containing about 1,500 inhabitants, and bearing on all sides evidences of depression and decay.

About 4 miles south of Monument 90 is located the Mexican custom-house of La Morita, recently moved there from the San Pedro River. From the Mule Mountains to the end of parallel 31° 20′ the country is fairly thickly settled, and the distance between watering places nowhere exceeds 10 or 12 miles; consequently in this region it is not necessary, as heretofore, to describe all available water in detail.

The San Pedro River, in the vicinity of the boundary line, is ordinarily a stream of about 15 feet in width and 6 or 8 inches in depth, fringed with a fine growth of cottonwood and willow, and possessing the distinction of being the only southern tributary of the Gila which has an uninterrupted flow throughout its entire length. The valley bordering the river is very fertile, but the bed of the river has sunk so deep that irrigation is attended with many obstacles, and consequently but a very limited portion of the valley is under cultivation. On the east bank of the San Pedro, a few miles south of the line, is the little village of San Pedro, where until very recently was located the Mexican custom-house, now removed to La Morita. A good road leads from Benson, through the San Pedro Valley, to the high table-lands of northern Sonora.

From the San Pedro River the slope rises rapidly, but uniformly, to the Huachuca Mountains, over the southeastern end of which the line passes at an elevation of about 6,100 feet. These mountains and their lower slopes are covered with a heavy timber growth generally similar to that found on the San Luis Mountains. They are the highest embraced within the limits of the survey, attaining, at a point about 4 miles north of the boundary, an elevation of about 9,400 feet. At the foot of the mountains, about 15 miles north of the line, is beautifully situated Fort Huachuca, an important post garrisoned by four companies of infantry and two of cavalry.

From the Huachuca Mountains to the San Rafael Valley the line passes over a beautifully picturesque grazing country, badly cut up by cañons, from which it descends into the San Rafael Valley, the name by which is known that portion of the valley of the Santa Cruz River lying east of the Patagonia Mountains and adjacent to the boundary line.

The Santa Cruz River rises in the hills a few miles north of the boundary, flows south into Mexico for about 15 miles, then turns around the south end of the Patagonia Mountains and flows north, again crossing the boundary line, and continuing its generally northern direction, flowing for a short distance and then sinking beneath the sands, to reappear again, until it disappears finally a short distance beyond Tucson. The stream is bordered by a noble growth of cottonwoods, whose bright green leaves were a welcome sight after the ashen-green color of the vegetation previously encountered. That portion of the valley of the river which lies in Mexico is very fertile, and a considerable part of it is under cultivation. The little town of Santa Cruz is picturesquely situated in this valley at the foot of the mountains, about 7½ miles south of the line.

In the San Rafael Valley, at La Noria, is situated the United States custom-house, from which a rough road leads to Crittenden, on the Arizona and New Mexico Railway, and a good road down the Santa Cruz Valley and around the Patagonia Mountains to Nogales.

Leaving the San Rafael Valley the line passes over the rough, oak-clad foothills of the Patagonia Mountains, which it crosses in a gap a short distance north of San Antonio Pass, at an elevation of about 5,600 feet. These mountains are quite picturesque, being heavily wooded, the growth consisting principally of oak, with a few conifers on the higher slopes. They are rich in minerals and contain some of the first mines worked by Americans in Arizona. The San Antonio Pass, an excellent one for pack animals, crosses this range a little south of the line and cuts off the tedious detour along the Santa Cruz Valley.

From the Patagonia Mountains the line descends over a badly cut up hill country to the Santa Cruz River, which it crosses for the second time. The elevation of the river is about 3,675 feet, and it is somewhat singular that the two lowest points on the boundary between the west end of parallel 31° 20′ and the Initial Point on the Rio Grande differ in elevation less than 16 feet from each other, and less than 23 feet from the Initial Point on the Rio Grande. The two points in question are at San Bernardino Creek and the second crossing of the Santa Cruz River, the former being the lower of the two.

From the Santa Cruz the line begins to ascend, passing over a hilly country, the broken and cut up character of which increases to the termination of the line in the Sierra de los Pajaritos at an elevation of about 4,800 feet.

Nestling amidst the hills, in a narrow valley about 8 miles east of the termination of parallel 31° 20′, lies the town of Nogales, containing about 3,500 inhabitants, and built on both sides of the boundary line, which passes tangent to the south front of the buildings on the United States side of International street. This street has a width of about 50 feet and lies entirely within Mexican territory. The grasping and overreaching action of the United States settlers in building right up to the boundary line results in many inconveniences to the customs officials and peace officers of the United States, who, in order to patrol this important street, must rely for permission to do so upon the kindness and courtesy of the Mexican officials. Open, yet lawful, evasions of customs duties result from the position of this street with reference to the boundary line, as in one somewhat noted case observed where liquors of United States manufacture were sold to the consumer in a saloon on the United States side of the line, while cigars of Mexican manufacture were sold by the same establishment from a stand in front of the saloon but on the Mexican side of the line, thus enabling consumers from either side to obtain, duty free, liquors and cigars from the same establishment.

At Nogales are located both the United States and Mexican custom-houses, the latter a fine, well-arranged building, the annual customs receipts of which are very large, as Nogales is situated on the railway which runs from Benson, Ariz., to Guaymas, on the Gulf of California, and is the only railway entering Mexico between the Rio Grande and the Pacific.

Good roads lead from Nogales north to Tucson, and south to Magdalena, Hermosillo, and Guaymas.

Section 4, the azimuth line from the west end of parallel 31° 20′ to the Colorado River.—A fine masonry monument, No. 127, situated in the Sierra de los Pajaritos, on the north slope of a steep ridge, marks the beginning of this section of the boundary line, which for about 21 miles continues in these mountains.

The term "Sierra," as applied to them, is a decided misnomer, for unlike the mountains previously encountered, they consist of a confused mass of rocky crags, peaks, flat-topped mountains with vertical sides, enormous trachyte dykes, steep, narrow ridges, and deep cañons, all mingled in startling confusion. The most common rocks are porphyry, red basalt, syenite, and volcanic breccia. Gold and silver veins are found in numerous places, and placer gold is obtained in most of the cañons.

The mountains are covered with a fine growth of evergreen oak, juniper, and manzanita, while magnificent walnut, sycamore, and ash trees line the cañons. Excellent grass covers the hills; thousands of beautiful wild flowers spring up on all sides during the rainy season; game is abundant, and the climate unsurpassed. From the highest part of these mountains the view is beautiful beyond description, and stretches away for 75 or 100 miles in every direction.

Throughout this entire region, probably one of the roughest and most cut up in North America, there are no roads and but a few blind trails. Little or no water is to be found during the dry season, except by digging, although there is evidently a considerable underground drainage, as the Altar River, Arivaca Creek, and Nogales Creek, all permanent streams, derive their waters from the drainage of these mountains, which were notable, not only on account of their beauty, but also because they constituted the last timber-covered mountains encountered on the survey until the Coast Range was reached, and because in them was seen for the first time the strange and ungainly "giant cactus" (cereus giganteus), called "suguaro" by the Mexicans.

Leaving the Sierra de los Pajaritos the line crosses in succession the Baboquivari Valley, the Baboquivari Mountains, and the Moreno Flat.

Although absolutely bare of trees and bushes, it is hard to picture a more beautiful valley than the Baboquivari, in the vicinity of Buenos Ayres, during the "rainy season." To the northwest towers the striking Baboquivari Peak, venerated by the Papagos as the abode of their God; in the foreground is a wide lake, while in every direction stretch gentle swells and hollows covered with magnificent grass and with a profusion of wild flowers. Thousands of cattle and horses find pasturage in this valley, and stock raising would be very profitable did this condition of things last; but the ranges here, as in all places along the border, are overstocked; the lake dries up in the spring, and water has to be pumped from bored wells several hundred feet deep. This valley marks the eastern limit of the region along the boundary reached by the summer

Mexican Custom-House, Nogales, Sonora.

Aduana Mexicana en Nogales, Sonora.

INTERNATIONAL STREET, NOGALES. CALLE INTERNACIONAL, NOGALES.

"sea breezes" from the Gulf of California, which here were constant and refreshing. In the hills, at the south end of the valley and a short distance below the line, is situated the Mexican custom house of Sasabe, while at Buenos Ayres, about 6 miles north of the line, is located the United States custom-house.

At the foot of the Baboquivari Mountains (here called the Pozo Verde Mountains), a little over a mile south of the line, is located the Papago Ranchería of Pozo Verde, named from a fine spring in the vicinity, which is the only natural water, except that in the Sonoyta Valley, until the Colorado River—200 miles distant—is reached. This ranchería consists of about 35 adobe huts, and contains a population of about 150 persons, who own several hundred head of cattle and horses. An excellent road leads from Tucson, via Buenos Ayres, La Osa, and the south end of the Pozo Verde Mountains, to Pozo Verde, while another and shorter road on the west side of the Baboquivari Mountains leads from Tucson, via La Ventana, to the same place.

The broad valley west of the Baboquivari Mountains is called the Moreno Flat, from a mountain of the same name on its west slope. The soil of this valley is very fertile and supports a fine growth of mesquite. In seasons of normal rainfall the grazing is excellent, but as little rain had fallen during the long drought preceding the survey, scarcely a blade of grass could be seen, while the surface of the entire flat was cut up by innumerable cattle tracks, leaving the soil loose and powdery for a depth of 2 or 3 inches.

In this valley, on July 3, 1893, was encountered a sand storm of frightful violence. About 4 o'clock in the afternoon a dense, dark-brown cloud was seen rising in the south, which presented a singularly threatening appearance. The sun, which until then had been shining brightly, was soon overcast, and in a few minutes after the cloud was first noticed the storm burst in all its fury, filling the atmosphere to a height of several hundred feet with the loose soil of the valley. In ten or fifteen minutes after the storm burst it became as black as midnight, respiration was almost impossible, and it was only by breathing through a handkerchief held in front of the mouth that suffocation was avoided. In about half an hour the wind began to subside and the darkness to diminish, and finally, in a little over two hours after the storm commenced, the setting sun shone faintly through the particles of dust which still filled the air.

Many sand storms were encountered during the progress of the work, but none so appalling as this in its suddenness, violence, and darkness, and none so remarkable for the brevity of its duration.

A few miles northeast of the Moreno Mountain, in the center of the valley, has recently been located a large cattle ranch, called La Ventana, at which a good supply of slightly alkaline water is pumped from two artesian wells, between eight and nine hundred feet deep. This ranch is the last white settlement in the United States near the boundary until the Colorado River Valley is reached.

From the Moreno Flat the line passes over a low saddle in the mountain of the same name, thence over the mesquite-covered flat northeast of the Cobota Range, passing but a few yards north of the low, rocky, vertical escarpment which marks the most northernly point of this range. The flat terminates at the Lesna Mountains, a jagged trap-like range, composed principally of porphyry, and forming a spur of the Cobota Mountains.

This range is bordered on both sides for a width of several miles by a luxuriant growth of mesquite, palo verde, palo fierro, and cactus. At the point where the line crosses is a remarkable peak, called Cerro de la Lesna, having vertical sides and two horn-like prominences, over the north one of which the line passes. About 6 miles southeast of this peak is the Papago Ranchería of Cobota, plentifully supplied with water from a shallow well. About 2 miles west of Cobota is a Yaqui and Papago Ranchería, called Pozo de Luis (and also El Vanorí), situated at the west entrance of the pass through the Cobota Mountains. At these rancherías were seen large herds of cattle and horses, all in excellent condition, and the former superior to any others seen on the survey. The water at Pozo de Luis is the last encountered until Sonoyta, distant 50 miles by wagon road, is reached.

About 2 miles north of Cerro de la Lesna a few "renegade" Papagos, called "Los Coches," were located at a well which is reputed to yield a very unreliable supply of water. These Indians were fugitives from Mexican justice, having been outlawed for their numerous crimes. They were much dreaded by the few travelers through this region, but failed to sustain their reputation, for on approach of the working parties they abandoned their ranchería with all its contents and did not return until the survey had progressed many miles beyond.

The country along the boundary on both sides of the line between the Baboquivari Mountains and the Sierra de las Tinajas Altas forms a part of the Papaguéria, a region probably as little traveled and as little known by white men as any in our country.

The Papaguéria, as indicated by its name, is settled almost exclusively by the Papagos, a tribe which numbers several thousand persons, only about one-half of whom reside within the limits of the United States. This entire region is a hopeless desert, on which none but these hardy Indians could find subsistence. At the few permanent wells and springs are located their rancherías, from which, as soon as the July rains begin, they scatter over the Papaguéria to their numerous "temporales."

These "temporales" are located near some natural or artificial water hole, from which their supply of drinking water is obtained, and are in close proximity to cultivable lands. The houses are generally built of adobe, and the fields protected by rude fences of mesquite brush. In the "temporales," so deserted and forlorn during most of the year, a wonderful change takes place within a day or two after the first rain of summer. Where before all was desertion and silence all is now life and activity. Cattle and horses are being driven to pasture; houses and fences repaired; Indian corn, beans, pumpkins, and melons planted, dams repaired, and shallow irrigation ditches cleaned out.

In many cases the natural rainfall alone is relied upon and no recourse is had to artificial water holes or ditches. Owing to the fertility of the fields and the heat of the climate the crops mature rapidly, and in three or four months the "temporales" are again silent and deserted. Occasionally, when the winter rainfall is unusually great, crops of wheat are also grown at the "temporales." During June and July the food supply is greatly augmented by the fruit of the giant cactus, which ripens then, and which is gathered in great quantities by the squaws. Some of it is eaten fresh; some dried for winter use; some boiled into preserves; from some a beautiful carmine sirup is made, and not a little is consumed in the manufacture of a slightly intoxicating fermented drink. Another drink, nonintoxicating and very refreshing, is made from a minute, gum-coated seed called "chilla," which partly dissolves when placed in water.

Every year the Papagos make long excursions to the mountains to gather acorns for food, and in times of scarcity they make great use of mesquite beans and seeds of certain grasses. They are an intelligent tribe, peaceably disposed both toward the United States and Mexico, but possessing an undying hatred for their old enemies, the Apaches. The men are well armed and are skillful hunters, and the young squaws far above the average in good looks. Like the Yumas, Co-co-pahs and Diegeños, the Papagos proved thoroughly honest as far as this expedition was concerned, not a single piece of property and not an article of food having been stolen, and this, too, notwithstanding the fact that throughout the Papaguéria, owing to the great scarcity of water, the escort was always camped many miles from the working parties.

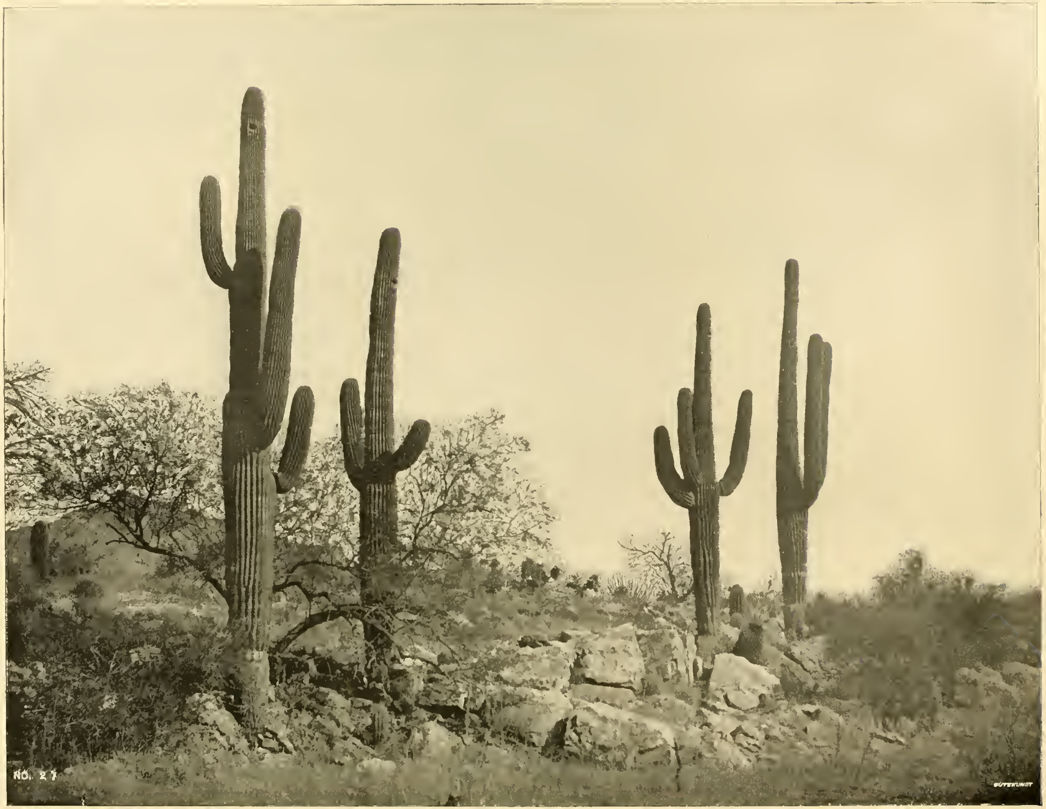
The Papagos look with longing for the coming of "Moctezuma," their promised Messiah, who is to right all wrongs and to make the arid desert a garden and his people greater than all others. Except in the vicinity of civilization, their houses are built with the doors facing the east, so that when Moctezuma comes with the rising sun he may find all doors open for him.

Leaving Cerro de La Lesna the line crosses a broad, mesquite-covered flat, about 18 miles in width, and then passes in succession over the east branch of the Sierra de la Nariz, the Santa Rosa Valley, in which is located a "temporal" of the same name, and the west branch of the Sierra de la Nariz. This range is a spur of the Sierra del Ajo on the north, and is a bare, rugged mass of igneous rocks overlaid with a capping of broken black lava, which gives it a most dreary and somber aspect. On the east branch of the range just north of the line is a most interesting and elaborate system of fortifications, formed of walls of lava about waist high and 2 or 3 feet in thickness, excellently located for defending the crest against assault. These fortifications were said to have been constructed by the Papagos for defense against Mexican troops when the region belonged to Mexico; but this is a mere tradition, which could not be verified.

At the south end of the east branch of the Sierra de la Nariz is located the Nariz Temporal, a little south of the road from Altar to Sonoyta.

Sonoyta River, Sonora.

Río de Sonoyta, Sonora.



GIANT CACTUS.
Near Tule Mountains.

CACTUS GIGANTE.
Cerca de la Sierra del Tule.

After leaving the Sierra de la Nariz the line passes over a valley about 12 miles wide and then crosses the Sierra de Sonoyta, at the end of which flows the Sonoyta River, a stream about 12 feet wide and 6 or 8 inches deep.

Sonoyta was formerly quite a flourishing little agricultural village, but heavy rains caused the river bed to sink so deep below the level of the surrounding lands that irrigation was attended with many difficulties, and by a lamentable want of energy and united action in constructing a dam to raise the level of the water the village fell into decay, family after family moving away, until now scarce a half dozen Mexican families remain, while abandoned fields and magnificent fig trees, dying for want of water, are painful reminders of past prosperity. About 8 miles west of Sonoyta is situated the Mexican custom-house at Santo Domingo, on the ranch of Don Cipriano Ortega, who cultivates about 300 acres of land, the largest area under cultivation by one person near the entire boundary. About 6 miles west of Sonoyta is the little settlement of Quitobaquita, near some fine springs, which burst out of the hills on the United States side of the line, but serve to irrigate a field near the river, on the Mexican side. Two families of Mexicans reside here, but the houses near the springs all lie within the limits of the United States. The valley of the Sonoyta is quite fertile and must at one time or another, as shown from evidences now remaining, have been almost all under cultivation. The Sonoyta River drains a very large basin, embracing almost the entire country between the Cobota Mountains and its actual source, a mile or so east of Sonoyta. For a short distance it continues as a running stream, then disappears, reappearing in the vicinity of Santo Domingo. Beyond this point it reappears, as a succession of shallow pools only, in two places, Agua Dulce and Agua Salada, the character of the water at each place being indicated by its name. Agua Salada is about 11 miles south of west of Quitobaquita. With the exception of the Mexican families located at the settlement before mentioned the other inhabitants of the Sonoyta Valley consist of Papago Indians, who engage in agriculture and placer mining. Rich gold mines have been located in the vicinity of San Antonio, about 30 miles south of the line, but the absence of water renders it extremely difficult and expensive to develop them. About the same distance southwest of Quitobaquita is the prominent Sierra Pinacate, near the foot of which are immense salt beds, at present almost inaccessible on account of the sandy roads and the absence of water.

From Quitobaquita good roads lead to Altar, Mexico (via the Nariz Temporal), Gila Bend, on the Southern Pacific Railway (via the old Ajo Mine), and Tucson, Ariz. (via Nariz Temporal, Pozo de Luis, and Cobota, uniting with the road from La Ventana to Tucson a few miles north of the former place). On all of these roads, however, there are stretches of from 40 to 50 miles without water, and a journey on them should never be attempted in summer unless an ample supply of water is carried along.

Probably nowhere along the boundary does the cactus growth attain such luxuriance as in the foothills of the Sonoyta Valley. The giant cactus here attains a height of 40 or 50 feet and forms perfect forests, if the word forest can properly be applied to a collection of these strange, ungainly, helpless-looking objects, which seem at times to stretch out clumsy arms appealingly to the traveler, and which one can not see on its native desert without unconsciously associating it with the uncouth forms of vegetation peculiar to the Carboniferous Era.

Another large and very striking cactus found in this vicinity is called "pitahaya" by the Mexicans, who esteem it very highly for its most palatable fruit. It consists of a cluster of incurving stems, several inches in diameter and 10 or 15 feet in height, which are covered with coarse, hair-like spines.

All the hills and mountains in this vicinity are covered with a thick growth of "cholla" cactus, the needle-like spines of which readily penetrated shoes, leggings, and clothing, and caused much pain and annoyance to the working parties.

From the Sierra de Sonoyta the line runs along the north slope of the Sonoyta Valley and then passes over the barren, cactus-covered ridges which lie between the Quitobaquita Mountains and the Cerro Salado and separate the Sonoyta Valley from the dreaded Tule Desert.

When the surveying party was working in this vicinity during the month of June, 1893, the heat was intense, the maximum temperature in the shade reaching 118° F. and the mean maximum in the shade for the whole month of June averaging 110° F. The standard thermometer used was not graduated sufficiently high to give the temperature in the sun after 8 or 9 o'clock a. m., at which time it ranged from 130° to 140° F.; the temperature in the shade at this time generally ranging from 95° to 105° F., a ratio which would seem to indicate an average maximum sunshine temperature during June of about 150° F. The temperature during June, 1893, must be considered, however, as in excess of the average, for a thermometer record kept at Sonoyta and covering a period of several years showed this to have been the hottest June during the period covered by the observations.

At times the breeze which had swept over the scorching sands to the south was so hot as to wither vegetation and burn the skin as would the heat from a furnace, rendering it necessary, even when in the shade, to screen the face from its scorching heat.

Leaving the divide north of the Cerro Salado the line strikes the Tule Desert, a wide, waterless area dotted with extinct volcanoes and numerous bare, isolated peaks of black or dark-brown igneous rocks, which but add to the loneliness and desolation of the scene.

About the middle of this desert is a broad, low depression called "Las Playas," which is bordered by a fringe of mesquite and greasewood, and in which a few "charcos," or natural water holes, retain water for a short while after the occasional rains. West of this depression is a considerable area covered with lava from one of the extinct volcanoes in the vicinity. Near the road in this vicinity is the skeleton of a camel, which, the Mexican guide stated with much relish, had been brought for use on the deserts in northern Sonora and had perished here of thirst.

Many miles to the south of the line the view is cut off by ridges of drifting sand, while to the north it is limited by jagged, rocky ranges, among the most prominent of which is the Sierra Pinta, a bare, rocky sierra, one-half of which is light gray while the other half is reddish brown.

Between the Sonoyta Valley and the Colorado River the vegetation consists almost entirely of palo verde, palo fierro, mesquite, greasewood, and giant cactus, while the only grass seen is a tall, uninviting-looking species, called "galleta" by the Mexicans, which mules and horses ate with avidity and which is sufficiently plentiful, when one becomes familiar with the localities where it grows, to supply the place of hay, were it not for the fact that the scarcity of water ordinarily renders it impossible for travelers to delay long enough to permit their animals to graze.

Leaving the Tule Desert the line crosses in succession the Sierra del Tule, the Lechuguilla Desert, the north end of the Sierra Lechuguilla, and the south end of the Sierra de las Tinajas Altas—the name by which this portion of the Gila Range is known.

The three sierras enumerated above present to the eye much the same general appearance, although differing greatly from all other mountains encountered heretofore. They are bare, desolate, rough, and jagged to an unusual degree, and so steep that in many places it is impossible to climb to the summit, while in most places it is both arduous and dangerous; and when the jagged, knife-like crest is finally reached it often proves to be so narrow that it is impossible either to walk along it or set up an instrument there.

All three of these ranges rise directly out of the surrounding desert and appear to be crests of mighty ranges whose foothills and lower slopes lie buried far beneath the drift and sand. The Sierra del Tule and the Sierra Lechuguilla are composed of a bewildering chaos of trachyte, porphyry, granitic rock, and lava, while the Sierra de las Tinajas Altas is composed of a coarse, grayish rock resembling granite, which appears at one time to have been washed by water, and as a consequence has been worn smooth and indented with numerous cavities similar to those found in rocks on the seashore. A few miles north of the boundary, in the Sierra del Tule, are several peaks of gray rock curiously capped with black trap or lava, one of which, called the Cerro de la Cabeza Prieta, is a very prominent landmark when crossing the Tule Desert. An extinct volcano, whose sides are curiously streaked with black lava, is situated on the west side of the Sierra del Tule, about 3 miles north of the wagon road, and the entire country south of this volcano is covered with a mass of broken, black lava.

During the "early sixties" there was a large influx of Mexicans from Sonora to the gold diggings on the Colorado River, and an enterprising Mexican dug two wells near the road, in the Tule Mountains, built a small adobe house, and occupied it with his family for two years, for the purpose of selling water to travelers. But the deaths from thirst along this route became so frequent that the road was soon abandoned, and for over twenty years had remained unused.

Trail to site of Monument No. 184.

Vereda al sitio del Monumento No. 184.

TINAJAS ALTAS. LAS TINAJAS ALTAS.

Having accidentally learned of the former existence of these old wells, which are not shown on any maps, arrangements were made to have them cleaned out as soon as possible. This was done by a party of Mexicans and Papagos from Sonoyta, who found them almost filled up.,

These important wells are situated on the road about 5 miles north of the point where the line crosses the summit of the Sierra del Tule, and when thoroughly cleaned out yield a supply of about 500 gallons per day. The water is beautifully clear, but owing to the presence of minerals has a vile taste and is very unwholesome. Near the wells stand the ruins of the old adobe house, the only building between Quitobaquita and the Colorado River.

About 6 miles northwest of these wells and about one-fourth of a mile east of the summit of the Cerro de la Cabeza Prieta, in a deep, rocky cañon, are a number of natural tanks, worn in the rocks and filled by the rains. These tanks when full contain about 5,000 gallons of water, all of which is seldom exhausted, by evaporation alone, before another rain fills them. These tanks are known as the "Tinajas del Cerro de la Cabeza Prieta," but were never much used by travelers, as they were off the road and could not be reached by vehicles.

Many years ago the Papagos were accustomed to camp at these tinajas and the Tinajas Altas for the purpose of hunting "big horns" or mountain sheep, which then, as now, constituted the principal inhabitants of these desolate sierras. In the vicinity of the tanks are still seen the remains of their old camps, around which are strewn the horns of the mountain sheep—as many as twenty or thirty pairs having been counted at a single camp.

This noble game is still plentiful in these mountains, fortunately protected by their ruggedness, their inaccessibility, the deserts which surround them, and the risk of death from thirst to which hunters would subject themselves.

In the side of a natural, semicircular amphitheater on the east side of the Sierra de las Tinajas Altas, about 3½ miles north of the boundary line, are the Tinajas Altas, a series of beautifully picturesque, natural tanks, worn in the solid rock by the waters of a narrow, rocky valley several hundred feet above, which, during the infrequent rains, come tumbling down the narrow gorge on the west side of the amphitheater and fill the tanks. These tanks hold about 15,000 or 20,000 gallons in all, when filled. They consist of seven large ones and a number of small ones; but with the exception of the lowest tank, which can be approached by animals, they are very difficult of access. The next three are reached with difficulty by climbing the steep, water-worn rocks on the left of the gorge, but the upper ones can only be reached by ascending, to a height of several hundred feet, the steep ravine on the right of the gorge. To render this water available for the uses of the survey it was siphoned from the upper tanks to the lower one by a suitable length of hose. The water, although sometimes covered with a green scum, is deliciously cool and palatable. Unless consumed by prospectors or smugglers, which is seldom the case, water can be found at all times in some of these tanks, as there is no loss from seepage, and as the steep, rocky surrounding and overhanging walls greatly retard evaporation; to what extent is shown by the fact that on the reconnoissance from Yuma to Quitobaquita in the winter of 1893 these tanks were found nearly half full, although the rainfall at Yuma for the preceding twelve months had aggregated less than three-fourths of an inch, a remarkable deficiency even for this dry section. That this water supply was a very uncertain one when the road from Sonoyta to Yuma was much traveled (as was the case during the rush to California in "the fifties" and to the Colorado River diggings in "the sixties") becomes painfully apparent from the number of graves, about fifty in all, on the bluff just east of the tanks. These graves, covered by stones laid on the ground in the form of a cross, mark the resting place of thirsty travelers who had pushed on to the tanks, hoping to find water there; but disappointed in this, and too weak to journey on, had perished miserably of thirst; their sufferings aggravated in many cases by the knowledge that the water which they craved could be obtained in one of the tanks but a few yards above them, had they but strength to climb to it.

Although these tanks are now but little known, few Americans having ever visited them, yet it is very interesting to note that they are shown on the map made by Father Kino, the Jesuit missionary, of the region around the Gila and the Gulf of California, as the result of his travels from 1698 to 1701.

Two other tanks, of which no previous knowledge had been obtained, were discovered a short distance above the heads of the two valleys which indent the east side of the mountains between 1 and 2 miles north of the boundary. These had each a capacity of about 600 or 800 gallons.

The road from Sonoyta to Yuma passes by Agua Dulce, Agua Salada, Tule Wells, and the Tinajas Altas, from which point it keeps on the east side of the mountain range and parallel to it to the valley of the Gila, down the south side of which it passes until the town of Yuma is reached. In "the fifties" the road forked about a mile north of the Tinajas Altas, the west fork going through the pass at this point, and thence directly over the Yuma Desert to the town of Yuma. This part of the route, however, was soon abandoned on account of the heavy sand and the loss of life from thirst. The road between Agua Dulce and Yuma is for the most part very heavy, and, until the Tule Wells were reopened, no certain supply of water could be counted on between Agua Dulce and the Colorado River. This road is appropriately called by the Mexicans "El camino del Diablo." When traveling it for the first time, alone or with but few companions, it is hard to imagine a more desolate or depressing ride. Mile after mile the journey stretches through this land of "silence, solitude, and sunshine," with little to distract the eye from the awful surrounding dreariness and desolation except the bleaching skeletons of horses and the painfully frequent crosses which mark the graves of those who perished of thirst—grim and suggestive reminders when the traveler's supply of water is running low. In a single day's ride sixty-five of these graves were counted by the roadside, one containing an entire family, whose horses gave out and who, unable to cross the scorching desert on foot, all perished together of thirst. Their bodies were found by some travelers during the following rainy season, and were all buried in one grave, which is covered with a cross of stones and surrounded with a large circle of stones, inside of which not a bush nor a blade of grass grows. Near by lie the skeletons of their horses and the broken fragments of their water bottles.

During the few years that this road was much traveled, over 400 persons were said to have perished of thirst between Sonoyta and Yuma, a record probably without a parallel in North America.

Leaving the Sierra de las Tinajas Altas the line crosses the Yuma Desert and descends into the valley of the Colorado, terminating at the point where it intersects the axis of the channel of that river.

The name Yuma Desert is applied to the entire country included between the Gila River, the Gila Range, the Gulf of California, and the Colorado River, a region without water and covered for the most part with shifting sands and a scrubby growth of greasewood. Parallel to the Gila Range and separated from it by a valley 4 or 5 miles in width is a range of hills which begins about a mile or two north of the line and extends northwest for a distance of 15 or 20 miles.

About halfway across the desert the line crosses a ridge of drifting sand 2 or 3 miles in width and then a low, volcanic ridge which borders it on the west. Many miles to the south is seen a perfect sea of sand out of which rise jagged, isolated peaks and extinct volcanoes. Everywhere else is an endless succession of sandy swells and hollows sloping gradually down to the Colorado River. Descending abruptly from the desert the line passes over the fertile valley of the Colorado and terminates in the channel of that stream.

Section 5, Colorado River.—The Colorado, like the Rio Grande, is a variable stream, carrying an immense amount of sediment, and is generally navigable by light-draft steamers throughout the year for several hundred miles above its mouth. The river floods in June, during which time great changes of channel take place in those reaches, which, like the boundary section, are bordered by alluvial banks. The river valley along this section is many miles in width and is covered with a dense growth of mesquite, cottonwood, willow, arrowwood, quelite, and wild hemp. The soil is exceedingly fertile from the frequent inundations, and would doubtless produce fine crops.

The Colorado River along the boundary is peculiar in that its course does not follow the lowest depression between the Gila Range and the Coast Range, but lies some 50 or 60 miles east of this depression, and at an elevation of over a hundred feet above it. Nor does it seem, as is sometimes contended, that this elevation is due entirely to the constant deposition of sediment along its banks and the consequent elevation of its bed, for the profile along the boundary over the Colorado Desert, west of Yuma, shows the same gradual and uniform downward slope, until the depression at Salton River is reached, and on this desert no alluvial sediment appears ever to have been deposited either in recent or past ages. Moreover, in slope, elevation, and composition, this desert appears but a continuation of that on the east side of the valley.

This river is also remarkable for the very high tides at its mouth, and for the "bores" which at certain phases of the moon come rushing up the tidal portion of the stream, threatening with destruction all small craft encountered.

At the junction of the Gila and Colorado is located the flourishing little town of Yuma, which before the advent of the Southern Pacific Railway furnished supplies for almost all of Arizona and New Mexico. The town still supplies the mining camps on the Colorado River and its vicinity, and has become quite a resort for persons afflicted with pulmonary troubles. Extensive projects for irrigating and cultivating the fertile lands of the Colorado River Valley and vicinity are now being promoted, but up to the present time practically none of this land is cultivated, except by Indians.

The river valley from Yuma to the gulf is inhabited only by Yuma, Co-co-pah, and Diegeño Indians, peaceable and light-hearted people, fond of games, excellent swimmers, and delighting, like all savages, in painting their faces and bodies. The men are noticeable for their splendid physique, but the women are generally fat and unattractive in appearance. As a rule they possess no firearms, and on the lower reaches of the river may yet be seen hunting with the bow and arrow. They still cremate their dead, frequently burning at the same time the rude hut and personal effects of the deceased.

Section 6, azimuth line from the Colorado River to the Pacific Ocean.—Starting at the Colorado River, the line passes for about two-thirds of a mile over the fertile river valley, then rises to the water-washed mesa southeast of Pilot Knob, a prominent, isolated mountain about a mile north of the line. Over this mesa the line passes for about 3 miles, when it encounters several high ridges of drifting sand, all of which it crosses in a distance of about 4 miles.

From the sand hills to Salton River, a distance of about 27 miles, the line passes over a flat desert, similar in appearance and vegetation to the Yuma Desert, and forming a part of the Colorado Desert, the name which is applied to the entire country included between the mountains north of the Southern Pacific Railway, the Colorado River, the Gulf of California, and the Coast Range. From Salton River to a point a little over a mile east of the north spur of Signal Mountain, a distance of about 21 miles, the line passes over an alluvial depression, a considerable portion of which is covered at intervals of several years by the overflow from the Salton and New rivers, as was the case in the summer of 1891, when their overflow filled the dry bed of the Salton Sea, and for a time threatened to submerge the tracks of the Southern Pacific Railway in this vicinity.

To understand the nature and cause of these overflows it is necessary to describe somewhat in detail the topography of this region for a considerable distance on both sides of the boundary line.

About 5 miles below the boundary the Rio Padrones, a branch of the Colorado, ordinarily about 75 feet in width, and having a very swift current, separates from the main stream and flows in a generally southwest direction, emptying into a lake several miles in length, called Jululu Lake.

This lake lies some 15 or 20 miles south of the boundary line, and near its west shore are the famous mud volcanoes of the Colorado Desert, while a short distance west of these loom up the bare, rocky ridges of the Co-co-pah Mountains. The outlet of this lake, known as Hardys River, flows in a generally southeast direction, and unites with the Colorado some 20 miles above its mouth.

The area included between the Colorado and these western branches is intersected by numerous "blind channels," which are all filled when the Colorado overflows.

At times of extraordinarily high water in that river another channel, which branches from the Colorado in the same locality as does the Rio Padrones, becomes filled, and under the name of Salton River flows west for about 30 miles, then northwest for about 50 miles, and empties into the depression called Salton Sea. At the same time Jululu Lake becomes so filled from the overflow that a portion of its waters seeks an outlet by a channel called New River, which flows in a northwest direction for about 60 miles, and also empties into Salton Sea. When the flood in the Colorado subsides these streams cease to flow, and their courses are marked by a succession of lagoons remaining in the deep channels which their waters have cut in the alluvial soil. Exposed to the dry atmosphere of the desert, these lagoons soon evaporate, and for years at a time not a drop of water can be found along their courses.

Ordinarily the height and duration of the flood in the Colorado barely suffices to fill Salton and New rivers for a short distance from their sources, and it is only at long intervals that any part of the waters of these streams reaches Salton Sea. This, however, occurred in 1891, when not only were these rivers filled, but so great was the volume of water poured into them that they in turn overflowed their banks and submerged much of the surrounding country, the overflow of the two rivers, which in the limits of the United States are approximately parallel to one another, in some cases uniting. The channels of these streams are fringed with a thick growth of mesquite, while the limits of overflow are plainly marked by a most luxuriant growth of an Amaranthus (called "quelite" by the Mexicans), a plant much esteemed as food for cattle.

The growth of quelite, mesquite, and grass following the overflow of 1891 furnished fine pasturage for several thousand head of cattle brought here from the overstocked ranges of Arizona and California.

The entire area between the head of Salton Sea and the Gulf of California once undoubtedly formed a part of this gulf, from which in comparatively recent geological times its waters were separated by some process still somewhat obscure.

By many it is believed that this separation was effected by an elevation or upheaval in the region between the boundary line and the present head of the gulf.

While admitting that this theory is perfectly plausible and quite possibly correct, yet from the present condition of things it seems more probable that this separation was effected by the deposition of sediment from the Colorado River, aided perhaps by the action of the winds and tides on this sediment.

From the configuration of the surrounding country it would appear that before this separation occurred the Colorado River must have flowed into the gulf on its east shore about 75 or 100 miles below its then head and at a point where the gulf must have been quite narrow, limited as it was by a spur of the Co-co-pah Mountains on the west and by the Yuma Desert on the east.

When we consider the immense amount of sediment brought down by the waters of the Colorado, and the further fact that rivers emptying into the sea invariably discharge their waters at right angles to the shore line, in this case directly across the narrow gulf, it does not seem improbable that in time this sediment would separate the waters above the mouth of the river from those below. If this theory is correct, the original bottom of the gulf would be found only in the vicinity of Salton Sea, which is about 250 or 275 feet below mean sea level, while from that point to Jululu Lake would be found a gradually increasing thickness of sedimentary deposit from the overflows, first, of the Colorado and afterwards of Salton and New rivers.

To the north of Salton Sea the old beach line is easily traced, and its elevation differs but little, if any, from that of the Pacific, showing that if any elevation or depression has occurred elsewhere, this locality at least has been practically unaffected thereby.

Salton and New rivers present the anomalous condition of two streams parallel to one another, and to the axis of lowest depression in their vicinity, the first being about 18 and the second about 8 miles east of this axis, as measured along the boundary. The corresponding elevations of the surface at each point being +26′, —7′, and —16′ respectively, referred to mean sea level; the last marking the lowest point along the entire boundary line. About 4 miles west of this point the line crosses the foot of the north spur of Signal Mountain, a prominent peak marking the north end of the Co-co-pah Range, and visible from all points of the Colorado Desert. For about 10 miles the line passes over a bare, rocky, water-washed mesa, about 300 feet above sea level, from which, by a succession of three or four terraces, indescribably bare, jagged, rough, and precipitous, the line, in a distance of about 11 miles attains the summit of the Coast Range at an elevation of about 4,500 feet.

This range acts as an effectual barrier in shutting off from the Colorado Desert the moisture-laden winds of the Pacific. This action was beautifully shown in March, 1893, when for three days it had been raining almost continually over the entire country west of the summit, several inches of rain having fallen in that time. During this entire period a gale from the coast was driving a continual mass of dark rain clouds over the crest of the Coast Range, where at the time it was alternately raining and snowing. Encountering the hot air rising from the desert these clouds rapidly began to dissipate, and finally disappeared entirely about 10 miles east of the summit, appearing when viewed from below like a vast cloud of steam exhausted into air.

Between the Co-co-pah Mountains and the Coast Range, and about 10 or 15 miles south of the boundary, is a large salt lake, called Lake Maquatá by the Indians, and about 9 miles east of the summit of the Coast Range and about 5 miles south of the boundary, in the mouth of a large cañon, is a small stream of pure mountain water.

During the years when New and Salton rivers remain dry no water is found near the boundary line between the valley of the Colorado River and Coyote Well, a very shallow well of wretched-tasting water, about 8 miles north of the boundary and about 12 miles east of the summit of the Coast Range. The entire Colorado Desert is subject to frequent sand storms and constant and violent winds prevail along the foot of the Coast Range. The summer heat is fearful; the highest temperature ever recorded at any Weather Bureau Station in the United States, 128° F. in the shade, having been obtained in July, 1887, at Mammoth Tank, a station on this desert about 25 miles north of the boundary. Although far less traveled than before the advent of the railroad, the desert continues to claim its victims, over half a dozen persons having perished of thirst on it during the past two years.

From the summit of the Coast Range to the Pacific, settlements become more frequent; the country is better known, and the maps more accurate; consequently less detail is necessary in describing it.

The descent from the summit to the Pacific is far more gradual than that to the Colorado Desert and the entire character of the vegetation undergoes an abrupt change; the mountains being covered with a dense growth of brush, while the valleys are dotted with beautiful evergreen oaks.

Leaving the summit of the Coast Range, the line crosses the Jacumba Valley and the broken country west of it, and passes just to the south of Round Mountain; thence it crosses successively the rocky ridges west of Round Mountain, Milquata Valley, another succession of ridges, Tecate Valley, and Mount Tecate, passing over the south slope of this mountain at an elevation of about 3,400 feet.

Leaving Mount Tecate, the line crosses Cottonwood Creek, the south slope of Otay Mountain, at an elevation of a little less than 1,700 feet, Otay mesa, Tijuana River, and the high, flat ridges in the vicinity of the ocean.

For many years previous to the completion of the Southern Pacific Railway a stage line had been maintained between Yuma and San Diego; wells had been sunk in many places on the desert, and stage stations established in their vicinity. At the time of the survey this road had remained untraveled for years; the wells had all filled up; the station houses were but ruins, and all traces of the old road were in many places obliterated for miles at a stretch. Although still known by their old names, the stations now afford neither a permanent water supply nor shelter. The road used on the survey followed the old stage route along the Colorado and Salton River valleys, via Hanlons, Cooks Wells, and Seven Wells, until Gardners Station was reached.

From this point to New River station the old road had been washed out by the overflow of 1891, and consequently it was necessary to continue down the Salton River Valley for several miles and then ascend to the sandy desert on the north, on which the road continued for a few miles, descending into Salton River Valley and crossing the dry bed of that river about a mile below the boundary. From this point the road continues to Indian Wells, crossing the boundary line about 3 miles east of New River, and uniting with the old stage road a short distance east of Indian Wells just after crossing the dry bed of New River.

From Indian Wells to San Diego the road follows the old stage route, via Laguna Station, Coyote Well, Mountain Spring, Jacumba, Campo, Potrero, and Dulzura. Between Cooks Wells and the point where it crosses Salton River the road is very heavy. Just before reaching Mountain Spring Cañon a stretch of very heavy sand is encountered, which continues up to the mouth of the cañon. The road through the cañon is rough beyond description, and although but 3 miles in length, caused more damage to vehicles than did any other road on the entire survey.

With these exceptions, the road is fair for the entire distance from Salton River to San Diego. It must be borne in mind, however, that between the Colorado River and Jacumba Valley there is ordinarily not a blade of grass, while often for months at a time not a drop of water can be found between the Indian village, a few miles east of Cooks Wells, and Coyote Wells, a distance of 80 miles by road. Twelve miles beyond Coyote Wells is Mountain Spring, affording a good supply of excellent water.

The next water, a bold sulphur spring, is found about 8 miles farther, at Jacumba, the first settlement encountered after leaving the valley of the Colorado River.

From this point to the Pacific, water is sufficiently plentiful to render a detailed description of its location unnecessary.

To persons unfamiliar with the deserts of the Southwest, it will doubtless appear that undue prominence has been given to the question of water in the preceding description of the country along the boundary, and in refutation of this idea it is necessary to call attention to the fact that supplying the working parties with water on the deserts was *the* problem of the survey, in comparison with which all other obstacles sank into insignificance. To the traveler on the desert the all-important questions are: The distance to the next water, the nature of the supply, and the character of the intervening roads. For while he may be able to live without food for several days, he knows that, exposed to the scorching heat of summer, men drinking their fill at sunrise frequently become crazed and in some cases perish of thirst before sunset.

Nor must it be forgotten that at such times so profuse is perspiration and so rapid its evaporation that the quantity of water consumed by men and animals is very large, averaging at one period of the survey about 7 quarts per day for the men and 20 gallons for the animals.

On the desert the mirage continually mocks the traveler with deceptions apparently so real that it is difficult to persuade him that what he sees is a mere atmospheric freak and has no actual existence.

Just before sunrise craggy peaks are seen, capped by similar, inverted peaks, which gradually become flatter and flatter, frequently stretching out like great arms from the summit and uniting with those from neighboring peaks. Once a city with all its buildings appeared in a valley many miles to the north, but the morning sun quickly resolved it into a number of large bowlders, near the foot of a craggy mountain.

At another time, on the flat, bare Yuma Desert, the reconnoissance party seemed to be in a level depression, surrounded on every side by a vertical, palisade-like wall of solid rock, 50 or 100 feet in height, which moved with them as they journeyed toward the river, but gradually diminished in height until it finally disappeared.

The most common deception, however, is seen in the heat of the day, when beautiful, quiet lakes and timber-fringed ponds lie in tantalizing attractiveness, apparently but a few hundred yards away, the details so perfect that the reflection of every object on the bank is faithfully reproduced, and it is little wonder that thirsty travelers unaccustomed to this mirage are lured from the road to procure this water, which ever appears but a little distance ahead, yet is never reached.

It was also in the heat of the day that distortions of the size and form of animals generally occurred; as in one case where a band of wild horses was mistaken for a herd of antelope, and followed for several miles as such before the mistake was discovered; and in another, where a coyote was mistaken for the same animal. At times a jack rabbit would loom up on the desert with the apparent size of a cow, while occasionally the legs of animals would be so comically lengthened as to give them the appearance of being mounted on stilts many feet in height.

RECONNOISSANCES.

Owing to the fact that a considerable portion of the country lying along the international boundary is of a character little calculated to invite travel by white persons, it was impossible to secure in advance reliable information concerning water, roads, and the general topographical features of the country, which information was essential to a proper prosecution of the survey.

To obtain this information mounted reconnoissances were made from time to time as required by the progress of the work.

With the exception of a reconnoissance of about 100 miles made by Mr. J. L. Van Ornum, assistant engineer in charge of the topographic party (who also formed one of the reconnoissance party on three other occasions when the aggregate distance covered was about 700 miles), these reconnoissances were made by Lieut. D. D. Gaillard, United States Corps of Engineers, with a party comprising from two to five persons in all.

Pack mules were used to carry supplies whenever the character of the country was such as to render the use of a spring wagon impracticable.

The total distance covered on the reconnoissances was 2,134 miles—2,008 miles on horseback and 126 miles on foot.

The time occupied in making a single reconnoissance varied from one to fourteen days, and the corresponding distances from 24 to 413 miles.

The usual discomforts incident to such expeditions were experienced and were aggravated, in the case of reconnoissances on the desert, by the intense heat and the scarcity and poor quality of the drinking water.

On a reconnoissance of 301 miles, made June 2–11, 1893, the maximum thermometer reading in the shade each day varied from 105° to 118° F. The discomfort of the trip was further increased by the fact that the first four watering places were 45, 40, and 50 miles apart, respectively.

In many cases there was little or no grazing for the animals, and as it was impossible to pack enough hay to last them for the entire trip they had to be fed principally on barley, and were often without water for considerable periods—on one occasion for a period of forty hours.

Yet in spite of privations it is pleasant to be able to record the fact that not a man nor an animal was injured or disabled on any of these expeditions.

CHAPTER III.

ASTRONOMY.

On the organization of the International Boundary Commission at Juarez, Mexico, November 17, 1891, the members of the Mexican section were present with a full outfit of instruments and observers ready for work.

These instruments had been purchased by the Mexican Government at the date of the first convention in 1882, and were used by them to determine the latitude and longitude of Juarez at that time while waiting for the United States Government to appoint a commission.

The United States commissioners having reached El Paso without instruments, men, or transportation, it was necessary for them to return north to organize their party, engage assistants, procure instruments, and purchase animals, wagons, and camp equipage before they would be able to begin field operations.

The time between December 1, 1891, and January 20, 1892, was spent in securing assistants and in organizing the transportation for the field parties.

Instruments used.—The question of the proper instruments to use for the observations of latitude, azimuth, time, and magnetics received careful consideration.

The time was too limited to have new zenith telescopes of improved pattern constructed, and as the old Wurdemanns used in the survey of the northwestern boundary in 1872–1876 were stored at the engineer depot at Willets Point, N. Y., a requisition was made for the following astronomical instruments in addition to barometers, surveyors' transits, etc., for the topographical work of the survey: Two Wurdemann zenith telescopes, Nos. 18 and 20; two sextants and artificial horizons; two mean time chronometers; two sidereal chronometers.

The two zenith telescopes were completely overhauled and were partially reconstructed by Fauth & Co., of Washington. In the field operations but one of them was actually used, the other being held in reserve. Each was furnished with spare level-tubes in case of accident to those attached to the instruments.

For azimuth observations a 10-inch repeating theodolite, reading to 5 seconds on horizontal limb, was made by Fauth & Co., having an eyepiece micrometer and high standards for supporting the telescope, enabling the telescope to be "transited through" for reversal instead of being lifted from the wyes. This instrument was used for azimuth observations, using the method of measuring by micrometer the angles between the star near elongation and the mark. The high standards, constructed of aluminum, were of great service in the field in running lines on the ground, while the micrometer in the eye end, together with the use of signals by heliotrope, facilitated the placing of the forward signal quickly in line with the back signal.

Micrometer readings on both back and forward signals afterward determined the small correction to be applied to the place of the forward signal.

Two direction theodolites of 8-inch limbs reading by two micrometer microscopes to single seconds were purchased from Fauth & Co., in January, 1893, and were used in measuring the angles of the triangulations made at Nogales and Yuma. These theodolites were made with low standards and telescopes of high power.

One 8-inch repeating theodolite or altazimuth was borrowed from the United States Coast and Geodetic Survey for the magnetic observations, and was used along the parallels of 31° 47′ and 31° 20′, after which it was returned, at the request of the Superintendent, to the Coast Survey office, being needed in Alaska. This instrument was wholly of bronze and brass, no steel or iron being used. The telescope was fitted with an eyepiece micrometer and could be used for latitude observations instead of a zenith telescope, and it carried above the telescope a box containing a 6-inch needle for measuring the magnetic declination.

The sextants and artificial horizons were used for time observations. Observations of the sun's altitude were made in forenoon and afternoon, and the resulting errors of chronometers were sufficiently accurate for use in latitude and azimuth observations.

The four chronometers were put in complete order by Negus & Co., of New York. For transportation each chronometer was inclosed in a leather case, and two of these cases were then inclosed in a well-padded wooden box. This box was then inclosed in an outer wooden box having a false inside cover and bottom, backed by a system of spiral springs to deaden jars. The chronometers were kept in these double boxes from the time of leaving New York to the end of the work at San Diego, except the chronometers used for astronomical observations, which were immediately returned to the boxes after the observations were finished.

This method of packing the chronometers was very satisfactory in its results, no injury to any chronometer having occurred, although transported many hundred miles over a very rough country with no roads, and the temperature of the chronometers changed very slowly, although the usual variation in the outside temperature during the twenty-four hours was from 50° to 70°.

For a detailed description of all these instruments see report of John F. Hayford, assistant astronomer.

Zenith telescope No. 20 was used for all the latitude observations and No. 18 held in reserve in case of accident to the former.

The mounting of the zenith telescope and theodolite under one cover, so as to combine stability of foundation with portability, was the subject of considerable study and experiment. An observatory of some sort was required, and it needed a floor. This observatory must be used also as an office for the astronomical party during the day in which to do the necessary computing and writing, none of our tents being large enough for this purpose. The whole must be portable and composed of parts small enough to load readily on a wagon.

Both the zenith telescope used for latitude and the theodolite used for azimuth observations were mounted on hollow, triangular wooden piers 5 feet long, hooped with iron, painted, and sunk like fence posts, after which the triangular inside was filled with earth well rammed. A floor of boards, 9 by 12 feet, made in six sections and to fit around the wooden piers, supported only at the four corners, was laid, on which was erected a tent in the form of a "lean-to shed," with roof sloping toward the north, and openings the whole length of the roof over each instrument. The sides and roof of the tent were supported and stiffened by a framework of wood and held in place by rope guys at corners and sides.

The hollow wooden piers were very satisfactory and proved as firm as masonry. At Nogales and Yuma the zenith telescope was mounted on the brick piers used by the United States Coast and Geodetic Survey longitude party, and at those places the observatories were of wood. A comparison of the results obtained at these stations with those where the wooden piers and tent were used were all in favor of the latter. The instrument changed less in level during the night when mounted on the wooden pier, and the temperature inside the tent was more nearly the same as the outside air. The usual difference was 1° C. only, which rendered the stars observed very steady.

Astronomical Observatory, Tijuana.

Observatorio Astronómico en Tijuana.

LONGITUDES.

The original plan agreed on by the joint commission for running the boundary was to determine both the latitude and longitude of the extremities and turning points of the boundary, at or near which points the monuments erected by Emory were reported as still standing, and to observe for latitude and azimuth on the parallels at points about 20 miles apart.

Dr. T. C. Mendenhall, Superintendent United States Coast and Geodetic Survey, at the request of the State Department, detailed a party to determine the longitude of five points, viz: El Paso, the monument at the intersection of parallel 31° 47′ with the meridian, Nogales, Yuma, and old Monument No. 1 on the Pacific, near San Diego. The field work was completed between January and June, 1892.

The method used was exchange of signals by telegraph. Usually ten nights' exchanges were obtained, five with one observer at eastern station and the other at western, then five more with the positions of the observers reversed. The same stars were observed at both stations for time and instrumental correction to eliminate errors in the right ascensions of the stars used.

Assistants C. H. Sinclair and G. R. Putnam had charge of the longitude parties, and the field expenses of both parties were paid by the United States section of the Boundary Commission, but no salaries to either officer.

The longitude of Monument No. 1, where the parallel of 31° 47′ leaves the Rio Grande, was fixed by a triangulation connecting the monument with the longitude station at El Paso. The longitude of monument 40 at the intersection of parallel 31° 47′ with meridian was obtained directly by using a temporary field telegraph line erected by direction of General Greeley, Chief Signal Officer, United States Army, connecting with the Western Union telegraph line at Separ, on the Southern Pacific Railway. General Greeley also furnished operators at both ends.

The line was very quickly and successfully erected under direction of Lieut. Frank Greene, signal officer, Department of Arizona, by a detachment from the Twenty-fourth Infantry under command of Maj. James N. Morgan, to whom we are indebted for the prompt and successful completion of the work.

The longitude of Nogales was transferred to monument No. 127, at the intersection of parallel 31° 20′ with the one hundred and eleventh meridian, as determined by Emory, by a triangulation connecting the monument with the longitude station at Nogales. The longitude of monument No. 204, 20 miles below Yuma, on the line connecting monument No. 127 with the initial point in the Colorado, was obtained from the observed longitude at Yuma by triangulation. The longitude of monument No. 207, where the line from the junction of the Gila and Colorado leaves the river, was obtained from the same triangulation. The longitude of monument No. 258, on the Pacific, was furnished by the Coast and Geodetic Survey, based on observations for longitude made at San Diego in 1892, connecting this point with the main chain of longitude stations on the Pacific Coast and reduced to the monument by Coast and Geodetic Survey triangulation.

Results for difference of longitude by United States Coast and Geodetic Survey of points on Mexican boundary.

SAN DIEGO, CITY PARK, CAL., AND YUMA, GOVERNMENT RESERVATION, ARIZ.

Date.	Δ λ	p.
	m. s.	
March 15, 1892	10 09.162	2
March 16, 1892	.095	4
March 17, 1892	.087	3
March 19, 1892	.100	8
March 20, 1892	.130	3
March 21, 1892	.144	3
Observers change stations:		
March 23, 1892	.109	6
March 24, 1892	.092	5
March 25, 1892	.112	4
March 26, 1892	.130	3
March 29, 1892	.152	4

Weighted mean, $10^m\ 09.114^s \pm 0.005^s$.

Transmission or wave and armature time $= 0.032^s \pm 0.002^s$.

Personal equation between C. H. Sinclair and G. R. Putnam, $S - P = +0.192^s \pm 0.004^s$.

Results for difference of longitude by United States Coast and Geodetic Survey of points on Mexican boundary—Continued.

YUMA, GOVERNMENT RESERVATION, ARIZ., AND NOGALES, IN REAR OF CUSTOM-HOUSE, ARIZ.

Date.	Δ λ	p.
	m. s.	
April 13, 1892	14 43.705	4
April 14, 1892	.631	5
April 15, 1892	.682	4
April 16, 1892	.715	6
April 17, 1892	.726	5
Observers change stations:		
April 19, 1892	.677	3
April 20, 1892	.662	7
April 21, 1892	.723	4
April 22, 1892	.693	3
April 23, 1892	.701	4

Weighted mean, $14^m\ 43.690^s \pm 0.007^s$.
Transmission or wave and armature time $= 0.045^s \pm 0.003^s$.
Personal equation between C. H. Sinclair and G. R. Putnam, $S - P = +0.150^s \pm 0.005^s$.

NOGALES, IN REAR OF CUSTOM-HOUSE, ARIZ., AND EL PASO, IN UNITED STATES RESERVATION, TEX.

Date.	Δ λ	p.
	m. s.	
April 29, 1892	17 48.603	3
April 30, 1892	.466	4
May 1, 1892	.525	4
May 2, 1892	.519	4
May 4, 1892	.511	7
Observers change stations:		
May 6, 1892	.560	4
May 7, 1892	.462	6
May 8, 1892	.531	5
May 9, 1892	.555	5
May 10, 1892	.517	6

Weighted mean, $17^m\ 48.520^s \pm 0.009^s$.
Transmission or wave and armature time $= 0.034^s \pm 0.001^s$
Personal equation between C. H. Sinclair and G. R. Putnam, $S - P = +0.126 \pm 0.004^s$.

CORNER OF BOUNDARY, NEAR MONUMENT NO. 40, AND EL PASO, IN UNITED STATES RESERVATION, TEXAS.

Date.	Δ λ	p.
	m. s.	
May 14, 1892	6 52.642	4
May 15, 1892	.660	4
May 16, 1892	.594	4
May 17, 1892	.604	3

Weighted mean, $6^m\ 52.626^s + .013^s$.
Transmission or wave and armature time $= 0.013^s \pm .001^s$.
Applied personal equation, $S - P = + 0.126^s \pm 0.08^s$.

Absolute longitudes of the several positions can only be given after the final adjustment of the general longitude system of the United States has been made; at present but a very few lines are wanting to complete the longitude net. Approximately we have:

	Time.	Longitude.
	h. m. s.	° ′ ″
El Paso, transit of 1892	7 05 57.350	106 29 20.25
Boundary corner	7 12 49.976	108 12 29.64
Nogales	7 23 45.870	110 56 28.05
Yuma	7 38 29.560	114 37 23.40
San Diego	7 48 38.674	117 09 40.11

The probable error of any of these results may be taken as $\pm 0.12^s$ or $\pm 1.80''$. We also have the resulting value for the supposed Wheeler station at El Paso: Time, $7^h\ 05^m\ 56.727^s$; longitude, $106^\circ\ 29'\ 10.90''$.

Longitude of prominent points on boundary.

Points.	Longitude.
	° ′ ″
Federal building, El Paso	106 29 9.58
Court-house, El Paso	106 28 55.11
Monument No. 1, Rio Grande	106 31 39.03
Cathedral +, Juarez, Mexico	106 29 4.72
Monument No. 40, upper corner	108 12 29.67
Monument No. 53, lower corner	108 12 29.67
Monument No. 122, Nogales	110 56 34.53
Monument No. 127, corner	111 4 34.45
Monument No. 204, east bank Colorado	114 46 48.64
Monument No. 207, west bank Colorado	114 43 54.31
Monument No. 258, Pacific	117 7 31.89

LATITUDES.

All the observations for latitude were made with zenith telescope No. 20, by the method of micrometer measures of difference of zenith distance of pairs of stars near the zenith. The time for latitude and azimuth was obtained by sextant observations on the sun.

As it was necessary to have the results for latitude and azimuth for the use of the tangent parties at each station without delay, and as no one catalogue would give the accurate places of a sufficient number of stars from which pairs could be selected to observe for latitude, arrangements were made, before leaving Washington, with Prof. T. H. Safford, of Williams College, to make selections for our use from the large number collected by him during many long years of labor, together with the latest publications available, and to furnish us with the mean declinations for 1892 of stars properly located for observation along the boundary.

By means of these lists of stars it was possible to observe as many pairs as were convenient on any one night, and to observe as many nights as were necessary to obtain a satisfactory result.

Usually about 100 results for latitude were obtained, the number of pairs used varying from 20 to 60, with a resulting probable error of from $\pm 0.03''$ to $\pm 0.05''$.

The apparent places were computed for the actual dates of observation, and the final result for latitude of the station was obtained within three or four days from the time of the last observation.

AZIMUTH.

The observations for azimuth were made with theodolite No. 725, 10-inch Fauth.

The method used was that described in Bulletin No. 21, United States Coast and Geodetic Survey, 1890, entitled "Determination of an azimuth from micrometric observations of a close circumpolar star near elongation, by means of a meridian or transit and equal altitude instrument, or by means of a theodolite with eyepiece micrometer."

This method is capable of great accuracy of result, but demands that an elongation mark be set up in the direction of a vertical plane passing through a close circumpolar star when near elongation, and that an instrument with an eyepiece micrometer be available to measure micrometrically the angle between the vertical planes passing through the mark and star. By this method a satisfactory result for azimuth for a night could be obtained in from thirty to fifty minutes; one set or result taking about ten minutes.

The instrument was too small and light to obtain the best results, but three sets per night and three nights gave an azimuth with a probable error of result of less than $\pm 0.3''$; the probable error of a single result was about $\pm 0.5''$.

More than four sets on the same night were found to add nothing to the accuracy of the mean for that night, but several nights' observations were needed as the mean results of different nights differed frequently by a second or more. Mean range for 15 stations = 1.2″.

As the observations were made very near elongation—within half an hour—and on both sides of that epoch, but a portion of one turn of the micrometer was used, and any error in the assumed values of the micrometer or of the chronometer correction was nearly eliminated from the mean result of the night.

The atmospheric conditions were very favorable for both latitude and azimuth observations, the stars showing as bright points and very steady. The temperature of the observing tent rarely differed more than a degree from that of the outside atmosphere.

All the observations for latitude, time, and azimuth were made by Assistant Astronomer John F. Hayford, and for a detailed description of the instruments used, method of observation and reduction, and for the results, see report of assistant astronomer hereto appended.

Mr. James Page served as computer during the whole time devoted to astronomical observations, and made all the astronomical computations, which were afterwards revised by Messrs. Hayford and Finley.

Mr. H. B. Finley served as recorder for the astronomical party, recording all the astronomical observations, and in addition assisted in the measurement of horizontal angles for the triangulation.

On the completion of the astronomical and triangulation observations at Yuma, Mr. John F. Hayford, assistant astronomer, and Mr. James Page, computer, were transferred to the party running the line between the Colorado River and monument 127, and Mr. H. B. Finley, recorder, to the party running the California line between the Colorado River and the Pacific.

These gentlemen performed all their duties while with the astronomical party, often exposed to great hardship and discomfort, with zeal, energy, and intelligence. At several stations observations were continued throughout the entire night between sunset and sunrise, and during the days they were kept busy at the observation of time and magnetic declination, and in computing. Owing to lack of laborers, they worked also with pick and shovel to set the wooden piers and erect the astronomical tent to be ready for observations the night following the moving of observatory and camp from one station to another.

The catalogue of stars furnished by Professor Safford is herewith given in tabular form.

In this catalogue the declinations are given to hundredths of a second, and have been revised by Professor Safford since the latitude observations were made. The original declinations were given to tenths of a second only and used in computing the resulting latitudes. The column headed $\Delta\delta$ in the catalogue gives the correction to be applied to the catalogue declination to obtain the value used in computing the latitudes along the boundary.

INTRODUCTION TO THE CATALOGUE.

[By T. H. Safford.]

This introduction is briefer than it would have been if I had not been taken suddenly and seriously ill when just completing the preparation for press.

1. *Selection of stars.*—The pairs were selected for the stations with especial reference to avoiding doubtful positions. The proper motions are the doubtful element owing to deficiency of old authorities. The best pairs then are those contained in Auwers' Bradley, and also observed very lately. The rejected stars were those which when data were collected, were found not to have been lately observed; when no good early authority was at hand.

2. *General basis.*—The system of the Berlin Jahrbuch (Auwers') was adopted. This is quite generally employed as a standard by many of the best modern observers. It is fortunately very near that of the American Ephemeris (Boss's), but is rather farther north on the average, a few hundredths of a second only for 1892. The Jahrbuch system agrees still more closely with the Pulkova Catalogue for 1885, which has reached me since the computations were closed. This catalogue is based on an entirely independent investigation, with newly graduated circle and new constants of refraction.

3. *Precession.*—Struve's were used, as in the principal ephemerides. The terms depending on the cube of the time were taken into account where necessary.

4. *Data employed in compilation.*—All respectable catalogues of 1855 or since, with partial omission of the Radcliff for 1860. In doubtful cases, the single years of the Radcliff 1862–1875 and of the Washington observations were consulted; and in all, the latest Greenwich volumes available and the Karlsruhe observations.

Special search was made for prime vertical declinations at Pulkova, Kasan, Gotha, and Washington; and in the other short but very accurate catalogue lately published in the Astronomische Nachrichten.

5. *Proper motions.*—Stars contained in Auwers' Bradley were examined if less than three observations in declination are there given. If indications were found that Bradley's observa-

tions were inaccurate, they were investigated from all available authorities old and new; but if Auwers' proper motion seemed to be correct, it was employed, as also in case of three or more observations.

Stars not in Bradley were also completely investigated; in this case Piazzi or Groombridge was most commonly the best old authority. The method of least squares was employed in nearly all cases, the few exceptions being those where there were but two groups of nearly contemporaneous good observations. The system on which the proper motions were calculated was intermediate between Auwers and Boss, to agree with those of the Jahrbuch stars which are not in Bradley. The weights were usually assigned on the system employed by Auwers in publications 14 and 17 of the Astronomische Gesellschaft; giving, however, one observation half weight, and unity 2–4. These values were also diminished for the less reliable series. Bradley's own data were taken with weight two-tenths for a single observation, three-tenths for two; for more, as beforesaid, Auwers' proper motions were used without least squares reduction. The final probable errors were estimated on an average scale, where weight = 1 receives probable error $\pm 0.5''$. This is too large for the best modern observations. Piazzi and Groombridge were allowed weights $=\frac{1}{2}$, no matter how many observations are given in their catalogues. On the whole I think the final probable errors assigned are not too small, perhaps rather too large.

6. *Final declinations.*—The final declinations are brought up by the help of the assigned proper motions and reduced to the Jahrbuch's system by Auwers' systematic corrections or others derived from Boss or other sources and reduced to Auwers'. The Jahrbuch stars were most commonly reduced with the proper motions there given; but more recent observations were added to the material there employed. They were found in the Ten Year Catalogue and in the Pulkova Catalogue of Romberg, besides frequently in others, in addition to the original material.

INTRODUCTION TO THE REVISION.

The systematic corrections on the Jahrbuch system by Professor Auwers within a short time were applied on the original calculation sheets, for the stars marked A and C in the revision sheets. Stars marked C will require an additional correction of $+0.1''$ to the declinations on the average owing to the different system by which the proper motions were calculated. Stars marked B have been investigated anew by least squares from all available material using the new systematic corrections throughout. New catalogues have been added in all these cases where such were published after the computations for the main catalogue; especially valuable were Greenwich 1890, year results, the new Glasgow Catalogue (1890), the prime vertical observations at Kasan, and the Cincinnati results reduced to 1900 for the proper motion stars. The following catalogues of fundamental stars received after the revision was nearly completed were not included: The Pulkova system of 1885 and the Madison of 1890. Both these agree closely in general with the Jahrbuch system, and the stars are so abundantly observed in detail elsewhere that the increase in accuracy would not be very considerable. Of course, if the latitudes on the boundary were to be redetermined the case would be different.

According to my calculation (not duplicated for want of time) the sum of the corrections $\Delta\delta$ to the catalogue positions is $+3.54''$; if we add to this $0.1''$ for each of the 68 stars C, where proper motions have not been recomputed, we shall have $+10.34''$ or $+0.016''$ for the average of the 624 stars. This is the mean reduction of the latitudes to the system of the Astronomische Gesellschaft, which, on the other hand, is now a few hundredths of a second north of the American Ephemeris system (Boss). The separate values $\Delta\delta$ for stars of Classes A and C are of no special importance except in the few cases where they are more than $0.1''$, owing usually to new material; but those for Class B, being derived from a complete new solution by least squares of equations derived from all available material, should be employed in any further use of this catalogue. The chief cause of variation is the change in the systematic corrections for older observations, especially Piazzi's; some rather doubtful cases have had new material.

The Jahrbuch star 33 Bootis was recognized as discrepant by Mr. Porro, of Turin, in the Astronomische Nachrichten, too late for any change, even in the revision. But I looked over the material collected by Argelander, and on the basis of this Mr. Porro prepared a later article in which he adopted my hypothesis that the discrepancy was due to proper motion, as in almost all similar cases. This again was put as doubtful by Argelander himself. Bradley has only two observations, one of which was made below pole, at a very low altitude, and hence can not be used as confirmation of the other, which is perhaps $3''$ wrong.

Mean declinations of latitude stars.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δδ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
C	1	....	6.1	0 3 18	+3.08	24 51 35.26	0.49	0.000	+20.051	—0.015	+0.14
A	2	16	5.2	4 42	3.10	45 28 15.75	.16	— .016	20.049	.018	+ .05
A	3	32	5.0	9 1	3.10	19 36 21.60	.18	+ .007	20.037	.026	+ .10
C	4	....	6.1	9 34	3.10	26 41 0.03	.28	— .030	20.035	.027	+ .03
A	5	52	4.7	11 27	3.11	38 4 55.38	.18	— .007	20.028	.031	— .08
C	6	57	6.8	12 15	3.08	1 5 17.67	.16	+ .015	20.024	.033	— .07
A	7	58	4.5	12 41	3.12	36 11 11.01	.21	— .047	20.022	.034	— .01
A	8	60	6.1	13 0	3.14	43 11 29.25	.23	+ .016	20.020	.035	+ .05
C	9	68	6.5	15 42	3.29	67 13 24.32	.26	— .055	20.006	.041	— .02
A	10	80	5.9	18 50	3.27	61 13 57.04	.17	— .006	19.985	.048	+ .06
A	11	87	6.0	19 52	3.07	1 20 29.52	.16	— .011	19.977	.047	— .02
C	12	92	6.5	20 45	3.25	56 2 35.30	.38	+ .010	19.971	.051	.00
A	13	109	5.6	24 25	3.15	29 9 21.93	.20	— .057	19.939	.058	— .03
A	14	112	6.1	24 32	3.06	—4 33 15.16	.13	— .009	19.938	.056	+ .06
A	15	pr 116	7.0	25 10	3.08	15 26 27.46	.24	+ .022	19.932	.058	+ .14
A	16	129	5.8	26 49	3.09	6 21 32.29	.21	+ .022	19.916	.061	+ .01
C	17	142	6.2	29 19	3.08	12 46 37.94	.28	— .054	19.889	.066	+ .06
C	18	152	5.6	30 54	3.24	43 53 33.61	.30	+ .020	19.871	.072	— .01
A	19	155	4.2	31 7	3.19	33 7 28.98	.16	.000	19.868	.072	+ .02
A	20	163	6.8	32 33	3.06	—1 5 51.44	.14	— .025	19.851	.072	+ .04
A	21	169	Var.	34 23	3.36	55 56 41.65	.16	— .038	19.828	.082	+ .05
A	22	173	5.3	35 16	3.24	38 51 57.29	.24	+ .011	19.816	.081	— .19
A	23	180	5.1	36 2	3.32	49 55 12.56	.18	— .003	19.805	.084	+ .04
C	24	182	6.4	36 18	3.41	58 9 40.39	.24	— .007	19.802	.087	— .02
A	25	189	5.0	37 30	3.30	46 26 1.33	.20	— .024	19.785	.087	— .03
C	26	197	5.7	38 26	3.31	47 16 20.30	.50	— .033	19.771	.089	.00
A	27	198	4.8	38 42	3.32	47 41 35.26	.16	— .016	19.767	.090	+ .04
A	28	211	5.5	40 54	3.17	14 53 10.23	.29	— .050	19.734	.090	+ .07
A	29	214	6.0	41 31	3.16	18 59 17.88	.23	+ .010	19.725	.091	+ .02
A	30	215	4.2	41 37	3.16	23 40 46.57	.16	— .072	19.723	.092	+ .03
A	31	219	5.0	42 43	3.37	50 22 44.63	.19	— .015	19.714	.100	— .02
C	32	221	5.9	42 43	3.09	4 43 30.39	.18	— 1.15	19.705	.092	+ .01
A	33	222	4.6	43 5	3.11	6 59 49.72	.14	— .037	19.700	.093	+ .08
A	34	223	5.5	43 18	3.17	16 21 26.68	.23	— .197	19.696	.095	+ .02
A	35	228	5.7	44 10	3.58	63 39 33.78	.17	— .018	19.681	.109	+ .02
C	36	237	6.4	45 45	3.08	2 47 56.26	.21	— .070	19.665	.098	+ .04
A	37	244	5.3	48 35	3.53	58 23 15.79	.23	— .080	19.604	.117	+ .01
A	38	247	5.9	48 52	3.16	18 36 9.33	.19	— .070	19.599	.106	— .07
C	39	253	2.1	50 11	3.57	60 7 54.18	.14	— .015	19.574	.122	+ .02
A	40	254	5.2	50 14	3.55	58 35 50 14	.22	— .070	19.573	.121	.06
C	41 foll	....	5.9	0 53 57	3.37	44 7 52.68	.32	— .025	19.500	.123	+ .02
A	42	285	5.3	56 54	3.27	31 13 27.30	.17	.020	19.438	.126	.00
A	43	288	4.2	57 23	3.11	7 18 50.43	.17	+ .039	19.427	.121	.03
A	44	307 prec	5.3	59 53	3.20	20 53 40.98	.22	— .015	19.372	.129	+ .12
A	45	311	6.4	1 0 14	3.10	4 19 58.96	.19	.119	19.368	.126	.04
A	46	3 1	6.3	2 3	3.30	31 26 8.38	.23	.033	19.322	.137	+ .02
A	47	327	5.7	3 25	3.98	68 12 13.15	.20	— .023	19.292	.167	— .02
C	48	....	6.8	3 38	3.94	67 12 13.57	.30	— .030	19.287	.166	+ .01
C	49	337	5.9	4 11	3.40	41 30 25.47	.24	— .040	19.272	.145	+ .03
A	50	338	5.7	4 39	3.84	64 26 39.34	.18	— .019	19.260	.165	+ .06
C	51	345	5.2	1 5 9	3.29	30 51 0.70	.37	.000	19.248	.143	.00
A	52	374	5.9	9 18	3.06	1 33 6.47	.18	.220	19.143	.141	+ .32
A	52[*]	384	5.8	11 7	3.05	—3 4 8 44	.18	— .060	19.095	.144	+ .01
A	53	388	5.2	12 14	3.09	3 2 43.98	.18	— .019	19.065	.148	+ .02
A	54	394	6.4	13 53	3.94	64 5 29.10	.33	— .045	19.029	.190	.00
A	55	401	5.2	15 9	3.30	28 10 24.53	.25	— .088	18.984	.163	— .03
A	56	404	5.0	15 59	3.50	44 57 45.37	.20	— .005	18.961	.175	+ .03
A	57	406	6.9	17 3	3.06	—1 0 52.62	.20	+ .002	18.930	.156	+ .02
A	58	409	5.8	17 30	3.41	37 9 3.91	.27	+ .001	18.917	.170	— .03
C	59	....	6.1	17 35	3.23	19 54 16.40	.37	— .004	18.915	.165	.00
A	60	416	3.0	18 45	3.87	59 40 25.94	.12	— .036	18.880	.197	— .04
C	61	425	6.0	1 19 58	3.49	42 53 49 84	.31	— .070	18.845	.182	+ .06

* Glasgow position erroneous and now corrected.

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δδ
				h. m. s.	s.	° ′ ″	″	″	″	″	
A	62	427	5.1	20 26	+3.22	18 36 36.48	±0.21	+0.029	+18.830	−0.170	+0.12
A	63	431	5.8	20 52	3.23	18 40 50.88	.23	−.038	18.818	.171	+.02
A	64	432	5.0	21 12	3.56	44 50 55.86	.17	−.104	18.808	.187	−.26
A	65	442	6.6	23 25	3.63	6 44 10.64	.25	−.057	18.739	.170	+.18
A	66	441	5.7	23 37	3.57	46 26 59.78	.25	−.042	18.733	.194	+.02
C	67	446	6.0	24 3	3.23	17 47 49.93	.37	−.000	18.719	.177	−.03
A	68	448	5.0	24 32	3.13	5 35 13.22	.18	−.031	18.704	.172	−.02
A	69	453	3.8	25 42	3.20	14 47 19.83	.16	−.003	18.667	.179	+.07
C	70	455	7.0	26 14	3.22	16 23 47.55	.30	−.210	18.650	.180	+.05
A	71	456	5.4	1 26 52	3.88	58 40 39.21	.13	−.025	18.629	.218	+.09
C	72	464	6.6	27 38	3.14	7 39 16.52	.22	−.030	18.604	.179	+.01
C	73	....	5.9	28 17	3.02	7 34 39.13	.26	−.075	18.583	.173	−.07
C	74	482	5.9	31 4	3.88	57 25 37.45	.34	−.005	18.490	.227	−.05
A	75	487	3.7	31 22	3.65	48 4 51.09	.14	−.111	18.480	.215	+.01
A	76	492	5.2	32 52	3.58	43 50 11.22	.25	−.003	18.429	.214	−.02
C	77	501	5.8	34 11	3.56	42 45 2.70	.32	−.060	18.383	.216	.00
A	78	499	5.5	34 33	4.55	70 4 36.34	.20	+.004	18.370	.274	−.04
C	79	....	6.1	35 17	3.32	25 11 59.94	.23	−.040	18.345	.204	−.04
A	80	518	4.7	35 49	3.12	4 56 27.25	.12	+.005	18.326	.193	−.05
A	81	523	5.4	0 36 38	3.25	19 44 35.88	.20	−.658	18.297	.203	+.02
C	82	525	6.4	1 37 10	3.74	56 59 35.20	.26	−.050	18.277	.243	−.03
A	83	537	4.4	1 39 41	3.16	8 38 50.29	.14	−.058	18.185	.202	−.03
C	84	544	6.1	42 16	3.51	37 24 53.57	.19	−.025	18.089	.229	+.03
C	85	562	6.4	45 56	3.81	50 56 27.46	.40	−.000	17.948	.255	+.04
A	86	564	3.4	46 38	4.25	63 8 16.52	.14	−.022	17.921	.286	−.02
A	87	569	3.7	46 55	3.41	29 3 8.89	.17	−.231	17.910	.231	−.07
A	88	574	4.4	47 58	3.10	2 39 14.88	.15	+.020	17.869	.213	+.03
C	89	579	5.8	49 31	3.53	36 44 52.58	.20	+.005	17.807	.244	+.01
A	90	580	5.8	49 44	3.53	36 43 18.22	.22	+.019	17.798	.245	−.04
C	91	609	6.0	1 53 39	3.20	11 46 14.23	.22	−.040	17.637	.230	−.03
A	92	611	5.9	55 1	4.37	63 52 5.18	.17	+.006	17.580	.315	+.02
A	93	614	5.1	55 7	3.96	53 57 54.46	.19	+.008	17.576	.285	+.07
C	94	624	5.5	56 39	3.49	32 45 47.95	.18	−.010	17.511	.256	−.05
A	95	630	5.9	57 32	3.38	25 24 53.34	.24	+.013	17.473	.250	+.06
A	96	633	5.8	57 39	3.07	−0 23 32.55	.26	+.032	17.468	.227	+.15
A	97	639	6.4	58 16	3.06	−0 51 30.62	.16	−.058	17.441	.228	+.02
A	98	649	5.0	2 1 58	3.59	37 20 47.48	.26	−.037	17.279	.273	+.02
A	99	656	3.1	3 7	3.55	34 28 34.36	.15	−.033	17.228	.272	−.06
A	100	661	5.8	4 20	3.62	38 31 46.26	.23	−.004	17.174	.280	−.06
A	101	665	5.8	2 4 38	3.30	18 59 26.08	.19	−.031	17.160	.257	+.02
A	102	666	6.8	5 3	3.40	25 25 38.34	.26	+.001	17.141	.265	+.16
A	103	667	6.4	5 6	3.49	31 1 1.17	.29	−.020	17.139	.272	+.01
A	104	668	6.1	6 1	4.61	66 1 4.03	.15	−.004	17.097	.353	−.02
A	105	675	5.3	6 6	3.46	29 47 47.92	.18	−.055	17.093	.272	−.02
A	106	676	5.2	6 27	3.74	43 43 28.93	.26	−.019	17.077	.293	+.07
A	107	684	4.5	7 17	3.18	8 20 23.61	.16	−.001	17.039	.252	+.05
A	108	691	5.3	9 33	3.53	32 51 24.10	.20	.021	16.933	.283	.00
A	109	693	5.8	9 35	3.40	24 32 31.67	.35	−.085	16.932	.273	+.03
C	110	694	6.6	10 28	4.54	63 55 26.23	.28	−.040	16.891	.365	−.03
A	111	696	6.5	2 10 29	4.18	57 0 54.32	.29	−.010	16.890	.336	.00
A	112	698	4.3	10 54	3.55	33 20 50.74	.17	−.034	16.870	.287	−.04
C	113	702	7.0	11 55	4.56	63 50 17.55	.35	.000	16.822	.369	+.05
A	114	707	5.6	12 7	3.32	19 24 4.58	.16	+.010	16.812	.272	+.02
A	115	710	5.5	12 41	3.46	28 8 38.02	.23	+.014	16.785	.284	−.02
A	116	721	5.4	14 50	4.14	55 21 3.50	.20	−.011	16.682	.343	−.09
A	117	732	5.8	16 42	3.07	−1 22 37.43	.21	−.052	16.590	.256	+.03
A	118	745	5.5	19 2	3.21	10 7 16.37	.17	−.013	16.475	.274	−.03
A	119	744	4.3	20 10	4.85	66 54 59.05	.15	+.003	16.418	.415	−.05
A	120	757	5.4	21 50	3.50	29 11 12.85	.18	−.085	16.334	.304	−.05
A	121	759	6.5	2 22 28	3.51	29 26 44.01	.27	+.066	16.301	.305	+.02
A	122	760	4.3	22 25	3.18	7 58 32.51	.13	−.001	16.304	.277	−.01
A	123	772	5.6	25 31	3.64	35 40 4.20	.22	+.014	16.145	.322	.00

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δδ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
A	124	786	5.6	29 13	+3.62	34 12 57.88	0.20	—0.036	+15.950	—0.327	—0.08
A	125	791	5.8	29 23	2.95	— 8 19 53.95	.28	— .071	15.942	.268	— .15
A	126	792	6.7	29 55	3.01	— 4 1 13.55	.23	— .427	15.913	.274	— .15
C	127	795	7.0	31 54	5.46	71 9 38.69	.21	.000	15.808	.499	+ .01
A	128	808	5.6	32 41	3.39	21 29 38.86	.16	— .011	15.765	.313	— .01
A	129	816	5.9	35 19	4.25	54 38 40.68	.27	— .025	15.621	.395	+ .22
C	130	819	6.1	35 23	4.19	53 3 54.50	.35	— .015	15.618	.390	.00
A	131	830	6.3	2 36 40	3.22	10 16 51.05	.24	— .028	15.547	.304	+ .05
A	132	829	5.7	37 3	3.89	43 50 14.63	.24	— .024	15.526	.365	— .03
A	133	831	4.9	37 7	3.50	27 14 50.02	.17	— .009	15.522	.331	— .02
A	134	844	5.1	39 4	3.26	11 59 27.51	.20	— .069	15.413	.310	— .01
A	135	845	4.2	39 6	3.23	9 39 28.32	.15	— .020	15.412	.307	— .02
A	136	861	4.9	41 29	3.56	28 47 53.48	.23	— .110	15.278	.342	+ .02
A	137	866	5.8	42 29	3.47	24 44 13.58	.28	+ .002	15.221	.336	+ .02
A	138	863	3.8	42 49	4.67	55 26 48.08	.19	— .034	15.201	.419	— .05
A	139	871	4.6	43 46	3.75	37 52 25.40	.21	— .087	15.147	.365	— .10
A	140	885	4.1	46 36	4.21	52 19 11.95	.13	— .009	14.984	.416	+ .05
A	141	....	7.0	2 46 51	4.16	50 43 30.36	.37	— .030	14.969	.410	+ .04
A	142	888	5.8	46 54	3.77	37 53 49.75	.20	— .063	14.967	.372	— .05
C	143	892	6.5	47 11	3.33	16 2 31.66	.34	— .075	14.950	.330	— .06
C	144	....	6.3	49 16	3.94	50 49 27.10	.32	— .030	14.827	.416	+ .10
C	145	914	5.7	52 30	4.05	46 47 15.68	.29	+ .020	14.636	.410	+ .02
C	146	948	5.0	57 26	4.46	56 16 51.85	.26	+ .065	14.338	.442	— .05
A	[a]147	[a]957	5.7	59 6	3.51	24 50 4.10	.23	— .013	14.235	.366	.00
A	148	963	var.	3 1 8	3.88	40 32 20.99	.16	+ .010	14.109	.409	— .01
A	149	967	4.3	2 13	4.02	44 26 51.60	.21	— .160	14.042	.423	+ .02
A	150	974	5.8	3 7	3.59	28 39 50.46	.21	— .026	13.985	.382	— .06
A	151	981	5.0	3 4 19	3.85	39 12 3.34	.21	+ .020	13.910	.411	— .07
C	152	987	6.3	5 26	3.29	12 38 16.49	.24	+ .010	13.840	.353	+ .01
A	153	986	4.3	5 27	3.42	19 19 4.27	.13	+ .005	13.838	.366	.03
C	154	991	6.0	6 42	3.18	6 15 13.29	.36	— .010	13.759	.343	.01
A	155	999	4.8	8 42	3.44	20 38 37.94	.18	— .070	13.632	.374	— .10
A	156	1,006	5.6	10 31	4.01	43 37 39.13	.23	— .044	13.514	.438	— .03
A	157	1,007	5.4	10 56	4.24	49 49 33.61	.17	— .027	13.487	.464	— .01
B	158	1,017	5.0	11 58	3.74	33 49 37.98	.21	— .002	13.420	.411	— .38
A	159	1,023	5.9	13 29	3.57	26 40 48.27	.27	— .080	13.322	.395	— .01
A	160	1,028	5.0	13 42	3.12	2 58 25.50	.17	+ .110	13.307	.347	.00
A	161	1,041	6.0	3 15 28	3.13	3 17 10.23	.23	— .037	13.191	.350	.03
A	162	1,058	4.5	20 19	4.82	59 33 48.15	.14	.012	12.868	.544	— .05
A	163	1,099	4.8	28 49	4.24	47 49 57.92	.20	.038	12.290	.494	+ .08
C	164	1,105	6.6	30 42	4.04	42 13 35.50	.30	.020	12.159	.473	.00
A	165	1,112	4.4	31 22	3.07	0 3 30.23	.20	— .501	12.113	.362	+ .07
C	166	1,114	6.5	31 44	3.37	15 4 31.54	.32	— .010	12.087	.396	+ .06
A	167	1,111	5.5	32 47	5.15	62 51 58.20	.18	+ .058	12.013	.608	.00
C	168	1,123	5.8	34 6	3.90	37 13 51.21	.27	— .040	11.921	.461	— .01
A	169	1,128	5.9	34 14	3.12	2 42 19.01	.22	+ .019	11.912	.372	.04
A	170	1,132	5.0	35 32	3.85	33 37 5.00	.26	— .003	11.820	.452	— .01
A	171	1,135	5.5	3 36 5	3.45	19 21 14.18	.18	— .007	11.781	.412	+ .02
B	172	1,133	5.3	36 36	5.19	63 0 11.80	.28	— .010	11.745	.620	+ .40
A	173	1,138	4.0	37 33	3.75	31 56 44.21	.22	— .010	11.677	.449	— .07
A	174	1,139	4.0	37 51	4.05	42 14 12.35	.17	.012	11.655	.487	+ .01
A	175	1,140	6.2	37 32	3.55	19 19 23.48	.21	— .034	11.677	.414	+ .02
C	176	1,143	5.9	38 11	3.48	20 35 13.82	.27	.000	11.632	.419	— .02
C	177	1,142	5.9	38 26	4.18	45 20 31.70	.31	— .020	11.614	.501	+ .10
A	178	1,137	4.5	38 58	6.22	70 59 54.94	.20	— .051	11.576	.748	+ .04
A	179	1,158	6.0	39 25	3.06	— 0 38 12.82	.21	.012	11.543	.370	+ .22
A	180	1,161	4.9	39 55	3.55	23 36 41.21	.20	— .042	11.504	.429	+ .03
C	181	....	5.9	3 41 41	4.12	43 37 44.38	.40	+ .010	11.381	.500	+ .02
C	182	1,192	5.8	43 49	3.59	25 15 10.72	.28	— .110	11.226	.439	— .02
C	183	1,206	6.0	46 59	3.43	17 0 17.90	.19	— .036	10.995	.421	.00
A	184	1,212	5.6	47 22	2.96	— 5 41 3.16	.18	— .007	10.969	.366	— .10

[a] A close double; — 1″ apart: mean of the two.

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
A	185	1,214	4.5	48 35	+4.43	50 22 55.01	±0.17	−0.125	+10.879	−0.547	+0.09
A	186	1,219	3.3	50 36	4.01	39 41 50.20	.15	−.016	10.730	.499	.10
A	187	1,228	4.1	51 57	3.88	35 28 47.69	.16	−.013	10.630	.484	−.09
A	188 pr	1,238[1]	6.7	54 32	3.58	22 53 48.05	.28	−.016	10.438	.447	+.05
C	189	1,240	5.9	54 35	3.44	17 53 19.52	.31	−.047	10.434	.433	.00
A	190	1,241	{3.4-4.2 var.}	54 42	3.32	12 11 4.89	.14	−.009	10.426	.418	+.01
A	191	1,262	5.3	59 59	3.67	27 18 29.44	.24	−.061	10.028	.468	+.06
A	192	1,266	4.3	4 0 49	4.33	47 25 24.72	.14	−.033	9.964	.553	+.08
A	193	1,268	6.3	1 7	3.65	37 26 37.25	.27	−.142	9.942	.506	+.05
A	194	1,279	5.8	4 15	3.64	26 11 54.98	.17	−.037	9.703	.470	−.08
A	195	1,287	4.1	6 58	4.38	48 8 3.33	.19	−.027	9.494	.567	+.07
A	196	1,302	6.2	9 38	3.40	15 7 47.90	.20	−.010	9.287	.442	−.10
C	197	1,301	4.9	10 7	4.48	50 1 45.36	.22	−.050	9.250	.585	+.04
A	198	1,322	5.4	13 24	3.89	34 18 19.31	.20	+.001	8.995	.511	.00
A	199	1,323	5.0	13 44	4.32	46 14 24.47	.22	−.040	8.968	.567	+.03
A	200	1,328	4.0	13 39	3.41	15 21 58.59	.16	−.030	8.975	.447	+.07
A	201	1,346	4.0	4 16 42	3.45	17 17 19.48	.16	−.025	8.735	.456	−.08
A	202	1,350	6.0	17 13	3.43	16 31 28.47	.23	−.032	8.694	.454	+.03
A	203	1,357	5.3	17 58	3.26	9 12 32.84	.26	−.004	8.635	434	−.04
A	204	1,364	5.7	19 14	3.81	31 11 40.55	.30	−.116	8.536	.506	+.03
A	205	1,371	5.9	20 50	3.58	22 45 8.50	.20	−.003	8.409	.478	.00
C	206	1,373	6.0	21 36	3.55	21 22 42.44	.31	−.050	8.348	.474	−.04
A	207 foll	1,382	5.7	23 29	4.73	53 40 31.30	.14	−.009	8.198	.633	+.10
C	208 foll	1,398	5.8	25 49	4.21	42 49 57.22	.21	.000	8.011	.566	+.07
A	209	1,414	4.8	29 12	4.14	41 2 31.84	.23	−.024	7.738	.561	−.04
A	209	1,421	4.6	29 43	3.21	9 56 18.84	.25	−.054	7.696	.446	+.06
A	210	1,424	5.7	31 25	4.73	53 15 34.46	.17	−.091	7.560	.627	.03
A	211	1,425	5.7	4 31 24	4.71	52 51 48.74	.20	−.019	7.560	.639	−.04
A	212	1,442	5.6	34 3	3.33	11 59 5.27	.25	−.022	7.346	.455	+.11
B	213	1,460	5.7	38 27	3.31	10 56 40.37	.32	+.007	6.986	.456	+.13
A	214	1,456	5.6	39 0	4.58	56 33 52.25	.14	−.155	6.940	.683	+.07
A	215	1,469	3.9	40 6	3.00	−3 27 11.14	.14	−.002	6.850	.413	−.06
A	216	1,474	4.5	43 19	5.92	66 9 30.08	.12	−.001	6.585	.820	.02
A	217	1,491	4.7	44 43	3.26	8 42 51.51	.21	−.031	6.468	.453	−.01
A	218	1,495	4.1	45 27	3.19	5 25 11.73	.16	−.002	6.408	.444	−.03
A	219	1,494	5.8	46 13	4.89	55 4 48.40	.22	−.009	6.345	.679	+.10
A	220	1,514	3.8	48 38	3.12	2 15 48.09	.13	−.007	6.145	.436	+.01
A	221	1,528	5.8	4 51 33	3.67	24 52 58.87	.20	−.019	5.901	.513	−.02
A	222	1,535	6.4	52 57	4.12	39 29 26.13	.27	−.006	5.784	.579	−.13
A	223	1,536	4.3	53 49	5.31	60 17 0.80	.14	−.014	5.711	.746	−.10
A	224	1,540	var.	54 13	4.30	43 39 46.21	.15	−.014	5.677	.603	+.03
A	225	1,541	3.9	54 56	4.18	40 55 3.36	.15	−.008	5.617	.588	−.07
A	226	1,551	4.8	56 38	3.58	21 26 6.42	.16	−.040	5.473	.504	−.02
A	227	1,558	3.5	58 56	4.20	41 5 16.16	.14	−.061	5.279	.593	−.06
A	228	1,568	5.2	5 1 4	3.54	18 29 58.20	.19	+.022	5.100	.497	+.08
B	229	1,572	5.8	1 32	3.65	24 7 18.68	.30	.000	5.061	.517	+.22
C	230	1,582	6.0	2 40	4.45	46 49 40.17	.26	−.160	4.964	.631	+.03
C	231	1,601	5.7	5 5 29	3.44	15 54 41.96	.27	+.010	4.725	.490	+.04
A	232	1,614	5.3	8 22	3.90	32 33 43.41	.22	+.013	4.479	.555	+.00
A	233	1,627	5.0	11 5	3.92	33 15 29.46	.22	−.154	4.247	.562	+.05
A	234	1,642	5.4	14 13	5.12	57 26 18.78	.20	−.058	3.979	.734	−.02
A	235	1,663	5.7	17 19	4.07	37 17 2.05	.21	+.001	3.713	.585	+.04
A	236	1,687	1.9	19 20	3.22	6 15 4.52	.16	−.015	3.539	.463	+.08
A	237	1,681	2.0	19 28	3.79	28 30 56.24	.14	−.180	3.528	.545	+.01
A	238	1,676	5.9	19 58	5.65	62 58 33.81	.14	−.008	3.485	.816	−.01
A	239	1,730	2.2	26 29	3.06	−0 22 46.83	.16	−.005	2.922	.443	+.03
A	240	1,748	4.9	5 28 53	3.29	9 24 57.10	.20	−.002	2.714	.477	+.09
A	241	1,766	4.6	5 30 58	3.29	9 13 53.20	.23	−.305	2.533	.477	+.07
B	242	1,751	5.9	31 37	6.00	65 38 16.87	.31	−.036	2.477	.870	+.03
A	243	1,794	1.9	35 19	3.02	−2 0 0.56	.16	+.010	2.156	.440	+.16
A	244	1,797	6.2	37 24	5.05	56 4 12.08	.20	−.054	1.974	.734	.00
A	245	1,837	5.2	42 23	3.68	24 31 50.69	.20	−.010	1.539	.536	+.01

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
A	246	1,845	4.1	44 0	+4.15	39 6 58.32	±0.16	+0.032	+1.398	−0.605	−0.02
C	247	1,876	4.8	47 59	3.55	20 15 19.65	.17	— .096	1.051	.520	.00
A	248	1,885	4.0	50 38	4.94	54 16 32.23	.14	— .117	.819	.719	— .03
C	249	1,896	5.3	51 18	3.72	25 56 23.31	.21	— .005	.762	.543	+ .04
A	250	1,895	2.0	51 36	4.40	44 56 8.65	.15	.011	.734	.642	+ .03
C	251	1,928	4.7	56 26	3.30	9 38 48.56	.31	+ .020	.311	.481	— .06
A	252	1,945	5.9	59 16	3.17	4 9 51.03	.16	— .013	.064	.462	— .03
A	253	1,958	4.6	6 1 24	3.42	14 46 50.97	.14	— .013	— .123	.499	+ .03
A	254	1,963	5.8	3 20	4.60	48 43 55.44	.24	— .063	.292	.670	+ .06
A	255	1,992	5.7	7 57	5.54	61 32 57.46	.21	— .005	.696	.807	— .06
A	256	2,009	5.6	9 11	3.46	16 10 32.72	.18	+ .005	.804	.504	+ .08
A	257	2,017	5.5	10 23	3.37	12 18 6.24	.18	+ .199	.908	.490	— .03
A	258	2,022	5.7	11 9	3.31	9 58 52.01	.23	— .059	.976	.481	— .01
A	259	2,024	5.7	12 59	4.87	53 30 1.93	.23	— .090	1.136	.709	+ .17
A	260	2,044	5.4	16 35	4.63	49 20 32.36	.16	— .012	1.450	.672	.00
C	261	2,046	5.7	6 17 19	5.07	56 20 29.22	.50	.000	1.513	.737	+ .18
A	262	2,074	6.2	21 24	5.22	58 14 28.30	.17	— .334	1.870	.757	+ .01
A	263	2,126	4.8	27 4	3.25	7 24 41.48	.21	+ .004	2.363	.469	+ .12
A	264	2,156	5.7	31 18	4.18	39 59 39.85	.22	— .011	2.730	.603	+ .09
A	264[1]	2,163	2.2	31 28	3.47	16 29 27.34	.13	— .035	2.745	.499	+ .04
B	265	....	6.1	31 37	3.22	6 13 32.59	.50	+ .037	2.757	.464	— .09
A	266	2,194	3.3	37 17	3.69	25 14 15.09	.14	— .005	3.248	.530	— .03
A	267	2,192	5.8	37 37	5.13	57 16 49.53	.22	— .037	3.277	.736	+ .07
A	268	2,200	5.6	38 57	4.33	43 41 3.05	.18	+ .147	3.392	.641	.00
A	269	2,201	5.7	39 26	4.58	48 54 10.21	.23	— .004	3.433	.677	+ .03
A	270	2,223	5.1	43 8	4.25	41 54 27.52	.27	— .130	3.751	.607	+ .08
A	271	2,233	5.6	6 45 5	3.60	21 53 16.70	.26	— .038	3.919	.513	.00
A	272	2,235	6.4	45 36	4.13	38 59 49.99	.22	+ .002	3.963	.589	— .03
A	273 pr	2,275	6.8	52 8	3.70	26 13 20.21	.21	+ .083	4.522	.526	+ .03
A	274	2,330	5.7	7 2 10	3.44	16 6 9.36	.19	— .104	5.374	.482	+ .04
A	275	2,350	5.9	5 53	3.65	24 18 31.45	.18	— .037	5.685	.508	— .03
B	276	2,361	5.7	7 49	4.46	47 25 52.25	.37	— .162	5.847	.620	....
A	277	2,381	5.8	10 32	4.19	41 4 28.15	.18	+ .023	6.074	.579	— .15
A	278	2,410	3.5	13 40	3.59	22 10 50.71	.17	+ .003	6.336	.494	+ .09
A	279	2,416	5.5	14 50	4.02	36 57 47.30	.16	— .009	6.431	.553	— .06
A	280	2,467	5.3	22 37	3.75	28 20 24.44	.22	— .053	7.073	.508	— .01
A	281	2,469	5.0	7 23 6	3.74	28 8 17.99	.22	— .018	7.112	.507	+ .01
A	282	2,480	5.6	26 30	3.12	2 8 35.22	.27	+ .023	7.390	.420	— .05
A	283	2,504	5.9	31 27	3.94	35 17 23.28	.24	+ .024	7.791	.526	+ .02
A	284	2,533	6.6	36 41	5.48	63 5 24.38	.19	— .066	8.210	.724	.00
A	285	2,549	5.9	37 32	3.67	26 2 26.70	.21	— .026	8.278	.483	+ .10
B	286	....	5.7	39 27	4.02	37 46 42.00	.40	+ .030	8.431	.527	+ .10
A	287	2,606	6.2	46 38	4.38	47 39 53.08	.25	— .014	8.997	.567	+ .02
A	288	2,639	6.1	50 52	3.41	16 4 41.97	.21	— .026	9.326	.436	+ .03
B	289	....	6.0	55 31	3.18	5 10 35.40	.50	+ .037	9.685	.401	.00
B	290	2,704	6.0	8 1 12	4.97	58 33 49.70	.33	— .075	10.117	.620	.00
B	291	....	6.1	18 10	3.85	35 21 36.56	.50	.000	11.370	.458	— .04
A	292	2,815	6.0	19 54	3.66	28 14 55.57	.26	— .117	11.494	.434?	+ .03
A	293	2,842	5.4	24 56	5.44	65 30 45.76	.17	— .063	11.852	.636	— .06
C	294	....	6.1	28 34	3.04	— 1 47 1.15	.50	.000	12.108	.348	+ .35
A	295	2,892	6.0	31 17	4.47	53 5 22.49	.25	— .031	12.296	.511	— .09
A	296	2,958	5.8	38 53	3.26	10 28 21.27	.31	+ .007	12.815	.363	— .07
A	297	2,976	5.4	41 47	3.05	— 1 30 6.06	.26	+ .017	13.008	.332	— .34
A	297[1]	3,003	5.8	47 22	5.22	65 0 59.26	.17	— .090	13.376	.560	+ .14
A	298 foll	3,052	5.6	51 33	3.36	15 59 44.59	.22	+ .036	13.647	.355	+ .01
A	299	3,075	3.5	56 15	4.13	47 34 59.41	.17	— .068	13.946	.426	— .01
A	300 foll	3,162	4.0	9 12 7	3.75	37 15 33.50	.17	— .114	14.909	.359	.00
A	301	3,204	4.6	18 22	3.51	26 38 49.13	.19	— .036	15.269	.320	— .13
B	302	3,273	5.6	30 18	3.57	31 38 44.45	.36	— .012	15.925	.311	— .95
C	303	....	6.1	35 12	3.56	31 46 5.64	.50	.000	16.182	.301	— .04
A	304	3,358	4.7	44 45	4.13	54 34 7.42	.18	+ .025	16.661	.227	— .02

[1] N. component.

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δδ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
A	305	3,407	6.4	52 24	+3.18	8 49 45.46	±0.25	-0.015	-17.024	-0.238	+0.04
A	306	3,505	3.5	10 10 35	3.64	43 27 12.02	.15	-.058	17.811	.238	-.02
A	307	3,522	5.7	13 51	3.27	20 1 7.76	.20	-.201	17.940	.207	-.06
A	308	3,531	5.0	16 20	4.40	66 6 44.40	.16	-.014	18.036	.272	.00
A	309	3,590	5.1	24 0	3.05	-2 11 11.39	.18	-.018	18.319	.173	+.19
A	310	3,593	4.9	25 54	5.28	76 16 8.71	.17	-.005	18.386	.298	-.01
B	311	3,637	var	10 32 13	2.96	-12 49 23.00	.36	.000	18.600	.153	.00
A	312	3,691	5.8	40 35	3.24	19 27 39.02	.21	-.036	18.861	.152	+.08
A	313	3,729	4.9	47 46	3.47	43 45 53.11	.19	-.027	19.065	.148	-.01
A	314	3,749	6.0	50 9	3.09	1 18 45.42	.20	+.008	19.129	.126	-.12
A	315	3,777	2.0	57 4	3.76	62 20 2.31	.15	-.071	19.301	.141	-.01
A	316	3,784	5.8	58 31	3.35	38 49 22.76	.21	-.013	19.336	.121	+.04
A	317	3,788	4.8	59 27	3.10	7 55 11.43	.15	-.022	19.357	.111	+.07
A	318	3,801	6.5	11 1 53	3.22	23 54 26.44	.29	+.016	19.411	.111	+.06
B	319	3,825	6.7	6 27	3.52	55 28 52.15	.50	-.002	19.508	.111	-.05
A	320	3,842	5.0	9 28	3.20	23 41 2.64	.21	+.003	19.567	.094	+.06
A	321	3,856	4.7	11 13 15	3.29	38 46 40.19	.26	-.068	19.637	.089	+.01
A	322	3,862	4.2	15 34	3.10	6 37 16.10	.14	.000	19.677	.079	.00
B	323	3,864	5.9	16 26	3.61	64 55 17.35	.17	+.040	19.692	.091	-.05
B	324	....	6.0	23 41	3.41	57 20 1.57	.36	-.012	19.802	.070	-.27
A	325	3,916	5.0	24 48	3.06	-2 24 27.53	.13	.000	19.817	.060	+.13
A	326	3,933	5.5	29 43	3.58	69 55 25.59	.17	-.127	19.878	.068	+.01
B	327	3,953	6.1	32 45	3.25	47 25 58.37	.32	-.034	19.911	.048	+.53
B	328	3,975	6.5	38 24	3.06	-6 4 35.56	.27	-.023	19.964	.034	+.36
A	329	3,981	4.0	40 21	3.19	48 22 41.60	.15	+.030	19.979	.032	.00
A	330	3,995	2.1	43 33	3.06	15 10 32.87	.14	-.098	20.001	.024	+.03
A	331	4,017	2.4	11 48 9	3.18	54 17 42.78	.15	+.008	20.026	.016	+.02
C	332	....	6.1	51 41	3.12	40 56 48.21	.34	-.060	20.040	.008	-.11
A	333	4,066	5.9	58 45	3.08	22 3 38.21	.22	+.004	20.053	+.001	-.01
A	334	4,072	4.2	59 42	3.06	9 19 58.17	.14	+.049	20.053	.008	+.03
A	335	4,110	5.8	12 6 40	3.06	21 8 36.41	.26	-.018	20.044	.020	-.01
A	336	4,126	5.8	10 43	3.02	41 15 40.83	.18	-.031	20.031	.029	-.03
A	337	4,151	5.2	14 52	3.04	3 54 50.55	.19	-.063	20.011	.037	+.05
A	338	4,195	4.6	21 33	3.00	28 52 7.56	.17	-.086	19.964	.050	-.06
B	339	....	6.6	22 15	2.96	41 57 10.73	.35	-.012	19.958	.050	-.03
A	340	4,212	5.8	24 18	3.01	21 29 39.39	.20	-.017	19.940	.056	+.01
A	341	4,216	5.6	12 24 55	2.83	59 0 0.23	.13	+.100	19.934	.053	-.03
B	342	4,233	5.3	28 20	2.96	33 50 39.60	.30	-.025	19.900	.062	-.50
A	343	4,246	5.2	30 10	2.57	70 37 1.38	.23	-.005	19.879	.058	+.02
A	344	4,248	6.0	31 33	3.01	17 41 4.57	.21	-.022	19.863	.069	+.03
A	345	4,257	4.9	33 40	3.09	-7 24 4.44	.13	-.021	19.837	.075	+.14
B	346	4,282	6.2	39 21	2.85	44 41 38.17	.36	.000	19.758	.080	+.03
B	347	4,287	5.5	40 3	2.83	46 1 50.09	.26	+.005	19.747	.080	+.21
A	348	4,315	5.0	46 26	2.93	28 7 42.37	.17	-.018	19.643	.094	-.07
A	349 prec	4,318	6.3	46 50	2.98	17 39 41.57	.31	.000	19.636	.096	-.07
C	350	....	6.2	49 4	2.88	34 7 10.23	.45	+.015	19.595	.098	-.03
A	351	4,347	5.1	12 51 11	2.41	66 1 27.65	.24	-.051	19.555	.087	-.05
A	352	4,351	5.1	53 35	2.97	17 59 30.43	.23	+.052	19.507	.109	+.17
A	353	4,352	5.9	54 6	3.09	-3 13 45.43	.17	+.010	19.497	.114	-.17
A	354	4,365	5.7	55 50	2.31	67 10 47.82	.18	-.013	19.461	.090	-.02
B	355	4,389	5.9	13 1 1	2.71	45 50 45.87	.32	+.025	19.346	.113	+.13
A	356	4,388	6.0	1 7	2.95	23 11 44.76	.26	-.031	19.344	.121	+.14
A	357	4,401	4.4	4 21	3.10	-4 57 44.57	.14	-.037	19.267	.134	+.07
A	358 prec	4,408	6.3	4 44	2.77	39 6 33.51	.27	+.007	19.258	.122	-.01
B	359	4,423	6.0	7 10	2.99	12 7 50.14	.28	-.024	19.198	.134	-.14
B	360	....	6.6	9 47	2.09	67 51 36.45	.34	+.004	19.131	.099	-.25
A	361	4,456	5.0	13 13 39	2.56	50 15 0.06	.22	-.001	19.026	.127	-.06
A	362	4,477	6.1	17 43	3.10	-4 21 33.45	.24	-.010	18.911	.159	+.45
B	363	4,497	6.6	22 18	2.06	63 48 56.75	.17	+.207	18.773	.117	-.35
A	364	4,506	5.9	23 23	1.52	72 57 8.33	.26	-.023	18.740	.088	+.07
C	365	4,502	6.5	23 42	3.08	-0 48 13.28	.32	-.060	18.730	.167	-.02
A	366	4,521	5.4	27 17	3.15	-9 36 30.37	.22	-.023	18.616	.179	+.17

Mean declinations of latitude stars—Continued.

Class	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	s.	° ′ ″	″	″	″	″	″
B	367	4,526	6.2	27 41	+2.84	24 54 27.80	± 0.31	—0.200	—18.603	+0.163	—0.10
C	368	4,536	5.2	29 58	2.68	37 44 8.58	.17	— .015	18.527	.158	+ .02
A	369	....	5.9	34 35	1.43	71 47 30.90	.19	+ .011	18.369	.092	.00
A	370	4,562	5.6	35 31	2.86	20 30 7.47	.19	+ .020	18.336	.177	+ .03
A	371	4,565	5.7	13 35 57	3.14	— 8 9 28.52	.14	.046	18.321	.195	+ .02
B	372	....	6.3	37 53	2.57	42 13 6.95	.27	+ .015	18.252	.163	— .15
B	373	4,596	5.7	41 38	2.56	41 37 49.18	.34	— .058	18.113	.168	+ .22
A	374	4,607	2.0	43 17	2.37	49 51 8.64	.13	— .014	18.051	.160	+ .06
A	375	4,618	5.0	44 36	2.83	21 48 1.15	.23	+ .016	18.000	.190	+ .05
B	376	....	6.2	47 1	2.94	12 41 56.58	.41	— .020	17.906	.201	— .28
A	377	4,649	5.8	49 52	2.22	54 15 35.20	.22	— .017	17.792	.157	— .10
B	378	....	6.5	54 14	3.10	— 3 1 24.71	.30	— .068	17.613	.223	+ .11
C	379	....	0.6	55 29	1.67	65 25 6.34	.40	.000	17.560	.125	+ .16
B	380	....	6.0	56 0	2.96	9 25 3.00	.31	+ .020	17.539	.217	— .10
C	381	....	6.4	14 5 26	1.87	59 50 57.60	.26	— .049	17.124	.150	.00
B	382	4,713	4.9	6 48	2.71	2 55 4.85	.34	— .020	17.061	.240	— .15
A	383	4,724	5.5	9 34	2.94	10 36 33.89	.25	— .153	16.933	.238	+ .11
A	384	4,741	4.1	12 17	2.28	46 35 3.56	.24	+ .151	16.804	.191	+ .04
A	385	4,742	4.5	12 20	2.13	51 51 55.60	.16	+ .085	16.801	.178	+ .10
A	386	4,753	5.0	14 39	2.84	16 48 6.57	.17	+ .058	16.691	.238	+ .03
B	387	....	6.2	17 44	3.05	1 44 51.76	.34	— .475	16.539	.259	— .26
	388	4,808	3.8	27 11	2.59	30 50 44.36	.16	+ .125	16.058	.234	+ .04
B	389	....	6.1	28 47	1.62	60 42 5.76	.20	+ .025	15.974	.152	+ .04
B	390	4,820	6.8	29 36	2.54	33 0 29.79	.26	+ .010	15.931	.232	+ .21
A	391	4,843	5.4	14 34 49	2.23	44 52 14.25	.21	— .049	15.649	.211	+ .05
B	392	....	6.1	35 28	2.73	22 26 20.13	.34	— .080	15.614	.257	— .23
B	393	4,870	5.7	39 33	2.33	40 54 58.60	.36	+ .020	15.386	.225	— .10
A	394	4,873	4.6	40 12	2.80	17 25 18.38	.27	— .052	15.350	.270	+ .02
B	395	....	6.0	43 36	2.67	24 48 55.30	.34	+ .035	15.157	.262	.00
A	396	4,903	5.8	45 28	2.14	46 33 58.48	.20	— .098	15.050	.212	+ .02
B	397	4,906	5.7	46 14	2.37	37 42 55.09	.23	+ .100	15.005	.237	— .59
B	398	4,918	5.7	48 42	1.52	59 43 58.80	.19	— .140	14.861	.156	.00
B	399	4,933	5.9	52 10	2.80	16 49 23.39	.30	.000	14.656	.285	+ .11
A	400	4,951	4.8	57 27	3.03	2 30 56.45	.25	+ .010	14.337	.315	+ .00
B	401	4,967	5.9	14 58 55	1.40	60 37 44.43	.32	+ .027	14.246	.150	— .33
A	402	5,031	5.2	15 9 58	2.51	29 33 55.16	.23	+ .033	13.549	.276	+ .04
B	403	5,033	6.2	10 16	2.16	42 34 24.70	.36	— .025	13.530	.239	.00
B	404	5,048	5.9	13 34	2.69	20 58 4.30	.33	— .012	13.316	.298	+ .10
A	405	5,061	5.7	15 40	2.48	30 0 29.01	.19	— .049	13.177	.280	— .01
A	406	5,072	5.4	17 29	2.40	33 19 12.91	.20	+ .004	13.057	.272	— .01
A	407	5,085	5.4	20 47	2.78	15 48 29.54	.21	+ .005	12.837	.317	+ .06
B	408	5,091	5.9	20 50	.99	63 43 37.51	.31	— .096	12.834	.116	+ .09
B	409	5,113	6.7	25 57	1.91	48 5 2.80	.33	— .010	12.486	.224	+ .40
A	410	5,119	5.9	27 24	3.08	— 0 49 10.85	.30	— .046	12.387	.359	+ .05
B	411	5,147	5.9	15 29 25	.84	64 34 19.31	.18	+ .078	12.248	.103	— .31
B	412	5,152	6.3	31 28	2.78	15 27 31.83	.26	+ .013	12.105	.328	+ .17
B	413	5,153	5.9	31 31	2.76	16 28 36.90	.33	.000	12.102	.326	+ .00
B	414	5,177	5.6	34 49	1.91	47 9 13.29	.31	— .133	11.871	.229	+ .11
A	415	5,214	4.6	41 12	2.91	7 41 30.21	.28	— .057	11.416	.356	+ .29
A	416	5,244	4.5	45 4	2.51	26 23 56.98	.21	— .078	11.136	.311	+ .02
B	417	5,248	5.7	45 1	1.44	55 42 27.24	.28	+ .010	11.139	.179	+ .06
A	418	5,259	4.7	47 10	2.26	35 59 33.04	.23	— .357	10.983	.280	+ .06
B	419	5,273	6.0	49 49	2.65	20 37 39.99	.34	+ .047	10.788	.330	+ .21
A	420	5,284	3.8	51 28	2.76	16 0 51.73	.13	1.280	10.666	.343	— .03
B	421	5,298	5.8	15 51 52	2.02	42 52 49.22	.26	.000	10.636	.254	— .12
B	422	5,313	5.1	55 14	1.41	55 3 18.23	.26	+ .118	10.386	.183	— .23
A	423	5,338	4.4	59 26	1.87	46 20 11.81	.19	— .064	10.069	.239	+ .09
A	424	5,366	6.0	16 3 16	2.89	8 49 18.02	.30	— .012	9.778	.372	.00
A	425 prec	5,367	5.4	3 12	2.70	17 20 5.44	.18	— .011	9.783	.350	+ .06
A	426	5,388	4.0	5 22	1.89	45 13 5.51	.17	+ .043	9.617	.246	— .01
A	427	5,411	5.9	7 51	2.19	36 42 14.50	.24	— .040	9.426	.286	.00
A	428	5,448	6.5	13 55	2.48	26 9 35.06	.29	— .007	8.954	.327	+ .04

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion	Annual precession.	Sec. var.	Δ
				h. m. s.	*s.*	° ′ ″	″				
A	429	5,456	5.0	16 36	+3.03	1 16 58.91	±0.26	+0.035	8.743	0.404	+0.09
A	430	5,512	2.7	22 32	.81	61 45 31.15	.15	.050	8.273	110	— .05
A	431	5,545	5.0	16 28 12	— .15	69 0 6.47	.14	+ .036	7.820	— .014	.07
B	432	....	6.1	32 14	+3.21	— 6 19 12.82	.40	.016	7.493	.438	.02
A	433	5,596	5.0	35 49	1.63	49 8 22.74	.20	+ .021	7.201	.225	.16
B	434	....	6.3	43 10	2.76	13 46 57.25	.29	— .016	6.597	.385	+ .05
B	435	5,647	5.9	44 36	2.77	13 27 0.63	.31	— .008	6.480	.385	.23
A	436	5,693	5.5	48 52	2.27	31 52 50.33	.20	.019	6.124	.319	— .03
A	437	5,731	3.7	56 9	2.29	31 5 8.41	.16	+ .032	5.514	.324	— .01
B	438	....	5.9	17 1 44	2.54	22 13 50.04	.30	.045	5.043	.362	.16
B	439	5,790	6.1	4 15	1.95	40 39 26.21	.22	.031	4.830	.279	.11
A	440	5,828	3.1	10 36	2.46	24 58 0.58	.18	— .153	4.289	.354	+ .02
A	441	5,847	4.8	17 13 57	2.07	37 24 17.73	.18	+ .084	4.003	.298	.03
A	442	5,871	5.7	17 18	1.70	46 20 48.07	.19	+ .032	3.715	.245	.13
B	443	....	5.8	19 41	2.68	16 24 2.76	.24	— .040	3.509	.388	— .36
B	444	5,917	5.7	24 18	.77	60 8 21.14	.27	+ .070	3.112	.112	+ .46
B	445	5,919	5.8	25 56	3.01	2 48 21.40	.25	+ .032	2.969	.436	— .30
B	446	5,944	5.9	29 42	2.70	41 19 11.89	.34	— .060	2.644	.277	— .29
B	447	....	5.9	31 23	2.56	21 3 56.24	.34	— .024	2.498	.372	— .34
A	448	5,975	5.8	33 48	1.56	48 38 54 59	.22	+ .051	2.287	.228	+ .11
B	449	....	6.2	38 27	2.73	14 20 38.94	.44	.010	1.883	.398	— .14
A	450	6,047	4.5	17 43 51	—1.08	72 12 6.18	.13	.268	1.411	— .157	+ .02
A	451	6,078	3.5	53 5	+3.30	— 9 45 35.45	.13	— .105	.605	+ .482	+ .05
A	452	6,142	4.9	18 2 8	2.87	8 43 13.49	.28	+ .033	+ .187	.418	— .09
A	453	6,157	4.4	4 8	2.56	20 47 51.68	.25	— .013	.362	.374	— .08
B	454	6,185	6.0	8 19	1.22	54 15 15.70	.23	+ .245	.727	.177	— .10
B	455	6,203	5.4	12 17	1.86	42 7 21.39	.19	.000	1.074	.271	+ .01
B	456	6,218	6.0	13 41	1.92	40 53 39.26	.31	+ .079	1.197	.279	— .16
A	457	6,221	5.5	15 44	2.53	21 54 56.69	.26	— .051	1.375	.369	+ .01
A	458	6,241	6.1	17 38	2.50	23 13 50.46	.21	+ .082	1.542	.363	— .06
A	459	6,251	4.1	19 6	2.55	21 43 14.97	.15	— .257	1.669	.369	+ .03
A	460	6,268	5.0	20 40	1.97	39 26 54.48	.21	— .001	1.806	.286	.08
A	461	6,297	4.4	18 22 18	— .85	71 16 48.57	.13	+ .021	1.949	— .125	+ .03
A	462	6,325	4.1	29 20	3.26	8 19 9.02	.14	— .307	2.559	.472	.12
B	463	6,373	6.7	37 6	.73	60 36 38.83	.28	+ .053	3.231	.104	+ .47
A	464	6,379	5.1	39 23	3.03	1 57 1.32	.25	— .026	3.429	.434	+ .08
B	465	6,404	5.9	42 46	1.92	41 19 32.92	.28	+ .003	3.720	.273	.38
B	466	6,428	5.9	45 25	1.58	48 37 38.50	.19	+ .053	3.948	.225	.00
B	467	....	6.1	47 5	2.75	13 50 12.52	.33	— .010	4.091	.390	— .52
A	468	6,438	5.3	47 40	2.56	21 17 43.02	.25	— .006	4.140	.364	— .02
A	469	6,466	4.4	50 44	2.10	36 45 42.14	.24	.020	4.402	.297	— .04
B	470	6,476	5.8	51 56	1.59	48 43 27.50	.34	— .133	4.506	.224	.30
B	471	....	5.8	18 55 21	2.44	26 4 53.11	.31	.003	4.797	.342	.31
A	472	6,528	3.1	19 0 27	2.75	13 42 11.54	.17	.089	5.228	.386	— .04
A	473	6,552	5.4	3 42	2.94	5 54 13.83	.22	— .064	5.503	.410	.03
A	474	6,583	5.4	9 38	1.13	56 40 30.88	.15	+ .045	5.999	.155	+ .02
B	475	6,602	5.8	13 9	2.54	22 49 52.35	.31	— .011	6.293	.349	— .25
B	476	6,624	5.4	15 21	1.38	40 9 40.49	.31	+ .005	6.475	.274	— .09
A	477	6,637	5.4	18 26	2.46	26 3 19.15	.21	— .013	6.729	.335	+ .05
A	478	6,662	4.9	20 7	.32	65 30 23.57	.15	+ .030	6.868	.041	+ .03
B	479	6,651	6.7	20 14	2.15	36 14 19.39	.44	+ .084	6.877	.292	— .39
A	480	6,674	4.5	24 13	2.49	24 26 47.26	.17	— .132	7.203	.338	— .06
A	481	6,679	5.4	19 25 1	3.14	— 3 0 48.78	.15	+ .004	7.269	.424	— .02
B	482	6,711	6.6	29 51	2.09	38 31 37.13	.32	+ .037	7.661	.280	— .23
B	483	6,723	5.8	31 32	1.55	51 0 17.87	.16	— .196	7.798	.205	— .17
A	484	6,734	4.7	33 33	1.61	49 58 15.82	.13	+ .239	7.960	.214	+ .08
A	485	6,739	4.4	35 16	2.68	17 45 56.89	.22	— .012	8.098	.355	+ .11
A	486	6,749	5.7	37 29	2.82	11 34 21.73	.21	.017	8.275	.372	+ .17
A	487	6,759	6.2	39 33	2.79	13 2 37.91	.32	— .017	8.439	.368	— .01
A	488	6,779	3.0	41 36	1.88	44 52 1.90	.15	+ .035	8.601	.363	+ .10
A	489	6,805	5.6	45 51	2.86	10 8 44.10	.24	.149	8.936	.369	+ .10

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	s.	° ′ ″	′	″	″	″	″
A	490	6,824	5.3	47 55	+1.51	52 42 50.57	± 0.22	—0.075	+ 9.097	+0.190	+0.03
B	491	....	6.3	19 48 0	2.99	4 7 16.09	.37	— .020	9.104	.385	+ .11
A	492	6,849	5.2	52 0	2.14	38 11 59.30	.19	+ .007	9.414	.274	.00
B	493	6,867	5.4	53 52	1.15	58 33 27.41	.19	— .018	9.558	.144	— .01
B	494	....	5.8	54 21	2.38	30 41 27.44	.29	+ .006	9.595	.300	.44
A	495	6,882	6.0	57 10	2.54	24 30 3.46	.14	— .001	9.811	.318	— .06
A	496	6,883	5.4	57 26	2.54	24 38 8.49	.23	+ .061	9.832	.318	+ .01
A	497	6,893	5.8	58 52	2.93	6 58 24.84	.21	+ .036	9.940	.317	+ .06
B	498	....	5.8	20 0 22	2.35	31 54 45 38	.30	— .006	10.054	.293	— .08
B	499	6,924	6.3	2 54	1.36	56 1 44.30	.22	+ .068	10.246	.167	+ .40
B	500	6,930	6.1	3 23	.76	63 34 45.99	.32	+ .043	10.282	.091	+ .01
A	501	6,937	5.2	20 5 25	2.23	36 31 19.05	.21	+ .050	10.437	.272	+ .05
A	502	6,934	3.1	5 44	3.10	— 1 8 29.64	.12	+ .014	10.457	.380	— .06
A	503	6,944	6.0	7 29	2 51	26 9 23.08	.24	— .027	10.588	.308	— .08
A	504	6,952	5.1	9 17	2.78	14 52 8.06	.19	+ .081	10.721	.337	— .06
B	505	6,966	5.0	10 41	2.54	25 16 44.05	.31	— .015	10.825	.307	— .35
A	506	6,968	5.6	10 50	2.59	23 10 43.94	.31	— .014	10.836	.314	.04
A	507	6,983	4.5	12 8	1.85	47 22 57.16	.19	— .008	10.931	.222	+ .04
A	508	6,990	var.	13 48	2.21	37 41 49.81	.25	.003	11.054	.264	+ .09
B	509	7,017	6.0	16 28	.61	66 30 23 27	.23	+ .284	11.247	.059	— .17
A	510	7,024	5.8	17 48	1.01	61 54 52.18	.20	+ .011	11.344	.117	— .08
A	511	7,022	2.6	20 18 21	2.15	39 54 40.33	.13	+ .020	11.383	.254	— .03
A	512	....	6.2	19 7	3.06	0 43 9.27	.27	+ .006	11.439	.361	.17
A	513	7,046	6.1	22 46	3.14	— 3 42 51.33	.20	— .005	11.699	.368	— .07
A	514	7,085	5.0	26 43	1.86	48 35 19.01	.19	+ .007	11.978	.212	— .01
A	515	7,098	4.6	27 46	1.02	62 37 51.79	.14	— .027	12.052	.113	+ .01
A	516	7,091	5.6	27 59	1.85	48 51 20.71	.20	— .040	12.067	.211	+ .09
A	517	7,107	4.7	30 16	2.80	14 18 6.46	.21	— .002	12.225	.319	+ .04
A	518	7,121	3.5	32 29	2.81	14 13 10 62	.17	— .031	12.379	.317	— .02
A	519	7.137	6.0	33 38	2.83	12 56 9.83	.27	— .006	12.458	.319	— .03
B	520	7,138	5.3	33 53	3.07	0 6 25.35	.22	— .010	12.475	.346	— .05
A	521	7,182	5.5	20 38 53	1.85	49 57 8.02	.19	— .002	12.815	.202	— .02
B	522	7,189	6.9	39 36	1.49	56 59 47.97	.31	.022	12.862	.160	— .17
A	523 foll	7,200	3.9	41 39	2.78	15 44 6.87	.18	.196	13.000	.304	.05
A	524	7,206	5.7	42 27	2.97	5 36 42.13	.19	+ .001	13.053	.324	+ .07
A	525	7,213	4.7	43 12	2.33	36 5 38.42	.17	+ .018	13.103	.252	.02
A	526	7,246	4.9	47 30	2.57	26 41 33.80	.21	— .074	13.386	.274	.09
A	527	7,257	5.6	50 29	2.86	12 9 20.41	.21	+ .010	13.579	.301	+ .09
B	528	7,268	6.0	52 11	2.02	47 0 13.83	.33	+ .004	13.688	.210	.03
B	529	7.278	5.8	53 0	1.90	50 18 50.00	.31	— .007	13.740	.195	.00
A	530	7.276	5.3	53 41	3.01	3 52 46.20	.21	— .139	13.783	.312	.10
B	531	....	6.0	20 55 32	2.74	18 54 35.19	.34	— .058	13.900	.282	— .29
B	532	7,310	5.8	56 46	1.47	59 0 59.25	.14	— .002	13.978	.148	+ .05
A	533 foll	7.302	6.4	56 53	2.96	6 45 19.94	.27	— .012	13.985	.306	— .04
B	534	....	5.9	59 10	1.65	56 14 35.37	.20	.006	14.128	.164	.13
A	535	7,333	4.0	21 1 0	2.18	43 29 49.08	.15	— .008	14.241	.218	+ .02
A	536	7,350	4.5	5 5	2.95	9 41 47.87	.21	— .167	14.491	.288	.03
A	537	7,351	6.1	5 16	2.95	9 36 30.92	.24	+ .019	14.502	.288	.02
B	538	7,365	5.8	6 55	1.85	53 7 19.84	.23	— .014	14.601	.178	— .04
A	539	7,380	4.1	10 25	3.00	4 48 5.47	.14	— .078	14.810	288	+ .03
A	540	7.398	4.5	13 10	2.35	38 56 31.32	.21	— .013	14.971	.222	.08
B	541	7,402	5.0	21 14 25	2.26	43 29 29.52	.26	— .012	15.043	.209	+ .08
B	542	7,410	5.9	16 11	2.69	23 24 4.42	.28	— .130	15.145	.153	— .42
A	543	7,417	5.9	16 16	1.66	58 9 59.35	.20	— .024	15.150	.209	— .05
A	544	7,418	4.3	17 5	2.77	19 20 33.38	.19	+ .075	15.196	.257	— .12
B	545	7,437	5.8	19 7	2.69	23 48 37.19	.28	+ .030	15.311	.247	.29
A	546	7,440	5.9	19 39	3.01	— 4 1 11.00	.32	— .068	15.347	.288	— .30
A	547	7,482	5.6	25 41	1.71	66 20 16.04	.19	— .042	15.676	.100	— .04
B	548	....	6.0	25 56	2.90	11 30 47.20	.24	— .004	15.690	.257	.30
B	549	7,512	6.1	30 44	2.06	51 13 1.81	.27	— .008	15.948	.176	+ .29
B	550	7,528	5.9	33 59	2.79	19 46 41.55	.38	+ .006	16.119	.236	— .15
B	551	7.530	6.1?	21 34 3	2.00	53 33 21.21	.25	— .018	16.122	.167	— .01
A	552	7,542	5.1	35 1	1.61	61 35 41.19	.18	— .012	16.173	.132	— .09

Mean declinations of latitude stars—Continued.

Class.	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	s.	° ′ ″	″	″	″	′	″
A	553	7,544	5.5	35 57	2.35	42 47 0.76	±0.18	+0.011	+16.220	+0.194	+0.04
A	554	7,546	5.9	36 40	3.06	0 47 36.76	.26	— .020	16.257	.255	— .26
A	555	7,561	2.4	38 53	2.95	9 22 48.00	.17	+ .011	16.370	.241	.00
B	556 pr	7,566	5.6	38 58	2.47	37 47 21.21	.22	+ .001	16.374	.201	— .11
B	557	7,586	6.8	41 29	2.72	25 3 48.33	.38	+ .038	16.500	.218	+ .17
A	558	7,587	5.6	41 45	3.04	2 11 11.80	.25	— .010	16.514	.245	.00
A	559	7,605	5.9	44 14	1.77	60 11 29.53	.28	— .001	16.636	.137	— .03
A	*560	7,631	6.0	48 22	1.75	55 17 20.91	.32	— .025	16.835	.153	— .31
B	561	....	6.4	21 54 25	1.53	65 38 27.51	.30	+ .003	17.117	.110	— .11
B	562	....	6.8	54 38	1.54	65 37 24.50	.30	+ .006	17.127	.110	+ .20
A	563	7,660	5.9	55 34	3.07	0 5 10.85	.23	— .001	17.169	.224	+ .05
A	564	7,662	5.9	55 48	2.98	7 44 17.92	.28	+ .005	17.179	.217	— .02
A	565	7,672	4.7	57 44	3.10	—2 40 35.69	.21	— .002	17.266	.222	— .01
A	566	7,685	5.8	59 14	3.09	—1 25 42.43	.21	— .031	17.333	.218	+ .03
B	567	7,699	5.7	22 0 39	1.79	62 35 39.31	.27	+ .034	17.394	.123	.29
A	568 foll	7,700	4.6	0 40	1.73	64 6 5.57	.17	+ .065	17.395	.116	+ .03
A	569	7,693	5.7	0 41	2.71	28 26 21.53	.21	— .010	17.396	.189	— .07
A	570	7,707	5.8	1 44	1.82	62 15 31.46	.17	+ .045	17.441	.124	+ .04
B	571	7,733	6.1	22 5 24	2.83	20 26 50.16	.28	— .008	17.598	.190	— .26
A	572	7,749	3.7	7 6	2.07	57 40 8.01	.15	— .006	17.669	.135	— .01
B	573	7,753	5.6	8 1	2.65	34 4 19.97	.30	— .041	17.706	.173	.27
B	574	7,770	5.8	10 12	2.51	42 25 5.58	.25	— .020	17.795	.161	— .08
A	575	7,788	5.5	15 1	3.02	5 14 48.43	.20	— .005	17.986	.187	— .03
A	576	7,795	3.7	16 5	3.10	—1 55 53.27	.13	— .017	18.026	.190	— .03
A	577	7,807	6.1	18 28	2.86	20 18 9.17	.20	— .019	18.117	.171	.13
A	578	7,837	5.7	23 37	1.91	64 34 53.59	.25	— .012	18.305	.106	+ .01
B	579	7,850	4.8	25 50	2.09	42 34 11.16	.27	— .002	18.384	.143	— .06
	580	7,868	4.0	29 48	3.08	—0 40 26.85	.12	— .053	18.520	.164	+ .05
A	581	7,893	5.9	22 33 39	2.90	18 57 48.21	.23	— .094	18.646	.148	+ .09
A	582	7,902	5.3	34 49	2.11	63 1 22.83	.18	— .039	18.684	.105	— .03
A	583	7,906	4.9	35 47	2.62	43 42 44.52	.22	— .016	18.714	.129	— .02
B	584	7,931	6.1	39 13	2.70	38 53 58.56	.25	— .030	18.820	.128	— .06
A	585	7,945	4.0	41 20	2.88	22 59 50.53	.15	— .004	18.883	.133	— .03
A	586	7,958	3.8	44 47	2.89	24 1 52.84	.16	— .042	18.983	.126	— .04
B	587	†7,963	{ 6.5 7.0 }	45 20	2.01	67 59 50.52	.28	+ .069	18.998	.087	— .12
B	588	7,984	5.9	49 10	2.73	39 48 4.20	.30	+ .039	19.103	.113	— .70
B	589	7,986	5.9	49 35	3.11	—5 33 47.57	.22	.000	19.114	.129	— .03
A	590	7,993	6.5	51 42	3.10	—5 23 13.91	.17	.005	19.169	.124	.01
B	591	7,999	5.3	22 52 18	2.64	48 6 24.78	.24	— .030	19.184	.104	+ .02
B	592	8,013	6.7	54 44	2.44	59 14 9.34	.24	— .021	19.245	.091	— .04
A	593	8,031	4.6	58 23	3.05	3 14 18.50	.20	— .015	19.332	.110	.00
A	594	8,034	2.2	59 23	2.98	14 37 27.23	.16	— .030	19.355	.105	+ .07
B	595	8,077	6.4	23 5 40	2.34	66 39 21.14	.33	+ .022	19.492	.073	+ .36
B	596	8,094	5.4	10 0	3.09	—4 5 6.53	.28	+ .005	19.578	.089	— .07
A	597	8,105	3.8	11 34	3.10	2 41 31.76	.13	+ .017	19.607	.065	+ .04
B	598	....	6.7	15 34	2.63	59 41 0.43	.33	— .031	19.677	.084	— .13
B	599	8,158	6.9	19 13	2.71	56 56 33.05	.23	— .013	19.736	.061	+ .05
A	600	8,162	5.5	20 2	2.64	61 41 23.38	.15	— .021	19.749	.058	+ .02
A	601	8,169	5.0	23 21 24	3.07	0 39 51.50	.15	— .102	19.769	.066	— .10
A	602	8,177	4.5	22 29	3.07	5 47 8.77	.18	— .045	19.785	.064	— .07
B	603	8,188	5.0	25 3	2.75	57 57 12.92	.28	+ .008	19.820	.052	— .12
A	604	8,195	5.7	25 59	2.94	38 38 34.48	.15	— .077	19.832	.054	+ .02
B	605	....	6.1	28 30	3.00	20 14 40.94	.31	— .014	19.864	.052	— .24
B	606	....	6.3	30 32	2.99	23 57 47.44	.31	— .023	19.887	.048	+ .46
A	607	8,229	4.1	32 50	2.93	42 40 12.20	.16	— .012	19.912	.042	.00
A	608	8,233	4.2	34 24	3.08	5 2 27.02	.14	— .443	19.928	.040	— .02
A	609	8,243	4.8	36 32	3.06	1 11 8.42	.19	— .137	19.948	.038	— .02
A	610	8,262	5.7	40 52	3.06	2 53 15.02	.18	— .023	19.983	.029	+ .08
A	611	8,279	5.8	23 43 35	2.89	61 36 51.20	.19	— .010	20.001	.022	.00

* Northern of two stars.

† Middle point between two stars nearly on same parallel.

Mean declinations of latitude stars—Continued.

Class	No.	B. A. C.	Mag.	AR. 1892.	Annual variation.	Declination, 1892.	Probable error, 1892.	Proper motion.	Annual precession.	Sec. var.	Δ δ
				h. m. s.	*s.*	° ′ ″	″	″	″	″	″
B	612	8, 280	6. 5	43 36	+2. 91	59 22 41. 61	±0. 23	—0. 003	+20. 002	+0. 021	—0. 01
A	613	8, 295	5. 9	46 26	3. 07	2 19 47. 80	. 19	— . 011	20. 018	+ . 018	. 00
A	614	8, 296	5. 9	46 54	3. 04	21 4 13. 40	. 26	— . 018	20. 020	. 018	+ . 10
B	615	....	6. 6	48 28	2. 95	60 15 9. 10	. 25	— . 006	20. 027	+ . 014	. 00
B	616	8, 315	7. 0	50 6	3. 06	7 37 20. 34	. 36	— . 007	20. 034	. 010	— . 04
B	617	8, 322	5. 8	51 42	3. 00	55 6 17. 11	. 19	— . 024	20. 040	+ . 007	— . 31
A	618	8, 330	5. 0	53 32	3. 01	55 9 13. 44	. 20	— . 015	20. 045	+ . 004	— . 04
B	619	8, 345	6. 0	56 12	3. 05	41 45 56. 51	. 35	— . 016	20. 050	0. 0	— . 01
A	620	8, 354	5. 9	56 58	+3. 06	7 53 8. 39	. 21	— . 027	20. 051	— . 002	+ . 01
B	621	....	6. 3	23 57 41	+3. 07	16 57 8. 86	. 27	— . 037	+ 20. 052	— . 004	. 36

Authorities for star catalogue.

First column: Number in catalogue.

Second column: Authority for proper motion.—"Brad. 11" denotes, for example, that the Proper Motions are from Auwers's Bradley, and that Bradley has eleven observations. "Piazzi and others" denotes that all available observations including and since Piazzi have been used. No statement in column 2 denotes in general that the old observations are rather scanty, chiefly zones.

Third column: Authorities used in the star places employed on the boundary.—They are abbreviations of the names of the observatories, with dates, in 1800-1900. "Yrnl." denotes Yarnalls' Catalogue, 3d edition. For Oxford, Greenwich, Washington, the observations not yet catalogued have been previously reduced to some mean epoch; for example, No. 602 (A. N. Am. Ephemeris star) was on revision brought up from Washington volumes for many years to the mean epoch 1876, 1884, and the Greenwich volumes for 1887-1890 were similarly treated.

Fourth column: Observations added on revision.

No.	Authorities for proper motion.	Authorities used for declinations in computing latitudes on the boundary.	Observations added on revision.
1	....	Paris 60, Pulkova 55, Greenwich 80	
2	Bradley 7	Berlin Jahrbuch, Pulk. 55, Oxford 60, Cambridge, Rome, Pulk. 75, Grnwch. 80.	
3	Bradley 5	Pulk. 55, Paris 60, Glasgow, Brussels, Grnwch. 64, 72, 80, Leipzig, Leiden, Rome.	
4	....	Pulk. 55, Brsls., Paris 75, Grnwch. 80, 89	
5	Bradley 5	Pulk. 55, Yarnall, Oxfrd. 60, Brsls., Grnwch. 72, 80, Cambr., Paris 75, Rome, Pulk. 75.	
6	Arglndr. 3—250	Paris 60, 75, Bonn, Pulk. 62, 75, Yrnl., Grnwch. 64, Edinboro, Glsgw., Melbourne, Albany Zone, Gotha.	
7	Bradley 3	Pulk. 55, Paris 75, Grnwch. 64, 72, 80, Yrnl., Rome	
8	Bradley 3	Pulk. 55, 75, Grnwch. 60, 80, Brsls	
9	Brad. and later auths.	Ednbro., Brsls., Pulk. 55, Oxfrd. 70, Grnwch. 72, A. G. Christiania Z	
10	Brad. 5	Paris 45, 60, Grnwch. 60, 72, 80, 87, Pulk. 55, Cambr., Rome, A. G. Helsingfors, Gotha.	
11	Brad. 12	Pulk. 55, 62, 75, Grnwch. 60, 64, 72, 80, 88, Brsls., Yrnl., Paris 75, Glsgw., A. G. Albny., Rome.	
12	Brad. 1	Pulk. 55, Yrnl., Grnwch. 72, A. G. Helsingfors	
13	Brad. 4	Pulk. 55, Yrnl., Grnwch. 64, 72, 89, Paris 75, Rome	
14	Brad. 11	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Yrnl., Paris 60, 75, Glasgow, Grnwch. 80, 88, Auwers's 303 Stars Auwers's	
15	Brad. 5	Pulk. 55, 75, Paris 60, Grnwch. 64, Brsls., Yrnl.	
16	Brad. 7	Pulk. 55, 75, Yrnl., Oxfrd. 60, Glsgw., Grnwch. 64, 80, Paris 75	
17	Piazzi and later auths.	Oxfrd. 65, Paris 75, Brsls., Glsgw., Grnwch. 88	
18	Piazzi and later auths.	Pulk. 55, Grnwch. 60, 80, Paris 75, Rome	
19	Brad. 5	Brln. Jrbh., Yrnl., Brsls., Pulk. 75, Rome, Paris, Grnwch. 80, 88	
20	Brad. 14	Pulk. 55, Paris 60, Yrnl., Grnwch. 64, 72, 80, 89, Brsls., Göttingen, Glsgw., Paris 75, Auwers's 303 Stars.	
21	Brad. 15	Brln. Jrbh., Yrnl., Oxfrd. 60, Paris 60, 75, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	
22	Brad. 5	Yrnl. Pulk. 55, Oxfrd. 60, Grnwch. 64, 88, Paris, Rome	
23	Brad. 6	Pulk. 55, Bonn, Grnwch. 64, 72, Lpzg., Leidn., Cambr., Rome, Paris 75	
24	Brad. 1 and later	Pulk. 55, Rome, Oxfrd. 70, Brsls., A. G. Helsingfors, Grnwch. 72, Berlin	

Authorities for star catalogue—Continued.

No.	Authorites for proper motion.	Authorities used for declinations in computing latitudes on the boundary.	Observations added on revision.
25	Brad. 5	Pulk. 55, Grnwch. 60, 72, Lpzg., Leidn., Rome	
26		Pulk. 55, Yrnl., Edubro., Grnwch. 64, Brsls.	
27	Brad. 9	Brln. Jrbh., Pulk. 55, 75, Cambr., Rome, Paris 75	
28	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, Glsgw. 75, Armagh	
29	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, 72, 80, Rome	
30	Brad. 3	Brln. Jrbh., Yrnl., Brsls., Cambr., Paris 75, Rome, Pulk. 75, Grnwch. 80, 88.	
31	Brad. 8	Pulk. 55, Yrnl., Grnwch. 60, 80, 88, A. G. Cambr., Paris 75, Rome, Gotha, Prime Vertical.	
32	Piazzi and others.	Pulk. 55, Oxfrd. 60, Brsls., Yrnl., Grnwch. 64, 72, Paris 60, 75, Glsgw., Rome, A. G. Albny., Gotha, Cincinnati.	
33	Brad. 10	Brln. Jrbh., Pulk. 55, 62, 75, Oxfrd. 60, Paris 60, 75, Yrnl., Brsls., Glsgw., Rome, Grnwch. 80, 89.	
34	Brad. 3	Pulk. 55, Oxfrd. 60, Grnwch. 64, Brsls., Paris 75, Rome, Cinn	
35	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Rome, Grnwch. 80	
36	Brad. 1 and later	Yrnl., Glsgw., Pulk., Brsls., Grnwch. 72, Cambr., A. G. Albny	
37	Brad. (Auwer's) and others.	Pulk. 55, Yrnl., Oxfrd. 60, Brsls., A. G. Hlgfrs., Grnwch. 72, Rome, Brln	
38	Brad. 4	Pulk. 55, 75, Paris 60, Brsls., Glsgw., Grnwch. 64, 72, 80, Rome	
39	Brad. 1	Brln. Jrbh., Oxfrd. 60, Paris 60, Yarnl., Brsls., Cambr., Rome, Pulk. 75, Grnwch. 80, 88, Rome.	
40	Auwers's Bradley.	Pulk. 55, Grnwch. 72, A. G. Helsingfors, Pulk. 75	
41	Groombridge and others.	Pulk. 55 Brsls., Paris 75, Grnwch. 80	
42	Brad. 4	Pulk. 55, Paris 75, Grnwch. 72, Rome, Cambr., Ann Arbor, Grnwch. 80, 87.	
43	Brad. 3	Brln. Jrbh., Oxfrd. 60, 75, Paris 60, 75, Yrnl., Bonn, A. N., Washington 68, Boss, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 89, Glasgow 90.	
44	Brad. 3	Pulk. 55, 75, Oxfrd. 60, Paris 60, Grnwch. 64, 88, Brsls., Rome	
45	Brad. 3	Pulk. 55, 75, Yrnl., Oxfrd. 60, Paris 75, Brsls., Grnwch. 64, 72, 80, 88, Glsgw., A. G. Albny.	
46	Brad. 3	Pulk. 55, Oxfrd. 60, Grnwch. 64, 80, Brsls., Rome, Paris 75	
47	Brad. 4	Pulk. 55, Brsls., Grnwch. 64, 72, 80, A. G. Christiania., Rome	
48	Arglnd. and later auths.	Bonn, Brsls. A. G. Chrstana., Pulk. 75, Cinn	
49	Brad. 2	Pulk. 55. Grnwch. 64, Brsls., Rome, Paris 82, Grnwch. 87	
50	Brad. 5	Oxfrd. 60, Brsls., Pulk. 55. Grnwch. 64, 80, 89, Rome. A. G. Helsingfors.	
51	Brad. 1	Pulk. 55, Grnwch. 64, Rome	
52	Brad. 7	Yrnl., Grnwch. 60, 64, 72, Oxfrd. 60, Pulk. 55, 75, Brsls., Göttingen, Cordoba, Pulk. 75, Paris 75, Glsgw., Karlsruhe.	
52a	Brad. 5	Pulk. 55, Paris 60, Oxfrd. 60, Brsls., Grnwch. 64, Yrnl., Auwers's 303 Stars	
53	Brad. 6	Pulk. 55, 62, Grnwch. 60, 64, 72, 80, 88, Yrnl., Brsls., Paris 75, A. G. Albny., Rome.	
54	Brad. 1	Oxfrd. 60, Pulk. 55, Grnwch. 64, Brsls., A. G. Helsingfors	
55	Brad. 5	Pulk. 55, Paris 60, 75, Grnwch. 64, Oxfrd. 65, Rome	
56	Brad. 11	Pulk. 55, 75, Grnwch. 60, 64, 72, 80, Paris 60, 82, Yrnl., Rome	
57	Brad. 5	Pulk. 55, Yrnl., Pulk. 62, Grnwch. 64, Göttingen, Paris 75, Cordoba, Karlsruhe.	
58	Brad. 4	Pulk. 55, Oxfrd. 60, Brsls., Grnwch. 64, Rome	
59		Pulk. 55, Paris 75. Grnwch. 80	
60	Brad. 15	Brln. Jrbh., Oxfrd. 60, Paris 60, Brsls., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80, Pulk. 90, 91.	
61		Pulk. 55, Grnwch. 60, 80, Paris 60, Glsgw., Rome	
62	Brad. 5	Pulk. 55, Grnwch. 60, 64, 72, 80, Brsls., Paris 60, Yrnl., Rome	
63	Brad. 5	Pulk. 55, Grnwch. 60, 72, 80, Yrnl., Brsls., Paris 75	
64	Brad. 7	Pulk. 55, 75, Oxfrd. 60, Brsls., Cambr., Rome, Brln., Paris 75, Grnwch. 80	
65	Brad. 7	Pulk. 55, Grnwch. 64, 72, Rome, Paris 75	
66	Brad. 4	Pulk. 55, Paris 60, 75, Grnwch. 64, 72, Oxfrd. 65, Yrnl., Glsgw. 90	
67		Pulk. 55, Grnwch. 64, Glsgw., Paris 75	
68	Brad. 8	Pulk. 55, 62, 75, Oxfrd. 60, Grnwch. 60, 64, 72, 80, Brsls., Yrnl., Paris 75, Glsgw., Rome.	
69	Brad. 4	Brln. Jrbh., Oxfrd. 60, Yrnl., Paris 60, 75, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	
70		Pulk. 55, 75, Grnwch. 64, 80, Brsls., Paris, 75, Glsgw., Cinn	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declinations in computing latitudes on the boundary.	Observations added on revision.
71	Brad. 13	Pulk. 55, A. G. Helsingfors. Rome, Brln., Grnwch. 80, Pulk. Prime Vertical.	
72	Piazzi, etc	Paris 60, 75, Brsls., Oxfrd. 64, Yrnl., Glsgw., Pulk. 75, Grnwch. 72, Gotha 85, A. N.	
73	Arglndr	Pulk. 55, 75, Konigsb. 61, Bonn, Paris 75, Brsls. 65, Cordoba, Grnwch. 80, Karlsruhe.	
74		Grnwch. 60, 80, Pulk. 55, Brsls., Yrnl., A. G. Hlgfrs., Rome	
75	Brad. 12	Brln. Jrbh., Oxfrd. 60, Paris 60, 82, Brsls., Yrnl. Cambr., Rome, Pulk. 75, Grnwch. 80, 88.	
76	Brad. 5	Pulk. 55, Grnwch. 64, 89, Paris 75, Rome.	
77	Groombridge and others.	Pulk. 55, Rome, Paris 82, Grnwch. 80	
78	Brad. 6	Oxfrd. 60, Pulk. 55, Brsls., Grnwch. 64, 72, A. G. Christiania, Rome	
79	Piazzi and others	Paris 60, Brsls., Pulk. 75, Cambr., Ann Arbor, Grnwch. 80	Pulk. 85.
80	Brad. 8	Brln. Jrbh., Pulk. 55, 62, 75, Oxfrd., Yrnl., Paris, 60, 75, Glsgw., Cambr., Rome, Grnwch. 80, 88, Auwers's 303 Stars.	
81	Brad. 7	Pulk. 55, 75, Paris 60, Grnwch. 60, 80, Oxfrd. 60, Brsls., Yrnl., Rome	
82	Brad 1 and later	Pulk. 55, Ednbro., Bonn, Brsls., Oxfrd. 75, A. G. Hlgfrs., Brln	
83	Brad. 6	Brln. Jrbh., Oxfrd. 60, Yrnl., Paris 60, 75, Brsls., Washgtn. (Boss), 68, Oxfrd. 75, Cambr., Pulk. 75, Rome, Grnwch. 80, 89.	
84	Piazzi and others.	Yrnl., Oxfrd. 60, Brsls., Grnwch. 64, 72, 80, Paris 60, Cambr., Rome, Pulk. 75.	
85		Yrnl., Pulk. 55, Ednbro., Grnwch. 64, Armagh 75, Cambr., Paris 82	
86	Brad. 10	Brln. Jrbh., Oxfrd. 60, 75, Yrnl., Brsls., Cambr., Rome, Pulk. 75, Grnwch. 80.	
87	Brad. 3	Brln. Jrbh., Paris 60, 75, Brsls., Yrnl., Rome, Pulk. 75, Grnwch. 80, 88	
88	Brad. 5	Brln. Jrbh., Paris, 60, 75, Yrnl., Pulk. 62, 75, Brsls., Oxfrd. 70, Glsgw., Rome, Albny., Auwers's 303 Stars.	
89	Brad. 2 (confirmed)	Yrnl., Pulk. 55, 75, Glsgw., Oxfrd. 60, 75, Brsls., Grnwch. 64, 72, 80, Rome, Paris 75.	
90	Brad. 3	Yrnl., Pulk. 55, Oxfrd. 60, 75, Grnwch. 64, 72, 80, Brsls., Rome, Paris 75	
91	Piazzi, etc	Pulk. 55, Yrnl., Glsgw., Grnwch. 72, 80, Brsls., Paris 75, Gotha 85	
92	Brad. 3	Pulk. 55, Brsls., Grnwch. 72, 80, A. G. Helsingfors, Rome	
93	Brad. 17	Pulk. 55, Paris 60, 75, Rome, Berlin, A. G. Cambr., Grnwch. 80, 87	
94	Brad. 2 and later	Pulk. 55, 75, Glsgw., Grnwch. 64, 72, 80, 89, Brsls., Paris 75, Rome	
95	Brad. 3	Pulk. 55, 75, Paris 60, 75, Grnwch. 64, Brsls	
96	Brad. 4	Pulk. 55, Grnwch. 64, Paris 75, Brsls., Göttingen, Glsgw., Cordoba	
97	Brad. 4	Pulk. 55, Grnwch. 64, 89, Brsls., Göttingen, Paris 75, Auwers's 303 Stars	
98	Brad. 5	Pulk. 55, Oxfrd. 60, Paris 60, Brsls., Grnwch. 64, Yrnl., Rome	
99	Brad. 4	Brln. Jrbh., Yrnl., Oxfrd. 60, Brsls., Paris 60, 75, Cambr., Pulk. 75, Rome, Grnwch. 80.	Glsgw. 90.
100	Brad. 4	Yrnl., Pulk. 55, Grnwch. 64, 88, Brsls., Rome, Paris 75	Washgtn. Prime Vert.
101	Brad. 3	Pulk. 55, Paris 60, 75, Grnwch. 60, 64, 72, 80, 88, Brsls., Yrnl., Rome, Brln.	
102	Brad. 3	Pulk. 55, Oxfrd. 60, Paris 60, 75, Brln.	
103	Brad. 1 and later auths.	Pulk. 55, Yrnl., Glsgw., Grnwch. 64, Paris 60, 75, Brsls., Oxfrd. 75, A. G. Leiden.	
104	Brad. 9	Brln. Jrbh., Pulk. 55, 75, Cambr., Rome, Grnwch. 80	
105	Brad. 3	Pulk. 55, 75, Oxfrd. 60, Paris 60, Grnwch. 64, 72, 80, 89, Rome	
106	Brad. 4	Pulk. 55, Paris 60, 75, Grnwch. 64, Rome	
107	Brad. 6	Pulk. 55, Paris 60, 75, Grnwch. 60, 64, 72, 80, 89, Brsls., Yrnl., Washgtn. 68 (Boss), Oxfrd. 75, Rome.	
108	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, 72, 80, 88, Rome	
109	Brad. 3	Pulk. 55, Brsls., Grnwch. 64	
110		Ednbro., Brsls., Pulk. 55, Brln., A. G. Helsingfors	
111	Brad. 7	Pulk. 55, A. G. Hlgfrs., Berlin	
112	Brad. 5	Brln. Jrbh., Pulk. 55, 75, Yrnl., Brsls., Paris 60, Cambr., Rome	
113		Yrnl., Ednbro., Pulk. 55, Brsls., Brln, A. G. Helsingfors	
114	Brad. 6	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Paris 60, Brsls., Yrnl., Armagh 75, Grnwch. 80, 88, Rome.	
115	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, 72, 80, Brsls	
116	Brad. 4	Pulk. 55, Ednbro., Yrnl., Rome, Brln., Cambr., Grnwch. 80	
117	Brad. 5	Pulk. 55, Paris 60, 75, Grwnch. 64, Göttingen, Yrnl., Glsgw., Cordoba., Karlsruhe.	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declinations in computing latitudes on the boundary.	Observations added on revision.
118	Brad. 5	Pulk. 55, Grnwch. 60, 64, 72, 80, 88, Paris 60, 75, Oxfrd. 60, Brsls., Yrnl., Oxfrd. 72, Glsgw., Rome.	
119	Brad. 1 (Auwer's) and Boss.	Brln. Jrbh., Brsls., Yrnl., Cambr., Pulk. 75, Rome, Grnwch. 80, 88	
120	Brad. 3	Pulk. 55, Paris 60, Brsls., Grnwch. 64, 72, 80, 89, Yrnl., Brln., Rome, Glsgw.	
121	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, Oxfrd. 75, Brsls., Glsgw	
122	Brad. 8	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Yrnl., Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	
123	Brad. 4	Pulk. 55, Yrnl., Glsgw., Grnwch. 64, 72, 80, Rome, Paris 75	
124	Brad. 3	Pulk. 55, 75, Brsls., Glsgw., Paris 60, 75, Grnwch. 64, 72, 80, Rome	
125	Brad. 3	Pulk. 55, Oxfrd. 60, Grnwch. 64, Paris 75, Cordoba	
126	Brad. 3	Grnwch. 60, Pulk. 55, Oxfrd. 60, Glsgw., Paris 60, Brsls. Cordoba, Krlsrhe (85), Cinn.	Karlsruhe, 1889.
127	Brad. 2 and later auths.	Paris 45, Oxfrd. 60, Brsls., Pulk. 55, Grnwch. 64, 72, 80 Dorpat, Dorpat	
128	Brad. 5	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Paris 60, Brsls., Yrnl., Cambr., Rome, Grnwch. 80, 88.	
129	Brad. 7	Pulk. 55, Brsls., Grnwch. 64, A. G. Cambr., Paris 75, Grnwch. 88	Kazan Prime Vertical.
130	Groombridge and latr. auths.	Rome, Cambr., Paris 82	
131	Brad. 3	Pulk. 55, Paris 60, Brsls., Grnwch. 72, 80, 89, Rome	
132	Brad. 4	Grnwch. 60, 64, 89, Pulk. 55, 75, Rome	
133	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Rome, Paris 75, Grnwch. 80	
134	Brad. 4	Pulk. 55, Grnwch. 60, 64, 72, 80, 89, Yrnl., Oxfrd. 60, Paris 60, Brsls., Glsgw., Rome.	
135	Brad. 6	Brln. Jrbh., Oxfrd. 60, Brsls., Paris 60, 75, Yrnl., Pulk. 75, Rome, Grnwch. 80, 88.	
136	Brad. 3	Pulk. 55, Oxfrd. 60, Paris 60, Brsls., Grnwch. 72, 80, Rome	
137	Brad. 4	Pulk. 55, Yrnl., Glsgw., Grnwch. 64, Brsls	
138	Auwer's	Brln. Jrbh., Yrnl., Brsls., Cambr., Rome, Pulk. 76, Paris 75, Grnwch. 87, 89.	Kazan Prime Vertical.
139	Brad. 3	Yrnl., Pulk. 55, 75, Oxfrd. 60, Grnwch. 60,* 64, 72, Brsls., Paris 75, Rome Cinn.	
140	Brad. 25	Brln. Jrbh , Yrnl., Cambr., Rome, Pulk. 75, Paris 82, Grnwch. 80, 88	
141	Groombridge and others.	A. G. Cambr., Gotha, Pr. Vrtcl. A. N	
142	Brad. 5	Pulk. 55, 75, Brsls., Grnwch. 64, 72, 80, Glsgw., Paris 60, 75, Yrnl	
143	Piazzi and others.	Grnwch. 60 rejected, about 5″ in error, Oxfrd. 60, Paris 60, 75, Brsls., Glsgw., Brln. 85.	
144	Groombridge and others.	A. G. Cambr., Göttingen, Prime Vertical, Paris 75	
145	Groombridge and others.	Paris 60, 75, Brsls., Rome, Glsgw., Grnwch. 80	
146	Piazzi and others.	Pulk. 55, A. G. Hlgfrs., Brsls., Glsgw., Rome, Grnwch. 80	
147	Brad. 4	Pulk. 55, 75, Paris 60, 75, Grnwch. 64, Glsgw	
148	Brad. 4	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Yrnl., Brsls., Cambr., Rome, Pulk. 75, Grnwch. 80.	Cambr. 93.
149	Brad. 11	Pulk. 55, 75, Grnwch. 60, 64, 80, Oxfrd. 60, Yrnl., Paris 60, Brsls., Rome	
150	Brad. 4	Pulk. 55, Paris 60, 75, Grnwch. 64, 72, 80, Glsgw., Rome	
151	Brad. 4	Pulk. 55, 75, Grnwch. 64, 72, 80, 87, 89, Rome	
152	Piazzi and others.	Paris 60, 75, Yrnl., Oxfrd. 70, Glsgw., Grnwch. 80, 89	
153	Brad. 12	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Yrnl., Paris 60, 75, Cambr., Glsgw., Rome, Grnwch. 80, 88.	Pulk. 85 not used as it was received too late.
154	Piazzi and others.	Pulk. 55, Glsgw., Oxfrd. 65, Paris 75, Grnwch. 80	
155	Brad. 5	Pulk. 55, Oxfrd. 60, Grnwch. 60, 64, 72, 80, Paris 60, 75, Brsls., Yrnl., Washgtn. 68 (Boss), Cambr., Rome.	
156	Brad. 3	Pulk. 55, Glsgw., Paris 75, Rome, Berlin., Grnwch. 80	
157	Brad. 27	Pulk. 55, Bonn, Grnwch. 64, 72, Lpzg., Leidn., Rome	
158	Piazzi and others.	Pulk. 55, Glsgw., Brsls., Paris 60, 75, Grnwch. 64, 72, 80, 87, Oxfrd. 75, A. G. Leiden, Rome.	
159	Brad. 4	Pulk. 55, Paris 60, Grnwch. 64, Brsls., Glsgw., Rome	

* The Greenwich result for 1860 for star 13.9 was corrected by means of a letter from Mr. H. P. Hollis of the Royal Observatory.

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declinations in computing latitudes on the boundary.	Observations added on revision.
160	Brad. 5	Pulk. 55, 75, Oxfrd. 60, Paris 60, Brsls., Cambr., A. G. Albany, Rome, Grnwch. 88, Cinn.	
161	Brad. 3	Pulk. 55, Grnwch. 60, 80, Glsgw., A. G. Albany, Rome	
162	Argelander	Pulk. 55, 71, 75, 81, Prime Vertical 91, Prime Vertical Cambr., Yrnl	Pulk. 68 Pr. Vrtcl.
163	Brad. 27	Pulk. 55, Rome, Brln., Paris 75, Grnwch. 80	
164	Groombridge and others.	Pulk. 55, Yrnl., Grnwch. 64, 88, Glsgw., Rome, Paris 82	
165	Brad. 5	Pulk. 55, 75, Oxfrd., Grnwch. 60, 64, Brsls., Göttingen, Paris 75, Yrnl., Rome, Krlsrhe.	
166		Paris 60, 75, Brsls., Oxfrd. 65, Glsgw., Gotha 85, A. N.	
167	Argelander	Pulk. 55, 71, 75, Lpzg., Yrnl., Cambr., Rome, Grnwch. 80	
168	Piazzi and others.	Pulk. 55, 75, Yrnl., Oxfrd. 60, 75, Paris 60, 75, Brsls., Grnwch. 64, 72, Rome.	
169	Brad. 4	Pulk. 55, Grnwch. 60, 80, Paris 60, Brsls., Glsgw., Yrnl., Rome, A. G. Albny.	
170	Brad. 2 (confirmed)	Leidn., Rome, Pulk. 55, Yrnl., Grnwch. 64, Oxfrd. 75, A. G	
171	Brad. 5	Pulk. 55, Paris 60, 75, 82, Grnwch. 64, 72, 80, 89, Brsls., Glsgw	
172	Brad. and others.	Pulk. 55, A. G., Hlgfrs., Rome, Grnwch. 80	
173	Auwer's	Brln. Jrbh., Yrnl., Brsls., Rome, Pulk. 75, Grnwch. 80, 89	
174	Brad. 13	Brln. Jrbh., Paris 60, Brsls., Cambr., Rome, Pulk. 75, Grnwch. 80, 89	
175	Brad. 5	Pulk. 55, Grnwch. 60, 64, 88, Paris 60, 75, Oxfrd., Glsgw., Brsls	
176	Piazzi and others.	Pulk. 55, Oxfrd. 75, Grnwch. 72, 80, 88, Brsls., Paris 75	
177	Groombridge and others.	Pulk. 55, Paris 60, 75, 82, Glsgw., Brsls., Rome	
178	Auwer's	Berln. Jrbh., Oxfrd. 60, Paris 45, Pulk. 55, 75, Brsls., Yrnl., Cambr., Rome, Grnwch. 80, 87, 88.	
179	Brad. 2 (confirmed)	Grnwch. 60, 80, Pulk. 55, Göttingen Crdba., Oxfrd. 75, Paris 75, Krlsrhe 85, Grnwch 80.	Karlsruhe.
180	Brad. 5	Grnwch. 60, 72, 80, Pulk. 55, 75, Yrnl., Brsls., Rome (Rutherfurd's photographs).	
181	Groombridge and others.	Pulk. 55, Paris 75, Grnwch. 80	
182	Piazzi and others.	Pulk. 55, 75, Grnwch. 60, 80, Oxfrd. 60, Brsls., Glsgw., Rome	
183	Piazzi and others.	Pulk. 55, 75, Paris 60, 75, Bonn, Oxfrd. 60, Yrnl., Glsgw., Brsls., Grnwch. 80, 88, Gotha 85.	
184	Brad. 3	Pulk. 55, Oxfrd 60, Paris 60, 75, Grnwch. 64, Auwers's 303 Stars	
185	Brad. 30	Pulk. 55, 75, Oxfrd. 60, Grnwch. 64, 88, Brsls., Cambr., Rome, Gotha Pr. Vertical.	
186	Brad. 5	Berlin Jrbh., Yrnl., Brsls., Paris 75, Rome, Cambr. 75, Pulk. 75, Grnwch. 80, 87.	
187	Brad. 5	Berlin Jrbh., Yrnl., Brsls., Paris 60, Cambr., Rome, Pulk. 75, Grnwch. 80, 89.	
188	Brad. 3	Paris 60, Glsgw., Grnwch. 64, Brsls	
189	Brad. and others.	Pulk., Paris, Brsls., Grnwch. 72, 80, Glsgw	
190	Brad. 8	Brln. Jrbh., Oxfrd. 60, Yrnl., Paris 60, 75, 82, Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	
191	Brad. 4	Pulk. 55, Oxfrd. 60, Grnwch. 60, 80, Brsls., Rome, Paris 75	
192	Brad. 19	Berlin Jrbh., Paris 60, 82, Brsls., Yrnl., Cambr., Berlin, Pulk. 75, Rome, Grnwch. 80, 87.	
193	Brad. 2	Pulk. 55, Grnwch. 64, Washington 1870, Brsls., Rome, Glsgw	Cinn.
194	Brad. 8	Pulk. 55, Grnwch. 64, 72, 80, Glsgw., Cambr., Rome	Paris 70.
195	Brad. 23	Pulk. 55, Grnwch. 60, 80, Yrnl., Brsls., Pulk. 75	Paris 60, 75.
196	Brad. 3	Pulk. 55, Glsgw., Grnwch. 64, 72, 80, Rome	Paris 60, Gwch. 87, 88, Brln. 85.
197	Groombridge and others.	Pulk. 55, Paris 60, Brsls., Glsgw., A. G. Cambr., Rome, Gotha, Pr. Vertical, Grnwch. 80.	
198	Brad. 3	Brln. Jrbh., Pulk. 55, 75, Rome	
199	Brad. 17	Pulk. 55, Paris 60, 75, Rome, Brln., Grnwch. 80	
200	Brad. 6	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Yrnl., Brsls. Washgtn. 68 (Boss), Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 87, 88, 88, 89.	
201	Brad. 4	Brln. Jrbh., Yrnl., Brsls., Armagh, 75, Paris 75, Cambr., Pulk. 75, Rome, Grnwch. 80.	
202	Brad. 3	Pulk. 55, Oxfrd. 60, Yrnl., Grnwch. 64, 72, Brsls., Glsgw., Rome	
203	Brad. 3	Pulk. 55, Grnwch, 64, 80, Glsgw., Rome	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
204	Argldr. (A. N.)	Pulk. 55, Brsls., Paris 60, 75, Glsgw., Rome, Grnwch. 89	
205	Brad. 5	Pulk. 55, Grnwch. 60, 64, 72, 80, Paris 60, 75, Brsls., Glasgow, Rome	
206	Piazzi and others.	Pulk. 55, Oxfrd. 75, Brussels, Grnwch. 72, 80	
207	Brad. 23	Brln. Jrbh., Pulk. 55, 75, Brsls., Cambr., Rome, Brln., Grnwch. 80	
208	Brad. 2 and others.	Pulk. 55, Grnwch. 60, 64, 72, Oxfrd. 60, Paris 60, 75, Brsls., Rome	
209	Brad. 5	Polk. 55, Grnwch. 64, 72, 80, 87, Rome	
209[1]	Brad. 2	Pulk. 55, Grnwch. 64, Brsls., Cape 80, Rome	
210	Brad. 25	Pulk. 55, 75, Brsls., Rome, Berlin, A. G., Cambr., Paris 75, Grnwch. 80	
211	Brad. 8	Pulk. 55, Grnwch. 64, 72, Amgh. 75, Rome, Brln	
212	Brad. 4	Pulk. 55, Grnwch. 60, 80, Yrnl., Paris 60, 75, Glsgw., Rome	
213	Piazzi and others.	Pulk. 55, Grnwch. 60, 80, Paris 60, Glsgw., Brsls., Yrnl., Rome	
214	Brad. 17	Brln. Jrbh., Pulk. 55, 75, Brsls., Oxfrd., Paris 60, 75, Cambr., Rome	
215	Brad. 6	Brln. Jrbh., Oxfrd. 60, Yrnl., Glsgw., Cambr., Pulk., Grnwch. 80, 88	
216	Auwer's, confrmd by Boss.	Washgtn. 68, Boss, Yrnl., Cambr., Pulk., Rome, Grnwch. 80, 88. (Brln. Jrbh. omitted.)	
217	Brad. 5	Pulk. 55, Grnwch. 60, 80, Brsls., Rome, Glsgw., Cape 80	
218	Brad. 5	Brln. Jrbh., Brsls., Cambr., Pulk. 75, Brln., Rome, Grnwch. 80	
219	Brad. 14	Pulk. 55, Grnwch. 64, Brsls., Rome, A. G. Helsingfors, A. G. Cambr., Kazan, Pr. Vertical.	
220	Brad. 6	Brln. Jrbh., Brsls., Pulk. 75, Grnwch. 80, Rome, Grnwch. 89, Auwers's 303 Stars.	
221	Brad. 3	Pulk. 55, Yrnl., Grnwch. 64, 72, 80, Brsls., Paris 75, Rome, Brln	
222	Brad. 2	Pulk. 55, Grnwch. 64, 72, 80, Paris 75	
223	Brad. 16	Brln. Jrbh., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80, 87	Paris 45, 60, 75.
224	Brad. 21	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Brsls., Cambr., Rome, Pulk. 75	
225	Brad. 12	Brln. Jrbh., Brsls., Paris 60, Cambr., Rome, Pulk. 75, Brln., Grnwch. 80	
226	Brad. 7	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Brsls., Yrnl., Glsgw., Cambr., Rome, Grnwch. 80, 89	
227	Brad. 16	Brln. Jrbh., Brsls., Cambr., Pulk. 75, Rome, Grnwch. 80	
228	Brad. 5	Pulk, 55, 75, Grnwch. 60, 64, 72, 80, Oxfrd. 60, Paris 60, 75, Yrnl., Brsls., Glsgw., Rome.	
229	Piazzi and later auths.	Pulk. 55, Paris 60, Grnwch. 60, 64, 72, 80, Brsls., Yrnl., Rome	
230	Piazzi, Groombridge, and others.	Pulk. 55, Yrnl., Brsls., Rome, Grnwch. 80, Cinn	
231	Piazzi and later auths.	Pulk. 55, 75, Brsls. 65, Glsgw., Grnwch. 80	
232	Brad. 3	Pulk. 55, Oxfrd. 75, A. G. Leidn., Grnwch. 72, 80, Rome, Paris 75	
233	Brad. 3	Pulk. 55, Oxfrd. 60, Grnwch. 64, Brsls., A. G. Leidn., Pulk. 75, Rome, Paris 75.	
234	Brad. 18	Pulk. 55, A. G. Hlgfrs., Rome, Brln., Grnwch. 87	
235	Brad. 4	Pulk 55, Grnwch. 64, 72, 80, Oxfrd. 75, Rome, Paris 75	
236	Brad. 9	Brln. Jrbh., Yrnl., Paris 60, Brsls., Pulk. 75, Rome, Paris 75	
237	Brad. 19	Brln. Jrbh., Yrnl., Oxfrd., Paris 60, Washgtn. 68, Boss, Glsgw., Paris 75, Cambr., Pulk. 75, Rome, Grnwch. 80.	
238	Brad. 18	Brln. Jrbh., Pulk. 55, 75, Cambr., Rome, Grnwch. 80, 89	
239	Brad. 5	Brln. Jrbh., Yrnl., Oxfrd. 60, Bonn, A. N. Washgtn. 68, Boss, Glsgw., Cambr., Pulk. 75, Grnwch. 80, 88.	Paris 60, 75.
240	Brad. 3	Brln. Jrbh., Pulk. 55, 75, Paris 60, Cambr., Rome, Grnwch. 80	
241	Brad. 4	Pulk. 55, Oxfrd. 60, Grnwch. 60, 88, Brsls., Paris 75, Rome, Cinn	
242	Radcliff and later.	Pulk. 55, Ednbro., Grnwch. 64, 72, 80, A. G. Christiania, Yrnl, Rome.	Oxfrd 70.
243	Brad. 15	Paris 60, 75, Grnwch. 60, 64, 72, 80, 88, Brsls., Pulk. 75, Karlsruhe, Cape	Greenwich 89.
244	Brad. 9	Pulk. 55, A. G. Hlgfrs., Rome, Brln., Paris 75, Grnwch. 80	
245	Brad. 3	Pulk. 55, 75, Paris 45, 60, 75, Brsls., Washgtn. 70, Grnwch. 72, Amagh. 75, Rome.	
246	Brad. 3	Brln. Jrbh., Brsls., Cambr., Pulk. 75, Brln., Rome, Grnwch. 80, 88	Greenwich 89.
247	Brad. 2 and later	Grnwch. 60, 64, 72, 80, 88, Paris 60, 75, Brsls., Yrnl., Rome	
248	Brad. 19	Oxfrd. 75, Cinn., Brln. Jrbh., Yrnl., Paris, Cambr., Brsls., Rome, Pulk. 75, Grnwch. 80.	Pulk 55.
249	Brad. 2 and later	Pulk. 55, Grnwch. 60, 72, 80, Oxfrd. 60, Paris 60, 75, Brsls., Yrnl., Rome	
250	Brad. 15	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Bonn 66, Brsls., Yrnl., Oxfrd. 75, Cambr., Rome, Pulk. 75, Grnwch. 80.	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
251	Auwers's	Pulk. 55, Grnwch. 64, Brsls., Yrnl., Glsgw., Cambr., Cape 80, Rome	
252	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Paris 60, Rome, Glsgw., Grnwch. 80	
253	Brad. 12	Brln. Jrbh., Yrnl., Paris 60, 75, Brussels, Glsgw., Cambr., Pulk. 75, Cape 85, Rome, Grnwch. 80, 88.	
254	Brad. 4	Pulk. 55, Grnwch. 64, Brsls., Washgtn. 70, Rome	Grnwh. 90.
255	Brad. 11	Pulk., Grnwch. 72, 80, A. G. Helsingfors, Rome	
256	Brad. 3	Pulk. 55, Paris 60, Oxfrd. 60, Brsls., Grnwch. 64, Glsgw., Rome	Glasgow 90.
257	Brad. 5	Pulk. 55, 75, Oxfrd. 60, Grnwch. 64, 80, Brsls., Cambr., Glsgw., Rome, Cinn.	Glasgow 90
258	Brad. 10	Pulk. 55, Paris 60, Brsls., Yrnl., Brln., Rome	
259	Brad. 8	Pulk. 55, Paris 45, 60, Oxfrd. 60, Grnwch. 64, Rome, A. G., Cambr	
260	Brad. 9	Brln. Jrbh., Pulk. 55, 75, Cambr., Berlin Grnwch. 80	
261	Groombridge and later.	Pulk. 55. Ednbro., A. G. Helsingfors	
262		Pulk. 55, 75, Oxfrd. 60, Grnwch. 64, 72, 80, A. G. Helsingfors, Brussels, Rome, Cinn.	
263	Brad. 5	Pulk. 55, Paris 60, Grnwch. 64, Cambr., Cape 80, Rome	
264	Brad. 3	Pulk. 55, Glsgw., Grnwch. 64, 72, 80, Paris 75, Brln., Rome	
264	Brad. 74	Brln. Jrbh., Oxfrd. 60, Paris 60, 75, Yrnl., Bonn 66, Washgtn. 68 Boss, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	Glsgw. 90. Grwch. 90.
265	Lalande and later.	Pulk. 55, Paris 60, 75, Grnwch. 80.	
266	Brad. 71	Brln. Jrbh., Oxfrd. 60, Brsls., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80.	Grnwh. 90.
267	Brad. 4	Pulk. 55, Washtn. 70, A. G. Helsingfors, Brln., Rome, Grnwch. 80	
268	Brad. 6	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Yrnl., Brussels, Cambr., Rome, Paris 75, Grnwch. 80.	
269	Brad. 4	Pulk. 55, Grnwch. 60, 80, Paris 60, Oxfrd. 75, Rome	
270	Brad. 6	Pulk. 55, Grnwch. 60, Brsls., Cambr., Paris 60, 75	
271	Brad. 2 and later.	Pulk. 55, Grnwch. 60, Brsls., Paris 60, Rome	Glsgw. 90 not used.
272	Brad. 2 and later.	Pulk. 55, 75, Oxfrd. 60, Yrnl., Grnwch. 64, 72, Brsls., Rome, Brln	
273	Brad. 3	Pulk. 55, 75, Oxfrd. 60, Brsls, Grnwch. 64, 72, 80, Glsgw	
274	Brad. 6	Pulk. 55, Grnwch. 60, 72, 80, 88, Paris 60, 75, Brsls., Rome	
275	Brad. 4	Pulk. 55, Grnwch. 60, 72, 80, 88, Yrnl., Paris 75, Rome	Glsgw. 90. Grnwh. 90.
276	Groombridge and later.	Pulk. 55, Grnwch. 64, Washgtn. 70, Brsls., Rome, Paris 75	Grnwh. 90. Cinn.
277	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Amgh. 75, Paris 75, Rome, Cambr., Greenwich 80	
278	Brad. 5	Brln. Jrbh., Yrnl., Paris 60, 75, Glsgw., Rome, Pulk. 75, Cambr., Cape 80, Grnwch. 80.	Grnwh. 88.
279	Brad. 3	Pulk. 55, Yrnl., Grnwch. 64, 72, 80, Lpzg., Leidn., Rome, Washgtn. Pr., Vrtcl.	Greenwich 90.
280	Brad. 3	Pulk. 55, 75, Grnwch. 60, 80, Paris 60, 75, Brsls., Rome	Glsgw. 90.
281	Brad. 3	Pulk. 55, 75, Yrnl., Grnwch. 60, 72, 80, Paris 45, 60, 75, Brussels, Rome	
282	Brad. 3	Pulk. 55, Paris 60, Grnwch. 64, Glsgw., Rome, A. G. Albany	
283	Brad. 2 (Cnfrmd.)	Pulk. 55, Yrnl., Paris 45, 60, 75, Washgtn. 70, Grnwch. 64, 72, Brussels, Rome, Glsgw.	
284	Brad. 3	Paris 60, Pulk. 55, Brsls., Grnwch. 72, 80, A. G. Helsingfors, Rome	
285	Brad. 3	Pulk. 55, 75, Paris 60, Grnwch. 64, 72, Brln	
286	Lalande and later.	Pulk. 55, Amgh. 75, Paris 75, Cambr., Grnwch. 87	
287	Brad. 3	Pulk. 55, Yrnl., Paris 75, Brln., Grnwch. 87	
288	Brad. 5	Pulk. 55, Paris 45, 60, Yrnl., Grnwch. 60, 64, 72, 80, 88, Rome	
289	Lalande and later.	Pulk. 55, Paris 60, 75, Glsgw., Grnwch. 80	
290	Groombridge and later.	Pulk. 55, Brsls., A. G. Hlgfrs., Rome, Greenwich, 80	
291	Lalande and later.	Yrnl., Brsls., Paris 75, Cambr., Grnwch. 87	Greenwich 89.
292	Brad. 3	Pulk 55, Paris 45, 60, 75, Grnwch. 64, 80, Washgtn. 70, Brsls., Glsgw	
293	Brad. 13	Pulk. 55, Grnwch 60, 64, 72, 80, 87, 88	Greenwich 89, 90.
294	Lalande and later	Pulk. 55, Gött., Crdba., Paris 75, Krlsrhe., Grnwch. 80	
295	Arglndr	Brln. Jrbh., Pulk. 55, 75, Yrnl., Rome, Grnwch. 80	
296	Brad. 3	Pulk. 55, Grnwch. 64, Glsgw., Paris 75	Glasgow 90.
297	Auwers's	Pulk. 55, Brsls., Göttingen, Cape 80, Grnwch. 80, Krlsrhe	Auwers's 303 Strs.
297[1]	Brad. 9	Paris 45, 60, Pulk. 55, Grnwch. 60, 64, 72, 80, Yrnl., Brsls., A. G. Chrstana., A. G., Hlgfrs., Rome.	Grnwh. 89, 90.
298	Brad. 4	Pulk. 55, Grnwch. 60, 64, 80, Yrnl., Rome., Paris 75	
299	Brad. 11	Brln. Jrbh., Yrnl., Paris 60, 75, Brsls., Rome, Pulk. 75, Cambr., Berlin, Paris, Grnwch. 80.	Grnwch. 90.

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
300	Brad. 3	Brln. Jrbh., Brsls., Glsgw., Rome, Pulk. 75, Grnwch. 80, 88	Grnwh. 90.
301	Brad. 5	Pulk. 55, 75, Grnwch. 60, 72, 80, 88, Paris 45, 60, 75, Rome	Grnwh. 89.
302	Piazza and others	Pulk. 55, Paris 20, Grnwch. 64, A. G. Leidn., Glsgw	Oxfrd. 64, Wash. 75-6, Glsgw. 90.
303	Piazza and others.	Pulk. 55, Amgh. 75, A. G. Leidn	Grnwh. 90.
304	Brad. 19	Pulk. 55, 75, Yrnl., Grnwch. 60, 80, Brsls., Cambr., Rome	A. G. Camb. Kazan Pr. Vertical.
305	Brad. 4	Pulk. 55, Paris 60, Brsls., Grnwch. 64, Glsgw., Rome	Glasgow 90.
306	Brad. 9	Brln. Jrbh., Paris 60, 75, Yrnl., Brsls., Rome, Pulk. 75, Cambr., Grnwch. 80.	
307	Brad. 3	Pulk. 55, 75, Brsls., Paris 60, Washgtn. 70, Brln., Rome, Greenwich, 80	Brln. 1888 A. N. No. 2912.
308	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Yrnl., Brsls., Cambr., Rome, Grnwcb. 80	
309	Brad. 3	Pulk. 55. Göttingen, Brsls., Paris 75, Brln., Crdba., Cape 80, Grnwch. 80, 88, Krlsrhe.	Greenwich 90.
310	Brad. 3	Brln. Jrbh., Yrnl., Brsls., Pulk. 75, Cambr., Brln, Rome, Grnwch. 80	Greenwich 87, 89, 90
311	Lalande and later.	Pulk. 55, Yrnl., Paris 60, 75, Brsls., Armgh., Grnwch. 80	Greenwich 90.
312	Brad. 3	Pulk. 55, Paris 60, Brsls., Brln., Rome, Cambr., Grnwch. 80	
313	Brad. 9	Pulk. 55, Grnwch. 60, 64, 72, Glsgw., Brsls., Cambr., Rome	
314	Brad. 2	Pulk. 55, Grnwch. 60, 64, 80, Brsls., Yrnl., Glsgw., Amgh. 75, Rome, A. G., Albny.	Paris 60.
315	Brad. 27	Brln. Jrbh., Yrnl., Paris 60, Rome, Pulk. 75, Cambr., Grnwch. 80, 88	Greenwich 89.
316	Brad. 4	Pulk. 55, 75, Paris 45, Glsgw., Grnwch. 64, 72, 80, Brsls., Rome	
317	Brad. 4	Brln. Jrbh., Pulk. 55, 75. Yrnl., Paris 60, 75, Glsgw., Cambr., Cape 80, Rome, Grnwch. 80, 87, 88.	Greenwich 90.
318	Brad. 4	Pulk. 55, Grnwch. 64. Washtn. 70, Oxfrd. 70	
319	Groombridge and later.	Grnwch. 60, 64, 72, Brsls., Washgtn. 70, A. G. Hlgfrs., Rome	Kazan Pr. Vertcal.
320	Brad. 4	Pulk. 55, 75, Yrnl., Grnwch. 60, 80, Paris 75, Rome	
321	Brad. 3	Pulk. 55, Grnwch. 60, 80, Brsls., Glsgw., Rome	
322	Brad. 8	Brln. Jrbh., Yrnl., Paris 60, 75, Brsls., Cambr., Glsgw., Pulk. 75, Grnwch. 80, 88. Cape 80, Rome 80.	Greenwich 89, 90.
323	Piazzi, Groombridge, and later.	Brln. Jrbh., Pulk. 55, 75, Brsls., Yrnl., Cambr., Rome, Grnwch. 80	
324	Groombridge and later.	Pulk. 55, A. G. Hlgfrs., Grnwch. 80	
325	Brad. 3	Pulk. 55, Oxfrd. 60, 65, Grnwch. 60, 64. 80, Paris 60, 75, Yrnl., Brsls., Glsgw., Auwers's 303 Stars.	Greenwich 90.
326	Brad. 12	Pulk. 55, Paris 60. Grnwch. 60, 64. 72, 80, Brsls., Yrnl., A. G. Chrstana., Rome.	
327	Brad. 1 and latr. revisn.	Pulk. 55, Paris 60, Grnwch. 64, 72, Rome	
328	Piazzi and later	Pulk. 55, 75, Paris 60, 75, Yrnl., Brsls., Glsgw., Crdba., Grnwch. 80, Cape 80, Krlsrhe. 85.	Karlsruhe 87.
329	Brad. 8	Brln. Jrbh., Yrnl., Brsls., Wasgtn. 70, Paris 60, 75, Glsgw., Cambr., Rome, Pulk. 75, Grnwch. 80, 88.	Greenwich 89.
330	Brad. 12	Brln. Jrbh., Yrnl., Paris 60. 75, Glsgw., Cambr., Cape 80, Pulk. 75, Rome, Grnwch. 80, 87.	Greenwich 89, 90.
331	Brad. 16	Brln. Jrbh., Yrnl., Paris 60, 75, Glsgw., Rome, Pulk. 75, Grnwch. 80, 87	Grnch. 90.
332	Groombridge and later.	Pulk. 55, Yrnl., Paris 75. Brsls., Grnwch. 80	Greenwich 88.
333	Brad. 5	Pulk. 55, 75, Yrnl., Paris 60, 75, Grnwch. 64, Brsls., Oxfrd. 70, Rome	
334	Brad. 7	Brln. Jrbh., Paris 60, 75, Yrnl., Brsls., Cambr., Glsgw., Pulk. 75, Rome, Grnwch. 80, 87, 88, Cape 80.	Greenwich 90.
335	Brad. 4	Pulk. 55, Greenwich 64, Oxfrd. 70, Glasgow, Rome	
336	Brad. 3	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 70, Cambr., Rome, Greenwich 80	
337	Brad. 5	Pulk. 55, 75, Oxfrd. 60, Grnwch. 60, 72, 80, Brsls., Yrnl., Rome, A. G. Albany	Cinn. Grnwh. 90
338	Brad. 4	Pulk. 55, 75, Oxfrd. 60, Grwnch. 60, 64, 72, 80, Brsls., Glsgw., Cambr., Rome	Grnwh. 89.
339	Groombridge and later.	Pulk. 55, Brsls, Grnwh. 80	
340	Brad. 2 (confrmd. on revisn.).	Berlin Jrbh., Pulk. 55, 75, Yrnl., Cambr., Glsgow, Rome	
341	Brad. 9	Berlin Jrbh., Pulk. 55, Pr. Vrtcl. 69, 75, Washgtn. 70, Pr. Vrtcl. 81, 90, Cambr., Rome.	Grnwh. 90.

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
342	Piazzi and later...	Pulk. 55, Brsls., Greenwich 64, 72, Oxfrd. 70, Armagh 75, A. G. Leiden, Cambr., Glsgw.	
343	Brad. 12..........	Pulk. 55, Yrnl., Greenwich 72, Rome..........	
344	Brad. 3..........	Pulk. 55. 75, Glsgw., Greenwich 64, 72, 80, Oxfrd. 64, Rome..........	
345	Brad. 6..........	Pulk. 55, Yrnl., Greenwich 60, 64, 80, 88, Brussels, Leiden, Leipzig., Cambr., Auwers's 303 stars.	Greenwich 90.
346	Groombridge and later.	Pulk. 55, Yrnl., Brussels, Rome, Grnwch. 80..........	
347	Groombridge and later.	Pulk. 55, Paris 64, Cambr., Rome, Grnwch. 80..........	
348	Brad. 4..........	Pulk. 55, Grnwch. 64, 72, 80, Brsls., Oxfrd. 70, Cambr., Rome..........	Grnwch. 90.
349	Brad. 4..........	Pulk. 55, Brsls., Greenwich 64, Armagh 75..........	
350	Lalande..........	Pulk. 55, A. G. Leidn., Grnwch. 80..........	
351	Brad. 1, cnfrmd. by Arglndr.	Brln. Jrbh., Oxfrd. 60, Pulk. 55, 75, Yrnl., Brussels, Cambr., Grnwch. 80..	
352	Brad. 3..........	Pulk. 55, Grnwch. 60, 80, 88, Cambr., Rome, materials do not agree very well.	Greenwich 90.
353	Brad. 4..........	Pulk. 55, Grnwch. 60, 64, 72, 80, Yrnl., Cordoba, Glsgw..........	Karlsruhe, Glasgow 90.
354	Brad. 8..........	Oxfrd. 60, Pulk. 55, Grnwch. 60,64,72,80, Yrnl., Brussels, A. G. Christiania.	
355	Groombridge and later.	Pulk. 55, Rome, Grnwch. 80..........	
356	Brad. 3..........	Pulk. 55. Grnwch. 64, Oxfrd. 70, Yrnl. 70, Brussels, Rome, Glsgw..........	Grnwch. 89, 90.
357	Brad. 8..........	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Yrnl., Glsgw., Cambr., Greenwich 80, Auwers's 303 stars.	Greenwich 88, 89, Glsgw. 90.
358	Brad. 2..........	Pulk. 55, Grnwch. 64, 80, Washgtn. 70, Rome..........	Cordoba 85.
359	Piazzi and later...	Yrnl., Grnwch. 60, 80, Oxfrd. 75, Glsgw., Rome, Paris 83..........	
360	Groombridge and later.	A. G. Chrstna., Grnch. 80..........	
361	Brad. 7..........	Pulk. 55, Grnwch. 60, Brsls., Cambr., Rome, Gotha, Pr. Vrtcl. A. N..........	
362	Brad. 2..........	Pulk. 55, Grnwch. 60, 64, 72, 88, Yrnl., Glsgw., Karlsruhe..........	Cordoba, Grnwch. 90, Karlsruhe 89.
363	Piazzi, Groombridge, etc.	Pulk. 55, 75, Oxfrd. 60, Bonn, Brsls., Grnwch. 72. 80, A. G. Helsingfors, Rome.	Cinn.
364	Piazzi, Groombridge, etc.	Brln. Jrbh., Yrnl., Pulk. 55, 75, Cambr., Rome, Grnwch. 80..........	
365	Piazzi, etc..........	Oxfrd. 60, Brsls., Gott., Glsgw., Krlsrhe., Gotha A. N..........	Crdba.
366	Brad. 2..........	Pulk. 55, Grnwch. 60, 64, 72, 80, Brsls., Glsgw., Crdba..........	Grnwch. 89.
367	D'Agelet, Lalande, etc.	Ednbro., Brussels, Washgtn. 70, Oxfrd. 70, Armagh 75, Paris 83, Grnwch. 87.	
368	Piazzi, Grmbdg., etc.	Brln. Jrbh., Pulk. 55, 75, Yrnl., Bonn, Cambr., Rome, Grnwch. 80, Washgtn., Pr. Vrtcl. A. J.	
369	Arglndr..........	Brln. Jrbh., Pulk. 55, 75, Cambr., Rome, Grnwch. 87, 88..........	Grnwch. 89.
370	Brad. 4..........	Pulk. 55, 75, Brsls., Grnwch. 60, 64, 72, 80, Washgtn. 70, Glsgw., Paris 82..	
371	Brad. 7..........	Pulk. 55, Grnwch. 60, 64, Yrnl., Brussels, Cambr., Grnwch. 72, 80, 87, 88, Auwers's 303 stars.	Grnwch. 89, 90.
372	Grmbrdg., etc....	Pulk. 55, Grnwch. 87, Brln. 88..........	
373	Grmbrdg., etc....	Pulk. 55, Washgtn. 70, Rome, Grnwch. 80..........	
374	Brad. 33..........	Brln. Jrbh., Yrnl., Oxfrd. 60, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, Gotha, Pr. Vrtcl. A. N.	
375	Brad. 2. cnfrmd. by Arglr.	Pulk. 55, 75, Grnwch. 64, Yrnl., Bonn, Brsls., Rome, Glsgw..........	
376	Piazzi, etc..........	Pulk. 55, Kngsbrg. 60, Brsls., Grnwch. 80..........	Glasgow 90
377	Brad. 4..........	Pulk. 55, Brsls., Rome, Brln., A. G. Cambr., Grnwch. 80..........	
378	D'Agelet, Piazzi, etc.	Glsgw., Crdba., Krlsrhe..........	Brln. 85.
379	Grmbrdg., etc.....	A. G. Chrstana., Grnwch. 88..........	Greenwich 90.
380	No very old data..	Pulk. 55, 75, Ednbro., Glsgw., Amgh. 75, Cambr., Grnwch. 80..........	
381	Arglndr..........	A. G. Hlgfrs., Pulk. 75, Grnwch. 87..........	
382	Piazzi, etc..........	Pulk. 55, Grnwch. 60, 64, Glsgw., Rome, A. G. Albny..........	Greenwich 89.
383	Brad. 3..........	Pulk. 55, Oxfrd. 60, Grnwch. 64, 72, 80, Brsls., Glsgw., Rome..........	Cinn.
384	Brad. 1, cnfrmd., Boss.	Brln. Jrbh., Brsls., Pulk. 75, Cambr., Rome, Grnwch. 80, 87..........	Greenwich 90.
385	Brad. 4..........	Brln. Jrbh., Brsls., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80..........	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
386	Brad. 4	Pulk. 55, 75, Brsls., Grnwch. 64, 72, 80, 88, Washgtn. 70, Glsgw., Rome	Grnch. 90.
387	Lalande, etc	Pulk. 55, 75, Glsgw., A. G. Albny., Grnwch. 87	Cinn., Glsgw. 90.
388	Brad. 4	Brln. Jrbh., Yrnl., Cambr., Glsgw., Pulk. 75, Rome, Grnwch. 80. 87	Greenwich 89, Glsgw. 90.
389	Grmbrdg., etc	Brln. Jrbh. *cretd.* for precsn., Pulk. 55, 75, Cambr., Rome, Grnwch. 80 88	Greenwich 90.
390	Lalande, etc	Glsgw., Brsls., A. G. Leidn., Rome, Amgh. 75, Brln. 88	
391	Brad. 2	Brln. Jrbh., Pulk. 55, 75, Brsls., Cambr., Brln., Rome	
392	Lalande and others	Amgh. 75, Cambr., Pulk 75, Grnwch. 80	
393	Grmbrdg. and others.	Rome, Grnwch. 80	
394	Brad. 2	Pulk. 55, Yrnl., Grnwch. 60, 64, 72, 80, Rome	
395		Pulk. 55, 75, Grnwch. 80	
396	Brad. 2	Pulk. 55, 75, Brsls., Brln., Rome, Grnwch. 80	
397	Arglndr. revised	Pulk. 55, 75, Yrnl., Brsls., Grnwch. 64, 72, 80, Rome, Cinn	
398	Arglndr. revised	Brln. Jrbh. *cretd.*, Pulk. 55, 75, Oxfrd. 60, Brsls., Cambr., Rome, Grnwch. 80.	
399	Piazzi and others	Pulk. 55, Grnwch. 64, 72, 80, Brsls., Glsgw., Rome	
400	Brad. 2	Pulk. 55, Grnwch. 60, 80, 88, Glsgw., A. G. Albny., Rome	Greenwich 89.
401	Groombridge and others.	Bonn, Pulk. 55, 75, Brsls., Cambr., A. G. Hlgfrs., Rome, Grnwch. 80	
402	Brad. 2	Pulk. 55, Grnwch. 60, 72, 80, Brsls., Rome	
403	Groombridge and others.	Washgtn. 70, Rome, Grnwch. 88	
404	Piazzi and others	Pulk. 55, Yrnl., Grnwch. 60, 80, Brsls., Rome	
405	Brad. 3	Pulk. 55, 75, Yrnl., Grnwch. 64, 72, 80, 88, Brsls., A. G. Leidn., Rome	Greenwich 90.
406	Brad. 3	Pulk. 55, 75, Yrnl., Grnwch. 64, 72, 80, A. G. Leidn., Rome, Glsgw	
407	Brad. 2	Brln. Jrbh., Pulk. 55, 75, Yrnl., Brsls., Glsgw., Rome	Glasgow 90.
408		Pulk. 55, Brsls., Ednbro., A. G. Hlgfrs., Cambr., Rome, Grnwch. 80	
409	Groombridge and others.	Glsgw., Rome	Greenwich 87.
410	Brad. 2	Pulk. 55, Grnwch., Yrnl., Gtngn., Brsls., Glsgw	
411	Piazzi, Groombridge and others.	Pulk. 55, Brsls., Grnwch. 72, 80, 88, A. G. Hlgfrs., Cambr., Rome, Brln. 88.	Grnch. 89, 90.
412	Brad. 1 and later	Pulk. 55, Grnwch. 64, 87, Oxfrd. 75, Paris 83	Greenwich 89.
413		Pulk. 55, Brsls., Brln., Rome, Grnwch. 80	
414	Piazzi, Groombridge and others.	Pulk. 55, Brsls., Washgtn. 70, Amgh. 75, Rome, Grnwch. 80	Paris 82, Greenwich 90.
415	Brad. 2 and others on revision.	Pulk. 55, Grnwch. 60, 80, 88, Brsls., Rome	Grnch. 89.
416	Brad. 2	Pulk. 55, 75, Grnwch. 60, 64, 72, 80, Brsls., Yrnl., Rome	
417	Ednbro. 44 oldest authority.	Pulk. 55, Brsls., A. G. Hlgfrs., Rome, Grnwch. 80	Kazan Prime Vertical.
418	Brad. 2	Pulk. 55, 75, Yrnl., Grnwch. 60, 72, 80, 88, Oxfrd. 60, Brsls., Rome	Grnch. 90, Cinn.
419	Piazzi and others	Pulk. 55, Yrnl., Brsls., Glsgw., Grnwch. 72, 80, Amgh. 75, Rome	
420	Brad. 6	Brln., Jrbh., Oxfrd. 60, Brsls., Glsgw., Yrnl., Cambr., Pulk. 75, Cape 80, Rome, Grnwch. 80, 88.	Grnch. 89, 90.
421	Brad. 1 and later	Pulk. 55. 75, Yrnl., Brsls., Brln., Rome, Grnwch. 80	
422	Arglndr (revised)	Brln. Jrbh., Pulk. 55, 75, Washtn. 70, Brsls., Cambr., Rome, Grnwch. 80	Kazan Prime Vertical.
423	Brad. 7	Pulk. 55, 75, Grnwch. 60, 80, Brsls., Rome	
424	Brad. 1	Pulk. 55, Brsls., Grnwch. 64, Glsgw., Rome	
425	Brad. 3	Pulk. 55, 75, Yrnl., Oxfrd. 60, Grnwch. 64, 72, 80, 88, Washgtn. 70, Cambr., Glsgw., Rome.	Greenwich 89, 90.
426	Brad. 4	Brln. Jrbh., Oxfrd. 60, Brsls., Cambr., Pulk. 75, Rome, Grnwch. 88	
427	Piazzi and later	Pulk. 55, 75, Brsls., Yrnl., Green. 72, 80, Rome	
428	Brad. 2	Pulk. 55, Grnwch. 64, Brsls., Oxfrd. 70, 75, Glsgw	
429	Brad. 3	Pulk. 55, Grnwch. 60, 80, Brsls., A. G. Albny., Rome	Greenwich 89, 90.
430	Brad. 6	Brln. Jrbh., Yrnl., Oxfrd. 60, Cambr., Rome, Pulk. 75, Grnwch. 80, 87	Greenwich 90.
431	Brad. 10	Brln. Jrbh., Yrnl., Cambr., Pulk. 75, Rome, Grnwch. 80, 87	Greenwich 89, 90.
432	Lalande and others.	Pulk. 55, Amgh. 75, Crdba., Grnwch. 80	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
433	Brad. 6	Pulk. 55, 75, Grnwch. 60, 80, 88. Yrnl., Rome	Berlin 85, Greenwich 90.
434	D'Agelet, Struve. etc.	Pulk. 55, Ednbro., Brsls., Glsgw., Rome, Grnwch. 80	
435		Yrnl. (crctd.), Amgh. 75, Glsgw., Paris 82, Grnch. 87	
436	Brad. 2	Pulk. 55, 75, Yrnl., Brsls., Grnwch. 60, 72, 80, Paris 64, A. G. Leidn., Rome.	
437	Brad. 3	Brln. Jrbh., Oxfrd. 60, Brsls., Yrnl., Glsgw., Cambr., Rome, Pulk. 75, Grnwch. 80, 87, 88.	Greenwich 89, 90.
438		Pulk. 55, Amgh. 75, Cambr., Grnwch. 80, Ann Arbr., Washgtn. 82	Glasgow 90.
439	Groombridge and others.	Brln. Jrbh. *crctd.*, Pulk. 55, Yrnl., Cambr., Rome, Grnwch. 80	
440	Brad. 3	Brln. Jrbh., Yrnl., Oxfrd. 60, Brsls., Washgtn. 70, Rome, Pulk. 75	Greenwich 89.
441	Brad. 3	Yrnl., Pulk. 55, 75, Oxfrd. 60, Grnwch. 60, 64, Brsls. 65, Washgtn. 70, Rome, Grnwch. 80, Washington, Prime Vertical.	
442	Brad. 3	Pulk. 55, 75, Lpzg., Leidn., Grnwch. 72, Glsgw., Rome	
443	Piazzi and others.	Pulk. 55, Brsls., Cambr., Greenwich 80, Ann Arbor	Washington 81.
444	Radcliff and others	Grnwch. 60, 64, 72, 80, 88, Pulk. 55, Ednbro., Brsls., Rome, A. G. Helsingfors.	Greenwich 89, 90.
445	Piazzi and others.	Pulk. 55, Brsls., Glsgw., Yrnl., Rome, A. G. Albny., Grnwch. 80	
446	Groombridge and others.	Pulk. 55, Grnwch. 60, 64, Washgtn. 70, Glasgow, Rome	Glasgow 90.
447	Piazzi and others.	Pulk. 55, 75, Brsls., Grnwch. 80	
448	Brad. 10	Pulk. 55, Yrnl., Grnwch. 64, 87, 88, Brsls., Glsgw., Amgh. 75, Rome	Berlin 85.
449	Rumker, etc	Bonn, Cambr. 75, Ann Arbr., Grnwch. 80	
450	Brad. 13	Brln. Jrbh., Oxfrd. 60, Pulk. 55, (65 Vrtcl. Crcl.) 75, Yrnl., Brsls., Cambr., Grnwch. 80, 88, Rome.	Greenwich 89, 90.
451	Brad. 5	Brln. Jrbh., Yrnl., Brsls., Glsgw., Pulk. 75, Brln., Grnwch. 80, Auwers's 303 Stars.	
452	Brad. 4	Pulk. 55, Grnwch. 64, Washgtn. 70, Glsgw., Rome	Grnch. 90.
453	Brad. 3	Pulk. 55, 75, Grnwch. 64, Brsls., Rome, Paris 82	
454	Arglndr	Pulk. 55, 75, Oxfrd. 60, Brsls., Washington 70, A. G. Cambr., Rome, Paris 82, Gotha 85, A. N. Grnwch. 80.	Cinn.
455	Groombridge and others.	Brln. Jrbh. *corrected*, Pulk. 55, 75, Cambr., Rome, Greenwich 80	Greenwich 90.
456	Groombridge and others.	Pulk. 55, Grnwch. 60, 80, Oxfrd. 60, Brussels, Rome	
457	Brad. 4	Pulk. 55, Grnwch 64, Brsls., Rome, Glsgw	
458	Brad. 1	Pulk. 55, Yrnl., Washgtn. 70, Brsls., Grnwch. 72, 80, Rome, Paris 83	
459	Brad. 5	Brln. Jrbh., Oxfrd. 60, Brussels, Cambr., Glasgow, Pulk. 75, Rome, Greenwich 80, Cape 84.	Grnch. 89, Glasgow 90.
460	Brad. 4	Pulk. 55, Grnwch. 64, 72, 80, Brsls., Rome	Berlin 84
461	Brad. 8	Brln. Jrbh., Pulk. 55, 75, Cambr. Rome, Grnwch. 80	Grnch. 89.
462	Brad. 12	Pulk 55, 75, Oxfrd. 60, Brsls., Yrnl., Grnwch. 64, 80, Cambr., Glsgw., Crdba., Cape 84.	Cinn.
463	Groombridge and others.	Grnwch. 72, 80, A. G. Hlgfrs., Rome	Greenwich 89.
464	Brad. 4	Pulk. 55, Cape 60, Grnwch. 64, Brsls., Glsgw., Rome, A. G. Albany	
465	Groombridge and others.	Pulk. 55, Amgh. 75, Rome, Paris 82, Grnwch. 80	
466	Groombridge and others.	Pulk. 55, 75, Grnwch. 60, 80, Brsls., Rome, Brln. 88	
467		Pulk. 55, Glsgw., Amgh. 75, Cambr., Ann Arbr., Grnwch. 80, Washgtn. 83	Glasgow 90.
468	Brad. 4	Pulk. 55, Glsgw., Grnwch. 64, Brsls., Rome, Paris 83	
469	Brad. 4	Pulk. 55, Yrnl., Grnwch. 60, 80, Rome, Paris 83	
470	Piazzi, etc	Pulk. 55, Yrnl., Rome, Grnwch. 80.	
471		Amgh. 75, Cambr., Grnwch. 80, Ann Arbr., Washgtn. 81 (Pulk. 55 used only for proper motion.)	
472	Brad. 6	Brln. Jrbh., Yrnl., Oxfrd. 60, Cape 60, 80, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80.	Greenwich 89, 90, Glsgw. 90.
473	Brad. 5	Pulk. 55, Yrnl., Glsgw., Brln., Rome, Grnwch. 80	
474	Brad. 59	Pulk. 55, 75, Yrnl., Grnwch. 60, 72, Leidn., Lpzg., A. G. Hlgfrs., Rome, Cambr.	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
475	....	Pulk. 55, 75, Yrnl., Ednbro., Brsls., Amgh. 75, Rome, Grnwch. 80........	
476	Groombridge and others.	Grnwch. 64, 87, Glsgw., Rome....	
477	Brad. 3........	Pulk. 55, Grnwch. 64, 72, 80, Glsgw., Rome....	Glsgw. 90, Greenwich 89.
478	Brad. 13........	Grnwch. 60, 64, 72, 80, Pulk. 55. 75, Brsls., Yrnl., Cambr., Rome	
479	....	Pulk. 55, Grnwch. 64, Brsls., Glsgw....	
480	Brad. 8........	Pulk. 55, 75, Grnwch. 60, 64, 72, 80, Oxfrd. 60, Cape 80, Rome........	Greenwich 89, 90.
481	Brad. 4........	Pulk. 55, Yrnl., Brsls., Glsgw., Grnwch. 80, Auwers's 303 Stars........	
482	Groombridge and later.	Glsgw., Yrnl., Rome, Washgtn. 82, Grnwch. 87........	Greenwich 89, 90.
483	Piazzi, Groombridge, and others.	Pulk. 55, Oxfrd. 60, Grnwch. 72, 80, Lpzg., Leidn., Brussels, Cambr., Rome, Ann Arbr., Washgtn. 83, Rauenburg.	
484	Brad. 48........	Brln. Jrbh., Pulk. 55, 75, Oxfrd., Yrnl., Brsls., Cambr., Glsgw., Rome, Gotha 80, Prime Vertical, Grnwch. 80.	
485	Brad. 7........	Pulk. 55, Yrnl., Grnwch., 72, 80, Glsgw., Rome........	Grnch. 90.
486	Brad. 4........	Pulk. 55, 75, Yrnl., Brsls., Glsgw., Brln., Rome, Grnwch. 80........	Grnch. 90.
487	Brad. 4........	Pulk. 55, Grnwch. 64, Brsls., Oxfrd. 65........	Grnch. 89, 90.
488	Brad. 23........	Brln. Jrbh., Yrnl., Cambr., Rome, Pulk. 75, Glsgw., Grnwch. 80........	Grnch. 90.
489	Brad. 4........	Pulk. 55, 75, Oxfrd. 60, Grnwch. 64, Brsls., Glsgw., Rome, Cinn........	Vienna (Ottakring).
490	Brad. 47........	Pulk. 55, Grnwch. 60, 80, Rome, Cambr., Paris 83........	
491	Lalande and others	Glsgw., Amgh. 75, A. G. Albny........	
492	Brad. 3........	Pulk. 55, Yrnl., Grnwch. 64, 80, Glsgw., Rome, Washgtn., Prime Vertical A. J.	
493	Piazzi, Groombridge, and others.	Pulk. 55, 75, 90 (Pr. Vrtcl.), A. N. Rome, A. G. Helsingfors, Grnwch. 80...	
494	....	Pulk. 55, Amgh. 75, A. G. Leiden, Cambr., Ann Arbr., Grnwch. 80........	
495	Brad. 2........	Yrnl., Grnwch. 60, Brsls., Pulk. 55, Rome, Grnwch. 80........	Grnch. 89, 90.
496	Brad. 3........	Pulk. 55, 75, Brsls., Yrnl., Grnwch. 64. 80, Glsgw., Rome........	
497	Brad. 3........	Pulk. 55, Yrnl., Grnwch. 64, Washgtn. 68 (Boss), Cambr., Rome, Glasgow	Washington 79, 85.
498	....	Pulk. 55, A. G. Leidn., Amgh. 75, Cambr., Ann Arbr., Grnwch. 80........	
499	Groombridge and later.	A. G. Hlgfrs., Brsls., Cambr., Pulk. 75, Rome, Grnwch. 87........	Grnch. 90.
500	Groombridge and later.	Grnwch. 72, 80, A. G. Hlgfrs., Rome........	
501	Brad. 3........	Pulk. 55, Yrnl., Grnwch. 60, 72, 80, 87, Oxfrd. 60, Brussels, Rome........	
502	Brad. 7........	Brln. Jrbh., Brsls., Yrnl., Glsgw., Cambr., Pulk. 75, Greenwich 80, 88, Auwers's 303 Stars.	Greenwich 89, 90, Glsgw. 90.
503	Brad. 3........	Pulk. 55, Grnwch. 64, 72, Cambr., Rome, Glsgw........	
504	Brad. 3........	Pulk. 55, 75, Grnwch. 60, 72, 80, Brsls., Yrnl., Cambr., Rome........	Greenwich 90, Glsgw. 90.
505	....	Pulk. 55, Grnwch. 60, 80, Bonn, Ednbro., Amgh. 75, Brsls., Glsgw., Rome.	
506	Brad. 3........	Pulk. 55, Grnwch. 64, Glsgw., Rome........	
507	Brad. 20........	Pulk. 55, Grnwch. 60, Lpzg., Leidn., Grnwch. 72, Rome........	
508	Brad. 5........	Pulk. 55, Oxfrd. 60, Yrnl., Greenwich 64, 88, Rome........	
509	Groombridge and others.	Oxfrd. 60, Pulk. 55, 75, Bonn, Grnwch. 64, 72, 80, Brsls., A. G. Chrstana., Grnwch. 80, Rome.	Cinn.
510	Brad. 4........	Pulk. 55, Yrnl., A. G. Helsingfors, Brln., Grnwch. 80........	Grnch. 90.
511	Brad. 24........	Brln. Jrbh., Oxfrd. 60, Brsls., Yrnl., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	Greenwich 89, 90.
512	Piazzi and later...	Pulk. 55, Brsls., Grnwch. 80........	
513	Brad. 5........	Pulk. 55, Grnwch. 64, 88, Brsls., Glsgw., Crdba., Krlsrhe........	Grnch. 89, 90. Glsgw. 90.
514	Brad. 15........	Pulk. 55, 75, Grnwch. 60, 72, Yrnl., Brsls. 65, Leidn., Rome........	
515	Brad. 15........	Brln. Jrbh., Brsls., Cambr., Rome, Pulk. 75, Grnwch. 80, 88........	Grnch. 89.
516	Brad. 22........	Pulk. 55, 75, Yrnl., Grnwch. 60, 80, Brsls., Rome, Glasgow........	
517	Brad. 4........	Pulk. 55, Grnwch. 60, 80, Oxfrd. 60, Brsls., Yrnl., Glsgw., Cambr., Rome...	
518	Brad. 3........	Brln. Jrbh., Oxfrd. 60, Brsls., Yrnl., Cambr., Pulk. 75, Brln., Grnwch. 80, 88, Rome.	
519	Brad. 3........	Pulk. 55, Grnwch. 60, 64, Glsgw., Rome........	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
520	Brad. 2 and later..	Pulk. 55, Oxfrd. 60, Grnwch. 64, Göttingen, Brussels, Yrnl., Glsgw., Rome, Krlsrhe.	
521	Brad. 23...........	Pulk. 55, Oxfrd., Grnwch. 64, 72, Lpzg., Leidn., Rome	
522	Piazzi and later...	Glsgw., A. G. Hlgfrs., Pulk. 75, Grnwch. 80	
523	Brad. 3............	Brln. Jrbh., Oxfrd. 60, Yrnl., Brsls., Cambr., Pulk. 75, Glsgw., Rome.....	Grnch. 89.
524	Brad. 3............	Pulk. 55, 75, Brsls., Brln., Glsgw., Rome, Grnch. 80.........................	
525	Brad. 6............	Brln. Jrbh., Pulk. 55, 75, Yrnl., Brsls., Glsgw., Rome	
526	Brad. 3............	Pulk. 55, Yrnl., Brsls., Glsgw., Grnwch. 72, 80, Rome......................	
527	Brad. 3............	Pulk. 55, Grnwch. 64, 72, 80, 88, Brsls., Glsgw., Rome......................	Greenwich 90.
528	Brad. 1 and later..	Pulk. 55, Oxfrd. 60, Grnwch. 60, 64, 72, 80, Yrnl., Ednbro., Brsls	
529	Groombridge and later.	Rome, Cambr., Gotha Pr. Vrtcl. A. N., Grnwch	
530	Brad. 4............	Pulk. 55, 75, Oxfrd. 60, Brsls., Grnwch. 64, 80, Glsgw., Rome, A. G. Albny .	Greenwich 89, 90, Glsgw. 90.
531	....	Pulk. 55, Grnwch. 80, Cambr., Ann Arbr.....................................	
532	Brad. 1 and later..	Pulk. 55 (62 Pr. Vrtcl), 75, 81 (Prime Vertical), 91 Pr. Vrtcl., Brussels, A. G. Hlgfrs., Grnwch. 72, Brln.	
533	Brad. 4............	Pulk. 55, Grnwch. 64, Glsgw., Yrnl., Rome	Glsgw. 90.
534	Groombridge and later.	Pulk. 55, 75, Brsls., A. G. Hlgfrs., Grnwch. 80	
535	Brad. 15...........	Brln. Jrbh., Rome, Cambr., Pulk. 75, Grnwch. 80	Grnch. 89, 90.
536	Brad. 5............	Pulk. 55, Oxfrd. 60, Grnwch. 60, 64, Brussels, Yrnl., Cambr., Glsgw., Rome	Grnch. 89, Cinn.
537	Brad. 6............	Pulk. 55, Oxfrd. 60, Glsgw., Brsls., Yrnl., Grnwch. 72, Brln...............	Glsgw. 90.
538	Piazzi and later ..	Pulk. 55, Brsls., Washgtn. 70, Glsgw., Lpzg., Leidn., Grnwch. 72, A. G. Cambr., Rome.	Glsgw. 90.
539	Brad. 5............	Brln. Jrbh., Yrnl., Glsgw., Brsls., Pulk. 75, Rome, A. G. Albany, Grnwch. 80, Auwers's 303 Stars.	Grnch. 89. 90.
540	Brad. 3............	Pulk. 55, Washington, Grnwch. 60, 72, 80, Rome, Cambr	Greenwich 89.
541	Piazzi, Groombridge, and others.	Pulk. 55, Yrnl., Glsgw., Grnwch. 64, 88, Pulk. 75, Rome.....................	Greenwich 89.
542	....	Ednbro., Brsls., Glsgw., Grnwch. 72, 80, Yarnall, Rome	Greenwich 90, Washington 75.
543	Brad. 12 (Sector obsrvns.).	Pulk. 55, 75, Yrnl., Ednbro., Grnwch. 72, A. G. Helingfors, Rome.........	
544	Brad. 2 (cnfrmd.) .	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Glsgw., Brsls., Yrnl., Rome, Grnwch. 80.	
545	Piazzi and later...	Pulk. 55, Brsls., Yrnl., Grnwch. 72, 80, Glsgw., Rome	
546	Brad. 4............	Pulk. 55, Grnwch. 64, Crdba., Glsgw. 70, rjctd	Karlsruhe, Glsgw. 90.
547	Brad. 9............	Pulk. 55, Grnwch. 60, 64, 72, 80, A. G. Chrstana., Rome	
548	....	Pulk. 55, 75, Bonn, Glsgw., Armagh 75, Cambr., Ann Arbr., Grnwch. 80 .	
549	....	Glsgw., A. G. Cambr., Pulk. 75. Rome	
550	....	Yrnl., Ednbro., Oxfrd. 65, Brsls., Amgh. 75, Grnwch. 80	Glasgow 90.
551	Groombridge and later.	Brsls., Cambr., Rome, Pulk. 75, Grnwch. 88................................	Greenwich 89.
552	Brad. 5............	Grnwch. 60, 72, 80, Pulk. 55, 75, Yrnl., A. G. Hlgfrs., Rome...............	Grnch. 89.
553	Brad. 5............	Pulk. 55, 75, Grnwch. 60, 64, 72, 80, Yrnl., Glsgw., Rome..................	Grnch. 90.
554	Brad. 6............	Pulk. 55, Grnwch. 64, Brsls., Glsgw., Rome.................................	Glsgw. 90.
555	Brad. 3............	Brln. Jrbh., Yrnl., Oxfrd. 60, Glsgw., Cambr., Pulk. 75, Rome, Grnwch. 80, 88.	Greenwich 89, 90, Glsgw. 90.
556	....	Pulk. 55, Yrnl., Ednbro., Rome, Brln., Grnwch. 80, Palmero (reduced from 6 Pr. Vrtcl. obsrvns.).	
557	....	Oxfrd. (rejected but retained on revision), Brsls., Grnwch. 64, Pulk. 55, Yrnl., Glsgw.	
558	Brad. 3............	Pulk. 55, Yrnl., Grnwch. 64, Brsls., Rome, Glsgw., A. G. Albny	
559	Brad. 5............	Pulk. 55, Grnwch. 64, Rome, A. G. Hlgfrs	Greenwich 89, 90.
560	Brad. 3............	Pulk. 55, Yrnl., A. G. Hlgfs., Grnwch. 72.................................	Kazan Prime Vertical.
561	Groombridge and later.	A. G. Chrstana., Grnwch. 80..	
562	Groombridge and later.	A. G. Chrstana., Grnwch. 80..	

Authorities for star catalogue—Continued.

No.	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
563	Brad. 5	Pulk. 55, Glsgw., Grnwch. 64, Gtngn., Rome, Krlsrh	Glsgw. 90.
564	Brad. 3	Pulk. 55, Amgh. 75, Grnwch. 64, Glsgw., Rome	
565	Brad. 4	Pulk. 55, 75, Grnwch. 60, 64, Yrnl., Cambr., Krlsrh	Greenwich 89, 90, Glasgow 90.
566	Brad. 4	Oxfrd. 60, Bonn, Pulk. 55, Grnwch. 64, Gtngn., Yrnl., Glsgw., Crdba., Krlsrhe.	
567	Piazzi, Groombridge, and others.	Grnwch. 60, 72, 80, Oxfrd. 60, Pulk. 55, Brsls., Rome, A. G. Hlgfrs	
568	Brad. 7	Grnwch. 60, 64. 72, 80, Oxfrd. 60, 70, Pulk. 55, Brussels. Yrnl., Rome, A. G. Helingfors.	
569	Brad. 3	Pulk. 55, Yrnl., Glsgw., Grnwch. 64, 72, 80, Rome	Glsgw. 90.
570	Brad. 4	Brln. Jrbh., Pulk. 55, 75, Cambr., Rome	
571	Brad. 2 and later	Pulk. 55, Grnwch. 64, 80, Glsgw., Rome	
572	Brad. 7	Brln. Jrbh., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80	Greenwich 89, 90.
573	Piazzi and later	Yrnl., Pulk. 55, Oxfrd. 60, Brsls., Glsgw., Grnwch. 80	
574	Groombridge and later.	Glsgw., Rome, Pulk. 75, Grnwch. 80	
575	Brad. 4	Pulk. 55, 75, Grnwch. 60, 80, Brsls., Yrnl., Glsgw., A. G. Albny., Rome	Glsgw. 90.
576	Brad. 5	Brln. Jrbh., Oxfrd. 60, Yrnl., Brsls., Glsgw., Cambr., Pulk. 75, Grnwch. 80, Auwers's 303 Stars.	Grnch. 89, 90, Glsgw. 90.
577	Brad. 4	Pulk. 55, 75, Oxfrd. 60, Brsls., Yrnl., Grnwch. 72, 80. (Nos. 3744 and 3745 are the same star.)	
578	Brad. 4	Grnwch. 60, 72, Pulk. 55, Brsls., Yrnl., A. G. Hlgfrs	
579	Brad. 2 and later	Pulk. 55, Glsgw., Grnwch. 64, Rome	
580	Brad. 10	Brln. Jrbh., Oxfrd. 60, Yrnl., Glsgw., Cambr., Pulk. 75, Grnwch. 80, 88	Greenwich 89, 90, Glsgw. 90.
581	Brad. 5	Pulk. 55, Grnwch. 64, 72, 80, Brsls., Rome	Greenwich 89, Glasgow 90.
582	Brad. 2 and Arglndr.	Brln. Jrbh., Yrnl., Pulk. 55, 75, Cambr., Rome, Greenwich 80	
583	Brad. 3	Pulk. 55, Grnwch. 60, 64, 72, 80, Oxfrd. 60, Brsls., Rome	Glasgow 90.
584	Groombridge and others.	Pulk. 55, 75, Glsgw., Rome, Grnwch. 80	
585	Brad. 5	Brln. Jrbh., Brsls., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80, 88, Glsgw.	Greenwich 89.
586	Brad. 4	Brln. Jrbh., Oxfrd. 60, Glsgw., Brsls., Yrnl., Cambr., Rome, Pulk. 75, Grnwch. 80.	Greenwich 89, 90.
587	Groombridge and others.	Brsls., A. G. Chrstana., Grnwch. 72, 80, Rome	
588	Groombridge and others.	Pulk. 55, Brsls., Grnwch. 72, 80, Rome	Greenwich 89, 90, Glsgw. 90.
589	Piazzi and others.	Pulk. 55, Yrnl., Brsls., Glsgw., Grnwch. 72, 80, Crdba., Krlsrhe. 85	Karlsruhe 89.
590	Brad. 4	Pulk. 55, Glsgw., Grnwch. 64, Yrnl., Auwers' 303 Stars	Glsgw. 90.
591	Groombridge and others.	Pulk. 55, Bonn, Brsls., Lpzg., Leidn., Glsgw., Grnwch. 72, 80, Rome	
592	Groombridge and others.	Pulk. 55, 75, 91 Pr. Vrtcl., Rome, A. G. Hlgfrs	Pulk. 62, Prime Vertical.
593	Brad. 8	Pulk. 55, 75, Oxfrd. 60, Grnwch. 60, 64, 80, Brsls., Yrnl., A. G. Albany, Rome.	
594	Brad. 6	Brln. Jrbh., Yrnl., Oxfrd., Glsgw., Cambr., Pulk. 75, Rome, Greenwich 80, 88.	Glsgw. 90, Greenwich 89.
595	Groombridge and others.	Brsls., Grnwch. 64, 72, A. G. Chrstana	
596		Pulk. 55, Grnwch. 60, 72, 80, Glsgw., Yrnl., Brsls., Crdba., Krlsrhe. 85 rejected (1 obsrvn).	Karlsruhe 88.
597	Brad. 9	Brln. Jrbh., Oxfrd. 60, Yrnl., Glsgw., Cambr., Pulk. 75, Rome, A. G. Albny., Grnwch. 80, Auwers's 303 Stars.	Greenwich 89, 90, Glsgw. 90.
598	Groombridge and others.	Pulk. 55, 75, A. G. Hlgfrs	Pulk. 62, Prime Vertical, Grnch. 89.
599	Brad. 1 and others.	Yrnl., Pulk. 55, 75, A. G. Hlgfrs., Brln., Rome, Grnwch. 80	
600	Brad. 10	Brln. Jrbh., Pulk. 55, 75, Yrnl., Cambr., Rome, Grnwch. 80	Greenwich 90.
601	Brad. 11	Brln. Jrbh., Pulk. 55, 75, Oxfrd. 60, Yrnl., Glsgw., Rome, Grnwch. 80, Auwers's 303 Stars.	Pulk. 85, Greenwich 89, 90, Glasgow 90.

Authorities for star catalogue—Continued.

No	Authorities for proper motion.	Authorities used for declination in computing latitudes on the boundary.	Observations added on revision.
602	Brad. 8	Pulk. 55, 75, Grnwch. 60, 64, Yrnl., Brsls., Cambr., Rome	Washington 76, 84, Grnch. 89, Glasgow 90.
603	Piazzi, Groombridge, and others.	Pulk. 55, 75, Grnwch. 60, 64, Brsls., Glsgw., A. G. Hlgfrs., Rome	Greenwich 89.
604	Brad. 5	Pulk. 55, 75, Yrnl., Oxfrd. 60, Grnwch. 64, 72, 80, Glsgw., Brsls., Rome, Pr. Vrtcl. Wshgtn.	Greenwich 89.
605		Grnwch. 80, Cambr., Ann Arbr.	
606		Pulk. 55, Grnwch. 80	Glasgow 90.
607	Brad. 5	Brln. Jrbh., Yrnl., Rome, Pulk. 75, Grnwch. 80	
608	Brad. 5	Brln. Jrbh., Yrnl., Oxfrd. 60, Cambr., Glsgw., Pulk. 75, Rome, Albny., Grnwch. 80, Auwers's 303 Stars.	Greenwich 89, 90, Glsgw. 90.
609	Brad. 6	Pulk. 55. Oxfrd. 60, Grnwch. 60. 64, 72, 80, Yrnl., Brsls., Glsgw.. A. G. Albny., Rome.	Cinn., Greenwich 89, Glsgw. 90.
610	Brad. 8	Pulk. 55, Grnwch. 60, 64, 80, Oxfrd. 60, Brsls., Yrnl., Glsgw., Rome, A. G. Albny.	Glasgow 90.
611	Brad. 6	Pulk. 55, 75, Brsls., Grnwch. 72, 80, Rome, A. G. Hlgfrs	
612	Brad. 1 and others	Pulk. 55, 62 (Pr. Vrtcl.) 75, 91 Pr. Vrtcl., Yrnl., Ednbrg., Brsls., A. G. Hlgfrs., Grnwch. 72, Brln.	
613	Brad. 6	Pulk. 55, Grnwch. 60, 64, 80, Oxfrd. 60. Glsgw., Yrnl., A. G. Albny., Rome	Glasgow 90.
614	Brad. 5	Pulk. 55, Grnwch. 60, Oxfrd. 70, Yrnl	
615	Auwers's Brad. least squares.	A. G. Hlgfrs., Pulk. 75, Brln	
616		Yrnl., Brsls., Glsgw., Pulk. 75	Greenwich 88.
617	Brad. 2 and others	Pulk. 55, A. G. Hlgfrs., Brln., Glsgw., Cambr., Rome, A. G. Cambr., Grnwch. 80.	Kazan Prime Vertical.
618	Brad. 6	Pulk. 55, Yrnl., A. G. Hlgfrs., Rome, Brln., A. G. Cambr., Grnwch. 80	Kazan Prime Vertical.
619	Groombridge and others.	Pulk. 55, Glsgw., Rome, Grnwch. 80	
620	Brad. 4	Pulk. 55, Greenwich 60, 64, 80, Glsgw., Yrnl.. Pulk. 75, Rome	
621	Piazzi and others	Brussels, Cambr., Greenwich. 80, Ann Arbor	

ASTRONOMY.

REPORT OF JOHN F. HAYFORD, ASSISTANT ASTRONOMER.

SAN DIEGO, CAL., *December 22, 1893.*

The work of the astronomical party began at Washington, D. C., in December, 1891. The instruments were there prepared for use and their principal constants determined. The early part of February, 1892, was spent at El Paso in making the final preparations for the field.

On February 12, 1892, the party went into camp near El Paso, in conjunction with the other survey parties, fully equipped and prepared for work. The party consisted of an observer in charge of the party, one computer, one recorder, and an expert workman as observatory attendant. At the first two stations the main camp of the survey was placed at the astronomical station. Afterwards the camps were separated and a cook was added to the astronomical party. With the exception of a spring-wagon team, which was stationed with it during a small portion of the time as a convenient means of securing supplies and water, the party had no separate transportation assigned to it. It was moved from station to station by the teams that served to supply and move the main camp. As each station was occupied for about a month this was conveniently done without sensibly increasing the transportation outfit of the survey.

The instrumental outfit of the party in the field consisted of one Wurdemann zenith telescope, one 10-inch repeating Fauth theodolite furnished with eye-piece micrometer, four chronometers, one Greenough sextant and artificial horizon, and one 8-inch Coast and Geodetic Survey repeating theodolite carrying a 6-inch needle for measuring the magnetic declination. The Coast and

Geodetic Survey theodolite was recalled at Nogales for use on the Coast and Geodetic Survey. At that point two 8-inch Fauth direction theodolites for use on triangulation were added to the equipment. A second zenith telescope was held as a reserve at the office of the survey.

The work of the party from February, 1892, to February, 1893, consisted of triangulation near El Paso, Tex., twelve latitude and azimuth determinations between that point and Nogales, Ariz., small triangulations near San Pedro River and near Nogales, an azimuth and latitude determination near Yuma, and another 20 miles below, and a triangulation connecting them.

The following table shows, in condensed form, the time expended at each of the astronomical stations No. 1 to No. 12, El Paso to Nogales, and the observations secured at each:

Station.	From—	To—	Number of latitude observations.	Number of azimuth sets.	Remarks.
	1892.	1892.			
No. 1	Feb. 12	Mar. 20	67	5	Also triangulation.
No. 2	Mar. 21	Apr. 7	39	5	
No. 3	Apr. 8	Apr. 16	46	5	
No. 4	Apr. 17	May 19	130	6	
No. 5	May 20	June 8	99	7	
No. 6	June 9	June 29	102	13	
No. 7	June 30	July 31	99	12	
No. 8	Aug. 1	Aug. 29	100	10	
No. 9	Aug. 30	Sept. 29	101	12	
No. 10	Sept. 30	Oct. 31	106	27	Do.
No. 11	Nov. 1	Nov. 17	126	9	
		1893.			
No. 12	Nov. 18	Jan. 11	121	9	Also triangulation and tangent.

The dates recorded opposite each station include the time spent in moving to the next station. The latitude observations were all made with a zenith telescope. Each set for azimuth consisted of ten pointings each on star and mark with eye-piece micrometer.

At each station the measurements of horizontal angles at the station necessary to connect the observed azimuth with the "tangents" ending and commencing there were made, and the magnetic declination was observed.

It being considered desirable to have the results of the observations available as soon as possible, the final computations for each station were made *before leaving the station* and between the dates recorded above. Each computation was verified by a second person before being accepted as final. In a few cases the *latitude* computation was not quite complete on leaving the station, but even in those cases it was so nearly complete that the result was known approximately and the reliability of the observations was well established. The original records were written in ink, and ink duplicates of them were made.

On January 12, 1893, the astronomical party left Nogales, Ariz., by rail for Yuma, Ariz. Between that time and February 28 they occupied Stations No. 13 and No. 14 at Yuma and 20 miles below, and executed a triangulation connecting those stations with each other and with other important points. At Yuma 105 observations were taken for latitude and 9 sets for azimuth, and at Station No. 14, 20 miles below, 25 observations for latitude and 9 sets for azimuth.

During the early part of March the astronomical party were busy with computing and other miscellaneous duties. About the middle of the month the party disbanded and its individual members were assigned to other duties on the survey.

Between the dates September 18 and October 3, 1893, Station No. 15, near Emory Monument I, at the Pacific south of San Diego, was occupied by myself and two assistants. Ninety-six observations were taken for latitude and 9 sets for azimuth.

From October 4 to December 22 I was busy with one assistant in preparing for publication the data of the astronomical and other determinations made under my direction during the progress of the survey.

All the observations for latitude, for azimuth, for time, for magnetic declination, and a part of the observations for horizontal angles were made in person by myself.

Mr. James Page made nearly all the original computations. To his efficiency as an accurate computer is due largely the success of the adopted method of making all computations at the station of observation.

Mr. H. B. Finley not only performed the ordinary duties of a recorder, but he was very efficient as an aid in computing and in the measurement of horizontal angles. Much of the work of verifying the original computations was done by myself and Mr. Finley working together. He observed most of the angles of the Nogales triangulation and nearly all in the Yuma triangulation.

Mr. J. S. Bilby, as expert workman, contributed largely to the comfort and success of the party.

To all these gentlemen I feel greatly indebted for the zeal and cheerfulness shown by them on occasions when it was desirable to work during very long hours and under trying circumstances.

All the azimuth observations were made with Fauth repeating theodolite No. 725. The horizontal circle, 25 cm. (10 inches) in diameter, is graduated in 5′ spaces and is read by two opposite verniers to 5″. It is furnished, on the horizontal motions, with axis clamps and tangent screws working against spiral springs. The telescope has a focal length of 41 cm. and an objective 45 mm. in diameter. The eyepiece used magnifies about thirty diameters, and is furnished with a micrometer with which the azimuth observations were made. The standard or yoke of the instrument is of aluminum.

The horizontal circle is covered with a protecting plate, which served its purpose so well that during two years of continuous service in a very dusty country, a part of the time on tangent work, so little sand and dust found its way to the graduated surfaces and the centers or spindles of the instrument that it was never found neccessary to take it apart for cleaning, and the graduation was brushed off but once, a discoloration having then collected on a few lines only.

There was always an apparent yielding of the clamps and other parts when the instrument was used as a repeater, which caused every measured angle to be ten to twenty seconds too large when all final pointings were made with the tangent screws *acting* against their opposing spiral springs. The yielding seemed an elastic motion, not jerky, and so nearly constant for any series of observations that it was eliminated, within the errors of observation, by the practice of "closing the horizon."

By "closing the horizon" is meant, in this connection, measuring *both* the required angle and its explement, or difference from 360°, always turning the upper motion over the measured angle in the direction in which the circle readings increase and making all final pointings with the tangent screws working *against* their opposing spiral springs. Such a procedure gives two values for the required angle—the directly measured value and the difference between the measured explement and 360°. The mean of these two is the true value of the angle independent of the *constant* yielding of clamps and allied parts.

That this method of observing sensibly eliminated the remarkably large clamp error was shown by the instrument giving consistent results in successive measurements of the same angle by the satisfactory closing of triangles in which angles were measured with this instrument, and by the fact that in cases in which the *same angle* was measured with this instrument and with a *direction* theodolite the results agreed within the errors of observation.

For azimuth observations the theodolite was usually mounted on a wooden pier in the large observatory tent. The pier was a hollow triangular column, built of 3-inch pine, put together with screws and banded at top and bottom with heavy hoop iron. The top of the pier was covered by a pine plank held in place by screws and having the instrument foot-plates screwed to its upper surface. This cap was removed during transportation from station to station. The pier was set like a fence post at each station, about 45 cm. of its length being below ground. The earth was tamped solidly around it and its hollow interior was also filled with earth to give it greater rigidity. It seemed to be as stable as a brick or stone cemented pier, and its use saved much time and transportation in a region where neither cement nor water could be obtained without hauling by wagon over considerable distances.

The observatory tent held both the azimuth theodolite and the zenith telescope mounted on their respective wooden piers about 1.3 mm. apart due east and west from each other. The floor space of the tent was 9 feet from north to south and 12 feet from east to west, and the shape of the tent was that of a "lean to" shed, with roof sloping downward toward the north. The sides and roof of the tent were securely supported throughout by a wooden framework. The floor was made so as to be portable, in six sections, and was so supported by sleepers that no pressure was transmitted to the ground except at the four corners of the tent, as far as possible from the piers. This tent served as an office as well as an observatory.

The mark used for azimuth work was an ordinary bull's-eye lantern, showing through a hole 1 inch in diameter in the front of the small box, which served to protect it from the wind. This light was placed from 1 to 3 miles from the theodolite at each station.

The time was obtained with sufficient accuracy for the azimuth work by sextant observations of the sun's altitude.

Two mean and two sidereal chronometers were carried. Each chronometer was kept in its own leather case, which was inclosed in a well padded box (two chronometers in a box), and this box was inclosed in turn in an outer box, having a false inner top and bottom backed by systems of spiral springs to deaden the jarring and shocks of transportation. The rates of the chronometers proved abundantly satisfactory for the purpose for which they were used. As all the azimuth observations were taken near elongation, errors in time affect the computed azimuth to a very slight degree only.

With the exception of one station, all the azimuth observations were taken with the eye-piece micrometer by the method described in Bulletin No. 21, December 12, 1890, of the Coast and Geodetic Survey.

On the first night after the pier and tent were ready a single pointing was made upon the star to be used, and the time and reading of the horizontal circle recorded. The instrument was then left standing covered to protect it from dust and sand, with the lower horizontal motion clamped and the upper one loose. During the next day the upper plate was set to such a reading computed approximately from the observation of the night before as would place the telescope in the vertical plane of the star about thirty minutes before or after the elongation near which it was to be observed. The azimuth light was then placed in this plane at a distance of 1 to 3 miles, according to the topography along the line of sight. The position of the light as thus located was always found to be sufficiently accurate. All observations were taken near elongation, usually within one hour, and Polaris was used at each station.

The azimuth light having been previously placed nearly in the vertical plane of the star, the observations consisted simply of the measurement with eye-piece micrometer of the small horizontal angle between star and mark, the chronometer time of each star pointing being noted. For each set of observations, the axis of the telescope being made as nearly horizontal as possible and the horizontal circles being clamped so that the line of collimation of the telescope was nearly in the vertical plane of the mark, the routine was as follows: Five pointings with eye-piece micrometer were made upon the mark, the telescope directed to the star, and striding level placed in position; three pointings were then made upon the star and the time of each noted by the recorder, the level was read and reversed; two more pointings upon the star with noted times, level read again; axis of telescope reversed in the wyes; striding level placed in position; three more pointings upon the star with noted times, level read and reversed; two more pointings upon star with times, and finally five pointings upon the mark. Three such sets required from thirty to fifty minutes.

At Station No. 5 the azimuth mark was placed to the westward of the station and its azimuth determined by using the theodolite as a repeater.

At Station No. 10, in addition to the observations upon Polaris, δ Ursæ Minoris and 51 Cephei were also observed.

The graduation on the striding level is numbered from the middle toward each end. The eye-piece micrometer was always used in the position in which increased readings of the micrometer correspond to a movement of the line of sight toward the east when the vertical circle is to the east, and toward the west when the vertical circle is to the west.

The computation of the horizontal angle between the mark and the mean position of the star during the set was made in the same way at every station, and is shown by the examples of computation given below.

The computation of the mean azimuth of the star during the set was made by three different formulæ at different stations. For Stations No. 2 to No. 4, No. 6 to No. 9, No. 11, No. 13, and No. 14 the azimuth of the star was computed as follows:

Let φ = the astronomical latitude of the station.

δ = the declination of the star.

A = the azimuth of the star counted from the north.

A_e = the azimuth of the star *at elongation* counted from the north.

t_e = the hour angle of the star at elongation.

t = the hour angle of the star at observation.

$\tau = t_e - t$, or, what is the same thing, the chronometer time of elongation minus the chronometer time of observation. Then the azimuth of the star counted from the north is at the time of any observation $A = A_e - \sin A_e \cos A_e \operatorname{cosec}^2 t_e \dfrac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} (1 + \cot t_e \sin \tau)$.

A_e and t_e are computed by the formulæ $\sin A_e = \sec \varphi \cos \delta$ and $\cos t_e = \tan \varphi \cot \delta$.

The factor $\sin A_e \cos A_e \operatorname{cosec}^2 t_e$ is a constant for the night. $\dfrac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} (1 + \cot t_e \sin \tau)$ varies rapidly with the hour angle, and must be computed for each separate pointing on the star. It varies quite slowly, however, for changes in the declination of the star and in the latitude of the station. This term was tabulated for an arbitrary latitude and declination of Polaris for every 10^s change in the value of τ from -61^m to $+61^m$. It was found that the values of this table were so nearly exact for the *actual* latitudes of stations and actual declinations of Polaris at the time of observation that it could be used without sensible error at all stations cited above, and was so used. The mean of the ten tabular values corresponding to the ten pointings on the star during a set being called M, the mean azimuth of the star for the set becomes

$$A = A_e - \sin A_e \cos A_e \operatorname{cosec}^2 t_e M.$$

AZIMUTH DETERMINATIONS.

Example of Record and Computation.

STATION No. 14. FEBRUARY 11, 1893.

Observations for azimuth of mark on Polaris near western elongation.

[Chronometer error = $+2^h 29^m 47.2^s$; one turn of micrometer = 123.73″; one division of level = 3.68″; $\phi = 32° 29' 01.12''$.]

Circle E. or W.	Level readings. W.	Level readings. E.	Chronometer time.	τ	Tabulated term.	Micrometer readings. On star.	Micrometer readings. On mark.	
	d.	*d.*	*h. m. s.*			*t.*	*t.*	
E	7.2	6.3	8 47 48.5	57 34.5	6496.9	19.219	18.400	Long. $2^h 31^m$ W. of
	7.2	6.4	48 31.0	56 52.0	6338.5	.189	.391	Washington.
	+14.4	—12.7	49 01.5	56 21.5	6226.3	.170	.387	
			49 47.0	55 36.0	6060.3	.146	.399	
E	....	....	50 20.0	55 03.0	5941.2	.124	.393	
						19.1696	18.3940	Means.
W	6.0	8.6	8 52 09.0	53 14.0	5556.9	17.790	18.470	
	6.1	7.8	52 36 5	52 46.5	5461.9	.800	.470	
	+12.1	—15.8	53 04.5	52 18.5	5366.1	.820	.469	
	—2.0	Sum.	53 57.5	51 25.5	5187.0	.852	.475	
W	....	....	54 28.0	50 55.0	5084.8	.871	.462	
					5772.0	17.8266	18.4692	Means.

α of Polaris $= 1^h\ 18^m\ 48^s$
δ of Polaris $= 88°\ 44'\ 33.4''$

log tan φ	$= 9.8039137$	log sec φ	$= 0.0738919$
log cotan δ	$= 8.3414167$	log cos δ	$= 8.3413121$
log cos t_e	$= 8.1453304$	log sin A_e	$= 8.4152040$
t_e	$= 89°\ 11'\ 57.5'$	A_e	$= 1°\ 29'\ 26.34''$
t_e	$= 5^h\ 56^m\ 47.8^s$		

log sin A_e $= 8.41520$
log cos A_e $= 9.99985$
log cosec $\frac{1}{2} t_e = 0.00008$

8.41513
log 5772.0 $= 3.76133$

log 150.13 $= 2.17646$

Constant for eight readings of level $= \frac{3.68}{8}$ tan $\varphi = 0.293''$
Level correction $= (-2.0)\ (0.293) = 0.59''$

Zenith distance of star $= 57°\ 09'$ (by computation).

h.	m.	s.	
1	18	48.0	$= \alpha$
+5	56	47.8	$= t_e$
+2	29	47.2	= chronometer error.
9	45	23.0	= chronometer time of elongation.

Collimation reads, ½ $(18.3940^t + 18.4692^t)$	$= 18.4316^t$		
		°	′ ″
Mark west of collimation, $18.4316^t - 18.3940^t$	$= 0.0376 =$		0 04.65
Circle east, star east of collimation, $19.1696^t - 18.4316^t$	$= 0.7380$		
Circle west, star east of collimation, $18.4316^t - 17.8266^t$	$= 0.6050$		
Mean, star east of collimation,	$= 0.6715 =$		1 38.90
Level correction,	=		−0.59
Mark west of star,	=		1 42.96
Reduction to western elongation,	=		2 30.13
Mark east of western elongation,	=		47.17
		°	′ ″
A_e	=	1	29 26.34
Mark west of north,	=	1	28 39.17
Mark west of south, = z′	=	178	31 20.83

In reducing the measured angle between the star and the line of collimation it must be remembered that the thread of the micrometer when not at the collimation reading describes a *small* circle on the celestial sphere as the telescope rotates about its horizontal axis.

Thus, star east of collimation =
$0.6715^t = (0.6715)\ (1.2373)$ cosec (zenith distance of star) $= (0.6715)\ (1.2373)$ cosec $57°\ 09' = 1'\ 38''.90$.

In reducing the measured angle between the *mark* and the line of collimation cosec (zenith distance of mark) may usually, as here, be assumed unity without sensible error, the elevation angle of the mark being generally small and the line of collimation being purposely placed very near the mark. The level correction for the *mark* is usually negligible.

At station No. 1 the azimuth of the star was computed by the less accurate but simpler formula:

$$A = A_e - \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} \tan A_e$$

At this station no observation was made more than 26^m from elongation, and this formula was sufficiently accurate.

At Stations No. 5, No. 10, No. 12, and No. 15 the azimuth of the star was computed by the following formulæ:

If A be the azimuth of the star, counted from the north, *corresponding to the mean hour angle of the set*, *t*,

$$\tan A = \frac{\sin t}{\cos \varphi \tan \delta - \sin \varphi \cos t}$$

If A^1 be the mean azimuth of the star for the set, counted from the north

$$A^1 = A - \tan A \frac{1}{n} \Sigma \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$$

in which n is the number of pointings upon the star during the set, τ is here the difference between the time of any one observation and the mean of the times, and $\Sigma \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$ is the sum of the individual values of that factor corresponding to the individual pointings. The quantity $\frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$ may be found tabulated in convenient form in Doolittle's Practical Astronomy. For this and other formulæ for reducing azimuth observations see Coast and Geodetic Survey Report for 1880, Appendix No. 14.

STATION NO. 10, OCTOBER 13, 1892.

Observations for azimuth of mark on Polaris near eastern elongation.

[Chronometer error = + $2^h\ 11^m\ 28.2^s$; one turn of micrometer = 123.73″; one division of level = 3.68″; $\phi = 31° 19' 35''$.]

Circle E. or W.	Level readings. W.	Level readings. E.	Chronometer time.	τ	$\frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$	Micrometer readings. On star.	Micrometer readings. On mark.	
	d.	d.	h. m. s.	m. s.		t.	t.	
E	8.0	9.9	9 06 38.0	3 58.6	31.05	18.379	18.310	Long. $2^h\ 12^m$ west of Washington.
	10.0	7.3	07 32.0	3 04.6	18.59	.388	.315	
	+18.0	−17.2	08 05.5	2 31.1	12.45	.400	.315	
			09 13 0	1 23.6	3.82	.424	.311	
E	....	....	09 48.0	0 48.6	1.29	.430	.316	
						18.4042	18.3134	Means.
W	9.0	9.0	9 12 01.8	1 25.2	3.96	18.100	18.290	
	7.0	10.9	12 24.7	1 48.1	6.37	.100	.275	
	+16.0	−19.9	12 48.3	2 11.7	9.46	.090	.279	
			13 36.3	2 59.7	17.61	.086	.281	
W	....	....	13 58.1	3 21.5	22.14	.080	.279	
			9 10 36.6		12.67	18.0912	18.2808	Means.
		d.						
	Sum	−3.1						

α of Polaris = $1^h\ 20^m\ 07.4^s$
δ of Polaris = 88° 44′ 10.4″
Constant for eight readings of level = $\frac{1}{8}$ (3.68″) tan φ = 0.280″
Zenith distance of star at observation (computed) = 58° 47′

$\log \frac{1}{n} \Sigma \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} = \log 12.67 = 1.10278$
log tan A = 8.40969

log δ A = 9.51247
δ A = 0.33″

Collimation reads, $\frac{1}{2}$ (18.3134ᵗ — 18.2808ᵗ) = 18.2971ᵗ
Mark east of collimation, 18.3134ᵗ — 18.2971ᵗ = 0.0163 = 02″.02
Circle east, star east of collimation 18.4012 — 18.2971 = 0.1071
Circle west, star east of collimation, 18.2971ᵗ — 18.0912ᵗ = 0.2059ᵗ
Mean, star east of collimation, 0.1565 = 22″.64
Level correction = (— 3.1ᵈ) (0.280) = −0″.87

Mark west of star = 19″.75

	h.	m.	s.
Mean chronometer time of observation	= 21	10	36.6
Chronometer correction	= −2	11	28.2
Mean sidereal time of observation	= 18	59	08.4
δ of Polaris	= 1	20	07.4
t = 95° 14′ 45.0 =	6	20	59.0

log cos φ = 9.9315695	log sin φ = 9.71593	log sin t = 9.9981771
log tan δ = 1.6563815	log cos t = 8.96108 n	log d = 1.5884838
{ 1.5879510	{ 8.67701 n	log tan A = 8.4096933
{ 38.72140	{ −0.04753	A = 1° 28′ 16″.92
d = 38.72140 — (—0.04753) = 38.76893		δ A = —0″.33

Star east of north = A′ = 1° 28′ 16″.59
Mark west of star (from above) = 19″.75
Mark west of south = Z′ = 181° 27′ 56″.84

The same remarks as before apply to the reduction of the angle between star and collimation and mark and collimation.

To all the azimuths as above computed there must still be applied the small correction +0.31″ for diurnal aberration. For convenience this small correction was applied only to the final *mean* value of the azimuth at the station instead of adding it to each individual value. Hence the symbol z' has been used for the computed azimuth as above *before* the correction for diurnal aberration has been applied and z denotes the corrected azimuth.

SUMMARY.

Station.	Date.	Star.	z'	Mean z' for night.	Mean z for station.	z for station.	e and e_0.
	1892.		° ′ ″	″	″	″	″
No. 1	Feb. 16	α	178 30 40.79				
No. 1	do	α	39.96				
No. 1	do	α	39.99	40.25			
No. 1	Feb. 18	α	39.02				e = 0.46
No. 1	do	α	39.23	39.12	39.80	40.11	e_0 = 0.21
No. 2	Mar. 22	α	178 30 37.27				
No. 2	do	α	36.34				
No. 2	do	α	38.06				
No. 2	do	α	36.09				e = ± 0.56
No. 2	do	α	37.97	37.15	37.15	37.46	e_0 = ± 0.25
No. 3	Apr. 9	α	178 31 48.31				
No. 3	do	α	47.19				
No. 3	do	α	47.27				
No. 3	do	α	46.52				e = 0.50
No. 3	do	α	46.44	47.15	47.15	47.46	e_0 = 0.23
No. 4	Apr. 18	α	1 26 16.65				
No. 4	do	α	15.33	15.99			
No. 4	Apr. 21	α	17.83				
No. 4	do	α	15.78				
No. 4	do	α	14.22				e = ± 0.83
No. 4	do	α	15.29	15.78	15.85	16.16	e_0 = ± 0.34
No. 5	May 22	α	89 57 23.4				Using the
No. 5	do	α	27.8				odolite as a
No. 5	do	α	29.2	26.8			repeater.
No. 5	May 24	α	24.2				
No. 5	do	α	29.4				
No. 5	do	α	28.6				e = ± 1.6
No. 5	do	α	27.3	27.4	27.1	27.4	e_0 = ± 0.7
No. 6	June 10	α	1 23 12.48				
No. 6	do	α	11.18				
No. 6	do	α	11.10				
No. 6	do	α	11.87				
No. 6	do	α	11.17				
No. 6	do	α	12.26	11.68			
No. 6	June 12	α	12.56				
No. 6	do	α	12.14				
No. 6	do	α	12.92				
No. 6	do	α	13.21				
No. 6	do	α	13.69				
No. 6	do	α	14.34				e = ± 0.83
No. 6	do	α	15.15	13.43	12.62	12.93	e_0 = ± 0.23
No. 7	July 7	δ	181 27 53.94				
No. 7	do	δ	54.87				
No. 7	do	δ	54.97				
No. 7	do	δ	53.83	54.40			
No. 7	July 8	δ	55.93				
No. 7	do	δ	55.16				
No. 7	do	δ	55.81				
No. 7	do	δ	55.07	55.49			
No. 7	July 9	δ	56.12				
No. 7	do	δ	55.23				
No. 7	do	δ	55.97				e = ± 0.50
No. 7	do	δ	55.65	55.74	55.21	55.52	e_0 = 0.14

SUMMARY—Continued.

Station.	Date.	Star.	z′	Mean z′ for night.	Mean z′ for station.	z for station.	e and e_0.
	1892.		° ′ ″	″	″	″	″
No. 8	Aug. 2	δ	181 28 32.10				
No. 8	do	δ	33.00				
No. 8	do	δ	31.50				
No. 8	do	δ	31.80	32.10			
No. 8	Aug. 3	δ	30.99				
No. 8	do	δ	31.85	31.42			
No. 8	Aug. 4	δ	31.19				
No. 8	do	δ	30.14				
No. 8	do	δ	30.41				e = ±0.60
No. 8	do	δ	32.31	31.01	31.53	31.84	e_0 = ±0.19
No. 9	Sept. 10	δ	181 28 11.79				
No. 9	do	δ	12.22				
No. 9	do	δ	12.99				
No. 9	do	δ	12.18	12.30			
No. 9	Sept. 12	δ	12.76				
No. 9	do	δ	13.92				
No. 9	do	δ	13.88				
No. 9	do	δ	13.48	13.51			
No. 9	Sept. 14	δ	11.14				
No. 9	do	δ	12.22				
No. 9	do	δ	12.85				e = ±0.56
No. 9	do	δ	12.41	12.16	12.65	12.96	e_0 = ±0.16
No. 10	Oct. 5	α	181 27 55.35				
No. 10	do	α	55.38				
No. 10	do	α	55.28	55.34			
No. 10	Oct. 10	α	55.81				
No. 10	do	α	56.35				
No. 10	do	α	56.23	56.13			
No. 10	Oct. 13	α	56.84				
No. 10	do	α	56.83				e = ±0.43
No. 10	do	α	56.63	56.77	56.08	56.39	e_0 = ±0.14
No. 10	Oct. 5	δ	176 02 51.29				
No. 10	do	δ	52.49				
No. 10	do	δ	52.72	52.17			
No. 10	Oct. 10	δ	52.95				
No. 10	do	δ	52.07				
No. 10	do	δ	52.26	52.43			
No. 10	Oct. 13	δ	52.14				
No. 10	do	δ	52.30				e = ±0.65
No. 10	do	δ	49.76	51.40	52.00	52.31	e_0 = ±0.22
No. 10	Oct. 5	51 C	183 15 19.19				
No. 10	do	51 C	18.52				
No. 10	do	51 C	19.33	19.01			
No. 10	Oct. 10	51 C	20.17				
No. 10	do	51 C	19.87				
No. 10	do	51 C	20.32	20.12			
No. 10	Oct. 13	51 C	21.72				
No. 10	do	51 C	19.26				e = ±0.61
No. 10	do	51 C	19.92	20.30	19.81	20.12	e_0 = ±0.20
No. 11	Nov. 3	α	178 31 28.47				
No. 11	do	α	27.93				
No. 11	do	α	29.16	28.52			
No. 11	Nov. 7	α	29.04				
No. 11	do	α	27.57				
No. 11	do	α	28.09	28.23			
No. 11	Nov. 8	α	30.26				
No. 11	do	α	28.22				e = ±0.60
No. 11	do	α	29.73	29.40	28.72	29.03	e_0 = ±0.20
No. 12	Dec. 3	α	178 33 37.99				
No. 12	do	α	40.56				
No. 12	do	α	38.82	39.12			
No. 12	Dec. 5	α	40.24				

SUMMARY.—Continued.

Station.	Date.	Star.	z′	Mean z′ for night.	Mean z′ for station.	z for station.	e and e₀.
	1892.		° ′ ″	″	″	″	″
No. 12	Dec. 5	α	178 33 39.71				
No. 12	....do ...	α	38.93	39.63			
No. 12	Dec. 8	α	37.03				
No. 12	....do ...	α	38.80				$e = \pm 0.77$
No. 12	....do ...	α	37.79	37.87	38.88	39.19	$e_0 = \pm 0.26$
	1893.						
No. 13	Jan. 21	α	178 32 01.67				
No. 13	....do ...	α	00.87				
No. 13	....do ...	α	00.50	01.01			
No. 13	Jan. 22	α	00.99				
No. 13	....do ...	α	01.17				
No. 13	....do ...	α	00.11	00.76			
No. 13	Jan. 23	α	59.67				
No. 13	....do ...	α	01.47				$e = \pm 0.42$
No. 13	....do ...	α	00.86	00.67	00.81	01.12	$e_0 = \pm 0.14$
No. 14	Feb. 11	α	178 31 20.83				
No. 14	....do ...	α	19.86				
No. 14	....do ...	α	20.02	20.24			
No. 14	Feb. 13	α	21.48				
No. 14	....do ...	α	21.84				
No. 14	....do ...	α	18.84	20.72			
No. 14	Feb. 14	α	21.32				
No. 14	....do ...	α	20.83				$e = \pm 0.64$
No. 14	....do ...	α	21.27	21.14	20.70	21.01	$e_0 = \pm 0.21$
No. 15	Sept. 21	α	181 28 37.39				
No. 15	....do ...	α	37.99				
No. 15	....do ...	α	37.92	37.77			
No. 15	Sept. 22	α	39.89				
No. 15	....do ...	α	38.79				
No. 15	....do ...	α	38.77	39.15			
No. 15	Sept. 23	α	41.31				
No. 15	....do ...	α	39.92				$e = \pm 0.81$
No. 15	....do ...	α	38.91	40.05	38.99	39.30	$e_0 = \pm 0.27$

The values of the above summary represent in each case the azimuth (west of south) of the mark as seen from the station. At Stations No. 4 and No. 6 the mark was placed to the *southward* of the station nearly in the vertical plane of the star. In those cases the topography was such that an azimuth light could not be placed at a sufficient distance to the northward of the station. Placing the light to the southward does not materially modify the method of observation or cause any especial inconvenience.

At Station No. 10 three marks were used, one for each star.

In the above summary "α" indicates α Ursæ Minoris (Polaris), "δ" indicates δ Ursæ Minoris, and "51C" indicates 51 Cephei.

All the observations were made by the micrometric method save those at Station No. 5.

The values of the probable error of a single set (e) and the probable error of the mean for the station (e_0), as given above, are computed by the ordinary formulæ for independent observations of equal weight. In reality, however, several azimuth observations made on any one night at nearly the same time of night are likely to be affected by a considerable error common to them all, a constant error peculiar to the night, which is probably the result of lateral refraction. Therefore several sets of observations taken in quick succession should not be considered to be independent. The values of e given above are for that reason slightly too small, and the values of e_0 much too small to represent the facts. They serve, however, as a rough indication of the *relative* accuracy of the determinations at the different stations.

The probable error of observation and the error peculiar to the night of observation may be separated by the same method that is used in computations of zenith telescope latitudes for separating the errors of observation from the errors of declination.

Let e be the probable error of observation of a single set, Δ be the difference between the value from each set and the mean for the night, Δ_z be the difference between the mean for each night and the mean for the station, and e_m the probable error of the mean result for a night.

Let e_n be the probable error peculiar to the night, affecting equally all the results for that night.

Then e and e_n may be derived from observations at a series of stations treated as a single group, as follows:

$$e=\sqrt{\frac{(0.455)\ \Sigma\ \Delta^2}{\text{No. sets}-\text{No. nights}}} \qquad E^2=\frac{e^2}{\text{No. nights}}\Sigma\frac{1}{n}$$

in which n is the number of sets on each night.

$$e_m=\sqrt{\frac{(0.455)\ \Sigma\ \Delta z^2}{\text{No. nights}-\text{No. stations}}} \qquad e_n=\sqrt{e^2_m-E^2}$$

All the observations for azimuth made with the micrometer (all stations except No. 5) when treated as a single group in this way give for the probable error of observation of a single set $e=\pm 0.54''$, and for the probable error peculiar to each night $e_n=\pm 0.38''$.

It is probable that the conditions under which these observations were made—in a very dry country, over surfaces usually free from water and bare of trees, and with the meteorological conditions subject to few sudden changes—are peculiarly favorable to making the value of e_n small. It is likely that it would be larger in most regions than it is for this series of stations.

With these values the probable error of the mean at a station at which three sets were observed on each of three nights is

$$\sqrt{\frac{1}{9}(0.54)^2+\frac{1}{3}(0.38)^2}=\pm 0.28''$$

The value of one turn of micrometer was observed four times:

At El Paso, February 8, 1892, one turn	$= 123.91''$.
At Station No. 1, February 19, 1892, one turn	$= 123.80$.
At Station No. 1, February 19, 1892, one turn	$= 123.44$.
At Station No. 6, June 11, 1892, one turn	$= 123.76$.

The first determination was made by measuring a small horizontal angle (about 1°) with both the micrometer and the horizontal circle of the instrument. The second was made by observing transits of ε Ursæ Minoris near culmination across the thread set successively at each half turn. The third and fourth determinations were made in a similar manner, using δ Ursæ Minoris and Polaris, respectively. The mean of the first three determinations, namely, 123.72″, was used at the first five stations. After that the mean of all four determinations, 123.73″, was used.

At each station the angle between the star and mark at the time of observation was so small that any error of micrometer value has but a small influence upon the computed azimuth. For the third set on June 10, 1892, at Station No. 6, the angle as measured with micrometer between the star and the mark was 2.93 turns, and the computed azimuth from that single set is in error by 2.93 times the error of the assumed value of one turn. Similarly the final mean value for the azimuth of the mark at that station is in error by 2.19 times the error of one turn.

In this connection it should be noted that the value of micrometer as redetermined at this station agreed almost exactly with the mean of the previous determinations. At all other stations except No. 6 the mark was in such a position that in very few cases is as much as one turn of micrometer used, and in most cases less than one-half of a turn, the star being also *both east and west of the mark* during different sets.

For the stations occupied the motion of Polaris in the azimuth even at one hour from elongation is only about one-tenth of a second of arc per second of time. As almost all the azimuth observations were made within less than one hour of elongation the errors arising from errors of time must be quite small. The error of the chronometer at the time of observing azimuth was always computed from sextant observations of the sun taken *both before and after* the azimuth observations.

The value of one division of the striding level was determined to be 3.68″ by comparing it with the latitude level of Wurdemann zenith telescope No. 20. During the comparison the striding level was lashed firmly to the latitude level and the whole combination moved by the use of the screw which changes the inclination of the telescope.

The observations at each station all being taken near one elongation the azimuth is in error by the error of the star's declination.

In order to determine whether there was any sensible error peculiar to the star Polaris, which was uniformly used at all stations, δ Ursæ Minoris and 51 Cephei were also observed at station No. 10 on the same nights as Polaris and in precisely the same manner. A separate azimuth mark was used for each star. The three marks were reduced to the same pole, *A*, by measuring the angle at the station between each mark and the pole.

Three sets for azimuth were taken on each star on each of three nights as shown in the above summary. The errors of observation seemed to be about the same for each of the three stars—being perhaps a little smaller for Polaris than for the other two. The probable error of the azimuth of each mark from nine observations on three nights may properly be considered to be ±0.28″.

The horizontal angle between each mark and pole A was measured twenty times with the theodolite used as a repeater, each measure consisting of six repetitions on the required angle and six on its explement. These measures gave a range of five to six seconds on each angle—the seeing being unsteady during most of the observations. At this station the violent apparent trembling of signals commenced almost immediately after sunrise and ended very nearly at sunset, leaving but a few minutes of steady seeing during the day. To have observed under favorable circumstances only would have required more time than was then at the disposal of the party for experimental work.

The mean results are:

	Polaris.		δ Ursæ Minoris.		51 Cephei.	
	° ′ ″	″	° ′ ″	″	° ′ ″	″
Azimuth of mark..........	181 27 56.39	±0.28	176 02 52.31	±0.28	183 15 20.12	±0.28
Reduction to A......	−56 06 56.16	±0.25	−50 41 51.43	±0.30	−57 54 18.25	±0.31
Azimuth of A	125 21 00.23	±0.38	125 21 00.88	±0.41	125 21 01.87	±0.42

The accuracy of the three results does not seem to be sufficient to insure that the differences between them are not *accidental* differences.

Having determined the azimuth of the mark, the problem arose of placing a point to the westward exactly in the prime vertical of the station—said point serving with the station to fix the direction of the "tangent" to be continued forward to the next station. A point was first placed as nearly in azimuth 90° as could be done by a single pointing and reading of the horizontal circle—usually within ten seconds. The distance to this point from the station was measured by chain or stadia, and the angle between the point and the azimuth mark was measured with the theodolite used as a repeater—each set of observations consisting of six repetitions on the angle and six on its explement. The *linear* correction at right angles to the line of sight necessary to place the point in the prime vertical of the station was then computed and the final point set by linear measurement from the approximate point.

In some cases, in which it was not convenient to measure by chain or stadia the distance to the approximate point, *two* approximate points were placed nearly in the prime vertical and at the same distance from the station. A linear measurement was made of the distance between the two points and the angle between each of them and the azimuth mark was observed. The final point was then located by *linear* measurements only from the two approximate points.

LATITUDE DETERMINATIONS.

All the latitude observations were made with Wurdeman zenith telescope No. 20. This instrument was formerly used on the Northern Boundary Survey from the Lake of the Woods to the Rocky Mountains. It was thoroughly cleaned and repaired by Fauth & Co., at Washington,

D. C., in December, 1891. The micrometer was there remodeled, and the old micrometer screw replaced by a new one of about the same pitch, 100 turns to the inch. The latitude levels were also replaced by new ones.

The principal dimensions of the instrument are: Clear diameter of objective, 67 mm.; focal length, 826 mm.; diameter of vertical circle, 144 mm., and side of equilateral triangle formed by foot screws, 368 mm. The eyepiece used magnifies about seventy diameters. The vertical circle is graduated to fifteen minute spaces and its vernier reads to half minutes.

The latitude level carries a 2 mm. graduation of 70 divisions, *numbered continuously from one end to the other.* The graduation nearest the eyepiece in the position in which the instrument was always used is marked "0" and the one nearest the object glass "70." The level tube is protected from sudden changes of temperature by an outer glass tube.

The instrument was always used in the position in which increased micrometer readings correspond to increased zenith distance of the object observed. The clamp for vertical motion of the telescope is an axis clamp. The time was computed from sextant observations of the sun's altitude.

The instrument was usually mounted on a wooden pier similar to that used for the azimuth instrument, but larger and heavier. The footplates supporting the foot screws of the instrument were screwed fast to the end of the pier without the intervention of any cap, the upper end of the hollow pier being left open. This pier was placed in position in the large observing tent in the manner described in connection with the azimuth instrument. At Nogales and at Yuma the zenith telescope was mounted upon the brick pier which had previously been used as a latitude pier by the Coast and Geodetic Survey longitude party.

In the following tables, showing the latitude observations, the star numbers, unless they are otherwise indicated, refer to Prof. T. H. Safford's list as published elsewhere in this report. Star numbers preceded by the letter "P" refer to Preston's Hawaiian list for 1887, Coast and Geodetic Survey Report for 1888, Appendix No. 14. Stars whose mean places were taken from the American Ephemeris are indicated by the letter "E" and the name of the star. Similarly stars from the Berliner Jahrbuch are indicated by their names and the letter "J."

These references will not only serve to identify each star, but to show the authority from which its mean place was taken. The Safford star places were furnished as needed, and in some cases the place furnished for a star at a later date differs slightly from that previously used. The notes as to mean places at the end of the published latitude record for each station cover all such cases. The differences between the places as there given and the published list are very small, and their effect upon the mean latitude for the station would hardly be appreciable.

Station No. 1, 4 miles above El Paso, Tex., near Monument No. 1.

Date.	Star No.	N. or S.	Micrometer reading.	Level		Star No.	N. or S.	Micrometer reading.	Level		Latitude, 31° 46′
				N.	S.				N.	S.	
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Feb. 26*	258	S.	23.180	17.9	51.1	259	N.	18.601	49.8	16.0	57.21
15	295	N.	20.240	46.0	13.0	296	S.	20.401	14.5	47.4	59.33
16	295	N.	20.070	62.8	14.0	296	S.	20.112	9.9	58.2	59.51
18	295	N.	19.883	51.9	19.8	296	S.	20.050	22.0	54.0	59.32
27	295	N.	20.129	52.2	17.0	296	S.	20.242	17.9	53.2	59.18
15	297	S.	21.769	15.6	48.9	297	N.	18.720	40.0	7.0	58.86
16	297	S.	21.132	10.0	58.4	297	N.	18.393	62.9	14.1	57.66
27	297	S.	20.907	16.9	52.2	297	N.	18.081	53.7	18.0	59.30
15	298	S.	20.497	17.6	50.8	299	N.	21.233	46.1	13.0	58.36
16	298	S.	19.490	9.0	57.9	299	N.	20.410	61.9	13.0	58.25
18	298	S.	19.629	15.9	47.9	299	N.	20.398	46.0	13.9	59.33
27	298	S.	20.169	9.7	45.2	299	N.	21.024	46.2	10.4	59.28
15	300	N.	30.840	54.0	20.7	301	S.	11.190	23.9	57.2	58.68
16	300	N.	29.975	41.0	9.9	301	S.	10.184	5.2	36.9	59.25
18	390	N.	30.441	50.9	17.9	301	S.	10.741	19.2	52.3	58.58
27	300	N.	31.418	49.3	13.4	301	S.	11.655	11.8	47.8	59.38
15	302	S.	20.044	21.0	54.3	303	N.	11.240	55.8	22.0	59.16
16	302	S.	24.410	17.9	49.8	303	N.	15.691	54.9	22.9	59.06

* Rejected.

Feb. 16, star 295 observed 27^s late; Feb. 18, star 295 observed 12^s late; Feb. 18, star 296 observed 11^s late; Feb. 27, star 298 observed 4^s late. Feb. 15, star 303 observed 5^s late.

Station No. 1, 4 miles above El Paso, Tex., near Monument No. 1—Continued.

Date.	Star No.	No. or S.	Micrometer reading.	Level N.	Level S.	Star No.	No. or S.	Micrometer reading.	Level N.	Level S.	Latitude, 31° 46′
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
Feb. 18	302	S.	24.133	16.6	49.8	303	N.	15.279	48.1	14.9	59.15
27	302	S.	24.031	11.0	47.5	303	N.	15.259	49.0	12.8	59.59
15	304	N.	15.019	51.3	17.9	305	S.	24.769	16.5	50.1	60.28
16	304	N.	15.060	50.6	18.4	305	S.	24.709	12.8	45.0	59.97
18	304	N.	15.664	51.5	17.9	305	S.	25.431	18.0	52.0	60.05
27	304	N.	15.532	52.3	15.9	305	S	25.230	14.2	51.0	59.86
15	306	N.	17.637	51.3	17.5	307	S.	23.139	15.9	49.5	59.81
16	306	N.	18.350	50.9	18.0	307	S.	23.809	16.4	49.1	58.57
18	306	N.	18.372	50.9	16.4	307	S.	23.938	17.9	52.0	60.17
15	308	N.	29.500	54.0	20.1	309	S.	8.730	18.9	52.8	59.40
16	308	N.	30.547	49.7	17.0	309	S.	9.759	14.8	47.6	59.52
18	308	N.	29.792	53.2	19.0	309	S	9.060	20.0	54.8	59.23
27	308	N.	30.376	47.0	10.2	309	S.	9.570	9.2	46.0	59.03
15	310	N.	15.939	49.1	15.0	311	S.	22.917	12.0	46.0	60.94
16	310	N.	16.221	52.1	19.2	311	S.	23.180	16.9	49.9	59.88
18	310	N.	16.161	52.0	17.2	311	S.	23.184	18.9	53.3	59.55
27	310	N.	16.018	50.1	13.1	311	S.	22.960	11.0	48.0	59.79
15	312	S.	30.855	16.9	50.9	313	N.	11.049	52.8	18.5	59.20
16	312	S.	30.265	18.0	51.1	313	N.	10.431	53.0	19.9	60.27
18	312	S.	30.621	20.7	55.3	313	N.	10.757	55.1	20.0	59.87
27	312	S.	30.592	14.2	51.4	313	N.	10.721	49.2	12.1	59.71
15	314	S.	17.685	23.0	57.1	315	N.	22.248	61.2	26.9	60.32
16	314	S.	17.409	18.5	51.9	315	N.	21.938	53.4	20.0	59.86
18	314	S.	18.348	18.3	53.3	315	N.	22.878	53.3	18.1	58.96
27	314	S.	18.873	15.0	52.1	315	N.	23.364	49.3	12.0	58.95
16	317	S.	25.491	21.0	54.8	319	N.	15.801	56.0	22.1	59.12
18	317	S.	25.078	17.6	52.7	319	N.	15.359	52.5	17.0	59.22
27	317	S.	21.782	13.0	50.2	319	N.	15.001	46.4	9.0	59.58
15	322	S.	9.393	16.3	51.1	324	N.	31.728	53.3	18.3	58.95
16	322	S.	9.167	17.8	51.4	324	N.	31.462	53.2	19.2	59.95
18	322	S.	9.179	16.5	52.0	324	N.	31.470	52.7	17.0	60.17
27	322	S.	9.535	11.2	48.9	324	N.	31.845	49.9	12.0	59.65
16	326	N.	27.641	52.0	18.0	328	S.	11.538	16.5	50.7	59.62
27	326	N.	27.912	51.2	13.4	328	S.	11.780	13.0	50.8	58.59
15	329	N.	19.798	52.8	17.8	330	S.	20.651	13.2	48.5	59.13
16	329	N.	19.680	50.0	15.9	330	S.	20.601	13.0	47.1	60.09
18	329	N.	20.442	56.1	20.2	330	S	21.391	20.0	55.6	59.62
27	329	N.	20.518	54.2	16.1	330	S.	21.431	14.7	52.4	59.67
16	331	N.	22.141	50.9	16.5	334	S.	18.761	14.0	48.8	58.83
18	331	N.	21.601	48.8	13.0	334	S.	18.238	11.3	47.3	59.04
27	331	N.	21.928	56.4	18.7	334	S.	18.598	17.7	55.8	60.03
15	339	N.	16.240	49.6	14.0	340	S.	23.417	11.9	47.2	59.16
16	339	N.	17.013	50.4	15.6	340	S.	24.160	13.4	48.2	58.31
27	339	N	16.667	50.9	12.5	340	S.	23.862	11.2	49.8	59.69
16	343	N.	9.251	46.9	12.0	345	S.	29.760	9.0	44.0	60.39
18	343	N.	9.398	48.0	11.9	345	S.	29.892	11.5	47.8	58.29
27	343	N.	9.390	56.1	17.9	345	S.	29.911	16.9	55.1	59.74
15	347	N.	24.313	50.5	15.0	349	S.	17.348	12.0	47.8	59.36
16	347	N.	23.982	50.9	16.0	349	S.	17.061	13.9	48.7	60.32
27	347	N.	23.360	55.0	16.5	349	S.	16.401	15.2	54.0	58.92

Feb. 15, star 308 observed 12^s late; Feb. 27, star 308 observed 22^s late; Feb. 15 star 310 observed 30^s late; Feb. 16, star 310 observed 26^s late; Feb. 27, star 310 observed 10^s late; Feb. 15, star 314 observed 6^s late; Feb. 16, star 317 observed 24^s late; Feb. 18, star 319 observed 8^s late; Feb. 27, star 319 observed 24^s late; Feb. 15, star 322 observed 20^s late; Feb. 16, star 322 observed 20^s late; Feb. 18, star 322 observed 20^s late; Feb. 18, star 324 observed 70^s late; Feb. 15, star 329 observed 45^s late; Feb. 15, star 330 observed 8^s late; Feb. 16, star 329 observed 11^s late; Feb. 18, star 329 observed 34^s late; Feb. 15, star 339 observed 6^s late; Feb. 15, star 340 observed 25^s late; Feb. 16, star 349 observed 16^s late.

One turn of micrometer = 62.225″.

One division of level = 1.28″.

Total, 67 observations on 19 pairs.

Latitude of Station No. 1 = 31° 46′ 59.40″ ± 0.06″.

Latitude of Monument No. 1 = 31° 46′ 59.40″ ± 0.06″.

Latitude of Station No. 1 was about 4 miles above El Paso, Tex., just east of the Rio Grande, near the Atchison, Topeka and Santa Fe Railroad, 364.1 meters east and 0.0 meter north of Monument No. 1.

Pairs observed four times were given weight 1, three times 0.8, and twice 0.6.

Station No. 2, near Monument No. 15.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 46′
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Mar. 21	306	N.	17.960	48.1	15.0	307	S.	23.392	15.8	48.9	59.65
21	308	N.	30.959	53.3	20.0	309	S.	10.120	19.3	52.8	60.55
21	310	N.	17.030	54.0	20.8	311	S.	24.001	20.7	54.0	60.97
21	314	S.	18.827	14.1	47.8	315	N.	23.400	47.0	13.6	60.36
21	317	S.	25.765	20.1	53.8	319	N.	16.091	50.9	17.0	59.01
21	322	S.	9.731	14.3	48.2	324	N.	32.110	49.0	14.9	60.71
21	326	N.	28.536	48.0	13.9	328	S.	12.428	16.0	50.8	60.06
21	329	N.	20.505	50.3	15.7	330	S.	21.403	14.5	49.1	62.00
21	331	N.	22.482	50.1	15.8	334	S.	19.089	15.6	50.1	60.27
21	343	N.	10.531	49.9	16.0	345	S.	31.070	17.0	50.8	60.44
21	352	S.	13.352	16.0	49.7	355	N.	28.732	48.2	14.9	59.57
21	364	N.	13.612	48.9	14.9	366	S.	26.862	15.8	49.7	61.26
21	369	N.	21.850	46.0	12.0	371	S.	18.321	13.5	47.4	60.46
21	373	N.	16.341	47.0	13.0	375	S.	24.649	14.1	48.2	59.96
21	384	N.	14.801	51.4	17.0	386	S.	25.738	17.7	52.0	60.14
21	392	S.	27.352	15.5	49.6	393	N.	14.540	48.0	13.9	60.20
21	396	N.	14.824	47.9	13.9	399	S.	25.669	14.9	49.0	60.87
22	291	N.	22.387	50.2	19.9	292	S.	19.710	20.0	50.3	59.99
22	293	N.	25.491	49.9	19.2	294	S.	15.879	19.2	50.0	60.28
22	295	N.	21.061	50.1	19.2	296	S.	21.119	17.0	48.6	61.32
22	298	S.	20.931	17.0	48.9	299	N.	21.819	49.1	17.0	60.15
22	300	N.	30.691	46.9	14.0	301	S.	10.859	13.9	46.6	59.61
22	302	S.	24.930	21.0	54.2	303	N.	16.178	55.0	21.9	60.91
22	304	N.	16.257	49.9	16.1	305	S.	25.920	14.9	49.0	60.64
22	312	S.	30.228	13.5	49.1	313	N.	10.481	50.6	15.0	60.45
22	339	N.	17.151	51.1	15.0	340	S.	24.252	13.0	49.1	59.80
22	347	N.	24.630	50.0	14.0	349	S.	17.605	11.8	47.7	60.38
22	360	N.	18.459	45.9	9.8	362	S.	22.537	7.7	43.8	60.72
22	377	N.	23.770	46.9	10.1	380	S.	17.748	9.8	46.2	59.38
22	388	S.	13.530	15.9	53.4	390	N.	29.651	53.6	16.0	60.27
22	400	S.	33.052	15.9	54.0	401	N.	8.100	55.0	17.0	60.94
22	403	N.	20.329	52.1	14.0	404	S.	22.333	13.0	51.0	59.19
22	405	S.	27.940	16.7	54.4	406	N.	13.577	54.2	16.1	58.71
22	407	S.	11.985	17.7	55.4	409	N.	30.300	56.4	18.8	59.30
22	413	S.	19.918	15.0	53.0	414	N.	23.039	54.0	16.1	59.78
22	415	S.	25.700	12.1	50.2	417	N.	15.441	52.0	14.0	60.49
22	419	S.	22.004	12.8	50.7	421	N.	18.011	51.9	13.9	59.68
22	422	N.	29.521	52.2	14.1	424	S.	12.137	11.1	49.2	60.24
25	285	S.	13.269	20.6	46.0	286	N.	28.164	46.1	19.9	59.64

Mar. 21, star 310 observed 29 s late; Mar. 21, star 314 observed 12 s late. Mar. 21, star 322 observed 16 s late; Mar. 21, star 328 observed 14 s late. Mar. 21, star 329 observed 54 s late; Mar. 21, star 343 observed 46 s late; Mar. 21, star 371 observed 26 s late; Mar. 21, star 392 observed 4 s late; Mar. 21, star 393 observed 13 s late; Mar. 21, star 399 observed 13 s late; Mar. 22, star 401 observed 4 s late.

One turn of micrometer = 62.163″.

One division of level = 1.28″.

Total, 39 observations on 39 pairs.

Latitude of Station No. 2 = 31° 47′ 00.21″ ± 0.07″.

Latitude of Monument No. 15, = 31° 47′ 00.34″.

Latitude Station No. 2 was 4.1 meters south and 5.3 meters west of Monument No. 15.

The mean place, 1892, for star No. 400 as used in the latitude computation was 2° 30′ 56.6″, and for star No. 414, 47° 09′ 12.8″

Station No. 3, near Monument No. 26.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 46′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
Apr. 8	306	N.	17.491	50.9	18.0	307	S.	22.681	13.5	46.2	57.76
8	308	N.	30.632	55.1	22.1	309	S.	9.579	18.8	52.0	57.89
8	312	S.	30.510	19.9	53.7	313	N.	10.842	53.2	19.2	58.59
8	314	S.	17.657	16.5	50.5	315	N.	22.391	49.4	15.1	57.24
8	317	S.	24.989	17.7	51.9	319	N.	15.455	51.1	16.9	58.21
8	322	S.	8.817	15.2	50.0	324	N.	31.387	50.7	15.9	56.78
8	326	N.	28.161	55.2	20.2	328	S.	11.844	19.8	55.0	57.71
8	329	N.	19.399	51.2	15.9	330	S.	20.128	14.6	50.0	58.98
8	331	N.	22.069	51.7	16.0	334	S.	18.498	15.0	51.0	57.82
8	339	N.	16.246	49.2	13.0	340	S.	23.242	11.5	48.0	58.65
8	343	N.	9.812	53.4	16.9	345	S.	30.213	15.2	52.0	59.09
8	347	N.	24.189	50.1	13.1	349	S.	17.020	12.1	49.0	57.98
8	352	S.	12.149	16.9	53.8	355	N.	27.720	54.0	17.0	57.70
8	364	N.	12.661	51.0	13.5	366	S.	25.720	12.9	50.1	57.96
8	369	N.	21.919	52.9	15.0	371	S.	18.190	14.5	52.0	57.70
8	373	N.	16.010	56.0	18.3	375	S.	24.140	17.9	55.3	58.05
8	377	N.	23.415	51.8	13.9	380	S.	17.251	13.0	50.9	57.80
8	388	S.	12.091	14.9	53.4	390	N.	28.409	54.7	16.0	57.76
8	392	S.	26.491	15.0	53.8	393	N.	13.857	54.6	15.5	58.14
8	396	N.	15.490	54.0	15.3	399	S.	26.139	15.0	53.9	57.75
8	400	S.	32.139	14.0	53.0	401	N.	7.288	53.3	14.8	58.92
8	403	N.	19.391	52.0	13.0	404	S.	21.261	12.1	51.2	57.43
8	405	S.	27.569	13.8	52.8	406	N.	13.318	52.9	13.8	57.47
8	407	S.	11.092	9.8	48.8	409	N.	29.539	49.0	10.0	57.22
8	413	S.	18.750	13.5	52.7	414	N.	21.980	52.9	13.5	57.93
8	415	S.	24.851	12.1	51.4	417	N.	14.679	52.0	12.6	58.59
8	419	S.	21.890	11.0	50.2	421	N.	17.992	50.9	11.2	58.18
8	422	N.	29.010	56.1	16.9	424	S	11.518	15.6	55.1	57.92
8	P 1341	S.	14.911	15.2	55.0	P 1350	N.	24.501	54.9	15.0	56.76
8	E. J. γ Draconis	N.	32.090	55.1	15.6	J. λ Ophiu.	S.	8.592	15.6	55.2	54.77
9	302	S.	24.192	18.0	51.5	303	N.	15.501	48.0	14.6	58.27
9	304	N.	15.748	51.0	17.1	305	S.	25.298	17.9	52.0	57.66
9	310	N.	15.501	52.0	17.0	311	S.	22.251	12.9	48.0	58.10
9	E. J. 41 Leon. Min.	S.	20.631	12.9	48.0	P 963	N.	19.582	50.0	14.6	58.11
9	P 999	S.	31.108	14.2	51.0	P 1004	N.	9.279	50.9	14.0	58.38
9	P 1025	S.	27.742	15.0	52.1	E. J. 2 Can. Ven.	N.	13.512	52.3	15.2	58.63
9	P 1054	N.	18.520	46.9	9.9	E. J. γ Virgin (m)	S.	19.908	9.2	47.0	58.10
9	P 1086	S.	20.756	14.0	51.9	P 1089	N.	18.933	52.2	14.7	58.22
9	360	N.	18.003	54.2	15.9	362	S.	21.991	15.0	54.0	59.09
12	295	N.	19.794	52.8	20.2	296	S.	19.732	20.8	53.2	57.72
12	297	S.	21.430	20.6	53.1	297′	N.	18.692	51.7	18.9	58.07
12	298	S.	19.482	17.8	50.3	299	N.	20.485	49.2	16.2	57.62
12	300	N.	29.970	50.2	16.6	301	S.	10.009	17.2	51.1	57.69
12	E. J. α Urs. Maj.	N.	21.390	53.6	19.6	P(5293)	S.	21.548	20.0	54.0	58.78
12	P 937	N.	26.359	52.1	15.6	J. 42 Leon. Min.	S.	13.350	15.3	52.0	57.93
13	P 815	N.	28.509	53.0	16.8	E. J. σ² Cancri. (m)	S.	10.806	17.0	53.4	57.61
13	J. ς Hydræ.	S.	20.911	15.0	51.5	P 848	N.	19.926	50.4	13.4	57.86

Rejected.

Apr. 8, star 329 observed 16ˢ late.

Apr. 12, star 295 observed 11ˢ late; Apr. 12, star 297 observed 7ˢ late.

One turn of micrometer = 62.118″.

One division of level = 1.28″.

Total, 46 observations on 46 pairs.

Latitude of Station No. 3 = 31° 46′ 58.00″ ± 0.05″.

Latitude of Monument No. 26 = 31° 46′ 58.08″.

Latitude Station No. 3 was 2.5 meters south and 4.3 meters east of Monument No. 26.

The mean place, 1892, for the star No. 400 as used in the latitude computation was 2° 30′ 56.6″, and for star No. 414, 47° 09′ 12.8″.

Station No. 4, intersection of parallel 31° 47′ and meridian, near Monument No. 40.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 46′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Apr. 18	314	S.	17.825	21.3	51.0	315	N.	22.581	52.0	22.1	59.11
20	314	S.	17.707	14.9	49.0	315	N.	22.442	47.2	13.0	58.23
21	314	S.	17.745	19.0	52.0	315	N.	22.490	50.0	17.0	57.96
22	314	S.	17.646	12.3	47.0	315	N.	22.459	49.1	14.0	58.47
23	314	S.	18.053	18.0	53.7	315	N.	22.829	54.0	17.9	58.59
25	314	S.	17.695	17.2	50.2	315	N.	22.470	50.2	17.0	58.74
26	314	S.	18.031	16.8	51.2	315	N.	22.886	54.1	19.0	58.08
18	317	S.	24.761	19.6	49.2	319	N.	15.258	45.8	15.6	56.63
20	317	S.	24.941	12.3	46.7	319	N.	15.462	43.0	8.7	56.17
21	317	S.	25.070	25.0	58.2	319	N.	15.529	55.4	22.3	58.79
22	317	S.	25.285	20.0	55.1	319	N.	15.852	57.7	22.0	58.84
23	317	S.	24.919	18.0	54.1	319	N.	15.408	53.1	16.5	59.14
25	317	S.	24.885	18.4	52.0	319	N.	15.410	52.0	18.0	58.97
26	317	S.	25.180	14.0	49.2	319	N.	15.754	52.0	16.1	59.25
18	322	S.	9.180	16.0	46.4	324	N.	31.814	50.1	19.6	59.09
20	322	S.	9.701	13.9	48.1	324	N.	32.346	51.2	17.0	58.64
21	322	S.	8.690	18.9	52.0	324	N.	31.270	51.8	18.2	58.54
22	322	S.	9.080	13.9	49.9	324	N.	31.683	51.9	15.1	59.40
23	322	S.	8.660	13.2	50.7	324	N.	31.273	50.6	13.0	58.01
25	322	S.	8.732	16.0	50.2	324	N.	31.350	50.9	16.3	58.56
26	322	S.	9.471	17.0	53.2	324	N.	32.093	54.9	18.0	59.13
18	326	N.	28.259	44.0	13.0	328	S.	11.911	13.6	44.8	57.31
20	326	N.	28.319	49.1	15.0	328	S.	11.943	13.9	47.9	57.85
22	326	N.	28.107	52.1	15.7	328	S.	11.703	12.9	50.0	58.07
23	326	N.	28.361	52.6	14.9	328	S.	12.018	14.4	52.3	58.80
25	326	N.	28.071	52.0	17.7	328	S.	11.690	16.3	51.0	58.37
26	326	N.	28.239	52.7	15.4	328	S.	11.850	13.1	51.0	58.75
18	329	N.	20.040	44.0	12.8	330	S.	20.686	8.9	40.0	59.74
20	329	N.	20.172	47.5	13.5	330	S.	20.848	11.9	45.8	59.41
21	329	N.	20.381	57.5	24.0	330	S.	21.058	23.8	57.1	58.77
22	329	N.	19.935	50.3	13.0	330	S.	20.565	10.0	47.2	59.24
23	329	N.	19.970	50.9	12.8	330	S.	20.648	12.9	50.8	58.69
25	329	N.	20.300	57.7	23.0	330	S.	20.931	21.7	56.2	58.74
26	329	N.	20.408	55.7	18.0	330	S.	21.019	16.4	54.1	58.41
18	331	N.	21.852	48.9	17.4	334	S.	18.262	14.1	46.0	60.21
20	331	N.	21.819	50.2	16.8	334	S.	18.185	15.8	49.1	57.81
21	331	N.	22.029	54.5	21.0	334	S.	18.421	20.3	54.0	58.21
22	331	N.	21.850	48.0	10.5	334	S.	18.233	9.7	47.7	58.36
23	331	N.	22.119	57.0	19.0	334	S.	18.499	18.0	56.7	58.50
25	331	N.	22.222	51.5	16.9	334	S.	18.572	15.0	50.1	58.54
26	331	N.	21.681	55.4	17.1	334	S.	18.010	15.0	53.3	58.32
18	339	N.	16.480	49.1	17.0	340	S.	23.492	17.5	49.6	59.67
20	339	N.	16.572	51.0	17.7	340	S.	23.511	17.0	50.3	58.49
21	339	N.	16.145	55.1	21.2	340	S.	23.051	19.9	53.8	58.03
22	339	N.	16.315	53.8	15.0	340	S.	23.242	14.0	53.0	58.61
23	339	N.	16.227	56.1	17.2	340	S.	23.141	16.1	55.1	58.51
25	339	N.	16.800	51.2	15.6	340	S.	23.700	14.0	49.9	58.71
26	339	N.	16.610	52.8	13.8	340	S.	23.540	14.5	53.5	58.45
18	343	N.	9.630	47.0	14.9	345	S.	30.035	15.6	48.0	58.92
20	343	N.	10.010	46.8	13.0	345	S.	30.381	12.8	46.4	58.81
21	343	N.	9.659	51.0	17.2	345	S.	29.998	16.7	50.2	58.19
22	343	N.	9.690	53.3	14.9	345	S.	30.032	14.0	52.8	58.46
23	343	N.	9.904	52.0	13.0	345	S.	30.203	10.0	49.0	58.74
25	343	N.	9.990	51.7	16.0	345	S.	30.298	14.0	49.9	58.62
26	343	N.	10.179	51.0	12.0	345	S.	30.539	12.8	51.9	58.64
18*	347	N.	23.735	48.0	15.7	349	S.	16.541	21.7	54.1	54.48
20	347	N.	23.603	52.8	18.8	349	S.	16.385	17.9	52.0	58.48
21	347	N.	23.579	47.5	14.0	349	S.	16.362	13.1	46.8	58.66
22	347	N.	23.820	55.7	16.9	349	S.	16.569	16.0	55.0	57.79
23	347	N.	24.300	54.0	15.0	349	S.	17.059	14.1	53.3	58.31
25	347	N.	23.804	53.3	17.7	349	S.	16.526	15.0	51.0	58.65
26	347	N.	23.658	52.6	13.6	349	S.	16.439	14.1	53.4	58.66

* Rejected.

Station No. 4, intersection of parallel 31° 47′ and meridian, near Monument No. 40—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 46′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
Apr. 18	352	S.	12.735	14.9	47.3	355	N.	28.331	47.1	14.6	58.62
20	352	S.	12.641	16.0	50.4	355	N.	28.280	51.4	16.9	58.38
21	352	S.	12.150	17.9	51.3	355	N.	27.795	52.0	18.4	58.14
22	352	S.	12.190	16.1	55.1	355	N.	27.833	56.3	17.1	58.72
23	352	S.	12.169	15.5	54.9	355	N.	27.810	54.7	15.5	58.24
25	352	S.	12.429	14.0	50.1	355	N.	28.060	50.3	13.9	59.05
26	352	S.	12.082	15.0	54.3	355	N.	27.719	53.3	13.9	58.36
18	360	N.	18.032	50.8	18.0	362	S.	21.980	17.7	50.8	58.90
20	360	N.	17.880	47.7	12.9	362	S.	21.821	12.0	47.0	59.35
21	360	N.	18.000	51.5	17.9	362	S.	21.939	17.0	50.8	59.43
22	360	N.	17.839	50.6	11.0	362	S.	21.732	9.5	49.0	58.65
23	360	N.	18.140	54.0	14.7	362	S.	22.069	14.0	53.7	59.27
25	360	N.	18.240	52.3	15.3	362	S.	22.174	15.0	52.2	59.57
26	360	N.	18.030	54.0	14.5	362	S.	21.952	14.3	54.4	59.19
18	364	N.	12.850	51.1	18.1	366	S.	25.890	17.8	50.9	58.38
20	364	N.	13.259	52.1	17.0	366	S.	26.267	15.7	50.6	58.36
21	364	N.	12.080	52.8	18.8	366	S.	26.106	16.9	50.9	59.38
22	364	N.	13.289	54.7	14.9	366	S.	25.295	12.9	52.8	58.93
23	364	N.	13.262	53.8	13.9	366	S.	26.292	13.5	53.2	58.91
25	364	N.	13.334	54.0	16.9	366	S.	26.348	16.5	54.0	58.56
26	364	N.	13.354	50.0	19.0	366	S.	26.365	18.9	49.9	58.55
18	369	N.	21.672	52.2	18.8	371	S.	17.927	17.9	51.0	58.88
20	369	N.	21.509	50.1	15.0	371	S.	17.751	14.0	49.0	58.70
21	369	N.	21.558	53.8	19.2	371	S.	17.788	18.0	52.4	58.64
22	369	N.	21.923	56.0	16.0	371	S.	18.139	13.5	53.5	59.13
23	369	N.	21.192	55.1	15.2	371	S.	17.419	14.5	54.1	58.57
25	369	N.	21.567	55.0	17.9	371	S.	17.789	17.9	55.0	58.21
26	369	N.	22.016	43.4	12.1	371	S.	18.231	12.0	43.1	58.30
18	373	N.	15.760	47.1	14.0	375	S.	23.839	13.5	46.8	58.27
20	373	N.	15.842	50.2	15.2	375	S.	23.910	14.7	49.8	58.29
21	373	N.	15.830	53.2	19.0	375	S.	23.889	16.9	51.0	59.31
22	273	N.	16.050	52.1	12.1	375	S.	24.110	13.0	53.1	57.54
23	373	N.	15.693	54.9	14.9	975	S.	23.728	14.0	54.0	58.19
25	373	N.	15.870	53.3	16.0	375	S.	23.929	17.0	54.1	58.21
26	673	N.	15.909	52.0	20.7	375	S.	23.940	20.9	52.2	58.02
18	377	N.	23.545	46.0	12.8	380	S.	17.363	12.2	45.8	58.93
20	377	N.	23.609	49.0	14.0	380	S.	17.382	12.1	47.6	58.47
21	377	N.	23.245	52.2	17.9	380	S.	17.050	19.0	53.2	57.94
22	377	N.	22.751	53.3	13.1	380	S.	16.550	12.8	53.0	58.79
23	377	N.	23.091	53.0	13.0	380	S.	16.849	11.9	52.0	58.21
25	377	N.	22.960	55.5	18.2	380	S.	16.720	17.9	55.2	58.23
26	377	N.	23.216	47.0	15.6	380	S.	16.978	15.1	46.9	58.52
18	384	N.	15.050	47.3	13.9	386	S.	25.750	12.3	46.0	58.30
20	384	N.	14.819	51.2	15.5	386	S.	25.505	13.9	49.8	58.24
21	384	N.	14.700	48.8	14.3	386	S.	25.429	15.5	49.9	58.07
22	384	N.	14.449	54.0	13.2	386	S.	25.160	13.0	54.0	58.51
23	384	N.	14.685	54.0	13.5	386	S.	25.351	11.8	52.0	58.46
25	384	N.	14.770	55.0	17.6	386	S.	25.450	17.0	54.8	58.43
26	384	N.	14.641	50.2	19.0	386	S.	25.345	18.2	49.6	59.59
18	388	S.	11.669	16.0	49.9	390	N.	28.019	50.3	16.8	58.48
20	388	S.	12.250	12.0	47.9	390	N.	28.630	49.1	13.1	58.26
21	388	S.	11.991	16.9	51.5	390	N.	28.332	59.2	15.5	58.6
22	388	S.	12.039	13.0	54.0	390	N.	28.391	53.7	12.8	58.64
23	388	S.	12.220	15.5	56.0	390	N.	28.639	57.2	16.8	57.75
25	388	S.	12.193	18.9	56.4	390	N.	28.602	57.6	20.0	58.47
26	388	S.	12.229	16.0	47.1	390	N.	28.600	46.9	15.6	58.96
18	392	S.	25.980	13.3	47.2	393	N.	13.435	48.9	15.0	58.14
21	392	S.	26.040	20.0	55.0	393	N.	13.439	54.8	20.0	69.26
22	392	S.	26.261	12.4	53.3	393	N.	13.700	53.5	12.6	58.42
23	392	S.	26.421	15.0	55.8	393	N.	13.890	57.1	16.3	58.42
25	392	S.	26.241	15.9	53.3	393	N.	13.700	53.4	16.0	58.42
26	392	S.	26.560	17.5	48.8	393	N.	14.000	47.6	16.7	58.55

Apr. 18, star 329 observed 21^s late; Apr. 26, star 329 observed 5^s late.
Apr. 23, star 390 observed 9^s late.

Station No. 4, intersection of parallel 31° 47′ and meridian, near Monument No. 40—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 46′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Apr. 18	396	N.	15.475	51.8	17.9	399	S.	26.051	16.3	50.3	58.22
20	396	N.	15.225	52.0	16.0	399	S.	25.789	16.0	51.9	57.20
21	396	N.	15.007	52.3	17.8	399	S.	25.609	17.9	52.5	58.45
22	396	N.	14.680	53.7	12.6	399	S.	25.278	12.9	54.0	58.42
23	396	N.	14.673	54.3	13.5	399	S.	25.235	12.0	53.1	58.60
25	396	N.	14.568	51.1	13.9	399	S.	25.130	13.0	50.5	58.68
26	396	N.	14.570	51.8	20.6	399	S.	25.161	20.5	51.8	59.36

One turn of micrometer = 62.105″.
One division of level = 1.28″.
Total, 130 observations on 19 pairs.
Latitude of Station No. 4 = 31° 46′ 58.55″ ± 0.04″.
Latitude of Monument No. 40 = 31° 46′ 59.72″.
Latitude Station No. 4 was 35.9 meters south and 9.9 meters west of Monument No. 40.
All pairs were given *equal* weight.

Station No. 5, intersection of parallel 31° 20′ and meridian.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 20′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
May 27	320	S.	26.160	15.6	49.8	321	N.	14.389	48.2	14.0	1.89
28	320	S.	25.987	20.0	55.3	321	N.	14.239	54.9	19.0	1.77
26	327	N.	19.159	52.2	16.4	330	S.	22.441	16.1	52.7	2.45
27	327	N.	18.761	51.0	15.1	330	S.	22.011	14.2	50.7	1.94
26	332	N.	30.048	52.8	16.0	333	S.	10.240	16.5	53.2	2.00
27	332	N.	30.532	54.3	17.9	333	S.	10.708	17.1	54.1	2.10
26	335	S.	27.759	19.2	56.2	336	N.	12.581	55.1	18.1	2.76
27	335	S.	28.117	13.8	51.0	336	N.	13.005	52.8	15.0	2.46
26	338	S.	18.832	16.4	53.5	242	N.	21.550	53.1	16.0	1.57
27	338	S.	18.812	15.6	53.7	242	N.	21.530	54.0	15.8	2.06
26	344	S.	28.998	14.0	51.3	346	N.	12.305	51.2	14.0	2.00
27	344	S.	27.767	15.0	53.2	346	N.	10.911	45.8	7.2	2.31
26	348	S.	32.420	14.8	52.2	350	N.	8.136	51.7	14.0	1.77
27	348	S.	32.078	15.6	54.0	350	N.	7.791	54.0	15.6	2.37
26	351	N.	24.251	52.8	15.0	353	S.	16.850	14.9	52.4	1.96
27	351	N.	24.010	53.8	15.0	353	S.	16.581	14.9	53.5	1.15
26	356	S.	30.262	15.0	53.0	358	N.	9.251	52.7	14.8	2.56
27	356	S.	31.314	15.6	54.5	358	N.	10.309	55.0	16.0	2.91
26	359	S.	28.969	12.8	50.9	361	N.	12.322	50.2	12.1	1.90
27	359	S.	28.437	15.0	54.1	361	N.	11.801	54.9	15.6	2.57
26	363	N.	30.448	55.1	16.9	365	S.	10.499	16.9	55.1	1.45
27	363	N.	30.272	55.9	16.0	365	S.	10.298	15.0	54.9	1.40
26	367	S.	20.750	17.1	55.9	368	N.	19.334	55.9	17.1	1.89
27	367	S.	20.871	15.0	54.9	368	N.	19.485	55.3	15.4	1.34
26	370	S.	18.992	14.9	53.7	372	N.	22.028	54.0	15.0	2.03
27	370	S.	18.758	13.5	53.6	372	N.	21.839	55.0	14.9	1.86
26	374	N.	16.689	55.7	16.3	376	S.	23.469	16.1	55.5	1.97
27	374	N.	17.059	54.9	14.7	376	S.	23.802	13.2	53.7	1.70
26	378	S.	28.462	11.8	51.3	379	N.	12.568	51.6	11.9	2.48
27	378	S.	28.275	14.2	55.0	379	N.	12.391	55.6	15.0	2.59
26	381	N.	22.458	53.4	13.3	382	S.	16.759	13.0	53.0	1.90
27	381	N.	23.151	56.1	15.3	382	S.	17.411	14.0	54.9	1.30
26	383	S.	26.377	15.9	56.0	385	N	15.119	56.1	15.9	1.85
27	383	S.	26.523	15.0	55.9	385	N.	15.271	57.0	16.1	2.49
26	387	S.	26.927	14.6	55.1	389	N.	14.142	55.1	14.2	1.92
27	387	S.	26.540	15.0	55.8	389	N.	13.770	56.2	15.5	2.00
26	391	N.	8.692	56.0	15.1	394	S.	30.560	15.2	56.1	1.56
27	391	N.	9.022	55.7	14.8	394	S.	30.878	14.0	55.0	1.92
26	395	S.	24.019	14.1	55.2	397	N.	15.946	55.9	14.9	1.95
27	395	S.	23.642	14.6	55.5	397	N.	15.583	56.6	15.5	1.84
26	398	N.	7.563	54.3	13.2	400	S.	32.018	12.1	53.7	3.05
27	398	N.	8.300	54.0	13.0	400	S.	32.716	12.0	53.0	2.10
26	402	S.	14.341	13.9	55.6	406	N.	26.807	56.1	14.2	1.59
27	402	S.	14.142	14.0	55.5	406	N.	26.632	57.3	15.7	1.93
26	408	N.	26.850	55.0	13.1	410	S.	13.128	12.5	52.8	1.44

May 27, star 394 observed 9s late.

Station No. 5, intersection of parallel 31° 20′ and meridian—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 20′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
May 27......	408	N.	26.974	55.4	13.8	410	S.	13.222	11.0	53.2	2.01
26......	412	S.	21.730	13.4	55.9	414	N.	18.330	56.3	14.0	1.95
27......	412	S.	22.150	13.5	55.9	414	N.	18.739	56.7	14.0	2.59
26......	416	S.	28.370	15.0	58.1	418	N.	12.160	59.4	16.4	1.96
27......	416	S.	28.552	13.8	56.7	418	N.	12.360	57.6	14.6	1.30
26......	420	S.	29.810	11.9	55.0	423	N.	11.209	55.7	12.3	1.80
27......	420	S.	29.691	11.6	54.8	423	N.	11.079	54.8	11.8	2.07
26......	427	N.	25.852	57.5	14.0	428	S.	14.702	12.5	56.0	1.14
27......	427	N.	26.030	56.7	13.8	428	S.	14.895	13.0	55.9	1.39
26......	429	S.	9.562	12.9	56.2	430	N.	30.999	56.8	13.2	1.01
27......	429	S.	9.241	13.9	56.8	430	N.	30.693	57.9	14.7	1.05
27......	431	N.	20.030	56.2	13.1	432	S.	19.490	12.5	55.5	1.99
27......	433	N.	27.011	55.2	12.2	434	S.	12.548	11.1	54.2	2.42
29......	433	N.	27.070	50.0	16.0	434	S.	12.655	17.8	52.0	2.46
27......	436	N.	28.261	55.2	12.2	437	S.	11.261	11.0	54.2	2.18
29......	436	N.	28.481	50.9	16.3	437	S.	11.507	17.4	52.1	2.02
27......	438	S.	13.590	13.0	56.0	439	N.	26.041	57.4	14.2	1.97
29......	438	S.	13.449	18.9	51.0	439	N.	25.869	52.0	17.0	1.31
27......	440	S.	29.100	12.8	55.9	441	N.	11.590	56.7	13.6	2.66
29......	440	S.	28.870	18.2	53.3	441	N.	11.335	51.9	16.3	2.35
29......	442	N.	21.660	53.1	17.9	443	S.	17.394	18.8	54.0	1.91
30......	442	N.	21.828	53.2	17.2	443	S.	17.541	17.8	53.8	1.66
26......	444	N.	28.231	56.0	12.0	445	S.	12.499	11.0	55.0	2.63
29......	444	N.	27.801	51.3	15.9	445	S.	12.091	16.7	52.0	2.82
26......	446	N.	11.974	56.2	12.1	447	S.	28.719	12.0	56.0	2.25
29......	446	N.	11.730	52.7	17.0	447	S.	28.481	18.5	54.0	2.18
29......	448	N.	29.893	54.2	18.9	449	S.	11.436	20.0	55.6	1.96
30......	448	N.	29.662	52.2	16.0	449	S.	11.168	16.0	52.7	1.65
27......	450	N.	12.668	56.0	11.9	451	S.	26.071	9.9	54.3	2.47
29......	450	N.	12.444	50.9	15.5	451	S.	25.929	17.5	52.8	2.96
27......	452	S.	11.461	12.0	56.9	454	N.	28.920	59.2	14.5	1.82
29......	452	S.	11.549	16.9	52.2	454	N.	28.959	51.0	15.1	1.30
30......	453	S.	12.762	15.0	52.2	455	N.	26.991	50.9	13.1	1.80
31......	453	S.	12.500	17.9	56.0	455	N.	26.791	57.2	19.2	1.91
27......	456	N.	23.710	56.1	11.2	457	S.	15.875	11.0	56.0	2.03
29......	456	N.	23.750	50.1	14.6	457	S.	15.912	16.4	52.0	1.16
30......	458	S.	20.068	16.5	54.0	460	N.	20.329	53.2	15.8	1.72
31......	458	S.	19.920	16.0	53.8	460	N.	20.163	52.8	15.0	2.36
27......	461	N.	28.083	56.9	11.7	462	S.	11.453	12.1	57.7	1.67
29......	461	N.	28.118	50.8	15.0	462	S.	11.512	16.3	52.0	2.39
27......	463	N.	16.214	57.5	12.0	464	S.	22.770	11.3	57.0	2.06
29......	463	N.	16.818	52.0	16.4	464	S.	23.411	17.9	53.5	2.32
27......	465	N.	18.670	57.8	12.0	468	S.	21.799	11.5	57.0	2.39
29......	465	N.	18.301	51.8	16.0	468	S.	21.455	17.0	53.0	2.56
30......	466	N.	14.461	52.0	14.0	467	S.	25.729	15.0	53.0	2.11
31......	466	N.	15.002	53.4	15.3	467	S.	26.260	16.8	54.9	1.70
27......	469	N.	24.355	56.7	11.0	471	S.	14.659	10.9	56.4	2.88
29......	469	N.	24.888	54.0	18.0	471	S.	15.182	19.0	55.1	2.30
30......	E. J. γ Lyræ.	N.	26.309	54.5	17.8	P. 1650	S.	14.460	17.2	55.9	2.17
31......	E. J. γ Lyræ.	N.	26.235	53.0	15.0	P. 1650	S.	14.385	15.7	54.0	2.10
27......	P. 1633	S.	8.270	10.9	56.6	P. 1646	N.	29.640	57.1	11.3	1.76
29......	P. 1633	S.	9.138	16.1	52.2	P. 1646	N.	30.492	51.2	15.1	1.83
27......	J. ω Aquil.	S.	13.199	11.4	57.3	J. ι Cygni.	N.	26.272	58.2	12.0	2.01
29......	J. ω Aquil.	S.	13.688	17.9	54.0	J. ι Cygni.	N.	26.749	53.0	16.2	1.25

May 26, star 430 observed 15s late; May 27, star 434 observed 19s late.
One turn of micrometer = 62.093″.
One division of level = 1.28″.
Total, 99 observations on 50 pairs.
Latitude of Station No. 5 = 31° 20′ 02.00″ ± 0.04″.
Latitude of Monument No. 53 = 31° 20′ 01.79″.
Latitude Station No. 5 was 6.4 meters north and 4.4 meters west of Monument No. 53.
All pairs were given *equal* weight.

Station No. 6, near Whitewater Spring.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
June 14......	348	S.	32.415	18.2	51.0	350	N.	8.393	53.9	21.0	58.06
14......	351	N.	24.820	51.9	18.8	353	S.	17.174	14.9	48.2	58.13
16......	351	N.	24.370	51.2	19.8	353	S.	16.781	19.3	51.2	57.76
14......	356	S.	30.650	16.8	50.9	358	N.	9.811	49.3	15.0	58.65
16......	356	S.	30.602	17.9	50.1	358	N.	9.802	49.3	16.9	58.17
14......	359	S.	28.338	16.6	51.0	361	N.	11.888	50.9	16.0	58.30
16...	359	S.	29.230	20.2	53.2	361	N.	12.782	53.0	19.9	58.54
14......	363	N.	30.465	50.0	15.0	365	S.	10.320	14.3	48.8	57.95
16......	363	N.	30.502	50.3	16.8	365	S.	10.340	15.0	49.0	57.94
14......	367	S.	20.410	18.5	54.0	368	N.	19.201	53.4	17.9	57.71
16......	367	S.	20.675	16.0	50.3	368	N.	19.480	50.3	16.0	57.90
14......	370	S.	18.152	19.0	55,0	372	N.	21.418	55.7	19.8	58.24
16......	370	S.	18.470	18.1	53.0	372	N.	21.772	55.0	20.0	58.13
14......	374	N.	17.358	54.9	19.0	376	S.	23.918	18.0	54.2	58.21
16......	374	N.	17.871	51.2	16.0	376	S.	24.420	15.1	50.3	58.17
14......	378	S.	27.949	17.5	54.0	379	N.	12.261	54.2	17.9	58.44
16......	378	S.	28.170	16.9	52.3	379	N.	12.505	53.3	17.7	58.34
14......	381	N.	22.590	54.0	17.0	382	S.	16.660	15.7	52.8	57.85
16......	381	N.	23.241	54.7	18.7	382	S.	17.279	15.9	51.9	58.11
14......	383	S.	25.831	16.0	53.3	385	N.	14.810	54.1	17.0	58.01
16......	383	S.	26.479	16.0	52.3	385	N.	15.473	54.5	18.1	58.60
14......	387	S.	26.723	18.1	55.6	389	N.	14.202	57.1	19.2	57.51
16......	387	S.	26.731	16.9	53.0	389	N.	14.149	52.0	15.5	58.06
14......	391	N.	8.838	55.0	17.0	394	S.	30.516	19.9	57.9	57.31
16......	391	N.	9.341	53.5	16.8	394	S.	31.000	17.0	54.0	58.67
14......	395	S.	23.879	15.9	54.0	397	N.	16.076	55.8	17.8	57.85
16......	395	S.	24.551	16.0	53.0	397	N.	16.712	52.8	15.8	57.99
14......	398	N.	8.110	52.7	14.8	400	S.	32.289	12.0	50.2	58.79
16......	398	N.	8.248	52.8	15.7	400	S.	32.469	15.6	53.0	58.67
14......	402	S.	14.201	16.8	55.3	406	N.	26.911	56.0	17.0	57.90
16......	402	S.	14.120	14.3	52.0	406	N.	26.851	52.0	14.4	57.38
14......	408	N.	27.198	52.0	13.2	410	S.	13.240	12.2	51.1	57.64
16......	408	N.	26.870	53.1	15.6	410	S.	12.911	15.6	53.1	57.30
14......	412	S.	21.449	14.9	53.9	414	N.	18.280	54.0	15.0	58.45
16......	412	S.	21.194	15.9	53.4	414	N.	18.050	53.8	16.0	57.85
14......	416	S.	27.869	15.0	54.2	418	N.	11.915	55.1	16.0	58.00
16......	416	S.	28.150	15.2	53.3	418	N.	12.170	53.0	15.0	58.45
14......	420	S.	29.630	14.2	53.4	423	N.	11.291	55.0	15.8	58.50
16......	420	S.	29.519	18.0	56.2	423	N.	11.161	57.0	18.9	59.00
14......	427	N.	25.958	54.0	15.0	428	S.	14.551	13.3	52.8	57.49
16......	427	N.	25.411	52.3	14.0	428	S.	14.001	12.9	51.2	57.61
14......	429	S.	9.570	16.2	55.8	430	N.	31.274	57.7	18.0	57.37
16......	429	S.	9.702	15.6	54.1	430	N.	31.409	55.3	16.8	57.20
14......	431	N.	19.999	51.2	11.9	432	S.	19.188	10.0	49.3	57.71
16......	431	N.	20.251	54.2	15.5	432	S.	19.458	14.8	53.2	57.93
14......	433	N.	18.072	55.0	15.5	435	S.	22.599	14.0	53.8	58.08
16......	433	N.	18.958	55.1	16.3	435	S.	23.489	15.3	54.2	58.40
14......	436	N.	28.735	54.9	15.0	437	S.	11.420	13.2	53.2	57.25
16......	436	N.	28.795	55.2	16.3	437	S.	11.490	15.2	54.0	57.63
14......	438	S.	13.790	14.0	54.2	439	N.	26.520	56.0	15.8	58.05
16......	438	S.	13.316	15.0	53.8	439	N.	26.061	55.0	16.6	57.80
14......	440	S.	28.741	14.1	54.9	441	N.	11.519	56.2	15.8	58.80
16......	440	S.	29.441	16.0	54.4	441	N.	12.240	54.8	16.4	57.93
14......	442	N	22.144	55.0	14.2	443	S.	17.478	8.8	49.2	57.61
16......	442	N.	22.490	53.0	15.7	443	S.	17.890	14.1	52.6	57.46
14......	444	N.	27.810	52.5	11.8	445	S.	11.878	14.0	54.9	58.50
16......	444	N.	27.640	52.2	14.0	445	S.	11.606	12.8	51.0	58.00
14......	446	N.	11.901	56.4	15.7	447	S.	28.370	16.0	57.1	58.17
16......	446	N.	12.370	54.9	16.5	447	S.	28.781	15.0	53.3	58.17
14......	448	N.	29.579	54.5	13.5	449	S.	10.825	13.9	55.0	57.18
16......	448	N.	29.380	52.3	14.0	449	S.	10.579	12.3	51.0	57.43
14......	450	N.	13.117	54.0	12.8	451	S.	26.318	13.2	54.9	58.17

¶ June 16, star 423 observed 12^s late; June 14, star 430 observed 18^s late.

Station No. 6, near Whitewater Spring—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
June 16......	450	N.	13.173	53.0	14.5	451	S.	26.340	13.1	52.0	58.65
14......	452	S.	11.749	14.1	56.0	454	N.	29.361	53.0	11.3	58.00
16.....	452	S.	11.760	17.2	56.1	454	N.	29.511	58.5	19.5	57.52
14......	456	N.	24.003	57.2	15.7	457	S.	15.850	14.0	55.7	57.77
16......	456	N.	24.108	53.4	14.3	457	S.	16.018	16.0	55.1	58.11
14......	461	N.	28.188	54.1	12.8	462	S.	11.259	11.0	52.8	57.41
16......	461	N.	28.557	52.8	13.3	462	S.	11.679	15.1	54.0	57.12
14......	463	N.	16.821	57.0	15.0	464	S.	23.099	13.1	55.2	58.48
16......	463	N.	16.683	54.8	15.0	464	S.	23.011	16.9	56.4	58.16
14......	465	N.	18.611	56.3	14.2	468	S.	21.437	12.9	55.0	58.17
16......	466	N	14.570	55.0	15.0	467	S.	25.580	16.2	56.2	58.41
21......	466	N.	14.102	52.2	17.9	467	S.	24.999	16.6	51.0	57.93
14......	469	N.	24.848	56.3	14.0	471	S.	14.815	12.6	55.0	57.91
16......	469	N.	25.498	54.0	14.0	471	S.	15.510	15.5	55.4	58.04
14......	473	S.	23.220	14.0	56.5	474	N.	17.945	58.0	15.6	58.45
16......	473	S.	22.584	12.0	51.9	474	N.	17.261	49.9	10.0	58.11
14......	475	S.	10.359	12.9	55.3	476	N.	29.070	57.2	14.9	57.1$_9$
16.....	475	S.	10.319	13.5	53.3	476	N.	28.979	52.0	12.1	57.1^5
14......	477	S.	30.820	13.8	56.1	479	N.	9.030	58.2	15.9	57.95
16......	477	S.	31.338	15.0	54.9	479	N.	9.490	53.2	13.5	57.89
14......	480	S.	10.834	15.0	57.5	482	N.	28.411	58.0	15.2	56.95
16......	480	S.	11.176	15.2	55.0	482	N.	28.710	53.3	13.8	57.56
14......	484	N.	29.827	56.2	13.9	487	S.	9.860	13.0	55.8	58.03
16......	485	S.	20.959	14.9	54.8	488	N.	18.763	53.6	13.5	57.96
14.....	489	S.	14.190	13.4	56.2	490	N.	25.175	57.0	14.0	57.37
16......	489	S.	14.943	13.3	53.6	490	N.	25.886	52.0	11.9	57.74
14......	494	S.	21.948	13.0	55.9	498	N.	18.063	57.0	14.0	57.73
16......	494	S.	22.318	14.8	55.0	498	N.	18.379	53.6	13.2	58.28
14......	P. 1775	S.	9.230	12.0	55.0	P. 1783	N.	31.799	55.9	13.0	57.81
16.....	P. 1775	S.	8.819	14.8	55.0	P. 1783	N.	31.379	54.0	14.0	57.40
14......	E. Groom 3241	N.	22.821	55.9	12.9	E. μ Aquarii	S.	16.585	12.3	55.6	58.19
16......	E. Groom 3241	N.	22.887	54.0	13.3	E. μ Aquarii	S.	16.656	14.0	55.0	57.98
14......	J. ξ Cygni	N.	24.820	55.0	11.6	E. J. 1 Pegasi.	S.	15.014	10.0	53.8	57.81
16......	P. 1900	N.	20.963	55.1	13.9	P. 1902	S.	19.741	14.0	55.3	58.08
16......	E. J. α Cephei	N.	26.545	54.0	12.8	P. 1950	S.	11.940	12.8	54.7	56.72
14......	E. ξ Aquarii	S.	25.489	10.7	54.2	E. J. 11 Cephei	N.	14.263	55.0	11.3	58.03
21......	P. 1337	S.	23.841	18.3	51.2	E. J. ϕ Herculis	N.	17.157	47.6	14.6	58.30
21......	P. 1358	S.	21.000	16.8	50.2	J. Groom 2343	N.	19.967	52.6	19.0	58.70
21......	J. ξ Herculis	S.	26.469	17.8	51.9	P. 1513	N.	15.420	53.2	19.2	57.29
21......	E. J. η Serpentis	S.	23.200	15.1	49.3	P. 1562	N.	17.471	50.1	16.0	58.45

One turn of micrometer = 62.101″.
One division of level = 1.28″.
Total, 102 observations on 57 pairs.
Latitude of Station No. 6 = 31° 19′ 57.94″ ± 0.04″.
There was no monument near the station.
Weight of pairs on which two observations were made, 1.0; one observation, 0.8.

Station No. 7, 8 miles west of San Luis Spring, near Monument No. 67.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude. 31° 19′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
July 7	452	S.	11.571	16.9	54.1	454	N.	29.479	54.1	16.9	56.68
8	452	S.	18.842	19.3	51.6	454	N.	29.781	52.2	20.0	56.35
8	391	N.	9.960	49.9	20.2	394	S.	31.252	11.4	41.1	55.82
8	395	S.	24.668	18.9	48.9	397	N.	16.992	50.1	20.0	56.94
8	398	N.	8.154	51.2	21.0	400	S.	32.168	19.3	50.1	55.66
8	402	S.	14.451	21.4	53.0	406	N.	27.403	56.1	24.0	56.17
27	402	S.	13.021	18.0	49.2	406	N.	25.940	49.8	17.9	57.25
8	408	N.	28.368	51.4	19.3	410	S.	14.279	20.0	52.3	55.99
8	412	S.	22.600	18.9	51.0	414	N.	19.562	49.3	17.0	57.36
26	412	S.	20.549	19.9	51.7	414	N.	17.646	52.7	20.9	56.80
8	416	S.	29.240	20.7	53.2	418	N.	13.409	51.7	19.0	56.97
27	416	S.	27.728	19.2	53.9	418	N.	11.968	51.8	17.0	56.64
8	420	S.	30.248	17.8	50.3	423	N.	11.989	47.6	14.7	57.49
26	420	S.	29.510	18.9	51.2	423	N.	11.389	51.6	18.9	57.34
8	425	S.	24.649	19.0	52.1	426	N.	18.203	53.7	20.8	57.66
27	425	S.	23.670	16.8	52.2	426	N.	17.261	51.1	15.3	57.01
8	427	N.	26.696	53.0	20.0	428	S.	15.114	18.9	51.7	57.08
27	427	N.	25.589	53.3	17.7	428	S.	13.939	17.9	53.9	56.54
8	429	S.	10.941	18.6	51.3	430	N.	32.810	52.0	19.3	56.14
8	431	N.	21.791	51.5	19.0	432	S.	20.848	18.5	50.8	56.85
9	431	N.	19.991	52.8	19.9	432	S.	19.029	17.9	51.0	57.21
8	433	N.	19.610	53.1	21.0	435	S.	23.940	20.8	53.0	56.33
9	433	N.	18.827	51.7	18.0	435	S.	23.131	15.3	49.8	57.06
8	436	N.	29.591	52.0	19.9	437	S.	12.089	18.9	51.0	56.84
9	436	N.	28.346	52.2	17.8	437	S.	10.851	17.0	52.2	56.86
8	438	S.	14.500	18.8	51.0	439	N.	27.456	52.0	19.8	56.41
26	438	S.	13.080	18.1	52.0	439	N.	26.128	54.0	20.1	57.39
8	440	S.	29.780	20.0	52.2	441	N.	12.761	53.3	21.2	57.96
21	440	S.	27.908	15.0	55.0	441	N.	10.991	54.3	14.2	56.20
8	442	N.	24.472	52.8	20.7	443	S.	19.679	20.2	52.3	56.26
21	442	N.	22.662	55.9	15.8	443	S.	17.769	14.0	54.0	56.61
8	444	N.	29.108	51.1	19.0	445	S.	12.889	18.4	50.4	56.98
21	444	N.	27.998	54.5	14.1	445	S.	11.670	12.0	52.3	56.95
8	446	N.	13.071	50.3	18.4	447	S.	29.314	18.0	49.9	57.57
9	446	N.	11.955	55.1	19.1	447	S.	28.173	18.3	54.2	57.28
8	448	N.	31.166	57.1	25.2	449	S.	12.159	24.3	56.2	56.34
9	448	N.	29.686	52.3	16.4	449	S.	10.648	13.9	49.8	56.61
8	450	N.	14.381	52.0	20.0	451	S.	27.349	19.3	51.7	56.23
27	450	N.	13.382	54.1	14.8	451	S.	26.270	13.5	53.2	56.96
8	456	N.	19.573	52.0	19.9	459	S.	22.499	19.2	51.7	56.74
8	489	S.	14.789	18.0	51.7	490	N.	26.010	52.3	18.9	56.82
28	489	S.	14.559	12.0	56.9	490	N.	25.902	56.1	11.3	57.13
8	494	S.	21.791	17.4	51.8	498	N.	18.150	53.1	18.2	57.17
28	494	S.	21.491	12.0	57.6	498	N.	17.991	57.0	11.5	57.27
8	P. 1775	S.	8.348	18.1	53.8	P. 1783	N.	31.230	56.3	20.8	56.46
8	E. Groom. 3241	N.	23.202	54.8	17.8	E. μ Aquarii	S.	16.682	14.9	52.3	56.49
8	J. ξ Cygni	N.	24.958	54.1	16.3	E. J. 1 Pegasi	S.	14.889	15.0	53.0	56.49
8	E. ξ Aquarii	S.	24.931	15.8	54.0	E. J. 11 Cephei	N.	13.950	55.6	17.0	56.08
9	E. J. α Herculis	S.	14.382	17.9	53.1	J. χ Herculis	N.	25.911	51.2	15.4	55.88
26	E. J. α Herculis	S.	14.978	17.9	51.8	J. χ Herculis	N.	26.599	50.9	16.9	56.98
9	J. ξ Herculis	S.	26.325	20.2	56.8	P. 1513	N.	15.410	55.8	19.2	56.13
28	J. ξ Herculis	S.	23.671	13.0	56.2	P. 1513	N.	12.888	54.2	11.0	55.46
9	453	S.	13.090	16.9	53.2	455	N.	27.820	52.0	15.4	57.15
26	453	S.	11.960	17.9	52.2	455	N.	26.791	50.0	15.2	57.38
21	458	S.	19.120	15.2	55.3	460	N.	19.992	53.7	13.8	56.07
21	463	N.	16.696	53.9	13.9	464	S.	22.706	14.9	55.0	57.06

July 27, star 402, observed 15s late; July 26, star 412 observed 7s late.

Station No. 7, 3 miles west of San Luis Spring, near Monument No. 67—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 30° 19′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
July 26	463	N.	17.094	54.0	19.0	464	S.	23.070	19.9	54.0	57.00
26	E. J. α Serpentis	S.	25.147	23.8	55.7	417	N.	14.121	56.1	24.0	56.90
26	P. 1358	S.	20.352	19.0	52.0	J. Groom 2343	N.	19.511	52.2	19.3	56.85
27	P. 1358	S.	20.248	17.0	53.2	J. Groom 2343	N.	19.384	53.0	16.4	57.27
26	P. 1492	S.	12.785	18.9	53.2	E. J. θ Herculis	N.	27.903	52.7	18.2	56.42
26	461	N.	28.046	52.0	17.2	462	S.	10.853	17.9	52.7	56.31
26	465	N.	19.039	54.0	19.0	468	S.	21.520	19.1	54.2	57.60
26	469	N.	25.793	52.2	17.2	471	S.	15.402	17.2	52.2	57.41
26	514	N.	27.140	54.4	17.0	517	S.	13.989	16.9	54.2	56.73
27	514	N.	26.968	56.3	15.8	517	S.	13.820	15.9	56.7	56.80
26	519	S.	13.800	16.2	53.9	521	N.	26.842	54.2	16.7	56.29
27	519	S.	13.959	14.2	55.1	521	N.	27.009	55.0	14.0	55.91
26	525	N.	24.072	53.2	15.9	526	S.	16.918	15.2	53.0	56.51
27	525	N	24.369	56.1	15.0	526	S.	17.223	15.0	56.0	56.74
26	530	S.	13.133	15.7	53.2	532	N.	26.612	54.0	16.1	56.49
27	530	S.	13.441	14.0	55.0	532	N.	26.921	55.9	14.9	56.87
26	537	S.	18.668	16.9	54.5	538	N.	22.575	55.8	17.9	56.88
27	537	S.	18.841	15.9	57.0	538	N.	22.741	57.5	16.2	56.85
26	539	S.	11.352	17.9	55.6	543	N.	28.996	55.8	18.0	56.66
27	539	S.	11.801	15.0	56.2	543	N.	29.469	56.9	15.6	56.44
26	546	S.	29.901	15.6	53.2	547	N.	9.863	53.4	15.9	56.62
27	546	S.	29.939	14.9	56.1	547	N.	9.891	56.3	15.0	57.08
26	552	N.	11.741	53.8	16.0	554	S.	27.689	15.5	53.2	56.55
27	552	N.	12.345	57.0	15.1	554	S.	28.280	14.2	56.2	56.54
26	558	S.	28.480	16.0	54.0	559	N.	11.935	54.5	16.7	56.93
27	558	S.	28.504	14.0	56.2	559	N.	11.979	58.0	15.7	57.28
27	P. 1275	S.	26.216	17.9	50.2	J. σ cor. bor. seq. ζ Cor. Bor.	N.	14.710	55.0	21.0	59.54
27	E. J. η Serpentis	S.	23.400	15.8	55.9	P. 1562	N.	17.950	56.3	16.8	57.06
28	E. J. η Serpentis	S.	21.108	14.0	57.5	P. 1562	N.	15.613	55.9	12.4	57.16
27	466	N.	15.170	56.2	16.2	467	S.	25.740	15.1	55.0	56.62
28	466	N.	15.678	57.0	13.3	467	S.	26.318	16.0	59.4	56.64
27	470	N.	13.868	55.0	15.0	472	S.	27.522	14.0	54.1	56.31
27	473	S.	22.568	14.9	54.9	474	N.	17.678	56.1	16.0	56.86
27	475	S.	10.599	15.0	55.0	476	N.	29.724	56.8	16.8	56.25
27	477	S.	31.001	15.0	55.0	479	N.	9.599	56.0	16.0	56.85
27	483	N.	17.852	57.0	16.8	486	S.	22.800	14.9	55.3	56.89
28	483	N.	17.728	58.3	14.4	486	S.	22.720	15.0	59.2	56.84
27	E. J. γ Aquil	S.	25.061	14.7	55.1	J. ψ Cygni	N.	15.753	57.6	16.8	57.17
27	497	S.	10.673	14.6	55.4	499	N.	30.338	56.0	15.0	56.69
27	504	S.	32.732	15.2	56.2	507	N	8.820	56.2	15.2	57.36
27	510	N.	18.975	56.2	15.4	512	S.	20.722	15.4	56.2	56.86
28	J. γ′ Bootis	N.	13.231	47.3	12.8	P. 1317	S.	22.424	13.0	50.1	55.84
28	P. 1621	N.	10.028	57.2	14.0	P. 1650	S.	29.259	16.8	60.3	56.74
28	478	N.	15.272	56.8	12.9	481	S.	25.187	13.8	57.8	56.52

Rejected; see level.

July 26, star P. 1358 observed 12s late.
One turn of micrometer = 62.078″.
One division of level = 1.28″.
Total, 99 observations on 63 pairs.
Latitude of Station No. 7 = 31° 19′ 56.73″ ± 0.04″.
Latitude of Monument No. 67 = 31° 19′ 56.86″.
Latitude of Station No. 7 was 4.1 meters south and 4.6 meters west of Monument No. 67.
Weight for pairs on which two observations were made, 1.0; one observation, 0.7.

Station No. 8, San Bernardino Ranch, Arizona.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			t.	d.	d.			t.	d.	d.	
Aug. 9......	539	S.	10.709	18.1	52.8	543	N.	28.360	50.8	16.0	58.40
9......	546	S.	29.064	16.9	51.7	547	N.	9.090	53.1	18.1	58.83
16......	546	S.	30.211	12.9	56.5	547	N.	10.259	57.6	13.8	59.62
9......	550	S.	22.820	19.9	54.9	553	N.	16.989	56.6	20.9	58.99
9......	556	N.	24.712	52.9	17.9	557	S.	13.689	17.9	52.8	58.72
9......	560	N.	30.290	52.5	17.6	564	S.	9.130	16.4	51.7	58.78
9......	566	S.	19.327	18.1	53.4	568	N.	19.915	54.2	19.0	59.68
9......	571	S.	15.059	19.0	54.0	574	N.	26.829	56.2	21.0	59.65
9......	576	S.	19.510	17.2	52.8	578	N.	18.782	53.3	17.8	58.97
9......	580	S.	28.183	16.9	52.4	582	N.	10.004	52.8	16.9	58.76
16......	580	S.	29.358	12.9	57.6	582	N.	11.230	58.0	13.0	58.93
9......	584	N.	27.160	54.0	18.1	586	S.	11.599	17.9	53.9	58.76
9......	591	N.	21.870	54.8	18.3	594	S.	17.859	17.4	54.1	58.32
9......	595	N.	16.611	54.0	17.1	596	S.	21.940	17.1	54.0	59.38
9......	599	N.	21.221	53.0	15.8	602	S.	17.420	15.4	52.8	59.44
9......	603	N.	29.039	53.9	16.5	608	S.	9.800	16.0	53.4	59.03
9......	609	S.	15.032	14.9	52.3	611	N.	22.980	52.9	15.0	59.48
9......	613	S.	21.630	15.7	53.3	615	N.	16.990	54.0	16.1	59.36
9......	618	N.	30.139	52.8	14.9	620	S.	8.291	14.6	52.0	59.28
15......	431	N.	20.491	51.1	20.0	432	S.	19.501	19.1	50.7	58.92
16......	431	N.	19.966	50.1	17.1	432	S.	18.982	18.6	51.3	58.07
15......	433	N.	18.152	52.5	20.9	435	S.	22.391	19.0	51.6	59.19
16......	433	N.	18.052	53.1	19.1	435	S.	22.330	18.7	53.2	59.68
15......	436	N.	29.098	52.2	19.6	437	S.	11.479	17.7	50.9	59.03
16......	436	N.	29.690	53.3	18.3	437	S.	12.092	18.0	53.4	58.82
15......	438	S.	13.676	16.3	50.0	439	N.	26.758	52.7	19.0	59.32
16......	438	S.	14.010	17.0	53.1	439	N.	27.070	54.0	17.9	58.96
15......	440	S.	28.901	24.0	58.0	441	N.	11.961	55.9	21.7	59.71
16......	440	S.	28.881	18.5	55.0	441	N.	11.992	55.0	18.3	59.60
15......	442	N.	23.280	52.6	18.1	443	S.	18.368	17.9	52.2	58.55
16......	442	N.	23.058	53.0	16.2	443	S	18.121	15.4	52.2	58.21
15......	444	N.	28.621	53.9	19.0	445	S.	12.304	17.9	52.6	59.79
16......	444	N.	28.790	52.1	15.0	445	S.	12.480	14.2	51.3	59.86
15......	446	N.	12.950	52.8	17.9	447	S	29.011	16.9	51.9	59.10
16......	446	N.	12.864	54.2	17.0	447	S.	28.928	16.0	53.5	59.26
15......	448	N.	30.236	51.9	16.9	449	S.	11.080	16.0	51.4	57.96
16......	448	N.	30.308	53.0	15.4	449	S.	11.160	13.8	51.4	58.91
15......	450	N.	13.576	54.9	19.0	451	S.	26.440	17.0	53.2	59.23
16......	450	N.	13.709	53.0	15.0	451	S.	26.578	13.2	51.7	59.23
15......	452	S.	11.097	16.3	53.3	454	N.	29.200	55.1	17.9	58.59
15......	456	N.	19.049	54.6	16.2	459	S.	21.770	14.8	52.7	58.87
18......	456	N	18.900	56.3	12.0	459	S.	21.638	12.0	56.3	58.97
15......	461	N.	28.062	55.4	17.5	462	S.	10.796	15.0	53.3	58.78
18......	461	N.	28.680	57.9	13.2	462	S.	11.450	13.5	58.6	58.68
15......	463	N.	17.180	54.1	15.6	464	S.	23.049	14.6	52.8	58.84
16......	463	N.	17.033	53.0	13.9	464	S.	22.962	15.5	55.0	58.79
15......	465	N.	19.219	54.2	15.3	468	S.	21.579	13.8	53.0	59.05
15......	504	S.	32.669	20.7	54.3	507	N.	8.818	52.0	18.0	58.89
15......	509	N.	23.470	51.9	17.8	513	S.	15.981	19.0	53.3	58.66
15......	514	N.	26.755	51.7	17.3	517	S.	13.530	18.7	52.9	58.50
15......	519	S.	14.079	18.6	52.8	521	N.	27.190	52.7	18.3	58.78
15......	523	S.	18.519	18.2	52.7	528	N.	22.959	52.0	17.2	59.19
15......	531	S.	28.370	18.3	53.0	535	N.	13.561	52.2	17.3	58.89
16......	531	S	28.569	14.8	57.8	535	N.	13.796	58.1	15.0	58.80
15......	537	S.	18.180	18.8	53.8	538	N.	22.159	52.3	17.2	58.08
16......	537	S.	18.441	13.0	56.3	538	N	22.432	56.1	12.9	58.90
15......	540	N.	11.479	53.6	18.2	542	S.	29.964	19.6	54.2	59.08
15......	548	S.	14.380	16.5	52.0	549	N.	27.034	51.9	16.6	58.98
15......	551	N.	28.242	53.8	18.3	555	S.	12.362	18.9	54.1	58.69
15......	558	S.	28.800	16.8	52.0	559	N.	12.342	53.0	17.8	59.71
16......	558	S.	29.011	14.7	58.7	559	N.	12.575	58.9	14.9	58.79
15......	562	N.	28.082	53.6	17.1	565	S.	11.570	18.0	54.0	58.26

Aug. 9, star 599 observed 15ˢ late; Aug. 15, star 450 observed 32ˢ late; Aug. 16, star 451 observed 7ˢ late.

Station No. 8, San Bernardino Ranch, Arizona—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			t.	d.	d.			t.	d.	d.	″
Aug. 15......	569	S.	24.570	18.1	54.0	573	N.	15.845	54.6	18.9	59.98
15......	577	S.	14.445	18.0	54.0	579	N.	26.651	54.1	18.1	59.02
15......	581	S.	20.425	15.4	51.7	583	N.	21.240	51.1	15.0	58.62
15......	585	S.	16.590	17.0	53.2	588	N.	24.502	52.7	16.0	58.68
15......	592	N.	14.732	52.1	15.5	593	S.	25.609	16.4	53.1	58.94
16......	592	N.	14.820	56.1	11.9	593	S.	25.650	11.0	55.5	58.87
15......	597	S.	28.120	15.0	52.3	598	N.	11.530	52.0	14.8	58.91
15......	600	N.	10.925	54.0	16.9	601	S.	28.753	17.0	54.2	58.84
16......	600	N.	11.518	56.3	12.2	601	S.	29.338	12.0	56.2	59.07
15......	604	N.	18.240	53.1	16.0	606	S.	21.461	16.0	53.2	59.10
15......	610	S.	32.350	15.7	53.0	612	N.	9.400	52.8	15.3	58.82
16......	610	S.	32.182	11.9	56.6	812	N.	9.249	56.3	11.8	58.62
15......	614	S.	15.353	16.0	53.1	619	N.	25.461	53.0	15.9	58.77
16......	453	S.	12.423	15.0	53.3	455	N.	27.393	55.0	16.5	59.08
16......	458	S.	19.966	17.0	55.5	460	N.	20.952	57.5	19.0	59.77
16......	466	N.	15.611	56.7	17.0	467	S.	26.196	19.9	59.5	58.73
18......	466	N.	15.740	57.3	12.7	467	S.	26.254	12.1	57.0	58.98
16......	470	N.	14.228	56.2	16.5	472	S.	27.819	15.6	55.8	58.49
18......	470	N.	14.058	58.0	13.0	472	S.	27.656	13.2	58.2	58.53
16......	473	S.	22.921	15.0	55.0	474	N.	18.070	55.0	14.9	59.07
18......	473	S.	22.761	12.5	57.3	474	N.	17.905	57.1	12.9	59.68
16......	478	N.	16.056	54.2	14.0	481	S.	25.925	14.9	55.1	58.99
16......	483	N.	18.080	55.5	14.9	486	S.	23.008	15.0	56.0	59.58
18......	483	N.	18.269	56.8	12.0	486	S.	23.164	11.8	56.2	59.43
16......	489	S.	14.814	14.3	55.3	490	N.	26.268	55.2	14.0	58.39
16......	494	S.	22.358	14.2	55.3	498	N.	18.960	55.4	14.0	59.35
16......	500	N.	13.751	56.1	14.9	502	S.	26.790	15.0	56.3	59.37
16......	505	S.	11.790	13.1	54.9	508	N.	29.051	55.0	13.1	58.49
16......	510	N.	19.189	56.0	14.5	512	S.	20.850	14.7	56.1	59.01
16......	515	N.	22.632	55.9	14.0	520	S.	18.250	14.0	56.2	59.17
16......	522	N.	20.128	56.4	14.0	524	S.	23.259	14.5	57.0	59.12
16......	527	S.	25.798	13.9	56.8	529	N.	14.640	56.5	13.4	59.11
16......	541	N.	25.790	56.1	12.6	544	S.	15.810	12.1	56.0	59.81
16......	552	N.	12.982	57.6	13.4	554	S.	28.333	12.4	56.6	59.23
16......	563	S.	29.554	13.0	57.0	570	N.	11.188	57.2	13.0	59.23
16......	572	N.	28.391	57.0	12.8	575	S.	13.662	11.9	56.3	59.24
16......	605	S.	13.160	12.9	57.0	607	N.	27.858	58.0	13.6	58.64
18......	477	S.	30.850	14.2	58.8	479	N.	9.522	59.0	14.9	59.52

Aug. 16, star 592 observed 8ˢ late.
One turn of micrometer = 62.099″.
One division of level = 1.28″.
Total, 100 observations on 75 pairs.
Latitude of Station No. 8 = 31° 19′ 59.01″ ± 4.03″.
Latitude of Monument No. 77 = 31° 19′ 58.99″.
Latitude of Station No. 8 was 0.7 meter north and 23.8 meters west of Monument No. 77.
Weight for pairs on which two observations were made, 1.0; one observation, 0.7.

Station No. 9, western part of Sulphur Spring Valley.

Date.	Star No	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 20′.
1892			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Sept. 7...	522	N.	18.590	50.1	14.6	524	S.	21.812	15.0	50.9	6.32
13....	522	N.	18.580	52.0	16.8	524	S.	21.737	16.3	51.9	6.01
7....	527	S.	25.209	15.4	51.7	529	N.	13.961	50.9	14.8	6.70
13....	527	S.	24.985	19.9	55.3	529	N.	13.800	55.3	19.9	6.41
7.....	531	S.	27.729	14.8	51.0	535	N.	12.875	50.3	13.9	5.96
13......	531	S.	27.210	17.3	53.0	535	N.	12.400	51.9	16.4	5.73
7....	537	S.	18.401	16.8	53.1	538	N.	22.319	52.2	15.8	5.22
10......	537	S	18.491	17.4	52.6	538	N.	22.391	49.9	14.9	5.34
7.....	540	N.	11.161	51.7	14.9	542	S.	29.694	15.0	52.0	6.85
13.....	540	N.	10.739	54.0	18.9	542	S.	29.208	18.9	54.1	6.29
7......	548	S.	14.181	16.9	54.0	549	N.	26.771	53.9	16.7	5.74
13....	548	S.	13.606	17.0	52.3	549	N.	26.241	53.0	17.6	6.17
7......	551	N.	27.431	52.3	15.0	555	S.	11.621	15.9	53.0	5.40
7....	558	S.	28.449	16.3	53.7	559	N.	11.930	53.6	16.4	6.55
13....	558	S.	27.851	17.9	53.2	559	N.	11.401	53.2	17.9	5.67
7....	562	N.	27.874	53.3	16.9	565	S.	11.456	17.7	54.1	5.66
13......	562	N.	27.820	54.0	18.5	565	S.	11.334	17.9	53.3	5.73
7......	569	S.	24.281	18.5	55.1	573	N.	15.528	54.7	18.1	6.28
7......	577	S.	13.701	18.4	54.4	579	N.	25.813	52.8	17.0	6.40
12......	577	S.	14.090	15.5	54.0	579	N.	26.320	55.5	17.0	5.85
7......	581	S.	19.579	18.5	53.9	583	N.	20.310	52.9	17.4	6.73
7	585	S.	15.889	17.0	52.0	588	N.	23.752	50.8	15.8	5.64
7....	592	N.	14.262	52.0	17.0	593	S.	25.202	18.0	53.2	6.60
13.....	592	N.	14.754	54.9	18.8	593	S	25.598	18.0	54.2	6.17
7.....	597	S	27.724	15.9	51.1	598	N.	11.082	50.1	14.9	6.02
13.....	597	S.	27.960	16.0	52.7	598	N.	11.390	53.2	16.7	6.19
7.....	600	N.	10.530	53.7	18.3	601	S.	28.411	18.9	54.0	6.24
13......	600	N.	10.651	53.2	16.3	601	S.	28.450	15.2	52.2	5.97
7.....	604	N.	18.259	52.7	17.2	606	S.	21.498	17.9	53.2	6.05
12....	604	N.	18.167	53.5	13.9	606	S	21.340	12.6	52.2	5.81
7.....	610	S.	32.041	16.9	52.6	612	N.	9.062	52.7	16.8	6.05
12.....	610	S.	31.742	16.3	56.2	612	N.	8.810	57.6	17.8	6.62
7......	614	S.	14.529	17.2	53.2	619	N.	24.591	53.9	17.8	6.26
10......	480	S.	10.779	18.9	52.0	482	N.	28.721	52.2	18.9	5.72
13......	480	S.	11.009	17.0	50.2	482	N.	28.979	51.0	17.6	5.70
10......	484	N.	30.511	52.9	19.2	487	S.	10.150	18.1	52.0	5.69
10......	489	S.	14.719	18.8	52.7	490	N.	26.070	53.7	19.7	6.12
13.....	489	S.	14.191	17.7	51.7	490	N.	25.560	52.7	18.7	6.09
10......	492	N.	21.121	54.7	20.8	495	S.	18.928	19.8	53.9	5.93
10......	500	N.	13.151	52.2	18.1	502	S.	26.262	17.8	51.8	6.40
13......	500	N.	13.002	52.8	18.1	502	S	26.120	18.1	52.7	6.90
10......	509	N.	23.539	54.1	19.9	513	S.	16.090	18.8	53.2	5.47
10.....	514	N.	27.469	51.1	16.4	517	S.	14.270	14.9	49.6	5.86
10......	519	S.	13.580	19.0	53.9	521	N.	26.651	55.4	20.7	6.05
10....	523	S.	17.940	17.8	52.3	528	N.	22.372	54.9	19.9	6.87
10......	533	S.	10.501	18.8	53.8	534	N.	29.901	52.2	17.2	5.99
10......	539	S.	11.569	15.9	50.9	543	N.	29.202	49.0	13.9	5.46
10......	546	S.	29.729	18.9	54.0	547	N.	9.670	52.0	16.8	6.51
12......	546	S.	29.519	17.0	53.9	547	N.	9.542	55.0	17.9	6.34
10....	550	S.	23.079	16.9	52.1	553	N.	17.250	52.7	17.1	6.53
10......	556	N.	25.071	52.8	17.2	557	S.	14.040	18.0	53.2	5.67
12......	556	N.	25.340	54.0	16.5	557	S.	14.260	15.0	52.8	5.90
10.....	560	N	30.791	53.2	18.0	564	S.	9.651	18.0	53.3	5.56
10......	566	S.	19.319	18.1	53.8	568	N.	19.891	53.2	17.9	6.41
13......	566	S.	19.512	19.0	54.9	568	N.	20.139	55.0	19.3	5.77
10......	571	S.	14.472	18.2	53.9	574	N.	26.260	54.2	19.0	5.87
13......	571	S.	14.641	18.9	54.2	574	N.	26.470	54.5	19.0	5.14
10......	576	S.	19.760	17.8	53.2	578	N.	19.021	53.4	17.9	6.20
[illegible]	576	S.	20.285	16.1	51.9	578	N.	19.582	51.9	16.1	5.68
10....	584	N.	27.928	52.9	17.0	586	S.	12.350	17.0	53.0	5.94
10......	591	N.	22.280	53.2	17.4	594	S.	18.272	17.8	53.8	5.56
[illegible]	591	N.	22.440	54.1	15.5	594	S.	18.379	14.0	53.0	5.60

Station No. 9, western part of Sulphur Spring Valley—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level.		Star No.	N. or S.	Micrometer reading.	Level.		Latitude, 31° 20′.
				N.	S.				N.	S.	
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Sept. 10......	595	N.	16.847	53.2	17.1	596	S.	22.159	17.0	53.2	6.15
12......	595	N.	17.081	57.6	18.4	596	S.	22.320	15.5	54.8	6.14
12......	456	N.	18.625	49.0	17.8	459	S.	21.520	18.0	49.4	6.16
13......	456	N.	18.280	54.0	16.9	459	S.	21.138	15.2	53.2	6.05
12......	483	N.	17.610	51.4	18.0	486	S.	22.630	19.0	52.3	6.42
12......	491	S.	19.738	16.3	49.6	493	N.	20.580	49.2	16.0	6.23
12......	497	S.	10.269	19.9	53.0	499	N.	29.905	53.8	20.2	6.20
12......	501	N.	20.070	52.7	19.1	503	S.	19.187	19.0	52.7	6.51
12......	505	S.	11.581	19.6	53.0	508	N.	28.779	53.2	19.8	5.25
12......	510	N.	18.385	51.0	17.2	512	S.	20.130	16.8	50.3	6.54
13......	510	N.	18.405	52.6	18.0	512	S.	20.140	17.9	52.2	6.20
12......	515	N.	21.832	52.1	18.0	520	S.	17.515	17.0	51.7	0.42
12......	525	N.	23.600	53.6	18.2	526	S.	16.390	17.4	53.0	6.18
12......	530	S.	12.820	17.7	53.6	532	N.	26.328	54.0	17.9	5.41
12......	541	N.	24.570	54.0	17.1	544	S.	14.595	16.1	53.0	6.23
12......	552	N.	11.590	53.2	15.9	554	S.	27.469	14.4	52.0	6.52
13......	552	N.	11.492	53.9	18.2	554	S.	27.375	18.1	53.9	6.03
12......	563	S.	28.950	15.2	53.2	570	N.	10.571	54.2	16.0	6.59
12......	572	N.	27.600	54.2	16.0	575	S.	12.876	14.5	53.0	5.46
12......	580	S.	28.374	17.0	55.6	582	N.	10.240	57.0	18.5	6.45
13......	580	S.	28.741	18.0	53.3	582	N.	10.600	54.0	18.1	6.25
12......	587	N.	13.011	55.3	16.9	589	S.	26.200	14.9	53.3	6.48
13......	587	N.	12.870	53.4	17.8	589	S.	26.089	17.0	53.0	6.74
12......	599	N.	21.520	55.5	15.9	602	S.	17.616	12.6	52.2	6.22
12......	613	S.	22.629	15.0	54.9	615	N.	18.059	56.0	16.1	5.55
12......	618	N.	30.310	54.9	15.0	620	S.	8.420	13.3	53.1	6.04
13......	450	N.	12.749	51.3	17.0	451	S.	25.832	16.8	52.0	6.51
13......	461	N.	27.620	54.9	16.9	462	S.	10.525	14.1	53.0	5.93
13......	463	N.	16.040	52.1	13.0	464	S.	22.125	15.4	54.9	6.25
13......	466	N.	15.305	50.3	18.9	467	S.	26.010	21.7	53.2	6.19
13......	470	N.	13.110	51.6	19.7	472	S.	26.830	18.5	51.0	6.70
13......	473	S.	21.701	18.0	50.9	474	N.	16.740	51.0	18.1	6.46
13......	477	S.	30.075	18.9	52.0	479	N.	8.678	52.8	19.2	6.36
13......	485	S.	21.075	17.5	51.2	488	N.	19.326	51.9	17.9	6.14
13......	494	S.	21.315	17.0	51.2	498	N.	17.868	51.2	16.9	6.14
13......	504	S.	31.719	18.1	52.8	507	N.	7.860	53.0	18.6	7.24
13......	605	S.	12.419	16.9	53.9	607	N.	27.108	54.0	16.7	5.03
13......	609	S.	15,851	15.0	52.3	611	N.	23.870	52.9	15.6	5.24
13......	616	S.	18.385	17.0	54.2	617	N.	22.191	55.0	17.8	5.52

One turn of micrometer = 62.164″.
One division of level = 1.28″.
Total, 101 observations on 72 pairs.
Latitude of Station No. 9 = 31° 20′ 06.07″ ± 0.03′.
There was no monument near the station.
Weight for pairs on which two observations were made, 1.0; one observation, 0.8.

Station No. 10, near San Pedro River, 1 mile southeast of Monument No. 98.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			t.	d.	d.			t.	d.	d.	″
Oct. 1......	523	S.	17.340	15.0	52.7	528	N.	22.828	52.0	14.0	35.51
1......	539	S.	10.495	15.9	54.7	543	N.	29.289	54.5	15.6	35.14
1......	548	S.	13.530	17.0	56.0	549	N.	27.270	55.4	16.1	34.85
10......	548	S.	12.899	18.0	52.7	549	N.	26.730	55.0	20.1	35.01
1......	550	S.	22.962	13.0	52.3	553	N.	18.245	52.3	13.0	35.13
13......	550	S.	21.826	19.6	53.0	553	N.	17.228	55.0	21.4	34.21
1......	556	N.	25.808	55.6	16.1	557	S.	13.628	16.9	56.1	34.74
10......	556	N.	25.302	51.7	16.9	557	S.	13.098	17.9	52.7	34.97
1......	560	N.	31.369	53.4	14.0	564	S.	9.060	13 9	53.7	34.60
1......	566	S.	18.860	14.7	54.5	568	N.	20.575	54.6	14.6	34.91
1......	571	S.	14.051	14.1	54.1	574	N.	26.982	54.0	14.0	35.07
1......	576	S.	19.670	15.0	54.8	578	N.	20.049	54.6	14.8	35.04
10......	576	S.	18.970	19.3	54.1	578	N.	19.390	53.0	18.1	34.40
1......	580	S.	27.885	13.2	53.3	582	N.	10.825	53.2	13.0	34.22
5......	580	S.	28.052	14.6	53.4	582	N.	10.990	52.6	13.6	34.30
1......	584	N.	28.653	55.0	14.9	586	S.	11.900	15.0	55.6	34.95
1......	591	N.	22.951	45.8	16.2	594	S.	17.788	16.0	45.9	34.86
10......	591	N.	22.696	52.9	17.9	594	S.	17.492	18.1	53.9	34.66
1......	595	N.	17.480	50.5	20.2	596	S.	21.640	19.0	49.7	34.63
1......	599	N.	21.990	51.4	20.7	602	S.	17.000	19.9	50.9	35.00
1......	603	N.	30.182	51.0	20.0	608	S.	9.762	19.1	50.8	35.28
1......	609	S.	15.200	18.9	50.1	611	N.	24.322	51.3	19.8	35.49
1......	613	S.	21.770	18.5	50.1	615	N.	18.300	50.9	19.0	34.70
1......	618	N.	31.371	50.6	18.9	620	S.	8.320	17.9	49.5	35.24
4......	514	N.	27.051	53.5	18.0	517	S.	12.750	17.0	52.8	35.16
4......	519	S.	13.305	18.5	54.2	521	N.	27.500	56.0	20.2	35.35
4......	525	N.	24.260	54.1	18.3	526	S.	15.931	17.0	52.8	35.29
4......	527	S.	24.560	17.8	53.4	529	N.	14.480	54.9	19.0	34.87
10......	527	S.	24.099	18.0	51.9	529	N.	14.040	52.8	19.0	34.60
4......	531	S.	26.481	19.9	55.4	535	N.	12.799	57.2	21.7	34.29
13......	531	S.	26.093	16.5	49.3	535	N.	12.431	50.9	18.0	34.49
4......	537	S.	17.218	16.7	52.2	538	N.	22.310	53.8	17.9	34.73
5......	537	S.	17.800	16.1	54.6	538	N.	22.900	56.4	18.0	34.85
4......	540	N.	11.360	54.1	18.1	542	S.	28.701	16.8	52.6	33.98
10......	540	N.	11.111	52.2	18.1	542	S.	28.433	16.7	50.9	34.12
4......	546	S.	28.836	15.6	51.5	547	N.	9.970	53.0	17.0	33.68
5......	546	S.	29.580	15.6	53.4	547	N.	10.720	55.8	18.0	34.18
4......	551	N.	28.130	53.3	17.1	555	S.	11.118	15.0	51.2	35.70
4......	558	S.	27.675	17.9	54.0	559	N.	12.349	56.0	19.9	34.04
5......	558	S.	27.018	16.0	53.8	559	N.	11.628	51.9	14.0	33.61
4......	562	N.	28.161	53.4	17.0	565	S.	10.518	15.0	51.4	35.13
4......	569	S.	23.680	16.1	52.8	573	N.	16.141	55.4	19.0	35.22
13......	569	S.	22.731	17.0	51.9	573	N.	15.251	54.1	19.0	34.38
4......	577	S.	13.730	18.1	55.0	579	N.	27.090	54.9	18.1	34.92
5......	577	S.	13.861	15.8	54.3	579	N.	27.209	54.2	15.4	35.31
4......	581	S.	19.324	17.0	53.6	583	N.	21.270	53.0	16.5	34.93
10......	581	S.	18.080	17.9	52.7	583	N.	20.955	51.2	16.7	34.54
4......	585	S.	15.650	16.3	53.0	588	N.	24.710	51.9	15.0	34.79
4......	592	N.	15.250	55.6	18.9	593	S.	25.004	19.7	56.3	34.44
5......	592	N.	14.820	55.2	15.6	593	S.	24.550	15.7	55.4	34.21
4......	597	S.	27.588	17.0	54.0	598	N.	12.110	53.2	16.0	34.05
12......	597	S.	26.579	19.9	50.4	598	N.	11.188	50.9	20.0	33.52
4......	600	N.	11.771	54.2	17.0	601	S.	28.519	18.1	55.2	34.63
12......	600	N.	10.801	48.9	17.9	601	S.	27.450	16.2	47.2	34.69
4......	604	N.	18.840	54.2	17.1	606	S.	20.900	17.9	55.0	34.41
4......	610	S.	31.090	14.0	51.2	612	N.	9.238	50.4	13.2	34.32
12......	610	S.	30.673	16.0	47.7	612	N.	8.901	48.8	17.0	34.45
4......	614	S.	14.399	16.0	53.4	619	N.	25.660	53.3	16.0	35.37
5......	469	N.	25.182	53.2	19.6	471	S.	13.740	17.0	51.3	35 48
5......	492	N.	21.960	54.2	17.1	495	S.	18.700	16.8	54.0	34.94
5......	500	N.	14.100	53.0	15.2	502	S.	26.160	16.0	54.0	34.27
13......	500	N.	13.622	50.9	19.8	502	S.	25.670	19.8	50.9	34.94
5......	504	S.	31.938	17.0	55.0	507	N.	9.161	56.1	18.0	34.44

Oct. 1, star 615 observed 16s late; Oct. 12, star 598 observed 12s late.

Station No. 10, near San Pedro River, 1 mile southeast of Monument No. 98—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 19′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Oct. 13	504	S.	30.890	20.2	51.6	507	N.	8.110	51.6	20.1	34.38
5	509	N.	23.960	54.5	16.0	513	S.	15.415	14.0	53.0	34.95
5	515	N.	22.381	54.0	15.0	520	S.	16.948	13.0	52.0	35.31
13	515	N.	21.718	51.7	19.8	520	S.	16.270	18.1	50.4	35.17
5	530	S.	12.618	16.1	54.7	532	N.	27.258	56.7	18.0	35.27
5	541	N.	25.719	53.9	15.7	544	S.	14.582	13.7	51.6	35.12
13	541	N.	25.209	51.0	18.0	544	S.	14.050	16.0	49.1	35.30
5	552	N.	12.175	53.2	15.6	554	S.	26.991	17.1	55.0	33.71
10	552	N.	12.374	51.2	16.6	554	S.	27.178	17.8	52.3	34.41
5	563	S.	28.298	16.9	54.9	570	N.	10.961	52.8	14.6	34.55
10	563	S.	27.901	17.1	52.7	570	N.	10.621	52.0	16.9	34.67
5	572	N.	27.501	55.9	17.8	575	S.	11.700	18.5	57.0	35.59
5	587	N.	13.281	54.0	14.6	589	S.	25.400	15.0	54.5	34.62
10	587	N.	12.575	52.0	17.0	589	S.	24.692	18.0	53.2	34.91
10	505	S.	10.568	19.5	51.9	508	N.	28.851	51.9	19.3	35.48
10	510	N.	18.662	52.3	19.8	512	S.	18.320	19.3	52.0	35.21
13	510	N.	18.797	51.1	19.9	512	S.	19.416	18.6	50.0	34.66
10	516	N.	31.980	51.0	18.0	518	S.	6.923	16.9	50.1	35.20
10	522	N.	19.688	52.1	18.9	524	S.	21.731	17.8	51.1	34.68
13	522	N.	19.250	49.2	17.0	524	S.	21.281	15.0	47.8	34.95
10	533	S.	9.740	18.5	52.3	534	N.	30.378	54.2	20.5	35.31
10	63	S.	22.859	17.0	54.5	76	N.	15.581	53.8	16.0	35.31
10	85	N.	22.070	54.5	17.0	91	S.	18.060	17.5	54.9	34.53
13	85	N.	21.140	57.0	19.5	91	S.	17.111	18.3	56.1	35.52
10	94	N.	17.301	54.2	17.0	105	S.	22.125	17.7	55.3	35.05
13	94	N.	16.926	54.0	16.0	105	S.	21.711	16.2	53.9	35.04
12	605	S.	11.501	18.9	50.0	607	N.	27.418	51.2	19.9	34.72
12	616	S.	17.202	17.7	49.2	617	N.	22.230	50.8	18.9	34.01
12	621	S.	26.040	17.9	49.6	2	N.	13.480	52.6	20.9	34.63
12	3	S.	15.129	20.9	52.9	8	N.	24.200	53.5	21.5	35.63
12	10	N.	18.015	49.6	17.5	11	S.	21.938	17.1	49.2	35.20
12	13	S.	29.810	19.9	52.0	19	N.	8.921	52.0	19.9	34.40
12	22	N.	16.530	51.7	19.3	30	S.	22.091	18.9	51.1	35.51
12	37	N.	21.619	50.9	18.0	45	S.	17.018	18.0	50.9	34.55
12	46	N.	9.261	51.9	18.9	51	S.	29.877	18.9	51.8	34.38
12	53	S.	16.780	17.1	50.3	60	N.	21.271	50.9	17.8	35.17
12	64	N.	19.930	49.9	16.8	67	S.	19.672	16.0	49.1	34.95
12	74	N.	11.930	50.9	17.9	80	S.	27.839	17.4	50.9	34.90
12	86	N.	22.491	52.0	18.5	96	S.	16.510	18.0	51.3	35.20
13	77	N.	15.461	53.3	16.4	81	S.	24.029	15.4	52.3	35.03
14	473	S.	21.092	22.3	50.1	474	N.	17.138	49.9	21.5	35.33
14	477	S.	29.400	17.9	47.0	479	N.	9.030	46.3	17.0	34.33
14	483	N.	18.120	52.0	22.0	486	S.	22.039	22.9	53.0	33.62

One turn of micrometer = 62.016″.

One division of level = 1.28″.

Total, 106 observations on 76 pairs.

Latitude of Station No. 10 = 31° 19′ 34.84″ ±0.04″.

Latitude of Monument No. 98 = 31° 20′ 04.67″.

Latitude Station No. 10 was on the east side of the San Pedro River; Monument No. 20—Emory—was on the west side of the river, about 1 mile northwest from the station. Near the station is a pile of stones, with inscription plates, which was at first mistaken for a boundary monument when locating the station.

Weight for pairs on which 2 observations were made, 1.0; one observation, 0.8.

The mean place for 1892, as used in the latitude computation, was for star No. 63, 18° 40′ 50.9″; for star No. 91, 11° 46′ 14.02″; for star No. 37, 58° 23′ 15.8″; for star No. 74, 57° 25′ 37.4″, and for star No. 86, 63° 8′ 16.5″.

Station No. 11, 1 mile east of La Noria, Ariz., near Monument No. 111.

Date.	Star No.	N. or S.	Micrometer reading.	Level.		Star No.	N. or S.	Micrometer reading.	Level.		Latitude, 31° 19′.
				N.	S.				N.	S.	
1892.			t.	d.	d.			t.	d.	d.	″
Nov. 2......	576	S.	20.545	21.5	53.8	578	N.	20.303	52.3	19.8	56.73
8.....	576	S.	19.800	20.0	52.2	578	N.	19.602	54.0	21.0	57.75
2......	580	S.	29.542	21.0	53.8	582	N.	11.864	52.8	19.9	57.28
5......	580	S.	28.521	18.6	55.3	582	N.	10.883	57.1	20.0	57.95
2......	584	N.	29.048	54.9	22.0	586	S.	12.920	22.0	54.8	57.74
2......	591	N.	23.320	52.0	19.0	594	S.	18.750	18.8	51.9	57.19
8......	591	N.	22.991	51.7	16.9	594	S.	18.330	13.4	48.8	56.92
2......	595	N.	18.823	54.9	21.5	596	S.	23.618	21.8	55.0	57.70
8......	595	N.	17.459	50.9	15.4	596	S.	22.213	15.5	51.0	57.10
2......	599	N.	22.457	51.2	17.3	602	S.	18.050	16.8	50.7	57.07
8......	599	N.	21.618	50.9	15.0	602	S.	17.191	14.0	49.9	57.43
2......	603	N.	31.031	51.9	18.0	608	S.	11.230	17.7	51.9	57.52
2......	609	S.	16.568	20.9	55.0	611	N.	25.102	56.8	22.3	58.08
8......	609	S.	15.356	17.0	53.5	611	N.	23.930	54.3	17.8	57.02
2......	613	S.	22.959	19.0	53.3	615	N.	18.920	54.0	19.8	57.17
8......	613	S.	22.379	17.9	54.7	615	N.	18.360	56.1	19.2	57.65
2......	618	N.	32.312	54.8	20.2	620	S.	9.880	19.0	53.2	58.22
2......	1	S.	12.880	17.9	52.0	5	N.	29.709	52.8	18.3	57.16
2......	9	N.	20.950	54.0	19.9	14	S.	19.940	17.9	52.4	56.60
2......	17	S.	19.520	19.0	54.1	23	N.	22.154	55.0	20.0	57.60
2......	27	N.	19.240	52.8	18.0	28	S.	23.420	16.7	51.0	57.31
2......	36	S.	12.929	19.9	54.7	39	N.	29.070	55.8	21.0	57.03
2......	46	N.	11.049	55.1	20.3	51	S.	32.241	18.4	53.2	57.81
2......	53	S.	17.940	19.0	53.9	60	N.	21.823	56.2	21.5	57.97
2......	64	N.	21.204	53.4	18.6	67	S.	21.529	17.0	52.0	56.72
2......	73	S.	24.160	21.1	56.2	78	N.	15.219	58.3	22.8	58.37
2......	85	N.	22.689	54.9	19.0	91	S.	19.280	17.0	53.0	58.06
5......	85	N.	21.481	55.5	14.2	91	S.	18.099	14.8	56.1	57.63
2......	94	N.	18 529	53.3	17.9	105	S.	23.890	15.9	51.3	57.52
2......	112	N.	17.320	53.8	18.5	120	S.	24.210	18.1	53.0	57.30
2......	123	N.	28.530	53.5	18.9	133	S.	13.381	17.8	52.0	57.68
2......	137	S.	21 611	17.0	51.2	139	N.	19.120	53.0	18.6	57.64
5......	137	S.	20.887	17.0	59.0	139	N.	18.360	58.6	16.7	57.78
2......	142	N.	22.882	52.7	18.1	147	S.	18.382	15.7	50.1	57.93
2......	153	S.	12.450	19.8	54.2	156	N.	29.240	53.0	18.5	57.43
3......	153	S.	12.229	18.0	55.2	156	N.	29.039	55.1	18.1	57.70
2......	165	S.	12.581	18.4	53.2	167	N.	28.102	52.0	17.1	57.28
3......	165	S.	13.280	18.0	55.3	167	N.	28.821	55.7	18.1	57.66
3......	504	S.	32.603	22.0	53.7	507	N.	9.112	53.9	22.1	57.41
8......	504	S.	31.282	19.9	55.1	507	N.	7.738	53.1	17.6	57.42
3......	509	N.	24.347	58.5	26.8	512	S.	16.538	25.3	57.3	57.52
3......	514	N.	27.942	54.1	22.0	517	S.	14.340	20.9	52.9	56.95
3......	519	S.	14.792	21.3	53.3	521	N.	28.281	54.8	22.7	57.10
3......	523	S.	18 462	19.0	51.0	528	N.	23.311	52.3	19.9	57.67
3......	531	S.	28.240	19.0	51.8	535	N.	13.889	53.2	20.9	57.14
8	531	S.	27.361	15.1	54.3	535	N.	13.040	57.2	17.9	57.02
3	537	S.	19.010	18.2	51.0	538	N.	23.430	52.1	19.2	56.69
5......	537	S.	17.683	18.9	53.2	538	N.	22.089	53.7	19.0	56.69
3......	539	S.	12.070	17.1	50.0	543	N.	30.240	51.0	18.0	56.29
3......	546	S.	31.120	21.1	54.1	547	N.	11.599	55.0	22.0	56.64
8	546	S.	29.431	18.3	50.0	547	N.	9.891	49.2	17.8	56.45
3......	550	S.	24.080	18.1	51.6	553	N.	18.762	52.9	19.3	57.45
3......	556	N.	26.320	52.8	19.3	557	S.	14.759	17.9	51.0	57.49
3......	560	N.	32.001	54.1	20.9	564	S.	10.320	18.6	52.1	57.25
3......	566	S.	20.268	21.0	54.7	568	N.	21.338	54.0	20.2	57.31
3......	571	S.	15.389	18.5	52.1	574	N.	27.673	51.4	17.8	57.48
3......	577	S.	15.060	17.1	51.2	579	N.	27.760	50.1	16.1	57.35
5......	577	S.	13.469	18.0	54.2	579	N.	26.200	55.1	18.3	57.60
3	581	S.	20.330	18.0	52.1	583	N.	21.678	51.8	17.7	57.05
8......	581	S.	19.100	17.8	51.0	583	N.	20.483	53.1	19.8	57.90
3......	585	S.	17.044	18.0	52.1	588	N.	25.500	51.5	17.1	57.06
3......	592	N.	15.829	53.1	18 9	593	S.	26.172	19.2	53.4	57.14
5......	592	N.	15.269	54.3	17.0	593	S.	25.590	17.8	54.9	56.37
3......	597	S.	28.270	16.2	50.9	598	N.	12.210	50.6	16.0	57.23
5......	597	S.	28.309	21.9	59.0	598	N.	12.268	60.0	22.9	57.65
3......	600	N.	12.235	52.2	18.0	601	S.	29.561	19.0	53.2	57.36
5......	600	N.	11.290	53.5	16.6	601	S.	28.591	16.9	53.8	57.23
3......	604	N.	19.261	52.0	17.7	606	S.	21.910	18.0	52.2	57.40
8......	604	N.	18.710	52.5	16.5	606	S.	21.316	16.0	52.1	57.17
3......	610	S.	32.161	17.7	52.1	612	N.	9.739	50.9	16.1	56.96

Nov. 8, star 594 observed 16s late; Nov. 2, star 147 observed 18s late.

Station No. 11, 1 mile east of La Noria, Ariz., near Monument No. 111—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level.		Star No.	N. or S.	Micrometer reading.	Level.		Latitude, 31° 19′.
				N.	S.				N.	S.	
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
Nov. 5......	610	S.	31.740	17.6	55.1	612	N.	9.351	55.1	17.4	56.99
3......	614	S.	15.720	19.2	54.0	619	N.	26.398	53.8	19.0	57.32
3......	3	S.	16.781	17.0	52.0	8	N.	25.201	51.8	16.8	57.98
3......	12	N.	13.341	53.8	18.9	16	S.	27.849	19.1	54.2	57.78
3......	18	N.	28.180	53.6	18.8	29	S.	14.910	19.1	54.2	57.27
3......	37	N.	23.145	53.1	18.2	45	S.	19.185	18.9	54.0	56.77
3......	50	N.	27.746	55.8	20.7	52	S.	13.893	21.1	56.2	58.23
3......	59	S.	16.442	17.9	52.8	61	N.	25.090	52.8	17.9	57.62
3......	65	N.	27.052	54.8	19.9	70	S.	15.814	20.0	54.9	57.32
3......	74	N.	12.970	51.7	16.8	80	S.	29.491	16.7	51.8	57.74
3......	86	N.	23.530	52.7	17.3	96	S.	18.192	17.8	53.2	57.18
3......	99	N.	20.014	54.1	18.8	115	S.	21.950	19.0	54.3	57.80
3......	119	N.	28.148	53.8	18.0	126	S.	14.140	17.8	53.9	57.04
3......	131	S.	22.430	18.2	54.5	140	N.	19.332	54.1	17.9	56.99
8......	131	S.	21.490	18.0	56.6	140	N.	18.451	59.2	20.7	57.74
3......	160	S.	24.220	18.0	55.0	162	N.	17.342	55.4	18.6	58.13
8......	160	S.	23.639	16.7	56.0	162	N.	16.781	55.0	15.9	57.16
3......	186	N.	19.110	55.2	17.0	188	S.	22.745	16.4	54.8	57.82
3......	192	N.	17.565	56.0	18.0	196	S.	23.561	17.9	56.0	57.27
8......	192	N.	16.549	55.5	16.0	196	S.	22.560	16.7	56.2	57.72
5......	505	S.	12.158	21.0	52.7	508	N.	29.738	54.9	23.0	57.41
5......	515	N.	21.570	50.4	17.9	520	S.	16.910	19.2	52.2	57.40
8......	515	N.	21.561	53.7	16.6	520	S.	16.841	15.0	52.9	57.27
5......	522	N.	19.091	52.3	19.3	524	S.	21.889	20.8	54.0	56.93
8......	522	N.	18.491	55.0	16.9	524	S.	21.231	15.0	53.2	57.35
5......	527	S.	24.369	16.1	50.1	529	N.	13.579	49.0	15.0	57.18
8......	527	S.	24.714	15.5	54.3	529	N.	13.991	56.9	17.9	57.42
5......	533	S.	10.590	17.1	51.2	534	N.	30.470	51.2	17.0	57.24
5......	540	N.	11.075	52.2	17.7	542	S.	29.089	16.2	51.1	57.60
8......	540	N.	11.070	47.8	16.2	542	S.	29.113	17.0	48.2	57.36
5......	548	S.	13.679	17.3	52.8	549	N.	26.804	54.0	18.5	56.99
5......	552	N.	12.199	50.4	15.0	554	S.	27.601	13.5	49.0	56.95
8......	552	N.	12.242	49.0	17.0	554	S.	27.651	16.3	48.1	56.90
5......	558	S.	27.710	17.8	53.1	559	N.	11.728	54.0	18.1	56.82
8......	558	S.	27.810	19.8	51.7	559	N.	11.822	51.8	19.8	56.84
5......	563	S.	28.391	19.0	55.0	570	N.	10.520	56.8	20.4	57.19
5......	572	N.	27.888	54.3	18.0	575	S.	12.653	15.8	52.0	57.21
5......	587	N.	13.389	53.1	15.9	589	S.	26.120	16.6	54.0	57.36
8......	587	N.	13.210	52.9	18.3	589	S.	25.854	15.0	49.9	57.48
5......	605	S.	12.330	18.1	55.1	607	N.	27.580	55.9	18.7	57.37
5......	616	S.	17.642	19.7	57.2	617	N.	22.000	58.0	20.1	57.11
5......	621	S.	27.058	17.1	55.1	2	N.	13.869	56.0	17.9	56.72
8......	621	S.	26.982	15.0	52.2	2	N.	13.815	54.0	16.7	57.03
5......	6	S.	29.160	14.9	53.0	10	N.	9.952	54.0	15.5	57.67
8......	6	S.	28.602	17.0	54.6	10	N.	9.450	56.9	19.2	57.27
5......	44	S.	26.889	17.8	57.7	49	N.	12.360	56.1	16.0	57.46
5......	54	N.	32.159	56.1	15.8	57	S.	7.620	16.9	57.3	57.31
5......	62	S.	25.719	14.6	55.1	76	N.	13.752	54.0	12.9	57.92
5......	77	N.	15.709	54.9	13.6	81	S.	24.901	14.0	55.1	57.38
5......	95	S.	16.673	15.6	57.0	98	N.	22.928	56.1	14.9	57.78
5......	101	S.	18.322	15.0	56.7	106	N.	21.903	56.1	14.9	57.83
5......	122	S.	20.611	13.9	55.9	129	N.	18.640	55.0	13.0	57.49
8......	569	S.	23.249	19.7	51.9	573	N.	15.070	52.3	20.1	57.30
8......	13	S.	30.865	16.0	53.6	19	N.	9.452	56.2	18.9	57.50
8......	22	N.	16.713	53.4	16.0	30	S.	22.860	15.7	53.3	57.80
8......	185	N.	17.831	56.7	17.0	190	S.	23.052	18.0	57.2	57.63

Nov. 8, star 522 observed 19ˢ late.

One turn of micrometer = 62.124″.

One division of level = 1.28″.

Total, 126 observations on 92 pairs.

Latitude of Station No. 11 = 31° 19′ 57.38″ ± 0.03″.

Latitude of Monument No. 111 = 31° 19′ 57.58″.

Latitude Station No. 11 was 2.0 meters east and 6.2 meters south of Monument No. 111.

Weight for pairs on which 2 observations were made, 1.0; one observation, 0.6.

The mean place for 1892, as used in the latitude computation, was for star No. 28, 14° 53′ 10.3″; for star No. 91, 11° 46′ 14.2″; for star No. 123, 35° 40′ 04.2″; for star No. 147, 24° 50′ 04.1″; for star No. 167, 62° 51′ 58.2″; for star No. 37, 58° 23′ 15.8″; for star No. 52, −1° 33′ 06.1″; for star No. 65, 46° 26′ 59.8″; for star No. 74, 57° 25′ 37.4″; for star No. 86, 63° 08′ 16.5″; for star No. 99, 34° 28′ 34.3″, and for star No. 192, 47° 25′ 24.8″.

Station No. 12, Nogales, Ariz., near Monument No. 122.

Date.	Star No.	N. or S.	Micrometer reading.	Level.		Star No.	N. or S.	Micrometer reading.	Level.		Latitude, 31° 20′.
				N.	S.				N.	S.	
1892.			t.	d.	d.			t.	d.	d.	″
Nov. 19......	580	S.	29.258	20.8	54.0	582	N.	11.349	52.6	19.0	4.83
23......	580	S.	28.724	17.7	52.0	582	N.	10.881	54.1	19.0	5.01
19......	584	N.	28.426	55.1	21.1	586	S.	12.491	21.7	55.9	4.01
26......	584	N.	28.343	50.0	21.7	586	S.	12.420	22.9	51.1	4.11
19......	591	N.	22.998	52.8	18.0	594	S.	18.649	18.7	53.3	4.48
26......	591	N.	22.330	48.0	19.2	594	S.	17.995	20.7	49.2	4.54
19......	603	N.	30.430	54.9	18.9	608	S.	10.808	17.9	54.1	4.77
26......	603	N.	29.627	50.0	20.8	608	S.	9.979	21.0	50.9	3.35
19......	609	S.	15.879	19.0	55.2	611	N.	24.201	55.3	19.0	5.04
26......	609	S.	15.811	21.5	51.1	611	N.	24.142	50.2	20.0	4.35
19......	613	S.	22.870	17.0	53.7	615	N.	18.648	54.0	17.1	3.88
26......	613	S.	22.610	20.0	50.1	615	N.	18.340	49.8	19.3	5.33
19......	618	N.	30.701	54.2	17.8	620	S.	8.451	17.0	54.0	4.75
26......	618	N.	31.008	50.3	19.9	620	S.	8.769	20.2	51.0	4.90
19......	1	S.	12.000	17.0	54.1	5	N.	28.649	54.2	16.9	3.97
19......	9	N.	20.491	54.0	16.2	14	S.	19.680	15.9	54.0	3.27
26......	9	N.	20.080	51.2	19.9	14	S.	19.300	20.3	52.2	4.22
19......	17	S.	18.836	17.0	55.1	23	N.	21.262	55.0	16.3	4.94
19......	27	N.	18.679	54.1	15.6	28	S.	23.061	16.0	54.9	3.98
19......	36	S.	12.652	15.0	54.0	39	N.	28.591	54.0	14.7	4.27
19......	44	S.	27.359	19.0	58.9	49	N.	12.660	58.3	18.7	5.08
19......	53	S.	17.579	22.0	52.3	60	N.	21.228	51.7	21.0	5.05
26......	53	S.	18.350	16.0	49.6	60	N.	22 003	47.9	14.2	5.04
19......	64	N.	19.911	50.9	20.0	67	S.	20.459	20.1	51.1	4.53
19......	74	N.	11.724	50.9	19.9	80	S.	28.450	20.0	51.1	5.77
19......	85	N.	21.589	49.4	18.1	91	S.	18.371	18.3	50.0	4.44
23......	85	N.	21.760	54.0	14.0	91	S.	18.549	14.1	54.2	5.32
19......	94	N.	17.401	48.8	17.0	105	S.	22.973	17.4	49.2	4.58
23......	94	N.	17 420	54.9	14.9	105	S.	23.011	16.0	56.1	5.21
19......	112	N.	16.429	51.0	19.0	120	S.	23.520	19.2	51.7	4.90
19......	123	N.	28.299	51.8	19.2	133	S.	13.324	19.3	52.0	4.19
19......	137	S.	21.032	19.7	52.0	139	N.	18.330	51.1	18.7	4.48
22......	137	S.	21.454	18.0	53.1	139	N.	18.768	54.0	18.8	5.52
19......	142	N.	21.929	53.2	21.0	147	S.	17.639	21.0	54.0	4.53
19......	153	S.	11.423	19.0	52.0	156	N.	28.041	50.9	17.9	4.75
19......	160	S.	23.700	20.4	53.4	162	N.	16.613	52.7	19.2	5.31
22......	160	S.	23.787	18.0	53.9	162	N.	16.741	54.1	18.0	5.04
19......	165	S.	12.490	19.2	52.9	167	N.	27.821	52.0	18.8	5.12
19......	186	N.	18.189	55.0	21.0	188	S.	22.060	21.5	55.7	6.00
23......	186	N.	18.110	51.7	20.9	188	S.	21.955	21.6	52.1	5.67
21......	548	S.	14.069	20.3	48.3	549	N.	26 902	47.8	19.2	4.48
22......	548	S.	13.551	19.0	50.1	549	N.	26.349	48.0	16.4	4.53
21......	550	S.	23.439	23.8	52.1	553	N.	17.851	52.1	23.7	4.81
21......	556	N.	25.230	49.9	21.0	557	S.	13.908	19.2	48.2	4.90
22......	551	N.	27.122	51.6	19.9	555	S.	10.990	18.1	50.6	3.80
22......	558	S.	27.778	20.0	52.3	559	N.	11.518	53.0	20.0	5.26
23......	558	S.	28.219	19.2	50.2	559	N.	11.929	49.9	18.8	5.69
22......	560	N.	30.930	52.0	19.0	564	S.	9.477	16.9	50.3	4.27
22......	566	S.	19.069	18.0	51.7	568	N.	19.959	53.2	19.4	4.64
22......	571	S.	14.322	17.9	52.0	574	N.	26.462	53.9	19.3	3.74
22......	576	S.	20.041	19.2	54.1	578	N.	19.621	55.1	19.9	4 53
26......	576	S.	20.250	24.0	52.0	578	N.	19.793	51.8	23.2	4.73
22......	581	S.	19.951	19.3	55.2	583	N.	21.120	56.3	20.3	4.15
26......	581	S.	19.479	21.5	50.0	583	N.	20.607	49.6	21.0	4.38
22......	585	S.	16 101	16.0	52.2	588	N.	24.440	54.0	17.0	2.91
22......	592	N.	14.980	54 4	17.6	593	S.	25.482	15.7	52.8	4.39
23......	592	N.	15.040	51.3	15.5	593	S.	25.551	15.0	51.1	3.80
22......	595	N.	17.647	54.0	16.7	596	S.	22.589	14.8	52.1	4.83
26......	595	N.	17.270	49.9	21.0	596	S.	22.279	21.5	50.4	5.43
22......	599	N.	21.680	53.1	15.0	602	S.	17.439	13.1	51.3	4.46
26......	599	N.	21.769	49.9	20.6	602	S.	17.592	21.6	50.9	4.73
22......	604	N.	18.568	54.9	16.2	606	S.	21.370	53.2	....	4.72
22......	610	S.	31.698	15.4	54.5	612	N.	9.101	55.9	16.9	5.69
23......	610	S.	31.878	18.0	55.3	612	N.	9.301	56.0	18.8	4.72
22......	614	S.	14.968	16.3	55.8	619	N.	25.461	57.9	18.0	6.04
22......	3	S.	16.569	22.0	53.2	8	N.	24.881	55.5	24.2	4.70
22......	12	N.	12.519	52.0	20.8	16	S.	27.209	19.0	50.3	6.57
22......	18	N.	26.961	52.1	20.4	29	S.	13.801	18.0	50.2	4.33
22......	37	N.	22.092	48.9	16.2	45	S.	18.300	15.1	48.0	5.10
26......	37	N.	22.079	53.9	21.0	45	S.	18.290	22.3	55.3	4.01
22......	46	N.	9.981	50.0	17.0	51	S.	31.368	16.8	49.3	5.20

Station No. 12, Nogales, Ariz., near Monument No. 122—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 31° 20′.
1892.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Nov. 22......	59	S.	15.850	18.1	51.3	61	N.	24.341	52.0	18.9	5.22
22......	65	N.	26.101	53.0	19.8	70	S.	15.010	18.5	52.0	4.89
22......	73	S.	24.511	19.0	52.2	78	N.	15.390	52.8	19.0	5.08
22......	86	N.	22.708	50.2	16.0	96	S.	17.510	15.0	49.4	4.49
26......	86	N.	22.290	53.8	19.2	96	S.	17.159	21.0	55.6	5.26
22......	99	N.	19.301	54.3	19.9	115	S.	21.358	18.9	53.8	4.50
22......	119	N.	26.780	51.1	16.0	126	S.	12.950	15.0	50.2	5.18
22......	130	N.	22.541	55.3	20.0	135	S.	18.739	19.0	54.5	5.85
22......	143	S.	15.070	17.9	53.1	145	N.	25.090	53.9	18.2	4.14
22......	146	N.	16.780	53.0	17.1	154	S.	23.905	16.9	52.8	4.63
22......	163	N.	27.787	51.2	15.0	166	S.	13.319	14.6	50.9	4.40
23......	163	N.	27.509	49.1	19.0	166	S.	13.060	19.1	49.8	4.64
22......	168	N.	14.821	54.0	17.7	182	S.	24.967	17.0	53.2	5.03
22......	185	N.	17.650	54.2	17.9	190	S.	23.048	17.1	54.0	5.27
22......	192	N.	16.595	55.2	18.8	196	S.	22.790	18.2	55.0	5.41
23......	192	N.	17.088	50.0	19.0	196	S.	23.304	19.2	50.2	5.80
23......	552	N.	11.700	42.7	17.8	554	S.	27.411	18.0	43.1	5.26
23......	563	S.	28.806	18.1	50.1	570	N.	10.622	49.9	17.0	5.66
23......	572	N.	29.240	50.9	18.0	575	S.	14.219	15.6	49.0	4.06
23......	577	S.	13.651	17.9	51.2	579	N.	26.195	53.1	19.0	4.36
23......	587	N.	13.260	52.7	17.0	589	S.	26.141	14.3	50.0	5.02
23......	597	S.	28.220	16.5	53.0	598	N.	11.979	53.0	16.3	4.22
23......	600	N.	11.081	54.0	17.0	601	S.	28.581	17.0	54.0	4.72
23......	605	S.	12.760	16.9	53.9	607	N.	27.881	56.0	19.0	3.50
23......	616	S.	19.018	16.5	54.0	617	N.	23.173	54.5	17.0	4.81
23......	621	S.	27.118	16.3	54.1	2	N.	13.720	54.8	16.7	4.57
23......	6	S.	29.802	18.0	56.3	10	N.	10.419	57.8	19.2	5.08
23......	13	S.	31.120	16.9	55.1	19	N.	9.452	56.1	17.3	5.40
23......	22	N.	16.729	55.9	16.9	30	S.	23.021	15.0	54.0	4.78
23......	38	S.	17.889	15.4	54.6	41	N.	22.483	55.9	16.8	5.10
23......	50	N.	27.360	54.1	14.9	52	S.	13.628	13.7	53.0	5.14
26......	50	N.	26.570	54.1	21.0	52	S.	12.873	22.0	55.5	4.94
23......	54	N.	32.111	54.1	14.9	57	S.	7.685	13.1	52.8	4.51
23......	62	S.	26.119	16.0	55.4	76	N.	14.041	57.1	17.4	5.37
23......	79	S.	21.100	16.4	56.1	84	N.	18.784	58.2	18.3	5.08
23......	113	N.	13.599	51.2	22.0	117	S.	24.977	23.0	52.2	5.48
26......	113	N.	14.096	52.7	17.8	117	S.	25.441	17.9	52.9	5.32
23......	122	S.	20.918	24.7	53.2	129	N.	18.808	50.9	23.1	3.25
23......	134	S.	18.518	21.9	49.2	141	N.	21.903	49.0	21.0	5.18
23......	152	S.	26.288	22.5	51.8	157	N.	15.009	51.1	21.9	5.43
23......	177	N.	11.033	48.8	18.0	183	S.	29.140	18.1	49.0	5.50
26......	569	S.	23.382	21.7	48.9	573	N.	14.918	47.4	19.9	4.50
26......	4	S.	13.880	19.9	51.0	7	N.	26.305	49.9	18.1	4.97
26......	20	S.	21.602	19.0	51.2	35	N.	16.142	49.9	17.0	4.36
26......	69	S.	13.392	19.0	52.8	75	N.	25.799	51.0	17.1	4.12
26......	77	N.	15.570	53.1	19.0	81	S.	24.948	21.0	54.9	4.51
26......	101	S.	17.931	21.0	55.6	106	N.	21.325	53.5	18.9	5.06
26......	131	S.	21.373	17.9	53.1	140	N.	18.112	52.0	16.2	4.05
26......	150	S.	24.179	17.9	53.8	158	N.	14.502	52.1	16.0	4.62
26......	172	N.	11.332	51.8	15.0	179	S.	28.340	16.0	52.9	5.86

One turn of micrometer = 62.124″.

One division of level = 1.28″.

Total, 121 observations on 93 pairs.

Latitude of Station No. 12 = 31° 20′ 04.77″ ± 0.04″.

Latitude of Monument No. 122 = 31° 20′ 00.73″.

Latitude Station No. 12 was 124.4 meters north and 170 meters east of Monument No. 122, in the grounds at the rear of the Montezuma Hotel.

The latitude and longitude piers, built of brick and cement, were left in position. These same piers were built and used earlier in the year by the Coast and Geodetic Survey.

Weight for pairs on which two observations were made, 1.0; one observation, 0.7.

The mean place for 1892, as used in the latitude computation, was, for star No. 28, 14° 53′ 10.3″; for star No. 74, 57° 25′ 37.4″; for star No. 91, 11° 46′ 14.2″; for star No. 123, 35° 40′ 04.2″; for star No. 147, 24° 50′ 04.1″; for star No. 167, 62° 51′ 58.2″; for star No. 37, 58° 23′ 15.8″; for star No. 65, 46° 26′ 59.8″; for star No. 86, 63° 08′ 16.5″; for star No. 99, 34° 28′ 34.3″; for star No. 135, 9° 39′ 28.3″; for star No. 192, 47° 25′ 24.8″, and for star No. 52, −1° 33′ 06.1″.

Station No. 13, Yuma, Ariz., in corral of quartermaster's department.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 32° 43′.
1893.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Jan. 18......	66	S.	21.223	17.0	49.6	71	N.	19.840	51.0	18.6	34.93
18......	82	N.	25.569	52.3	19.9	83	S.	15.752	18.9	51.3	34.61
18......	87	S.	9.301	18.0	50.8	89	N.	30.341	51.2	18.2	34.12
18......	91	S.	11.880	16.7	49.7	93	N.	29.160	50.9	18.0	34.67
24......	91	S.	11.521	18.9	50.2	93	N.	28.761	49.3	18.0	34.19
25......	91	S.	11.250	15.7	46.9	93	N.	28.527	47.9	16.8	34.20
17......	97	S.	28.239	21.6	53.3	104	N.	12.109	56.0	23.9	34.64
25......	97	S.	28.819	18.9	50.0	104	N.	12.619	49.9	18.8	34.86
18......	99	N.	22.024	50.2	17.0	103	S.	18.780	15.7	48.7	34.47
24......	99	N.	21.747	49.0	17.8	103	S.	18.569	18.1	49.7	34.92
18......	107	S.	22.464	18.7	51.7	111	N.	17.680	53.3	20.2	34.38
24......	107	S.	22.259	19.0	50.2	111	N.	17.410	49.3	18.0	34.53
18......	116	N.	21.230	53.0	19.9	118	S.	19.223	17.9	51.1	34.55
24......	116	N.	21.070	50.2	18.9	118	S.	19.119	18.6	50.1	34.90
25......	116	N.	21.027	51.8	20.7	118	S.	19.037	19.2	50.3	34.46
17......	121	S.	30.011	19.0	51.8	123	N.	11.200	50.3	17.9	33.63
18......	121	S.	29.759	19.9	53.3	123	N.	10.966	55.1	21.6	35.03
24......	121	S.	29.725	20.2	52.0	123	N.	10.879	51.0	19.3	34.66
25......	121	S.	30.127	19.5	50.7	123	N.	11.318	51.9	20.8	34.85
17......	128	S.	23.511	18.4	51.1	132	N.	17.319	50.8	17.9	34.41
18......	128	S.	24.010	17.5	51.2	132	N.	17.852	53.1	19.0	34.72
24......	128	S.	23.921	20.3	52.0	132	N.	17.708	51.2	19.7	34.67
25......	128	S.	23.871	20.0	51.3	132	N.	17.702	52.7	21.1	34.49
17......	135	S.	29.669	19.0	51.9	138	N.	10.283	51.7	18.9	35.14
24......	135	S.	29.370	19.1	51.0	138	N.	9.996	50.9	19.0	34.69
25......	135	S.	30.184	15.6	47.0	138	N.	10.841	49.0	17.7	35.06
17......	147	S.	22.186	19.0	52.2	148	N.	18.371	51.0	17.9	34.98
24......	147	S.	22.210	17.8	50.0	148	N.	18.408	49.1	16.9	34.66
18......	149	N.	10.741	51.9	17.0	155	S.	30.890	17.6	52.8	34.30
25......	149	N.	10.708	49.1	17.0	155	S.	30.889	18.8	50.9	34.52
17......	151	N.	32.274	50.9	17.4	159	S.	6.651	16.8	50.6	34.59
24......	151	N.	32.760	51.9	19.3	159	S.	7.140	18.9	51.8	34.52
17......	167	N.	23.308	54.0	19.9	169	S.	15.718	19.3	53.4	35.28
18......	167	N.	24.160	53.0	17.8	169	S.	16.601	19.0	54.2	35.15
25......	167	N.	23.763	50.9	18.1	169	S.	16.192	19.0	51.6	35.07
24.....	170	N.	23.675	51.6	17.7	173	S.	16.493	16.8	50.9	34.82
17......	174	N.	31.632	53.0	19.0	180	S.	7.971	19.2	53.2	34.28
25......	174	N.	31.468	51.0	18.6	180	S.	7.790	18.2	50.9	34.13
18......	178	N.	16.480	52.6	17.2	184	S.	23.839	18.6	54.0	34.58
17......	189	S.	24.216	19.0	53.2	192	N.	16.781	53.5	18.9	34.03
18......	189	S.	24.260	17.3	53.1	192	N.	16.809	51.9	15.9	33.73
24......	189	S.	24.370	17.0	52.0	192	N.	16.918	52.2	17.0	34.78
25......	189	S.	24.241	18.3	51.7	192	N.	16.780	50.9	17.0	34.32
17......	197	N.	18.911	56.1	20.9	200	S.	21.599	21.7	57.0	34.78
24......	197	N.	18.638	52.7	17.6	200	S.	21.311	17.8	52.9	34.96
18......	198	N.	21.640	54.9	18.9	204	S.	18.272	19.6	55.3	34.69
25......	198	N.	21.412	53.1	18.1	204	S.	18.006	17.9	53.0	34.15
17......	205	S.	15.860	18.1	53.9	208	N.	24.160	54.1	18.6	34.31
24......	205	S.	15.930	16.9	52.2	208	N.	24.250	53.3	17.9	34.43
17......	210	N.	14.489	52.7	17.0	212	S.	25.938	16.0	51.4	34.12
18......	210	N.	14.730	54.0	18.0	212	S.	26.219	18.9	54.8	34.16
24......	210	N.	14.990	52.0	16.3	212	S.	26.483	16.0	51.9	35.18
25......	210	N.	14.909	52.3	17.0	212	S.	26.367	15.9	51.2	34.66
17......	214	N.	16.143	53.3	18.0	217	S.	25.650	17.0	52.6	34.66
24......	214	N.	16.216	53.0	17.0	217	S.	25.692	15.3	51.7	34.46
25......	214	N.	16.511	52.5	17.0	217	S.	26.008	16.0	51.7	34.73
18......	218	S.	13.650	18.0	54.2	223	N.	28.683	54.1	17.9	35.39
17......	221	S.	9.640	17.0	52.7	225	N.	30.350	53.2	17.9	34.51
25......	221	S.	10.071	17.2	53.0	225	N.	30.800	53.7	17.7	34.26
24......	224	N.	9.849	53.9	17.6	226	S.	29.839	15.8	52.0	34.68
17......	227	N.	13.381	53.2	17.9	229	S.	26.960	17.0	52.6	34.96
24......	227	N.	13.509	57.0	20.4	229	S.	27.069	20.0	56.3	34.66

Station No. 13, Yuma, Ariz., in corral of quartermaster's department—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 32° 43′.
1893.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	
Jan. 18......	228	S.	24.034	17.0	53.6	230	N.	17.259	53.1	16.6	34.66
25......	228	S.	23.840	16.0	52.8	230	N.	17.078	53.0	16.3	35.02
17......	232	S.	9.030	15.4	51.8	233	N.	30.800	52.2	16.0	34.90
18......	232	S.	9.431	16.3	53.2	233	N.	31.219	53.3	16.7	34.53
24......	232	S.	9.159	18.0	54.2	233	N.	30.968	55.1	19.0	34.71
25......	232	S.	9.033	17.9	54.8	233	N.	30.811	55.1	18.0	35.21
17......	235	N.	30.276	53.0	16.3	237	S.	9.709	15.0	51.7	34.80
18......	235	N.	30.468	52.7	15.6	237	S.	9.921	14.9	51.9	35.18
24......	235	N.	30.674	53.2	17.0	237	S.	10.080	15.7	51.8	34.48
25......	235	N.	30.500	55.0	17.5	237	S.	9.950	16.4	54.0	35.65
17......	240	S.	19.120	18.0	54.8	244	N.	21.439	55.6	18.2	34.58
18......	240	S.	19.252	16.9	54.1	244	N.	21.560	54.9	17.2	35.07
24......	240	S.	18.759	17.0	53.0	244	N.	21.101	53.9	17.8	34.57
25......	240	S.	18.799	16.6	53.9	244	N.	21.125	54 1	17.0	34.74
17......	246	N.	8.900	56.5	19.0	249	S	31.530	17.0	54.9	35.15
24......	246	N.	8.470	53.3	17.3	249	S.	31.081	16.4	52.7	34.43
18......	247	S.	27.481	15.9	53.2	250	N.	12.683	54.0	16.3	34.18
25......	247	S.	27.952	16.1	53.9	250	N.	13.121	54.0	16.4	35.41
17......	252	S.	12.681	15.0	53.0	255	N.	28.110	54.1	16.5	33.95
24......	252	S.	13.272	15.7	51.8	255	N.	26.719	53.1	17.0	33.93
18......	256	S.	18.349	17.0	54.3	260	N.	22.391	55.2	17.9	34.92
25......	256	S.	17.978	15.1	53.3	260	N.	22.012	54.9	16.3	35.98
17......	257	S.	10.401	18.6	56.2	259	N.	30.929	58.4	21.0	35.43
24......	257	S.	9.672	16.1	52.3	259	N.	30.250	54.1	18.0	34.15
17......	262	N.	26.558	53.4	16.0	263	S.	14.740	14.0	51.3	34.91
18......	262	N.	26.586	53.0	15.6	263	S.	14.799	14.7	52.0	35.28
24......	262	N.	25.680	53.2	16.9	263	S.	13.849	14.0	51.2	35.31
25......	262	N.	26.851	55.1	16.6	263	S.	15.010	14.8	53.8	34.46
17......	264	N.	13.891	53.3	15.9	266	S.	26.542	16.9	54.3	34.43
25......	264	N.	14.111	55.1	16.0	266	S.	26.729	14.2	54.0	35.58
18......	264	S.	22.561	16.5	53.9	269	N.	19.309	54.3	16.9	34.58
24......	268	N.	24.019	57.4	19.2	271	S.	16.899	17.0	55.1	34.52
17......	272	N.	13.925	54.6	16.9	273	S.	27.411	18.8	56.3	35.60
18......	272	N.	14.149	55.1	17.7	273	S.	27.528	16.3	54.0	34.30
17......	275	S.	21.932	16.8	55.0	277	N.	17.958	55.9	17.2	33.87
18......	275	S.	22.531	16.0	53.9	277	N.	18.520	54 3	16.4	34.98
24......	275	S.	22.501	18.1	56.2	277	N.	18.480	54.9	16.8	34.71
17......	279	N.	16.200	55.5	17.0	280	S.	24.870	16.0	55.0	34.50
18......	279	N.	15.892	54.8	17.0	280	S.	24.600	16.3	54.2	35.69
24......	279	N.	15.859	54.0	16.0	280	S.	24.574	17.7	55.8	34.87
17......	282	S.	26.790	17.1	55.9	284	N.	13.990	55.9	17.2	34.71
18......	282	S.	26.811	15.6	53.3	284	N.	14.029	54.0	16.0	34.59
24......	282	S.	26.560	14.8	52.8	284	N.	13.719	50.9	12.3	35.08

One turn of the micrometer = 62.124″.
One division of level = 1.28″.
Total, 105 observations on 45 pairs.
Latitude of Station No. 13 = 32° 43′ 34.69″ ±0.03″.

Station No. 13 is in the east room of the adobe building which forms a part of the north wall of the old corral of the Quartermaster's Department, U. S. A. It is marked by a brick and cement pier which was built and used in 1892 by a Coast and Geodetic Survey longitude party. The latitude computation for this station made the probable error of a single observation ±0.28″, and the probable error of the mean of two star declinations ±0.02″. As it is certain that the declination errors are much larger, the weights for the separate pairs were assigned on the assumption that the probable error of the mean of two declinations was 0.9 of the probable error of a single observation.

Weight for pairs observed once, 1.0; twice, 1.4, three times, 1.6; four times, 1.7.

The mean place for 1893, as used in the latitude computation was, for star No. 91, 11° 46′ 31.8″; for star No. 97, —0° 51′ 13.2″; for star No. 99, 34° 28′ 51.5″; for star No. 123, 35° 40′ 20.3″; for star No. 135, 9° 39′ 43.7″; for star No. 147, 24° 50′ 18.3″; for star No. 167, 62° 52′ 10.2″; for star No. 192, 47° 25′ 34.7″; for star No. 223, 60° 17′ 06.5″; for star No. 226, 21° 26′ 11.8″; for star No. 227, 41° 05′ 21.4″; and for star No. 230 46° 49′ 45″

Station No. 14, 20 miles below Yuma, Ariz., near Monument No. 204.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 32° 29′.
1893.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Feb. 15......	E. J. c Persei	N.	12.241	45.2	15.2	J. ε Tauri.	S.	26.308	13.5	44.0	0.43
16......	P. 418	N.	23.178	51.1	19.0	204	S.	16.288	17.2	49.5	1.41
16......	209[1]	S.	18.399	18.9	51.8	219	N.	22.018	54.0	20.2	.63
15......	J. 4 Camelop	N.	29.361	50.4	19.9	217	S.	10.661	16.9	47.4	.63
15......	J. ε Aurigæ	N.	23.570	52.0	20.8	J. ι Tauri.	S.	15.432	21.0	52.2	.40
15......	J. η Aurigæ	N.	26.741	49.3	18.1	229	S.	12.149	18.0	49.0	.97
16......	P. 509	S.	12.930	17.8	52.0	235	N.	25.659	56.0	21.7	1.55
15......	232	N.	10.838	50.1	19.0	E. χ Aurigæ	S.	27.380	18.0	50.0	2.57
15......	241	S.	10.097	17.0	48.9	244	N.	29.901	48.9	16.8	.27
15......	E. J. ν Aurigæ	N.	22.590	52.0	19.4	249	S.	17.050	18.9	51.2	1.26
16......	E. β Aurigæ	N.	9.851	52.7	17.1	P. 602	S.	29.163	16.8	52.1	1.17
15......	P. 600	N.	11.881	54.0	21.3	E. J. ν Orionis	S.	27.973	23.7	56.2	.51
16......	254	N.	18.968	53.3	18.1	256	S.	22.061	17.9	53.0	.43
15......	E. J. 22 H. Camelop	N.	10.890	51.7	18.9	J. 10 Monocerotis	S.	28.338	16.4	49.9	1.67
15......	J. 51 Aurigæ	N.	12.542	53.0	19.6	J. ε Gemin	S.	26.541	21.6	55.1	1.51
16......	J. 51 Aurigæ	N.	11.911	52.2	17.1	J. ε Gemin	S.	25.858	17.0	52.2	1.28
15......	269	N.	24.958	53.2	19.8	P. 677	S.	15.331	19.2	53.7	1.56
15......	275	S.	8.169	19.7	54.0	J. 64 Aurigæ	N.	32.358	54.2	19.9	1.03
15......	279	N.	19.989	53.3	18.9	J. ι Gemin	S.	19.487	18.8	53.3	1.48
15......	P. 733	N.	9.494	52.9	17.6	285	S.	28.994	18.8	53.9	1.67
15......	286	N.	15.021	54.2	19.0	E. ϕ Gemin	S.	23.421	18.8	54.0	1.05
15......	289	S.	15.820	16.3	52.0	P. 774	N.	22.092	52.2	16.8	1.09
15......	292	S.	16.516	18.6	54.2	P. 795	N.	21.141	55.4	19.8	1.55
15......	J. Groom 1460	N.	24.772	54.0	17.9	P. 822	S.	15.732	15.6	52.0	1.59
15......	211	N.	16.204	52.0	21.3	212	S.	22.423	19.1	50.0	.34

One turn of micrometer = 62.124″.
One division of level = 1.28″.
Total, 25 observations on 24 pairs.
Latitude of Station No. 14 = 32° 29′ 01.12″ ± 0.08″.
Latitude of Monument No. 204 = 32° 29′ 0.91″.
Latitude Station No. 14 was 6.4 meters north and 1.5 meters west of Monument No. 204.
The only pair which was observed twice was given weight 1.4, and the other pairs weight 1.
The mean place for 1893, as used in the latitude computation, was, for star No. 217, 8° 42′ 57.9″, and for star No. 229 24° 07′ 23.95″.
February 15, star No. 249 observed 25[s] late.

Station No. 15, 13 miles south of San Diego, Cal., near Monument No. 258.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 32° 32′.
1893.			t.	d.	d.			t.	d.	d.	″
Sept. 27	E. J. β Cygni	S.	26.271	17.2	57.0	J. 15 Cygni	N.	12.953	56.0	16.0	1.41
30	E. J. β Cygni	S.	26.738	15.0	55.4	J. 15 Cygni	N.	13.412	54.2	13.0	1.55
Oct. 1	E. J. β Cygni	S.	26.268	21.1	53.0	J. 15 Cygni	N.	13.008	53.4	21.0	.68
2	E. J. β Cygni	S.	26.149	19.0	49.6	J. 15 Cygni	N.	12.861	49.2	18.8	1.32
Sept. 27	E. J. β Aquilæ	S.	31.069	15.2	55.2	493	N.	10.129	54.1	14.0	1.17
30	J. χ Cygni	N.	14.979	55.8	15.6	P. 1668	S.	25.119	16.9	57.0	1.40
30	P. 1742	N.	12.690	56.7	14.9	P. 1775	S.	28.350	15.5	57.9	.75
30	505	S.	15.480	13.0	55.1	511	N.	22.450	53.9	11.8	1.26
Oct. 2	505	S.	16.170	20.3	51.1	511	N.	23.180	51.2	20.8	1.19
Sept. 30	526	S.	23.600	14.0	56.0	E. J. 61 Cygni Pr	N.	15.638	55.8	13.4	.54
Oct. 1	526	S.	23.169	18.9	52.6	E. J. 61 Cygni Pr	N.	15.221	52.9	19.0	.65
Sept. 30	538	N.	12.068	55.0	13.0	548	S.	27.391	13.1	55.7	1.07
30	E. π Aquarii	S.	9.259	14.4	56.0	578	N.	30.351	55.9	14.1	1.27
Oct. 1	E. π Aquarii	S.	8.839	18.8	51.9	578	N.	29.951	52.0	18.9	1.02
2	E. π Aquarii	S.	9.990	20.7	51.2	578	N.	31.080	51.0	20.1	1.57
Sept. 30	J. 31 Cephei	N.	15.841	55.5	14.0	E. J. λ Aquarii	S.	22.709	14.0	55.9	.93
30	588	N.	9.192	56.8	14.9	P. 2095	S.	30.020	15.7	57.6	1.51
Oct. 2	588	N.	8.771	50.9	19.8	P. 2095	S.	29.566	18.9	51.0	1.74
Sept. 30	598	N.	9.081	56.0	13.8	608	S.	27.691	13.1	56.0	.99
Oct. 2	598	N.	10.130	50.0	17.9	608	S.	28.720	17.1	50.2	.77
Sept. 30	J. ρ Caesiop	N.	12.734	56.8	14.0	620	S.	27.869	13.8	56.7	1.33
Oct. 2	J. ρ Cassiop	N.	12.481	50.1	17.0	620	S.	27.599	17.0	50.9	.90
Sept. 30	2	N.	20.951	56.3	13.5	3	S.	19.069	13.0	56.0	1.33
Oct. 2	2	N.	20.250	52.5	18.8	3	S.	18.349	18.8	52.7	.93
Sept. 30	7	N.	28.231	56.0	13.0	13	S.	10.963	12.2	55.4	1.60
Oct. 2	7	N.	28.121	50.8	17.0	13	S.	10.842	17.8	51.2	.94
Sept. 30	32	S.	25.552	13.0	56.2	39	N.	14.590	56.6	13.3	1.00
30*	41	N.	18.885	56.8	13.9	44	S.	20.470	13.0	55.8	16.27
Oct. 1*	41	N.	18.621	51.9	15.7	44	S.	20.210	15.5	52.2	16.02
2*	41	N.	19.410	52.2	18.7	44	S.	20.980	19.9	53.2	15.00
Sept. 30	47	N.	21.970	57.9	15.1	52[1]	S.	16.819	14.2	57.1	1.28
Oct. 1	47	N.	22.741	54.8	17.9	52[1]	S.	17.629	18.0	54.7	2.18
2	47	N.	22.431	51.3	18.0	52[1]	S.	17.282	18.3	52.0	.92
Sept. 30	55	S.	12.138	12.0	54.8	58	N.	28.300	55.6	12.9	1.76
Oct. 2	55	S.	12.121	18.3	51.9	58	N.	28.279	51.0	17.8	1.38
Sept. 30	62	S.	19.850	14.7	57.3	65	N.	20.650	58.1	15.4	2.16
30	72	S.	19.390	14.0	56.7	74	N.	21.438	57.8	15.0	1.63
Oct. 1	72	S.	18.748	16.0	52.0	74	N.	20.781	52.0	16.1	1.67
Sept. 30	97	S.	16.660	13.9	57.1	104	N.	23.120	57.5	14.0	1.36
Oct. 1	97	S.	16.858	17.0	53.3	104	N.	23.300	52.8	16.0	1.47
Sept. 30	120	S.	26.218	15.8	58.9	123	N.	14.979	59.2	16.0	1.37
30	129	N.	16.623	58.0	15.0	131	S.	23.779	14.1	57.0	1.35
Oct. 2	129	N.	15.988	52.0	19.1	131	S.	23.162	19.3	52.0	1.63
Sept. 30	135	S.	17.768	15.0	58.0	138	N.	20.960	60.9	18.0	3.04
30	E. σ Arietis	S.	10.409	12.9	55.4	141	N.	28.519	56.8	14.0	1.42
30	147	S.	9.090	12.9	55.9	148	N.	27.825	56.8	13.8	1.82
30	171	S.	29.989	12.8	56.2	177	N.	9.299	57.0	13.1	1.55
30	182	S.	21.889	14.3	58.1	186	N.	15.988	58.5	14.6	1.51
30	189	S.	12.361	13.0	57.1	192	N.	27.317	57.2	13.0	1.22
30	197	N.	29.221	57.4	13.0	200	S.	9.477	11.0	55.9	1.78
30	P. 418	N.	20.509	59.0	14.1	204	S.	19.409	13.0	57.9	1.43
30	211	N.	14.920	57.9	12.8	212	S.	26.963	11.1	56.4	.62
30	214	N.	26.230	59.9	14.6	217	S.	13.390	13.1	58.7	1.56
30	224	N.	21.031	59.1	13.9	226	S.	18.746	12.8	58.0	1.48

*Observed wrong star; rejected.

Station No. 15, 13 miles south of San Diego, Cal., near Monument No. 258—Continued.

Date.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Star No.	N. or S.	Micrometer reading.	Level. N.	Level. S.	Latitude, 32° 32′.
1893.			*t.*	*d.*	*d.*			*t.*	*d.*	*d.*	″
Oct. 1......	224	N.	20.972	51.2	13.2	226	S.	18.720	13.8	51.7	1.52
Sept. 30......	227	N.	24.049	58.3	13.0	229	S.	15.321	13.0	58.2	1.03
30......	P. 509	S.	17.301	13.0	58.2	235	N.	24.051	59.4	13.6	2.93
30......	239	S.	14.774	12.7	58.6	242	N.	26.231	59.2	13.2	.60
30......	246	N.	18.599	59.0	13.8	249	S.	18.990	13.0	58.0	1.24
30......	P. 600	N.	8.175	57.0	12.0	253	S.	30.165	11.8	56.1	.42
Oct. 1......	J. ο Draconis	N.	20.452	47.8	17.0	473	S.	14.609	16.9	48.0	1.22
1......	P. 1646	N.	17.379	51.8	20.6	477	S.	19.780	20.3	51.9	1.23
1......	P. 1715	N.	27.861	54.8	22.0	498	S.	8.459	21.0	54.1	1.84
1......	502	S.	10.671	18.4	51.6	509	N.	28.706	52.8	19.0	1.10
1......	J. 73 Draconis	N.	8.720	52.0	18.1	J. ε Aquarii	S.	29.560	17.9	51.8	.47
1......	E. J. τ Cygni	N.	10.191	52.2	18.8	P. 1928	S.	29.091	18.3	52.2	1.98
1......	E. J. 74 Cygni	N.	20.175	53.4	19.0	J. χ Pegasi	S.	18.470	18.1	52.9	1.09
1......	562	N.	11.970	52.8	19.0	E. J. α Aqnarii	S.	27.560	18.9	52.1	1.38
1......	580	S.	21.879	17.0	50.1	E. J. ι Cephei	N.	16.749	50.0	16.9	.87
1......	591	N.	22.618	52.2	19.1	P. 2104	S.	18.509	19.0	52.1	2.75
1......	J. χ Androm	N.	12.929	50.8	17.0	614	S.	26.748	17.0	50.9	1.27
1......	E. J. ω Piscium	S.	25.901	17.2	51.2	E. J. β Cassiop	N.	12.800	51.3	16.9	1.10
1......	4	S.	27.691	18.2	53.0	5	N.	11.481	53.0	18.0	1.78
1......	15	S.	11.172	15.6	51.0	23	N.	29.472	50.8	15.1	2.19
1......	28	S.	13.817	15.9	51.7	31	N.	26.571	51.7	15.9	1.66
1......	60	N.	26.061	54.2	18.0	68	S.	13.648	18.3	54.2	2.34
1......	121	S.	18.820	16.0	53.0	123	N.	22.581	52.2	15.5	1.11
2......	121	S.	18.561	20.6	53.5	123	N.	22.321	53.2	20.3	1.58
1......	128	S.	11.842	14.4	51.0	132	N.	28.223	50.3	13.9	.85
1......	134	S.	18.209	16.9	53.5	J. ν Persei	N.	19.600	53.4	16.0	1.19
1......	149	N.	21.139	54.0	16.2	155	S.	18.788	16.8	55.0	.95
1......	173	S.	30.909	15.0	55.4	P. 350	N.	10.681	53.2	12.9	2.05
1......	191	S.	27.762	14.9	55.1	193	N.	10.169	54.0	13.8	1.77
1......	199	N.	23.236	56.0	16.3	E. J. ε Tauri	S.	16.021	17.0	57.0	1.19
1......	P. 444	S.	13.511	14.9	54.8	P. 477	N.	24.949	53.1	14.8	.57
1......	228	S.	11.762	15.2	53.0	230	N.	27.318	53.0	15.2	.83
1......	232	N.	8.041	53.9	16.2	E. χ Aurigæ	S.	30.510	17.2	53.8	2.57
1......	241	S.	13.011	16.0	53.8	244	N.	26.862	53.0	15.0	1.76
1......	250	N.	10.151	55.8	17.7	P. 605	S.	28.390	17.8	57.0	1.28
2......	E. J. β Lyræ	N.	24.748	47.2	18.0	P. 1621	S.	14.688	17.7	47.3	.77
2......	E. J. ι Lyræ	N.	27.217	49.0	19.1	P. 1669	S.	10.740	18.2	48.8	1.75
2......	494	S.	27.411	21.8	52.2	P. 1771	N.	12.731	52.8	22.0	1.25
2......	533	S.	23.601	19.2	50.2	543	N.	16.186	50.6	19.1	.72
2......	E. J. ε Pegasi	S.	30.711	20.0	51.0	560	N.	8.749	50.1	19.1	.09
2......	564	S.	8.941	19.7	50.5	572	N.	29.808	50.1	19.3	.95
2......	J. 13 Lacertæ	N.	27.719	51.0	20.2	586	S.	13.909	20.3	51.2	1.60
2......	24	N.	23.180	52.7	18.4	33	S.	16.626	19.0	53.0	1.55
2......	66	S.	9.169	17.9	50.9	71	N.	30.470	50.9	17.9	1.99
2......	107	S.	11.432	20.6	53.1	111	N.	29.259	52.8	20.0	.67

One turn of micrometer = 62.059″. One division of level = 1.28″. Total, 96 observations on 76 pairs.

Latitude of Station No. 15 = 32° 32′ 01.36″ ± 0.04″.

Latitude of Monument No. 258 = 32° 32′ 01.34″.

Latitude Station No. 15 was 0.6 meters north and 5.1 meters east of Monument No. 258.

Weight for pairs on which one observation was made, 1.0; two observations, 1.2; three observations, 1.3; four observations, 1.3.

The mean place for 1892, as used in the latitude computation, was for star No. 65, 46° 27′ 18.5″; for star No. 74, 57° 25′ 55.9″; for star No. 97, −0° 51′ 13.2″; for star No. 135, 9° 39′ 43.7″; for star No. 147, 24° 50′ 18.3″; for star No. 192, 47° 25′ 34.7″; for star No. 217, 8° 42′ 57.9″; for star No. 226, 21° 26′ 11.8″; for star No. 227, 41° 05′ 21.4; for star No. 229, 24° 07′ 23.4″; for star No. 246, 39° 06′ 59.7″; for star No. 28, 14° 53′ 30″; for star No. 230, 46° 49′ 45″.

Star No. 123 was by mistake used twice at this station in different pairs.

The computations of the latitude were made by the formulæ and tables given in the Coast and Geodetic Survey Report for 1880, Appendix No. 14, with the exception of certain changes noted below.

The formula for the level correction as there given is intended for a level in which the graduations are marked from the middle outward in both directions. The graduation on the level used in these observations is numbered *continuously from one end to the other*, the zero being nearest the eyepiece. If n and s be the north and south reading of the level for the south star, and n' and s' the same for the north star, and b the value of one division, then the correction for *this* level is $\frac{b}{4}\left\{(n'+s')-(n+s)\right.$.

The table given in the appendix referred to for the difference of refraction of the two stars of a pair is based upon the supposition that the refraction at the station corresponds with sufficient accuracy to the mean refraction at sea level. The elevation above sea level at the station occupied was great enough in some cases to diminish the refraction by 15 per cent or more. In these cases the values given for the differential refraction were diminished in that ratio.

The latitude from each individual observation being computed, these values were combined and the probable errors computed as follows:

Let N = total number of observations at the station;
n = number of observations on any pair;
p = number of pairs;
Δ = difference between the latitude from each observation and the mean result for the pair;
$\Delta\varphi$ = the difference between the result for latitude from any one pair and mean result from all pairs;
e = the probable error of a single observation;
e_ϕ = the probable error of the mean result from a single pair;
e_δ = the probable error of the mean of two star declinations;
e_0 = the probable error of the final weighted mean of the pairs;
w_1, w_2, w_3 = the weight assigned to the separate pairs;

Then,

$$e^2=\frac{0.455\Sigma\Delta^2}{N-p} \qquad e_\phi{}^2=\frac{0.455\Sigma\Delta\varphi^2}{p-1} \qquad \varepsilon^2=\frac{e^2}{p}\Sigma\frac{1}{n} \qquad e_\delta{}^2=e_\phi{}^2-\varepsilon^2.$$

The weights w_1, w_2 assigned to the separate pairs, must be proportional to the quantities $\frac{1}{e_\delta{}^2+\frac{e^2}{n}}$ for the respective pairs.

$$e_0{}^2=\frac{0.455\ \Sigma\ w\ \Delta\varphi^2}{(p-1)\Sigma\ w}$$

The following table indicates the degree of accuracy attained at each station and the plan of work as to number of observations and number of pairs:

Station.	Number observations.	Number pairs.	e.	e_δ.	e_0.	Total range.	Greatest range on any pair.	Number observations rejected.
			″	″	″	″	″	
No. 1	67	19	±0.38	±0.15	±0.06	3.28	2.10	1
No. 2	39	39	....	....	± .07	3.29	....	....
No. 3	46	46	....	....	± .05	2.33	....	1
No. 4	130	19	± .36	± .09	± .04	4.04	3.08	1
No. 5	99	50	± .22	± .21	± .04	2.04	.95	....
No. 6	102	57	± .20	± .24	± .04	2.28	1.26	....
No. 7	99	63	± .26	± .20	± .04	2.50	1.76	1
No. 8	100	75	± .21	± .18	± .03	2.02	.95	....
No. 9	101	72	± .19	± .24	± .03	2.21	.88	....
No. 10	106	76	± .21	± .25	± .04	2.18	.99	....
No. 11	126	92	± .23	± .14	± .03	2.08	1.06	....
No. 12	121	93	± .31	± .29	± .04	3.66	1.45	....
No. 13	105	45	± .28	± .02?	± .03	2.35	1.40	....
No. 14	25	24	....	....	± .08	2.30	....	....
No. 15	96	76	± .22	± .32	± .04	2.95	1.26	3
	1,362	....	....	....	....	....	....	7

The number of observations as given in the table is the number actually used after the rejection of erroneous observations, as indicated in the last column.

At Stations Nos. 2 and 3, where only one observation was taken on each pair, and at Station No. 14, where but one pair was observed more than once, the probable error of a single observation can not be computed by the formula given above. In those cases the ordinary formulæ for independent observations of equal weight were used to compute the probable error of the result for latitude from any one pair (including *both* errors of observation and of declination). The probable error of the latitude from a single pair observed once as thus derived is for Station No. 2, ± 0.44″; for Station No. 3, ± 0.35″, and for Station No. 14, ± 0.38″.

The computed value for the probable error of a single observation depends only upon observations on pairs which were observed more than once. For Stations No. 5 to No. 12, and No. 15, it therefore depends upon but a small portion of the observations. As the computed probable error of declination, however, depends upon the difference between e_ϕ^2 (computed from *all* the observations) and e^2, too small a value for e will give too large a value for e_δ, and vice versa. For this reason the two columns giving e and e_δ should *both* be considered in judging of the accuracy of the observation.

At Station No. 4 the formulæ gave for e ± 0.36″ and for e_δ ± 0.09″. This value for e_δ is evidently much too small. Instead of assigning weights according to these values of the probable errors all pairs were given equal weight, each pair being observed either six or seven times. On the first night of observation and during the early part of the second night the wind was blowing in through the slit in the observatory roof in *puffs*; the latitude level showed rapid changes of inclination of the vertical axis, and the residuals indicate a less accuracy than usual.

At Station No. 13 the formulæ gave for e ± 0.28″ and for e_δ ± 0.02″. This computed value of e_δ being evidently much smaller than the reality, the different pairs were given weights on the assumption that in fact $e = 0.9\ e$.

Most of the observations were made under meteorological conditions very favorable to accurate observation. The typical working night was perfectly clear, with no strong winds, and with air so dry that no dew fell even during the cool morning hours. Under such conditions the stars, except near sunset, showed very brightly and with little or no twinkling or dancing as seen with the telescope.

The door of the observatory tent was kept open and the circulation of air through floor, sides, roof, and door of the tent usually kept the temperature inside the tent within less than a degree centigrade of the temperature outside. This seemed to be an important factor in controlling the apparent steadiness of the stars; for at Nogales in a wooden building and at Yuma in an adobe building, with the outside meteorological conditions just as favorable as before, there was a much greater difference between the inside and outside temperature, and the stars showed a marked unsteadiness as compared with their usual appearance.

The value of micrometer was determined at every station save No. 14. In each case, except at Station No. 11, transits across the thread of Polaris near elongation were observed, the thread being set at each half-turn in succession for the twenty turns nearest the middle of the field of the telescope and the time of transit observed by eye and ear. At Station No. 11 similar observations were made upon λ Ursæ Minoris.

The value of micrometer was computed from these observations by the formulæ of the appendix already referred to. (Coast and Geodetic Survey Report, 1880, Appendix No. 14.)

During the first set of observations, on February 15, 1892, the quarter-turns were also observed on the middle ten turns to detect periodic error in screw value. The values of the four quarter-turns as derived separately agreed with each other within the respective probable errors, and thus gave a nil result.

Summary of micrometer determinations.

Station.	Date.	Value of one turn.	Probable error of one turn.	Temperature during observation.
		″	″	C
No. 1	Feb. 15, 1892	62.227	±0.008	....
No. 1	Feb. 19, 1892	62.107	± .010	9
No. 1	Feb. 27, 1892	62.223	± .012	10
No. 2	Mar. 23, 1892	62.163	± .014	12
No. 3*	Apr. 10, 1892	62.118	± .008	26
No. 4	Apr. 22, 1892	62.105	± .006	7
No. 5	May 30, 1892	62.093	± .008	16
No. 6	June 21, 1892	62.101	± .017	26
No. 7	July 26, 1892	62.078	± .009	19
No. 8	Aug. 15, 1892	62.099	± .017	23
No. 9	Sept. 7, 1892	62.164	± .010	23
No. 10	Oct. 4, 1892	62.016	± .011	24
No. 11	Nov. 8, 1892	62.025	± .016	2
No. 12	Nov. 25, 1892	61.898	± .014	8
No. 13	Jan. 25, 1893	61.994	± .031	10
No. 15	Sept. 25, 1893	62.059	.009	16

* Illumination from sky only.

The observed micrometer value apparently is not a function of the temperature at the time of observation.

The latitude at Station No. 1 was computed with the value of one turn = 62.225″, the mean of the observations of February 15 and 27, rejecting the observation on February 19. The value of one turn as derived from the *latitude* observations at the station is 62.207″.

At Stations No. 2 to No. 10, and No. 15, the value of micrometer as observed at the station and shown above was used in computing the latitude.

The mean of the first twelve values of one turn in the above table is 62.124″. At Station No. 11 the latitude observations, when reduced with the value, 62.025″, as observed at that station, showed a total range of 3.85″, apparently systematic with reference to micrometer differences. The micrometer value was then derived from the latitude observations and found to be 62.123″. As this corresponded very closely with the mean value given above, the observed value at the station was rejected and the observations reduced with said mean value, 62.124″. The total range in the results for latitude as thus computed was 2.08″.

At Station No. 12 the values for the latitude showed an abnormal range when reduced with the value of micrometer as observed at the station, namely, 61.898″. The value was then deduced from the latitude observations and found to be 62.086″. The final latitude computation was made with the mean value mentioned above, 62.124″.

At Station No. 13 a similar condition of affairs was again found. The latitude observations, as reduced with the value of micrometer observed at the station, 61.994″, showed a range of 4.10″. The micrometer value, as deduced from the latitude observations, was 62.120″. The final latitude computation, as made with the mean value, 62.124″, showed a total range of results of 2.35″ only.

No adequate explanation was found for the apparently erroneous observations of micrometer value at Stations No. 11 and No. 12. At Station No. 13 the observations were taken in an adobe building; the temperature was remarkably different inside and outside; the line of sight passed through a comparatively small hole in the wall; the apparent motion of the star was unsteady, and the computed probable error of the result is two or three times as large as for similar observations at other stations.

The micrometer value was deduced from the latitude observations in the cases mentioned above, as follows: Let φ be the mean latitude (as deduced with an approximate micrometer value), from pairs on which the micrometer difference (S–N) was positive, φ_2 the mean latitude from pairs with minus micrometer difference, D_1 the mean of plus micrometer differences, and D_2 the mean of minus micrometer differences. Then the correction to the approximate value for one turn of micrometer is $\frac{2(\varphi_2-\varphi_1)}{D_1-D_2}$

The effect on the computed latitude of an error, *m*, in the assumed value of one turn of micrometer may be estimated as follows: Let d_1, d_2, d_3, ... be the micrometer differences, and w_1, w_2, w_3, ... the assigned weights of the respective pairs Then the computed value of the altitude will be in error by $\frac{\Sigma wd}{2\Sigma w}.m$

This is upon the assumption that the actual value of micrometer remains sensibly constant during the stay at any one station. The focal adjustments were never changed at a station after they were made at the beginning of the first night's observations. An increase of temperature lengthens the barrel of the telescope and *also* lengthens the micrometer screw. The first change *decreases* the micrometer value and the second *increases* it. The combined effect is to change the micrometer value by a very small amount, depending upon the difference of the coefficients of expansion of the brass telescope barrel and the steel screw. The other effects of temperature are difficult to predict.

At each station the value $\frac{\Sigma wd}{2\Sigma w}$ was made as small as was conveniently possible. The *actual observed* micrometer differences multiplied by approximate weights were summed for each night, and the list for the last night so chosen as to make the sum for the station nearly zero. The values of $\frac{\Sigma wd}{2\Sigma w}$ for the separate stations are: At No. 1, −0.10; at No. 2, +0.03; at No. 3, +0.18; at No. 4, −0.01; at No. 5, +0.06; at No. 6, −0.02; at No. 7, −0.16; at No. 8, +0.02; at No. 9, −0.17; at No. 10, −0.18; at No. 11, +0.36; at No. 12, −0.06; at No. 13, +0.02; at No. 14, −0.08; and at No. 15, −0.04. It is probable that the error of latitude from this cause is not greater than 0.01″ at any of the fifteen stations. An error in the assumed micrometer value tends, by increasing the range of results, to make the computed probable error of the final result for latitude greater than it actually is, provided the micrometer differences nearly balance.

The levels furnished with the zenith telescope were tested with a Coast and Geodetic Survey level trier under favorable conditions at the Coast and Geodetic Survey Office at Washington, D. C., in January, 1892. The mean values from the observations are:

Level marked "20*a*", with Wurdemann zenith telescope, No. 20, one division =1.04
Level marked "20*b*", with Wurdemann zenith telescope, No. 20, one division =1.28
Level marked "19*a*", with Wurdemann zenith telescope, No. 19, one division =1.45
Level marked "19*b*", with Wurdemann zenith telescope, No. 19, one division =2.08

The greatest variation in the value of one division in any of these tests was 0.06″ from the mean. Level "20*a*" carries 1 mm. graduations and the others 2 mm. graduations.

Level "20*b*," one division = 1.28″, was used during all the latitude observations. A test of this level by intervals of about two divisions showed it to be sensibly regular, even to the extreme ends. The bubble moves with a remarkably smooth motion.

At Station No. 1 the average level correction is about + 0.5 division. The assumed value of one division may be in error by as much as 0.04″, and therefore the computed latitude may be in error 0.02″ from this cause. At all the remaining stations the instrument was releveled as soon as the level correction became as much as one division. No difficulty was found in keeping almost all the level corrections within this limit, and the *average* level correction at each station is but a small fraction of a division. At these stations the error in latitude arising from error in level value is probably not greater than 0.01″.

The uniform practice was for the recorder to call out the chronometer time of transit of the star across the meridian for every star observed. This enabled the observer to detect any motion of the telescope in azimuth and to keep it so nearly in the meridian at all times as to prevent any sensible errors from that cause.

But *one* of the three horizontal threads was ever used for latitude observations. That one was adjusted before beginning observations at each station so as to be so nearly horizontal that a series of pointings on a star passing through the field when the telescope was in the meridian all agreed within the hour of pointing. This adjustment was sometimes found slightly disturbed after transportation, but usually remained perfect.

The star was bisected as soon as it reached the safe portion of the eyepiece field and kept bisected until it reached the meridian.

The wooden pier used as a support for the zenith telescope proved to be as stable as a masonry pier. The instrument, after having been leveled, usually remained for two or three hours with its vertical axis so nearly vertical that the level correction was less than one division (1.28″).

It was not uncommon for the level correction to remain without releveling less than one division during the whole of a night's work, even in cases in which the observations extended through nearly all the hours of darkness. When using the *wooden pier* the observations for a night usually show a very slow motion of the vertical axis of the instrument so as to incline more and more to the southward, as if the southern side of the pier were gradually becoming shorter relatively to the northern side. This motion was exceedingly slow; so slow that, as stated above, the level correction usually remained less than one division for hours at a time without releveling.

To obtain an additional check on the degree of accuracy of the star places and of the observing, advantage may be taken of the fact that on each of the parallels *the same pairs were observed at several stations.* Each observation may be considered as a determination of the correction to the mean declination of the two stars observed.

Let R $=$ Final mean latitude of station minus the latitude from any one observation;

Then $\varDelta\delta$ $=$ Most probable correction to the mean declination for the pair;

$=$ Mean value of R for that pair from all observations at all stations;

Let r $= R - \varDelta\delta$.

Let N be the total number of observations at the series of stations treated as a single group; P the total number of pairs observed, and n the total number of observations *on any one pair* at all the stations.

The probable error of a single observation $= e = \sqrt{\frac{0.455 \Sigma r^2}{N - P}}$

By the same process of reasoning as is employed in separating errors of observation and of declination in the latitude at a single station there is obtained:

$e_\delta =$ the probable error of the mean declination for a pair;

$$= \sqrt{E_\delta^2 - E^2} \text{ in which } E_\delta^2 = \frac{0.455 \Sigma \varDelta\delta^2}{P - 1} \text{ and } E^2 = \frac{e^2}{P} \Sigma \frac{1}{n}$$

The above formulæ presupposes that the several determinations of the declination correction to a pair made at any one station are independent, which they are not, inasmuch as they involve a common error—the error of the mean latitude for the station; but this inaccuracy of the formulæ is hardly appreciable for the series of stations in question.

An error of declination which is constant for the whole list of stars used will not, of course, be detected by this method.

For the parallel 31° 47′, 272 observations at Stations No. 1 to No. 4 on 40 pairs, all from Professor Safford's list, treated by the above formulæ give for the probable error of a single observation $e = \pm 0.35''$, and for the probable error of the mean of two declinations $e_\delta = \pm 0.20''$. This value for e agrees quite closely with that derived from the latitude computations for each station, namely, $\pm 0.38''$ at No. 1 and $\pm 0.36''$ at No. 4. The latitude computation gave for e_δ at these stations $\pm 0.15''$ and $\pm 0.09''$, considerably smaller values than that given by the group of stations. The probable errors for the separate stars, as stated in Professor Safford's list, gives for $e_\delta \pm 0.18''$. Of the derived corrections $\varDelta\delta$ to the mean declination for a pair the greatest was $\pm 1.02''$; but 9 of the 40 exceeded 0.50″ and 19 were less than 0.20″.

At Stations No. 5 to No. 12, on the parallel 31° 20′, 819 observations on 183 pairs, all from Professor Safford's list, gave for $e \pm 0.28''$ and for $e_\delta \pm 0.17''$. For the same stations the mean results from the latitude computations were $e = \pm 0.23''$ and $^e\delta = \pm 0.22''$. The probable errors of declination for the separate stars as given in Professor Safford's list would make e_δ for these stars $\pm 0.17''$, in agreement with the result from the group of stations.

Of the 183 corrections, $\varDelta\delta$ in this group the greatest was $- 1.10''$; but 23 exceeded 0.50″ and 80 were less than 0.20″.

The indications given by these two computations are that the probable error of a single observation as derived from the latitude computations is slightly too small and that the accidental errors in the star places are about as indicated by the probable errors given in Professor Safford's star list.

At several stations a portion of the observations were taken on stars from Professor Safford's list and a few supplementary pairs were chosen from the American Ephemeris, the Berliner Jahrbuch, and Preston's Hawaiian list. That there is no sensible common error in either of these lists not common to all is put in evidence by the agreement between the latitude as derived from Safford pairs exclusively or from supplementary pairs alone.

		°	'	''
Latitude of Station No. 3, from all observations, 46 pairs	=	31	46	58.00 ± 0.05
Latitude of Station No. 3, from Safford pairs only, 36 pairs	=			57.98 ± 0.06
Latitude of Station No. 3, from supplementary pairs, 10 pairs	=			58.04 ± 0.11
Latitude of Station No. 5, from all observations, 50 pairs	=	31	20	02.00 ± 0.04
Latitude of Station No. 5, from Safford pairs only, 47 pairs	=			02.01 ± 0.04
Latitude of Station No. 5, from supplementary pairs, 3 pairs	=			01.86 ± 0.15
Latitude of Station No. 6, from all observations, 57 pairs	=	31	19	57.94 ± 0.04
Latitude of Station No. 6, from Safford pairs only, 47 pairs	=			57.95 ± 0.04
Latitude of Station No. 6, from supplementary pairs, 10 pairs	=			57.91 ± 0.09
Latitude of Station No. 7, from all observations, 63 pairs	=	31	19	56.73 ± 0.04
Latitude of Station No. 7, from Safford pairs only, 50 pairs	=			56.77 ± 0.04
Latitude of Station No. 7, from supplementary pairs, 13 pairs	=			56.54 ± 0.08

At Stations No. 14 and No. 15, a Safford star being used in many cases with a star from some other list to form a pair, such a test as that given above can not be made. At Stations No. 1, No. 2, No. 4, and No. 8 to No. 13 only Safford stars were used.

As the general plan of observation adopted at most of the stations of this survey differs materially in one important respect from that usually followed, it is pertinent here to point out the reasons which led to the change from usual practice and to note how the results have justified the change.

The ordinary procedure at a first-class zenith telescope latitude station is to observe the *same list* of about 20 pairs on from four to seven nights. That plan was followed at Stations No. 1 and No. 4. Starting with the premise that the prime object of latitude observations is to secure with a minimum expenditure of time and money a result for latitude having a given probable error, say ± 0.05″ or less, a study of the relative magnitude of the errors arising from various sources and the cost of reducing these errors led to the conclusion that the number of independent pairs observed should be greatly increased relatively to the number of observations. It seemed that the greatest accuracy for a given amount of money would be secured by observing each pair but once, or at most twice. Accordingly the method of securing as many independent pairs as possible was followed at all stations except No. 1 and No. 4. The results of this procedure serve as its best champion.

A simple comparison of the probable errors of the final results at Stations No. 1 and No. 4 with the corresponding probable errors at later stations is not fair to the old plan of work; for at those stations unfavorable conditions, namely, inexperience of observer at No. 1 and bad meteorological conditions at No. 4, made the probable error of observation at those stations greater than for any succeeding station.

At Stations No. 2 and No. 3, however, the probable error of a single observation was about the same as at No. 1, and a comparison is just. At No. 2 and No. 3, 39 and 46 observations respectively, no pair being observed more than once, gave about the same degree of accuracy in the final result as 67 observations at No. 1.

At Stations No. 5 to No. 12, where the plan of work was most uniform, from 99 to 126 observations were taken at each station on from 50 to 93 pairs, no pair being observed more than twice.

The probable error of the final result for each of these stations is either ± 0.04″ or ± 0.03″. Taking the average values at these eight stations for the number of observations and number of pairs, for e and e_δ there is obtained as a typical station 108 observations on 72 pairs with $e = \pm\ 0.23''$ and $e_\delta = \pm\ 0.22''$. (See table, page 180.)

For this typical station the probable error of the result is

$$\sqrt{\frac{(0.23)^2}{108}+\frac{(0.22)^2}{72}}=\sqrt{(0.022)^2+(0.026)^2}=\pm 0.034''.$$

If the same number of observations were taken upon 18 pairs, 6 observations per pair, e and $e\delta$ remaining the same, the probable error of the final result would be

$$\sqrt{\frac{(0.23)^2}{108}+\frac{(0.22)^2}{18}}=\sqrt{(0.022)^2+(0.052)^2}=\pm 0.056''.$$

An *infinite* number of observations on 18 such pairs would give a result with a probable error of $\frac{0.22}{\sqrt{18}}=\pm 0.052''$, that being the error from declination alone. Even if the probable error of a single observation were twice as great as in the actual case, namely, $\pm 0.46''$, and e_δ were $\pm$ 0.22″ as before, 108 observations on 72 pairs would give a result with a probable error of

$$\sqrt{\frac{(0.46)^2}{108}+\frac{(0.22)^2}{72}}=\sqrt{(0.044)^2+(0.026)^2}=\pm 0.051''$$

a more accurate result than could possibly be obtained from only 18 such pairs observed any number of times with any degree of accuracy.

In cases in which the accuracy of the available star places is not as great as for the list here used there is still greater advantage in the method of observing a large number of pairs.

This method of work involves the necessity of computing a greater number of mean star places than usual; but the cost of that part of the work is but a small portion of the total cost. A considerable portion of this list would have been needed even if the ordinary plan of work had been followed.

An accidental, but important, advantage of the method of observing *many* pairs is the way in which partially cloudy nights and isolated clear nights in the midst of a cloudy season may be utilized. If one is observing in the ordinary way on a list of, say, twenty pairs, only about three or four hours of a perfectly clear night can be utilized, even though there may be great anxiety to finish the work at the station. On the other hand, the observations are entirely prevented for the night if it is cloudy during the three or four hours covered by the limited list, and the whole night is lost even though it may be clear during the greater portion of the time.

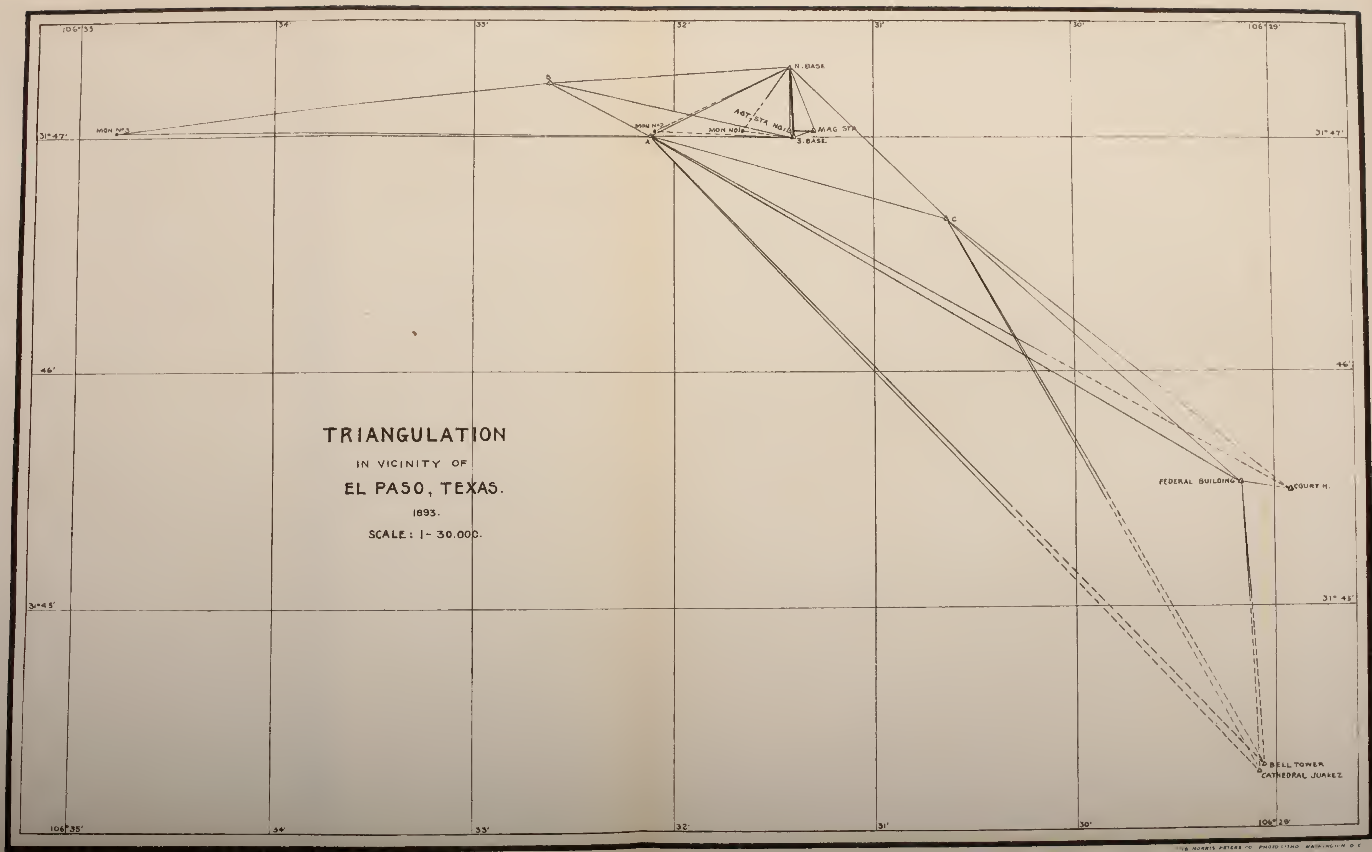
At Stations No. 5 to No. 12 and No. 15 the available pairs formed a double (and in some cases even a triple) list extending through most or all of the available hours of darkness. At these stations there was not the slightest difficulty in utilizing partially cloudy nights, or in utilizing *all the hours of darkness* on clear nights when there was a necessity for rapid work. At Station No. 6, 49 and 48 observations, respectively, were taken on the nights of June 14 and 16, thus nearly finishing the work of the station in two nights. At Station No. 15 the observations were greatly delayed by clouds. When the weather at last cleared, 72 observations were taken on the nights of September 30 and October 1, and the work at the station finished on the 2d by 22 observations.

Taking most or all of the observations for a station on one, two, or three nights will decrease the accuracy of the result if there are *constant errors peculiar to each night*, but not otherwise.

The results, as classified by nights and given below, serve to show that for this series of observations the discrepancies between the results for different nights are no greater than should be expected from the accidental errors of observation and declination.

The column headed "Residual" shows the difference between the result for the night and the mean for the station. The column headed "e_o (observations only)" shows the probable error of the mean result for the night as arising from errors of observation only, neglecting the declination error, or, in other words, the probable error of a single observation divided by the square root of the number of observations on the night in question.

Station.	Date.	Number of observations.	Seconds of latitude.	Residual.	e_0 (observations only).
	1892.				
No. 1	Feb. 15	15	59.40	0.00	0.10
Do	Feb. 16	19	59.39	— 01	.09
Do	Feb. 18	15	59.37	.03	.10
Do	Feb. 27	18	59.41	.04	.09
No. 2	Mar. 21	17	.38	.17	.09
Do	Mar. 22	21	.11	.10	.08
Do	Mar. 25	1	59.64	.57	.35
No. 3	Apr. 8	29	57.93	.07	.06
Do	Apr. 9	9	58.28	.28	.12
Do	Apr. 12	6	57.97	— .03	.15
Do	Apr. 13	2	57.73	— .27	.25
No. 4	Apr. 18	18	58.66	.11	.09
Do	Apr. 20	18	58.29	26	.09
Do	Apr. 21	18	58.55	.00	.09
Do	Apr. 22	19	58.58	.03	.08
Do	Apr. 23	19	58.52	.03	.08
Do	Apr. 25	19	58.62	.07	.08
Do	Apr. 26	19	58.69	.14	.08
No. 5	May 26	29	1.96	.04	.04
Do	May 27	42	2.02	.02	.03
Do	May 28	1	1.77	.23	.22
Do	May 29	17	2.06	.06	.05
Do	May 30	6	1.85	— .15	.09
Do	May 31	4	2.02	.02	.11
No. 6	June 14	49	57.94	.00	.03
Do	June 16	48	57.95	.01	.03
Do	June 21	5	58.13	.19	.09
No. 7	July 7	1	56.68	— .05	.26
Do	July 8	29	56.68	.05	.05
Do	July 9	8	56.77	.04	.09
Do	July 21	5	56.58	— .15	.12
Do	July 26	21	56.86	.13	.06
Do	July 27	26	56.81	.08	.05
Do	July 28	9	56.62	— .11	.09
No. 8	Aug. 9	17	59.05	.04	.05
Do	Aug. 15	37	58.93	.08	.03
Do	Aug. 16	39	59.05	.04	.03
Do	Aug. 18	7	59.11	.10	.08
No. 9	Sept. 7	19	6.14	.07	.04
Do	Sept. 10	22	5.97	— .10	.04
Do	Sept. 12	26	6.12	.05	.04
Do	Sept. 13	34	6.08	.01	.03
No. 10	Oct. 1	18	34.96	.12	.05
Do	Oct. 4	21	34.73	— .11	.05
Do	Oct. 5	18	34.71	— .13	.05
Do	Oct. 10	18	34.84	.00	.05
Do	Oct. 12	16	34.74	.10	.05
Do	Oct. 13	12	34.84	.00	.06
Do	Oct. 14	3	34.43	— .41	.12
No. 11	Nov. 2	27	57.49	.11	.04
Do	Nov. 3	40	57.34	— .04	.04
Do	Nov. 5	32	57.32	.06	.04
Do	Nov. 8	27	57.32	— .06	.04
No. 12	Nov. 19	26	4.65	.12	.06
Do	Nov. 21	3	4.73	— .04	.18
Do	Nov. 22	35	4.81	.04	.05
Do	Nov. 23	32	4.92	.15	.05
Do	Nov. 26	25	4.67	— .10	.06
	1893.				
No. 13	Jan. 17	27	34.64	— .05	.05
Do	Jan. 18	28	34.70	.01	.05
Do	Jan. 24	28	34.66	— .03	.05
Do	Jan. 25	22	34.81	.12	.06
No. 14	Feb. 15	19	1.14	.02	.07
Do	Feb. 16	6	1.08	— .04	.14
No. 15	Sept. 27	2	1.29	— .07	.16
Do	Sept. 30	37	1.38	.02	.04
Do	Oct. 1	35	1.42	.06	.04
Do	Oct. 2	22	1.19	— .17	.05



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The mean value of the residuals, or differences between the result for the night and the mean for the station, is 0.09″. On 31 nights, out of a total of 68, the residual was not greater than the probable error in the result arising from observation only.

TRIANGULATION.

The triangulation near El Paso was intended merely to connect Astronomical Station No. 1 with Emory Monuments No. 1, No. 2, and No. 3, but was extended to connect with prominent buildings in El Paso and Juarez, and with the triangulation of the Coast and Geodetic Survey longitude party at El Paso in 1892. The measurements of base and angles were made conjointly by the tangent party under Mr. E. L. Ingram, assistant engineer, and the astronomical party.

A base 550 feet long was measured with 20 m. and 50 m. steel tapes on the railroad track near the astronomical station. During the measurement the tape was placed upon the rail and was therefore supported throughout its whole length. The temperature of the rail, as recorded by a thermometer placed against it, was assumed to be the same as the temperature of the tape. The lengths of the tapes used in this and later base measurements were determined in January, 1892, on the mural standard of the United States Weights and Measures Office at Washington, D. C. The lengths were determined with the tapes supported throughout their whole length. Three double measures of the base, each forward and back, using two different tapes and on two dates, by different men, gave a range of 0.021 m.

The horizontal angles were measured with three different instruments—Wurdemann 8-inch repeating theodolite No. 85, Coast and Geodetic Survey 8-inch repeating theodolite No. 149, and Fauth theodolite No. 725 (described as the instrument used for azimuth). The observations were made upon poles at convenient hours of the day, the observing not being confined to the hours of steady seeing. The instrument was usually mounted on its tripod and was unprotected from sun and wind.

The sketch of the triangulation shows which stations were occupied. The average closing error of the triangles was 15.3″ and the greatest closing error 20.4″.

The azimuths and geographical positions given depend upon the observed azimuth and latitude at Astronomical Station No. 1 and the longitude observed by the Coast and Geodetic Survey in El Paso in 1892.

The tables of geographical positions are given in Chapter IV of United States Report.

The astronomical station was marked by a stone weighing about 250 pounds, having a lead plug in the top and sunk just below the surface of the sand.

North Base and South Base were marked by stakes about 67 mm. square, driven nearly down to the surface.

The station on the Federal building is the flagstaff at the northwest corner of the tower.

The station on the court-house is the flagstaff on the dome.

The station on the cathedral at Juarez is the large cross.

Stations A, B, and C are marked by wooden stakes.

At San Pedro River the triangulation consisted of a single quadrilateral, of which one diagonal was the measured base and the other a line joining Astronomical Station No. 10 with a point called A, near Monument No. 98. This quadrilateral served to connect the astronomical station with the monument and with the tangent to the westward, which begins at A. All four stations were occupied and the closing errors of the three principal triangles of the figure were 8.4″, 0.6″, and 6.2″. The observations were made with Coast and Geodetic Survey theodolite No. 149 and with Fauth theodolite No. 725.

The base, 484 m. long, was measured with a 50 m. tape, supported by the ground throughout its length. Four measurements giving a range of 0.024 m. were made just before and after sunset. The temperature of the tape was assumed to be the same as that recorded by a thermometer lying on the ground.

The observed latitude of Astronomical Station No. 10 is 31° 19′ 34.84″; and the azimuth of the line to A, 125° 21′ 0.8″, (back azimuth = 305° 20′ 35.1″). The distance to A was 1,601.3 m. The latitude of A is 31° 20′ 04.92″, and its longitude 0° 00′ 49.40″ west of Astronomical Station No. 10.

Monument No. 98, 8.1 m. west and 7.7 m. south of A, is in latitude 31° 20′ 04.67″.

The astronomical station and Station A are marked by pine stakes about 65 mm. square.

The triangulation at Nogales served to connect the latitude, longitude, and azimuth stations with prominent points in the town, with Monuments No. 122 and No. 127, and with the instrumental line which afterwards connected Monument No. 127 with Monument No. 204 at the Colorado River.

The base, 725 m. long, was measured between the rails of the railroad track just south of town, at night, with a 50 m. steel tape. The tape was supported throughout its whole length by the ties and ballast. The position of the end of the tape for each tape length was marked with an awl on a zinc plate previously placed in position on a tie or on the head of a stake driven flush with the surface. The temperature was recorded by a thermometer placed on the ballast near the tape. Three measurements gave a range of 0.005 m.

The angles were measured with Fauth direction theodolites No. 433 and No. 813. These are twin instruments, the only marked difference being in the style of finish. The horizontal circles, 20 cm. (8 inches) in diameter, are graduated in ten-minute spaces and every degree is numbered. The circle is read by two opposite micrometer microscopes. Each *half-turn* of micrometer head corresponds to 1 minute on the circle and is graduated to *thirty* divisions (2 seconds each). Hence the *sum* of the forward and back readings on the head gives the number of seconds of the reading of the circle, except for error of run. The standard or yoke of the instrument is quite low and the telescope will not transit.

The observations were made at convenient hours of the day, not being confined to the short hours of steady seeing. As a rule the observations at a station were completed on the first day it was occupied. Poles were used as signals. The instrument was usually supported simply on its tripod, and was not protected from the sun or wind.

The routine of observation, as is usual with a direction instrument, consisted of a pointing and reading of horizontal circle for each signal in turn from left to right, and then back again in the contrary order after reversing the telescope. Five positions of the circle, 72° apart, were used. The minimum of observation at a station was one set in each position of the circle, and as a rule the number of sets was between five and ten.

The greatest range in the different measurements of any one direction was 21.8″ and the mean range 11.8″. One triangle had a closing error of 18.9″, and all the others closed within 10″. The mean closing error was 5.3″.

The azimuths depend upon the observed azimuth of the line, azimuth station to azimuth mark; the latitudes upon the observations at Station No. 12, and the longitudes upon the observations at Station No. 12, by the Coast and Geodetic Survey in 1892.

The tables of geographical positions are given in Chapter IV of United States Report.

The point called "Astronomical Station No. 12 (observing stand)" in the list is the center of the tripod, which was built just outside the observatory to support the instrument when measuring horizontal angles. It is 2.22 m. south and 1.28 m. east of the latitude pier and due south of the longitude pier. The latitude of the piers is 31° 20′ 4.77″. These piers of brick and cement were left standing, inclosed in a small wooden observatory in the grounds at the rear of the Montezuma Hotel.

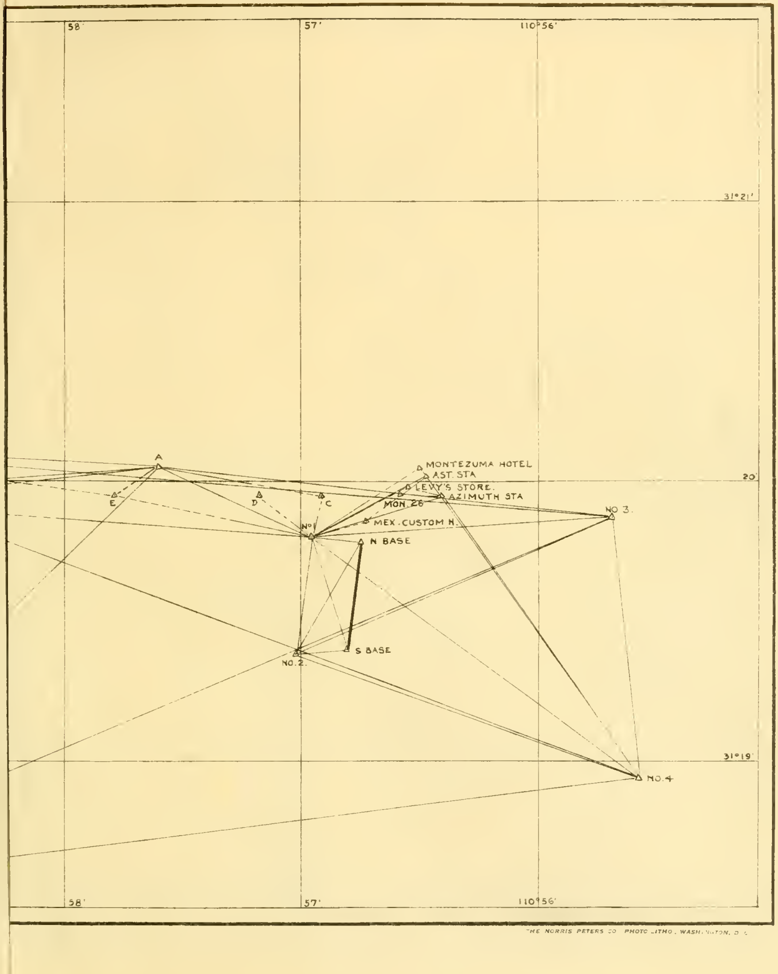
The reference marks at each station were, unless otherwise stated, placed approximately north, east, south, and west from the station mark, and the monuments given below are from the station mark to each reference.

Azimuth station, station mark 2-inch by 4-inch pine stake, references 1-inch by 1-inch pine stakes, N. 0.831 m., S. 1.025 m., W. 0.844 m., E. 0.989 m.

North Base is in the switch yard of the Sonora Railroad, on the prolongation of the center line of the track on last tangent before entering the yard from the south; station and references, 2-inch by 4-inch pine stakes, N. 0.975 m., S. 1.077 m., W. 0.899 m.

South Base is 9.58 m. eastward from the center line of the Sonora Railroad track; station and references, 2-inch by 4-inch pine stakes, N. 0.765 m., E. 0.845 m., W. 0.734 m.

No. 1, station 2-inch by 4-inch pine stake: references, five-eighths-inch iron rods, N. 1.082 m., E. 1.182 m., S. 1.182 m., W. 1.220 m.



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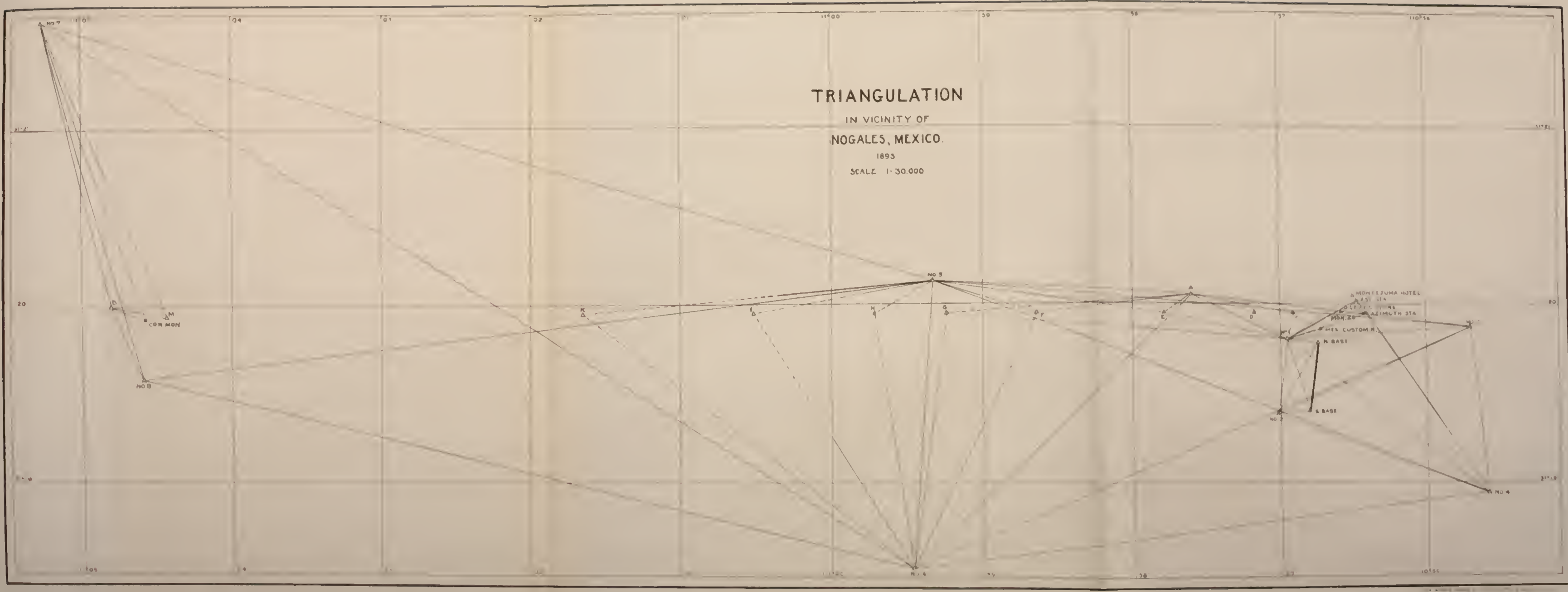
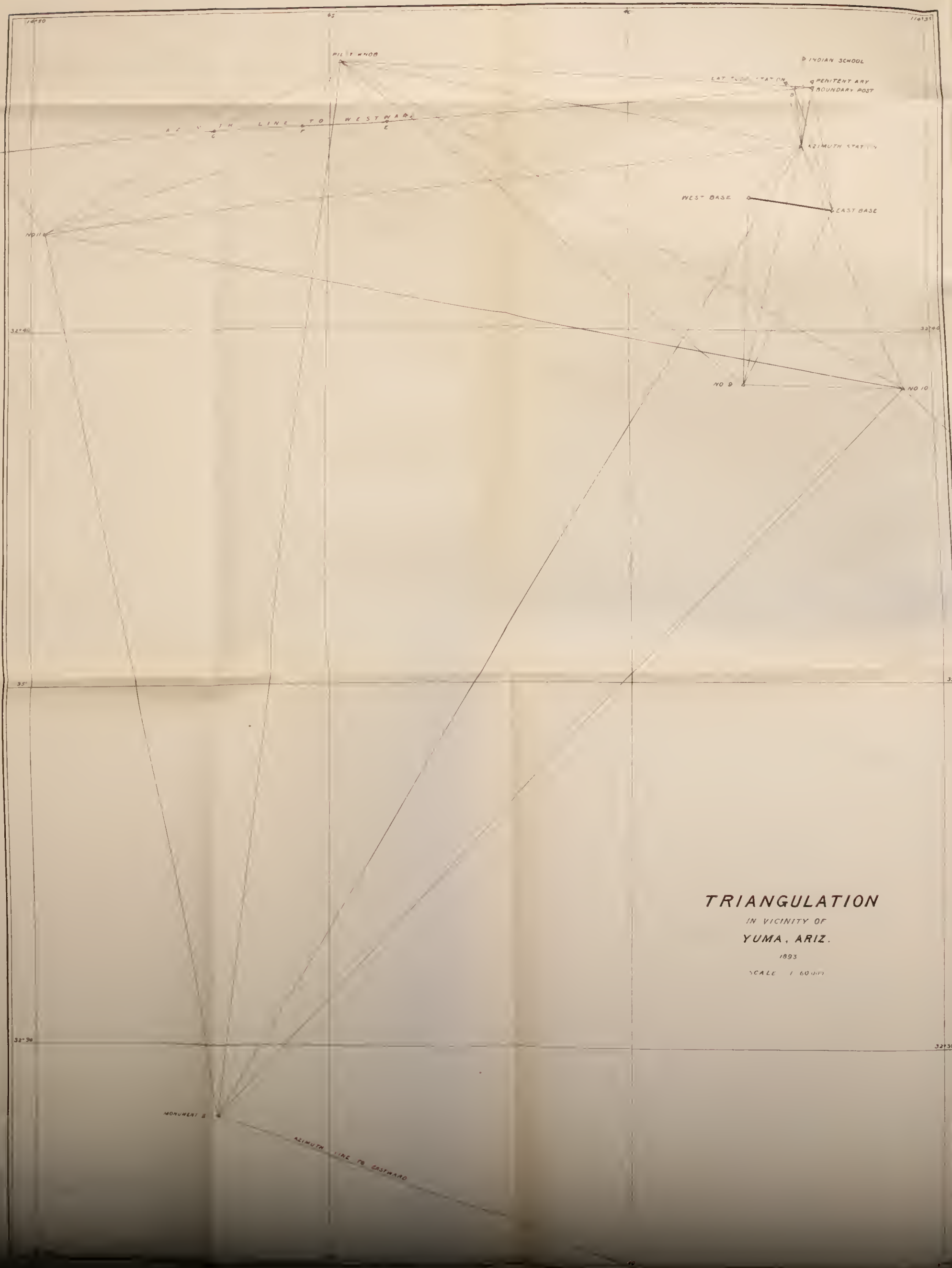


TRIANGULATION
IN VICINITY OF
NOGALES, MEXICO.
1893
SCALE 1-30.000
NO 7
NO 8
COM MON
NO 5
NO 6
NO 4
A
B
D
E
F
G
H
I
K
M
MONTEZUMA HOTEL
AZIMUTH STA
MON. 26
MEX CUSTOM H.
N BASE
S BASE


TRIANGULATION
IN VICINITY OF
YUMA, ARIZ.
1893
PILOT KNOB
INDIAN SCHOOL
PENITENTIARY
BOUNDARY POST
AZIMUTH STATION
WEST BASE
EAST BASE
NO 11
NO 9
NO 10
32°40
32°35
32°30
AZIMUTH LINE TO EASTWARD
AZIMUTH LINE TO WESTWARD

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No. 2, station and references, five-eighths-inch iron rods, N. 1.088 m., E. 0.971 m., S. 0.923 m., W. 0.926 m.

No. 3, station and references, five-eighths-inch iron rods, N. 1.140 m., E. 1.080 m., S. 0.966 m., W. 1.110 m.

No. 4, station and references, five-eighths-inch iron rods, N. 0.972 m., E. 0.976 m., S. 1.017 m., W. 1.070 m.

No. 5, station 4-inch by 4-inch pine stake; references, 2-inch by 2-inch pine stakes, N. 1.008 m., E. 1.171 m., S. 1.102 m., W. 1.041 m.

No. 6, station and references, five-eighths-inch iron rods, N. 1.140 m., E. 1.113 m., S. 1.128 m., W. 1.225 m.

No. 7, station and references, five-eighths-inch iron rods, N. 1.605 m., E. 0.930 m., S. 1.600 m., W. 1.152 m.

No. 8, station mark five-eighths-inch iron rod; reference, NW. to nail in stump 1.254 m., SE. to nail in tree 3.757 m., SW. to nail in tree 6.570 m.

B, 4.76 m. south and 4.11 m. west of Emory Monument XIX, station five eighths-inch iron rod, reference nails in trees, N. 6.431 m., E. 2.827 m., S. 5.159 m., W. 3.634 m.

The astronomical party also ran a tangent to the prime vertical at the azimuth station westward to a point near Monument No. 127, and determined by intersections from triangulation stations the distances to ten points on the tangent, for the use of the topographical party and the monument party.

As a check upon the accuracy of the triangulation it may be mentioned that the azimuth of the line azimuth station to B, as given by the latitudes and longitudes of those stations computed through the whole triangulation, was 90° 29′ 0.6″, while a direct measurement at the azimuth station of the angle between B and the azimuth mark gave for the same line $z = 90° 29' 2.7''$, a difference of 2.1″.

The triangulation near Yuma, Ariz., served to connect Astronomical Stations No. 13 and No. 14 with each other, with prominent points in Yuma, with Monument No. 207, just west of the Colorado River and the instrumental line westward to the Pacific, and with Monument No. 204, 20 miles below Yuma, and the instrumental line eastward to Nogales.

The base, 2,205 m. long, was measured on the mesa just south of Yuma with a 50-m. tape at night. With the exception of certain fractional tape lengths the line was measured with the tape supported by the sand throughout its whole length, the very few slight inequalities of the ground having been removed. The base was nearly level, with the exception of two tape lengths at the east end. Here the line rose to the top of a rocky hill about 19 m. above the remainder of the base. The ascent was made by two tape lengths on a considerable inclination, the difference of height of the different points of support of the tape being measured with a spirit level. The position of the end of the tape for each tape length was marked with an awl on a zinc plate on the head of a stake driven flush with the surface of the sand. The temperature of the tape was assumed to be the same as that recorded by a thermometer placed near the surface of the sand near the tape. Two measurements of the base made on the nights of January 28 and 30 under very favorable conditions—little or no wind, clouded sky, and nearly constant temperature—differed by 0.007 m.

The angles were measured with Fauth direction theodolites No. 433 and No. 813. The general plan of observation was the same as at Nogales. The observations were not limited to the hours of steady seeing. Both poles and heliotropes were used as signals. The instrument was not protected from sun and wind. At Monument No. 204 a tripod and scaffold about 8 m. high was built to place the instrument high enough to see over the slight swell of the mesa between that point and Yuma.

As before, five positions of the circle were used. The minimum of observation at a station was one set in each position of the circle, and the actual number of sets was usually between five and ten.

The greatest range in the measurements of any one direction was 17″ and the mean range 7.2″. The greatest error of closure of a triangle was 5″ and the mean closing error 2.6″.

The triangulation was adjusted by least squares to satisfy the side and angle conditions. The greatest correction to any observed direction from this adjustment was 2.2″ and the mean of the corrections 0.9″.

The azimuth of the line Monument 204-Azimuth Mark, as computed through the triangulation from the observed azimuth at Yuma is 178° 31′ 20″. The azimuth of the same line as observed at Monument 204 is 178° 31′ 21″.

In the table the azimuths and latitudes depend upon the observations at Yuma and the longitudes upon the observations at Yuma by the Coast and Geodetic Survey in 1892.

The tables of geographical positions are given in Chapter IV of United States Report.

The location of each station will be found upon the published topographical maps.

The latitude and longitude piers of brick and cement were left standing in the east room of the adobe building which forms a part of the north wall of the old Government corral in Yuma. The brick pier at the azimuth station was left standing.

B Tangent 16 is marked by a pine stake.

East Base, station and references five eighths-inch iron rods, N. 1.353 m., E. 1.038 m., S. 0.672 m., W. 1.347 m.

West base, station and references 2-inch by 4-inch pine stakes, N. 2.078 m., E. 1.951 m., S. 1.766 m., W. 2.223 m.

No. 9, station and references 2-inch by 4-inch pine stakes, N. 0.660 m., E. 1.512 m., S. 1.010 m., W. 1.913 m.

No. 10, station and references five-eighths-inch iron rods, E. 2° N. 3.085 m., S. 27° E. 1.971 m., W. 2° S. 2.172 m. (distances measured on slant).

No. 11 was on the sand hills west of the Colorado, and the station marks were doubtless blown away in a short time.

MAGNETIC OBSERVATIONS.

The observations for magnetic declination at the first twelve astronomical stations were all taken with Coast and Geodetic Survey repeating theodolite No. 149. The horizontal circle, 20 cm. (8 inches) in diameter, is graduated in five minute spaces and is read to five seconds by two opposite verniers. On the top of the telescope was mounted a compass box containing a 6-inch magnetic needle and carrying compass sights of the usual form. No iron or steel was used in the construction of this instrument or its tripod.

Astronomical station.	Dates.	Magnetic declination (E. of N.)
	1892.	° ′
No. 1	Feb. 20, Feb. 22, Mar. 12	11 53
No. 2	Mar. 25, 26, 28, 29, Apr. 2	10 16
No. 3	Apr. 13	11 56
No. 4	Apr. 30, May 2, 3	12 00
No. 5	June 2, 3, 4	12 03
No. 6	June 27	11 54
No. 7	July 7, 12, 20, 28	12 14
No. 8	Aug. 15, 18, 19	11 57
No. 9	Sept. 2, 5, 7	12 23
No. 10	Oct. 20	12 19
No. 11	Nov. 12, 15	12 06
No. 12	Dec. 12, 13	12 25

CHAPTER IV.

GEODESY.

The geodetic operations executed by the United States section of the commission were as follows:

I. Tracing parallels 31° 47′ and 31° 20′ by means of tangents to the prime vertical at the point of beginning and offsets from the same.

II. Tracing the meridian section by simple alignment, its direction having been previously verified.

III. Tracing the azimuth lines, either by straight lines connecting accepted existing old monuments or by offsets from auxiliary lines differing as little as practicable from these lines.

IV. Triangulation made in the vicinity of the initial monument on the Rio Grande to refer this monument to the United States astronomical observatory and to prominent public buildings in El Paso, Tex., and Ciudad Juarez, Mexico.

V. Triangulation made in the vicinity of Nogales, to refer Monument 127, at the west end of parallel 31° 20′, to the United States astronomical observatory in Nogales, Ariz.

VI. Triangulation made in the vicinity of Yuma, Ariz., to refer Monuments 204 and 207 to the United States astronomical observatory in Yuma.

The geodetic constants conform to Clark's 1866 Spheroid. The principal constants which enter into the formulæ adopted are as follows:

Major semiaxis $= a = 6{,}378{,}206.4$ meters.

Minor semiaxis $= b = 6{,}356{,}583.8$ meters.

Eccentricity $= \frac{a^2 - b^2}{a^2} = e^2 = 0.006768658$.

$a : b :: 294.98 : 293.98$.

Radius of sphere with volume of Clark's 1866 Spheroid = 6,370,991 meters.

Radius of sphere with surface of Clark's 1866 spheroid = 6,370,997 meters.

Length of meridian quadrant = 10,001,887 meters.

1 meter = 3.2808693 feet = 39.3704316 inches.

1 kilometer = 0.6213768 statute mile.

1 foot = 0.30479727 meter.

1 statute mile = 1,609.3296 meters.

$\pi = 3.14159265$.

Before entering into a description of the methods employed in tracing the different sections of the boundary line, it is necessary to explain what is meant by a "straight line," since, as shown at the beginning of the chapter, every portion of the boundary line as marked was traced either by the aid of auxiliary straight lines or by straight lines joining consecutive old monuments.

The theoretical straight line joining two points on the surface of the earth lies in the plane which passes through both points and the center of the earth, and if traced would mark the intersection of this plane with the surface of the earth.

Owing, however, to local deflections of the plumb line, it is practically impossible to trace this theoretical line, but a number of so-called straight lines, differing but little from one another and from the theoretical line, can be traced, the particular line obtained in each case being dependent both upon the method employed and the locations of the instrument stations.

For example: If two points, A and B, are visible from one another and from intermediate points, and if, as is almost invariably the case, local deflections of the plumb line exist at both A and B and also at intermediate points, a number of different lines, apparently straight, may be run joining A and B, thus: (1) If the instrument remains at A and the foresight at B and intermediate points are "lined in," a certain line will be traced; (2) again, if the foresight at B remains fixed but the instrument is moved up successively to each intermediate point as established, a second and different line will be obtained; (3) if the backsight at A remains fixed and intermediate points are successively established by the method of reversals, the instrument in each case being moved up to the point last established, yet another line will be obtained; (4) if the intermediate points are located by the method of reversals, the instrument being moved up as in the last case and the backsight established at the next preceding point, a fourth line will result; (5) if both foresight at B and backsight at A remain fixed, and intermediate points are established by "lining in" the instrument, a fifth line will be traced.

Now, if exactly the same methods are followed, working in an opposite direction (B toward A), five additional lines will be obtained, and by a combination of the preceding methods a still greater number of lines will result, all differing slightly from one another and from the theoretical straight line sought.

Computations having shown that for the distances to be encountered on this survey, and for ordinary local differences of deflection of the plumb line, lines accurately traced by any one of the preceding methods would be sufficiently accurate, all of them were used at one time or another, as found most convenient. In general, however, a combination of the first and second methods was employed as being quite expeditious, and dispensing with the necessity of a backsight.

The instruments used in tracing straight lines were Fauth repeating theodolite No. 725, with 10-inch horizontal circle graduated to 5-minute spaces and read by two opposite verniers to 5 seconds, and Würdemann repeating theodolite No. 85 of the pillar pattern, with 8-inch horizontal circle.

At the commencement of operations wooden targets about 3 feet square, mounted on tripods, and similar to those described on page 345 of the report of the survey of the "Northern Boundary of the United States from the Lake of the Woods to the Summit of the Rocky Mountains," were tried, but owing to the fact that during the greater part of the day they were seldom visible more than 3 miles, and to the further fact that, due to the constant winds to which they opposed so large a surface, they were continually displaced, the use of these targets was soon abandoned and heliotropes were substituted for them with results entirely satisfactory.

These heliotropes were rather crude affairs, with mirrors of 3 and 4 inches diameter, and were unprovided with any means for imparting a uniform slow motion to the mirrors. At first the mirrors were so mounted on their tripods as to admit of a lateral, sliding motion, but this arrangement was found to be of no practical advantage, and they were afterwards rigidly attached to the tripods.

After the completion of the tracing of the meridian section of the boundary a reconnoitering telescope, with heliotrope attachment (but without any means for imparting slow motion to the mirrors), was obtained, and proved to be a valuable addition to these instruments.

The heliotropes were plainly visible to the naked eye up to 30 or 40 miles, and on rare occasions up to 85 miles, at which last distance they could generally be seen through the telescope of the theodolite.

Not only did the heliotropes prove valuable as targets, but they also afforded a ready means of communication between the observer and the heliotropers, sometimes by means of the Morse code and sometimes by a shorter special code.

The advantage of being able to communicate freely with an isolated party 20 to 80 miles distant, in an unsettled region where supplies are scarce and roads bad, and where, as in one case, it took five days' hard travel by pack train to reach it, can scarcely be overestimated, and much anxiety is spared when it is known that such a party is well, and properly provided with water and provisions.

In connection with heliotrope communication should be mentioned the experience of Mr. E. L. Ingram, assistant engineer, with the 80-mile sight on the California azimuth line between the sand dunes west of the Colorado River and the summit of the Coast Range, where the signals were hard to understand and easily mistaken when the light was poor. They failed repeatedly until he devised a rough method for imparting slow motion to the mirrors, after which signals were received by the front heliotroper, 80 miles distant, with absolute certainty.

If the heliotrope mirror, as ordinarily mounted, is fastened in its bearings tightly enough to resist the action of the wind, it is impossible to impart to it a uniform slow motion, even when moved in the most delicate manner by the method generally employed—that of tapping it gently with a pencil—and on long sights, where the light is faint and the atmosphere in a state of vibration, these irregularities of motion are sometimes confused with the flashes of the signal code, and it would seem that for extensive use over long distances heliotropes provided with telescopic lines of sight and with mirrors capable of a slow and uniform motion would amply repay in efficiency their increased first cost.

To avoid confusion, and in order that the original monuments already alluded to may be more readily located on the map, only the numbers placed upon them when repaired or rebuilt are given in the description which follows.

PARALLEL 31° 47′.

The successive steps in tracing the parallels were as follows:

1. Azimuth observations at the initial point of the tangent.
2. Tracing the tangent.
3. Observations at the end of the tangent to determine its back-azimuth error.
4. Computing the offsets.
5. Locating the monument sites.

1. *Azimuth observations at the initial point of the tangent.*—The instruments and methods employed and the results obtained are described in Chapter III, Astronomy, and in the report of Mr. J. F. Hayford, assistant astronomer, and need not be repeated here.

2. *Tracing the tangent.*—The instruments and targets used in tracing the tangents have already been described. The initial direction of the tangent was obtained by turning off an angle of 90° from the meridian through the point of beginning and establishing a point on the tangent at as great a distance as practicable. The tangent was then prolonged by the method of reversals, the instrument being set up over the last point established and the backsight being located at the most distant previously established point of the tangent visible from the instrument. The telescope was then transited over and a new point established as far as possible in advance.

This operation was repeated four times with the telescope alternately direct and reversed, and the mean of the four points thus established was accepted as the true prolongation. Each tangent was prolonged until it reached the meridian of the next succeeding astronomical station. When a point in advance had thus been established, a heliotrope was set up over it as a foresight and intermediate points were generally "lined in," using range poles as targets, the instrument being moved forward from time to time as necessary, as the pole was seldom readily visible more than about 3 miles.

On parallel 31° 47′ distances along the tangents were measured both by chain and stadia, and the stations marking the tangents were located at a distance of 1 kilometer apart. These stations were generally marked by a 2-inch by 3-inch stake driven into the ground and projecting from 7 to 18 inches above the surface. Around the stake was piled a mound of stones to protect it from injury.

A small witness stake was driven out of sight 1 meter south of the station stake, by means of which the latter could be replaced in case of removal.

In establishing points in advance on the tangents by the method of reversals, the two points established with the telescope in the same position seldom differed more than a few inches, even for distances as great as 80 miles, while the other two points established with the telescope in a reversed position sometimes differed as much as 10 feet, due largely to the fact that the collimation error was very variable owing to the jolting received by the instrument during transportation over rough roads.

Six tangents in all were traced on parallel 31° 47′, which are fully described in the table in section 9, geodesy, of the Report of the Joint Commission. Tangents Nos. 1, 2, 3, and 5 of that table are main tangents. The other two are check tangents.

Owing to the great scarcity of water and the difficulty of getting supplies to the tangent party, tangent No. 1 was traced at all hours of the day, regardless of atmospheric conditions, and on account of the flat character of the country the average length of each prolongation was less than 3 miles. As a result of these and other unfavorable conditions the tangent rapidly deviated to the north, with a final back-azimuth error at the meridian of Monument No. 15 of 186.6″. Before commencing the erection of monuments this tangent was retraced, for direction only, with a probable back-azimuth error of 1″. In locating monuments offsets between Monuments Nos.

3 and 11 were referred to the original tangent and corrected to conform to the new tangent. Between Monuments Nos. 11 and 15 offsets were referred to tangent No. 2, and the original tangent was not used.

3. *Observations at the end of the tangent to determine its back-azimuth error.*—The azimuth observations at the end of the tangent were identical with those at its initial point and served both to determine the back-azimuth of this tangent and to give the initial direction to the new one. The difference between the observed and theoretical value of the back-azimuth is designated as the "back-azimuth error," and indicates the degree of accuracy with which the tangent was traced.

Back-azimuth error of tangents on parallel 31° 47′.

Tangent.	Back-azimuth error.	Character of tangent.
	″	
No. 1, original	186.6	Main.
No. 1, as retraced	1.0	Check.
No. 2.	0.0	Main.
No. 3.	34.8	Do.
No. 3*a*		Check.
No. 4		Do.
No. 5	3.4	Main.

4. *Computing the offsets.*—From Appendix 7, Report for 1884 of the United States Coast and Geodetic Survey, we have the following general formula for computing difference of latitude: $-d\ L = K \cos Z.B + K^2 \sin^2 Z.C + (\delta L)^2\ D - h\ K^2 \sin^2 Z.E$, in which K = distance in meters; L = latitude; Z = azimuth of line; R = radius of curvature; N = normal to the polar axis at the station: $B = \frac{1}{R \text{ arc } 1''}$; $C = \frac{\tan L}{2\ R.N \text{ arc } 1''}$

When Z = 90° the above formula becomes $-d\ L = K^2\ C$, in which $-d\ L$ is expressed in seconds of arc.

To obtain the offset in meters this must be multiplied by the value of 1″ of arc in meters for the latitude used.

For parallel 31° 47′, 1″ of arc = 30.800 meters, and the working formula for this parallel becomes:

$$\log d\ L = 2 \log K - 7.3140232.$$

The offset obtained from this formula is from a theoretically accurately traced tangent to the geodetic parallel 31° 47′ passing through the initial point of the tangent, and may properly be designated as the "theoretical offset."

The identity of the original monuments having been established and their positions located, it became necessary to compute the offsets from the tangents, as traced, to a curved line joining consecutive accepted original monuments, which line should have as nearly as possible the same degree of curvature as parallel 31° 47′, and would form the actual boundary line to be marked by monuments.

The offset from the tangent actually traced to the monument curve is composed of four parts:

(*a*) The theoretical offset already described.

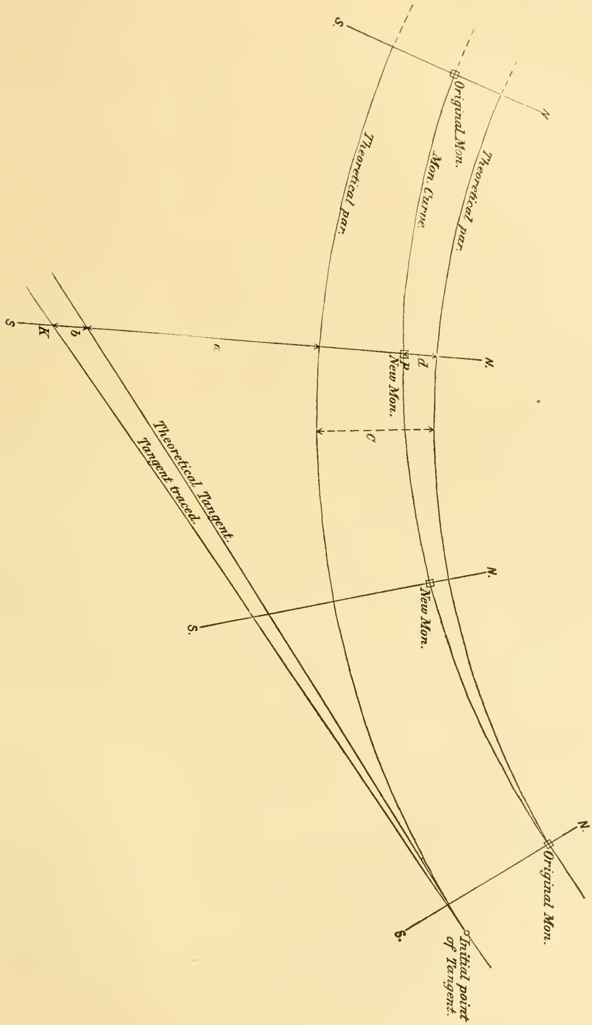
(*b*) A correction for error in tracing the tangent.

(*c*) A constant, measuring the distance of the initial point of the tangent north or south of one of the original monuments.

(*d*) A proportional part of the distance by which a true geodetic parallel through one original monument passes north or south of the other original monument.

This may be shown graphically in the following sketch (p. 117), in which the offset, K P, to the monument curve is $a + b + c - d$.

The distribution of the back-azimuth and tangent errors was made in such a manner that they would harmonize, inasmuch as one is practically a direct function of the other. In some cases the tangent error was measured in the field, and in others it was computed in conformance with the distribution of the back-azimuth error. In all cases the known errors received careful


S.
N.
Original Mon.
Theoretical par.
Mon. Curve
Theoretical par.
S
K
b
a
d
P
N.
New Mon.
c
Theoretical Tangent.
Tangent traced.
N.
New Mon.
S.
N.
Original Mon.
S.
Initial point
of Tangent.

consideration and were distributed in the simplest possible manner consistent with observed facts. (For further details relating to this subject see report of Mr. E. L. Ingram, assistant engineer, Appendix 1 of this chapter.)

Probably the best check upon the method of distribution employed is given in the table of "Final distances between monuments on parallel 31° 47′," in section 9 of the Report of the Joint Commission, where it will be seen that although the United States and Mexican tangents were totally different, and traced at different times, the average discrepancy in a north and south direction between their locations of the 30 new monument sites on this parallel was but 0.435 meter.

5. *Locating the monument sites.*—The field maps and the profiles obtained from the line of levels carried along the tangents afforded the means of locating approximately beforehand the monument sites at such points that any completed monument would be visible from the two adjacent ones.

Each approximate site was afterwards visited in the field when the monument party arrived in the vicinity in order to verify the indications of the field maps and profiles.

The meridian in which the offset was to be measured was obtained by turning off from the tangent an angle dependent upon the theoretical azimuth at the point plus or minus the distributed azimuth error at the same point. In this meridian was measured the offset computed as already described. Precisely the same operations were executed by the Mexican section of the commission from their own tangent and their own measured distances, and the mean of the two points thus located was taken as the true location.

THE MERIDIAN SECTION.

The methods employed were substantially those used on parallel 31° 47′ except that chaining was abandoned; stations were placed at unequal distances apart and at probable monument sites instead of at intervals of 1 kilometer, and the line actually traced was one joining the 3 original monuments which marked the meridian.

It was found that from a point on the summit of a hill 2 miles south of Monument 40, and in the same meridian, Monuments 40 and 46 and a point on a hill one third of a mile north of Monument 53 were visible.

From this last point, on which was afterwards established a heliotrope as a front sight, Monument 53 was also visible.

Observations showed that the 3 original monuments were in the same straight line, and that this line was a true meridian.

It was intended to locate the intermediate stations on the same line, but owing to the small size of the transit used a slight deviation occurred between Monuments 46 and 53 amounting to a maximum of 1 decimeter. The small offsets from this portion of the line as traced to the true meridian were computed and the necessary corrections made before monuments were erected.

Parallel 31° 20′.

The azimuth observations at the initial point and the methods employed in tracing the tangent were similar to those already described on parallel 31° 47′ except that, as in the case of the meridian section, the tangent stations were placed at unequal intervals on prominent points along the tangent. The use of the chain in measuring distances was abandoned at the west end of parallel 31° 47′ and never afterwards resumed.

Eight tangents in all, numbered from 8 to 15 inclusive, were traced on parallel 31° 20′, and are fully described in the table in section 9, geodesy, of the Report of the Joint Commission.

All of these tangents except Nos. 12 and 15, on which Fauth repeating theodolite No. 725 was used, were traced with Würdemann repeating theodolite No. 85, which had been used exclusively heretofore.

Back-azimuth error of tangents on parallel 31° 20′.

Tangent.	Back-azimuth error.	Character of tangent.	Tangent.	Back-azimuth error.	Character of tangent.
No. 8	—9.4	Main.	No. 12	12.6	Main.
No. 9	+2.7	Do.	No. 13	32.3	Do.
No. 10	+6.7	Do.	No. 14	32.9	Do.
No. 11	—2.1	Do.	No. 15	Not measured.	Do.

Computing the offsets.—For parallel 31° 20′, 1″ of arc = 30.798 meters, and the working formula for computing the theoretical offsets for this parallel becomes:

$$\log d\,L = 2 \log K - 7.3216616.$$

The actual offsets from the tangents as traced to the monument curve were obtained as decribed for parallel 31° 47′.

After careful consideration, aided by experience gained on the preceding sections of the boundary line, it was decided that no attempt would be made to distribute back-azimuth errors of less than ten seconds, but that such errors would be neglected and the tangent assumed to be theoretically accurate.

When the error exceeded ten seconds a careful investigation was made of the conditions under which the tangent was traced, and the error was distributed at the points where, in the judgment of the assistant engineer who traced the tangent, a short back sight, wind, poor light, or some similar cause rendered it most probable that the error had occurred. By reference to the table of back-azimuth errors it will be observed that but 3 tangents on this parallel, Nos. 12, 13, and 14, had back-azimuth errors greater than ten seconds.

The error of tangent 12 was distributed uniformly at each azimuth station; that of tangent 13 at 3 stations where it seemed most probable that errors had occurred, and that of tangent 14 was distributed throughout its entire length.

Again applying the only available check upon the accuracy of the treatment of the tangent error, i. e., the discrepancy in a north and south direction between the United States and Mexican locations of the monument sites, we see that the average discrepancy for the 31 new sites located from the 5 tangents on which the back-azimuth error was less than ten seconds, and therefore neglected, was 0.454 meter, and that of the 29 sites located from the 3 tangents on which the error was distributed was 0.579 meter; the average for the entire 60 new sites being 0.514 meter.

The monument sites were located in the same manner as were those on parallel 31° 47′.

THE SONORA AZIMUTH LINE.

In order that operations might be prosecuted on the Yuma and Colorado deserts in winter, the most favorable season for work in these localities, the entire party was transferred to Yuma, Ariz., in January, 1893, immediately upon the completion of the survey of parallel 31° 20′.

Two "line parties" were there organized, one under charge of Mr. John F. Hayford, assistant astronomer, to trace the boundary line, or the necessary auxiliary lines, from the Colorado River to the west end of parallel 31° 20′, and the other under charge of Mr. E. L. Ingram, assistant engineer, to operate in a similar manner between the Colorado River and the Pacific Ocean.

A reconnoissance between Yuma, Ariz., and Sonoyta, Mexico, made in January and February, 1893, disclosed the fact that no original monument existed between Monuments 204 and 175, a distance of over 101 miles; that certainly two, and possibly three, excessively rugged mountain ranges intervened, and that so precipitous and inaccessible were some portions of these ranges that at these points offsets even but a few meters in length could be measured only with the greatest difficulty. As the two points to be connected were not intervisible, it was of vital importance that the auxiliary line traced should approximate as closely as possible to the straight line joining them. It was decided, therefore, to establish a preliminary point on the nearest mountain range as close as practicable to the line joining Monuments 204 and 175. This work, which proved to be the most difficult and arduous of the entire survey was successfully accomplished by

Mr. J. L. Van Ornum, assistant engineer, aided by Messrs. L. S. Smith, transitman, and Ernst Franké, levelman, as follows:

More extended investigation having shown that the line of sight between Monuments 204 and 175 was obstructed by but two mountain ranges, distant about 45 and 60 miles, respectively, from Monument 204, heliotropes were established at each monument and a small transit and a heliotrope on each of the intervening ranges. On one range a trial point was assumed, and the transit on the other range lined in between it and the adjacent monument heliotrope. This transit was then replaced by a heliotrope, and that on the first range was lined in between this heliotrope and that at the nearest monument. By numerous repetitions of the same operations successive and close approximations to the desired point were obtained, until finally it was located, and a station was established on the nearer range (La Sierra de las Tinajas Altas), on what was believed to be the straight line joining the two monuments in question.

When the line was carefully traced with the Fauth theodolite it was found that this point differed but 0.87 meter from the United States determination of the line joining the monuments, and but 0.15 meter from the mean of the United States and Mexican determination of this line. It is due to the gentlemen who accomplished this work so successfully to state that operations were conducted on the dreaded Yuma and Tule deserts; that the two mountain ranges mentioned were composed of numerous parallel ridges, rugged and precipitous beyond description, and so intersected by huge ravines and deep cañons that a change of a few feet in the points established by successive approximations frequently necessitated the scaling of a new ridge or peak, an operation which sometimes occupied an entire day.

To add to the difficulties under which they labored, nearly half of the rodmen deserted on this their first experience of the desert, and all of those remaining gave out at the end of two or three days, leaving the instrument men to perform their work unassisted.

A heliotrope was placed as a foresight at the point just described, and the line was traced toward it from Monument 204, 73 kilometers distant. This line was produced by three successive prolongations, of 25, 4, and 4 kilometers, respectively, to a point on the east ridge of the Tule Mountains. This last point was connected with Monument 175 by means of a heliotrope placed as a target directly over the monument.

Fauth repeating theodolite No. 725 was used exclusively in line work on the Sonora azimuth line, and intermediate points were located at an average distance apart of about 2 kilometers. The line was traced in sections by running toward a heliotrope established as far as possible in advance.

Intermediate points were fixed by causing a second heliotroper to establish himself near the site of the proposed station, and as closely as possible to the line joining the instrument and fixed heliotrope. The angle between the two heliotropes was then measured by the micrometer. The observer communicated the result to the intermediate heliotroper by means of the Morse code, using a heliotrope kept at his station for this purpose. Knowing that each micrometer division corresponded to an offset of 6 mm. per kilometer of distance, and estimating his distance from the theodolite, the heliotroper readily computed the approximate offset to the desired line. This he then measured upon the ground and showed his heliotrope from the new position. The observer again measured the angle between the heliotropes and communicated the result as before.

The difference between the first and second micrometer readings, and the known length of the measured offset, enabled the heliotroper to determine his previously estimated distance from the instrument, and to compute quite accurately a new offset from the point last established.

This process was repeated until the angle between the two heliotropes measured less than two micrometer divisions (2.5″), when the observations were completed by a measurement of this angle by 27 pointings, in sets of 3 alternately, with eyepiece micrometer on the two heliotropes. Using this measurement and the more accurate stadia distance afterwards determined by the topographical party, the small offset from the station as marked to the true line was computed and furnished to the monument party previous to the erection of monuments.

Sometimes as many as seven intermediate points were established from a single instrument station; sometimes the instrument was moved up to every new station as established, and occasionally it was lined in between two fixed points.

NOGALES, LOOKING N. E.

NOGALES, VISTA AL N. E.

The time occupied in establishing an intermediate station within 2.5″ of the line, and then measuring the final angle, varied from about thirty to sixty minutes.

From Monument 175 to Monument 127 each original monument, except Monument 150, was visible from the preceding one, and the line was traced by placing a heliotrope over one monument and running toward it from the preceding one.

Monument 150 was not visible from Monument 160, and the peak which intercepted the view, Cerro de la Lesna, had sides so nearly vertical and a crest so narrow and disintegrated that it was practically impossible to set up an instrument on it in order to "line in" a point on its summit. Accordingly, a strong geodetic connection was made around the south side of the peak, by means of which points on the line joining the two monuments were established on both its eastern and western base, as well as on its summit. (For details of this connection see report of Mr. John F. Hayford, assistant astronomer, Appendix 4 of this chapter.)

Between Monument 127 and the Colorado River the boundary line as finally marked by monuments is a broken line of 12 straight sections, changes of direction occurring at Monuments 129, 136, 137, 141, 146, 150, 160, 162, 168, 175, and 204. That actually traced by the line party was a broken line of 14 straight sections, which at no point, except at Monument 128, differed as much as a meter from the line afterwards marked by monuments.

An old monument which stood 1.81 meters north of Monument 128 was connected by the line party with Monuments 127 and 129, but this monument was afterwards considered by the engineers in chief as unauthentic, and the boundary line finally adopted was the straight line joining Monuments 127 and 129.

The inital direction of the line from Monument 204 eastward was obtained from the Yuma triangulation.

All angles in the broken line traced were measured by micrometer except that at Monument 175, which was too large for micrometer measurement and was measured by the theodolite used as a repeater. In the vicinity of Monument 127 this line was connected with a line of the Nogales triangulation, and the accumulated errors of the azimuth observations at Yuma and Nogales, the triangulations at these places, and the measurement of 16 angles along the broken line traced was found to be but 6.7″.

To show more clearly the departure of the line as marked by monuments from the theoretical straight line joining Monuments 127 and 204, the offsets from the latter to the accepted original monuments were computed by Mr. John F. Hayford, assistant astronomer. These offsets are all measured to the south and perpendicular to the theoretical line

Offsets from theoretical straight line joining Monuments 127 and 204.

To Monument—	Offset.	To Monument—	Offset.
	Meters.		*Meters.*
127	0.0	150	657.7
129	35.1	160	974.9
136	231.1	162	1023.8
137	259.4	168	1183.6
141	359.9	175	1413.2
146	540.8	204	0.0

The computed angles between the different sections of the Sonora azimuth line, as marked by monuments, are given in the following table. The angle is the deviation to north or south of the next section from the preceding section produced.

At Monument	Deviation.	Direction of deviation.	At Monument—	Deviation.	Direction of deviation.
	′ ″			′ ″	
129	3 28	S.	160	0 29	N.
136	0 13	N.	162	0 34	S.
137	0 27	S.	168	1 46	S.
141	0 56	N.	175	55 2	N.
146	2 20	N.	204	51 46	S.
150	3 8	S.			

In establishing the monument sites the very small offsets from the line as traced to that which was to be marked had been previously computed by the assistant astronomer who traced the line, and were measured at right angles to this line.

The average discrepancy in a north-and-south direction between the United States and Mexican locations of the 67 new monument sites on the Sonora azimuth line was 0.368 meter.

THE CALIFORNIA AZIMUTH LINE.

As no two of the six original monuments which marked this line were intervisible, it was impossible to follow the method employed in tracing the Sonora azimuth line.

Accordingly, the line actually traced was a broken line of five straight sections, which at no point diverged more than 63 meters from the line finally marked by monuments, itself a broken line of five straight sections with changes of direction at Monuments 220, 221, 252, and the monument at Tijuana, destroyed by flood in January, 1895, and replaced by the present Monument 255, situated a little over a kilometer further east.

The initial direction of the first section traced was a prolongation in two sights, to the summit of the Coast Range, of the line joining "Boundary Post" (Monument VII of the original survey, which located the junction of the Gila and Colorado rivers) and Monument 207. The second section was purposely deviated to the south, and prolonged in a single sight to Mount Tecate, with the object of drawing the line traced closer to the boundary line and thus reducing the length of the offsets, a result which was not attained, owing to the effects of local deflections of the plumb line. For the purpose of back-azimuth and latitude computations this last section was produced to the meridian of Monument 258, passing 140.07 meters south of the monument. The third section connected the station on Mount Tecate directly with Monument 252; the fourth section was traced between Monument 252 and the monument at Tijuana, afterwards destroyed by flood, and the fifth section connected this last monument and Monument 258 on the Pacific.

Intermediate points were generally established with range poles by running toward a heliotrope previously located in advance, the instrument being moved forward as found most convenient.

As the theodolite used by Mr. E. L. Ingram, the assistant engineer who traced this line, had no micrometer, it was impossible to adopt the method employed on the Sonora azimuth line in establishing intermediate points, and was difficult to estimate correctly the distance that the intermediate targetman should move to come upon the line. Flashes of five seconds' duration indicated a movement to the north and of one second a movement to the south, the number of flashes giving an approximate idea of the distance.

Computing the offsets.—The formulæ used in computing the offsets from the broken line traced to that to be marked by monuments are given in the report of Mr. E. L. Ingram, assistant engineer, Appendix I of this chapter, and are based on the original stadia measurements, reduced to sea level, as the final adjusted latitudes and longitudes, by the use of which were obtained the distances in column 7 of the table of "Final distances between monuments on the California azimuth line" (section 9, geodesy, of the report of the Joint Commission), and the corrections due to remeasurements were not then available.

From the data then at hand the computed length of the straight line joining Monuments 207 and 258 was 225,586.2 meters, and the corresponding back-azimuth error 23.8″, which, before computing the offsets, was equally distributed at each of the three main heliotrope stations. These were located on the sand dunes west of the Colorado River, on the summit of the Coast Range, and on Mount Tecate, respectively. This back-azimuth error represents the accumulated errors due to the azimuth observations at Yuma and Monument 258, the errors in triangulation at the former place, those in tracing the different sections of the broken line, and in measuring the various angles along this line and in the vicinity of Monument 258.

Later computations based on the final adjusted latitudes and longitudes give the distance between Monuments 207 and 258 as 225,570.2 meters, which would reduce the back-azimuth error of 23.8″ by but a fractional part of a second. If, as indicated by the close agreement between the United States and Mexican stadia measurements of this distance, there is a considerable "station error" in longitude between Monuments 207 and 258, and the back-azimuth error be computed, using the mean of the United States and Mexican stadia measurements, it will be found to be less than sixteen seconds.

The average discrepancy, measured in a north-and-south direction, between the United States and Mexican locations of the 48 new monument sites on the California azimuth line was 0.467 meter.

Passing from the Colorado River toward the Pacific Ocean, the following appreciable computed changes of direction occur in the line as finally marked by boundary monuments, the angle given in the table being the deviation to north or south of the next section from the preceding section produced.

At Monument—	Deviation.	Direction of deviation.
	′ ″	
220	4 26	S.
221	0 47	S.
252	2 42	N.
255	0 42	N.

In spite of these deviations, however, the most distant monument—No. 220—from the theoretical straight line joining Monuments 207 and 258 is situated less than 70 meters north of this line.

GENERAL REMARKS ON TANGENT AND LINE WORK.

Mr. John F. Hayford, assistant astronomer, personally traced the Sonora azimuth line and also tangents 12 and 15 of parallel 31° 20′. All other tangent and line work was executed personally by Mr. E. L. Ingram, assistant engineer.

The successive tangents and straight lines were connected with one another and with the astronomical stations, thus forming a geodetic chain from the Rio Grande to the Pacific, by means of which could be computed the station error at the various stations—*i. e.*, the difference between the observed latitude of the station and that transferred, geodetically, from the preceding station, a difference due to local deflections of the plumb line.

These station errors have been computed and are given in section 13 of the Report of the Joint Commission, "Construction of the maps of the boundary."

All distances measured along the tangents and auxiliary lines, as well as all bases employed in triangulation, were reduced to mean sea level of San Diego Bay, California, by the formula $\delta = \frac{Ba}{r}$, in which r = the normal corresponding to the base, b, at the level of the sea; $r + a$ = that referred to the level of the measured base, B; δ = the desired correction.

Owing to the intense heat, so great was the personal discomfort suffered by those engaged in work on the desert, and so difficult and expensive was it to supply the working parties with provisions, forage, and water, that it was deemed expedient to hasten work with but little regard for conditions most favorable for observations, as it was believed that sufficient accuracy could be obtained and a great saving in expense effected.

As an extreme instance of the difficulties under which work was prosecuted, it may be mentioned that at one point on the Tule Desert all of the water for men and animals was carried 102 miles—30 miles in tank cars, from Yuma to Adonde Siding on the Southern Pacific Railway, and 72 miles in water wagons, from that point to the camp on the desert.

As much of the observing, both on the Sonora and California azimuth lines, was done under conditions apparently so unfavorable, it may be interesting to give, in addition to the back-azimuth errors and discrepancies between United States and Mexican locations of monument sites already mentioned, the results of experiments made by Mr. John F. Hayford, assistant astronomer, on the Sonora azimuth line, as to the accuracy of pointings upon the heliotropes and the remarkable variations in the apparent size of their lights, which variation was fully confirmed in every respect by observations made by Mr. E. L. Ingram, assistant engineer, on the California azimuth line.

From May 8 to September 15, 1893, a record was kept during observations, of the temperature, the appearance of the heliotropes, and the apparent diameter of the heliotrope light as measured by the micrometer.

The shade temperatures during observations varied from 77° F. to 118° F., averaging about 100° F.

The apparent diameter of the heliotrope light in divisions of the micrometer, 1.24″ each, varied from 5 to 104 divisions; the first occurring in the morning or on a cloudy day, and the last, in a single case, a little before noon of a very hot July day on a sight of 2 kilometers, passing within 3 meters of almost bare sand. The average apparent diameter of the light from all measurements was 25 divisions=31″. The diameter of the principal mirror of one heliotrope was 10 centimeters, that of the other was 7.5 centimeters.

Computations based upon the distance to the heliotrope light and its apparent diameter, as measured by the micrometer, showed that the mirror itself was visible upon very rare occasions, if ever, but that the apparent diameter of the light was many times that of the heliotrope mirror; for example, in one instance the measured apparent diameter of the light of the 10-centimeter mirror corresponded to that of a target 11.4 meters in diameter placed where the heliotrope was located, 43 kilometers distant.

Although varying greatly at different times, it may be stated in general terms that the measured angle, subtended by the apparent diameter of the light, was independent of its distance from the instrument; for example, at 2,000 meters a mean of 3 different measurements gave the apparent diameter of the light of the 10-centimeter mirror as 19 micrometer divisions, while at a mean distance of 40,500 meters the mean of 37 different measurements was 20 divisions. Not only were there abnormal variations in the apparent size of the light, but also in its form. When a steady breeze was blowing across the line of sight the disk of light appeared flattened on the windward side and blown out on the leeward side, very much as would be the flame of a candle. When great distortion of the size of the light occurred it frequently appeared blurred, and always with one part of the blur brighter than the rest. Generally the bright region was in the center, but sometimes it was unsymmetrically situated with reference to the outline of the light. "In those cases the brightest region was always to windward of the center of the blur and the leeward part of the outline vibrated more violently than the windward side." (For further details of these investigations see report of Mr. John F. Hayford, assistant astronomer, Appendix 4 of this chapter.)

In all cases pointings were made in sets of 3, upon the center of the brightest part of the light.

In spite of the apparent distortion of the light as regards size and form, the accuracy of the pointings was not greatly affected thereby, as is shown by the following table, in which $\triangle_3$ is the mean of the differences between each of the 3 pointings of the set and the mean of the 3.

Heliotrope with 10-centimeter mirror.			Heliotrope with 7.5-centimeter mirror.		
Diameter, micrometer divisions.	$\triangle_3$	Number of observations.	Diameter, micrometer divisions.	$\triangle_3$	Number of observations.
	″			″	
0–15	0.82	42	0–20	0.78	77
16–28	1.05	46	21–34	0.88	71
29–67	1.43	38	35–104	1.51	48

The maximum value of $\triangle_3$ in the above table corresponds to $\pm 2.7''$ for the probable error of a single pointing, and justifies, so far as accidental errors are concerned, observations made under such apparently unfavorable conditions.

Observations made in the Tule Mountains to determine whether there was any apparent displacement of the light when the heliotrope was neglected, and whether the apparent position of the light coincided with the actual position of the heliotrope mirror, showed that at 4 kilometers distant the heliotrope light seemed to be 0.19″ south of a pole with which it had been accurately ranged in line, but did not prove "conclusively that there was any apparent change in the position of the light when the mirrors were neglected" from fifteen to twenty-five minutes at a time.

"The accidental errors of pointing seemed to be slightly greater when the mirrors were first adjusted than later when the light had become less bright and apparently smaller."

Observations made at a distance of 5,800 meters to ascertain the effect of reducing the 7.5-centimeter mirror to a diameter of 2.5 centimeters showed that the apparent diameter of the full-sized light was 25 divisions, while that of the reduced light was 23 divisions, and that the latter appeared almost as bright as the former. "The accidental errors were as great with the reduced as with the full light."

At Monument 168 special investigation was made "to determine whether there was a systematic difference between forenoon and afternoon observations, and whether there was any systematic error due to the position of the back glass."

The result showed that the heliotrope appeared to be 0.71″ farther south in the forenoon than in the afternoon, and that the position of the back glass north or south of the line did not affect the result.

To detect constant or systematic errors a line 25,800 meters in length was located, both by lining in points ahead and by lining in the instrument between two known points.

"The greatest difference between the two locations at any of the 10 intermediate stations was 32 centimeters and the average difference 17 centimeters. With one exception, all stations as located by the second method were farther south than by the first method."

A few experiments made by Mr. E. L. Ingram, assistant engineer, seemed to indicate that an east-and-west line traced toward the west, with heliotropes as targets, had a tendency to turn toward the north, a statement which is partially confirmed by the fact that 9 out of 11 lines checked had positive back-azimuth errors, and consequently deviated toward the north.

Another peculiar phase of heliotrope action was often observed, i. e., the much greater actual dispersion of the exterior rays of the cone of reflected rays than should have been the case theoretically.

In conclusion it may be stated that all experiments and investigations confirmed in the most satisfactory manner the reliability of heliotropes as targets under the apparently unfavorable conditions under which they were employed on this survey.

TRIANGULATION IN VICINITY OF EL PASO.

A base was measured on the railroad near Astronomical Station No. 1 and a triangulation laid out from this base connecting Astronomical Station No. 1 with Monuments 1, 2, and 3, and the magnetic station near No. 1, and with the United States longitude station at El Paso; also with the public buildings in El Paso and Juarez.

The following is a list of the geographical positions of the objects determined, and a sketch of the triangulation is given at the end of this chapter.

Geographical positions of points in the vicinity of El Paso, Tex.

Stations.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To stations.	Distance.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		*Meters.*
Astronomical, No. 1	31 46 59.40	106 31 25.07	90 00 16.4	270 00 09.1	Moonment No. 1	365.4
			180 58 23.2	0 58 23.4	North base	496.7
			178 30 40.1	....	Azimuth mark	1,805.8
North base	31 47 15.53	106 31 24.81	36 58 21.1	216 58 13.6	Monument No. 1	621.7
			357 44 20.5	177 44 20.9	South base	550.035
			65 24 48.6	245 24 26.9	Monument No. 2	1,193.6
			64 29 24.1	244 29 02.0	A	1,223.4
			86 13 20.5	266 12 42.3	B	1,911.4
			313 49 15.4	133 49 40.0	C	1,707.0
South base	31 46 57.68	106 31 23.98	97 37 00.9	277 36 53.0	Monument No. 1	399.1
			92 44 18.0	272 43 55.9	Monument No. 2	1,108.4
			91 09 23.1	271 09 00.6	A	1,126.1
			102 23 14.2	282 22 35.6	B	1,975.0
Monument No. 1	31 46 59.40	106 31 39.03	....	....	....	....
Monument No. 2	31 46 59.40	106 32 6.07	....	....	....	....
Monument No. 3	31 46 59.40	106 34 48.07	263 50 38.6	83 51 47.5	B	3,460.4
			270 23 45.2	90 25 10.1	A	4,243.8
A	31 46 58.42	106 32 06.78	285 39 37.1	105 40 23.8	C	2,425.9
			298 59 29.1	119 01 10.0	Court-house	5,766.1
			300 19 53.4	120 21 26.7	Federal building	5,403.5
			316 14 26.2	136 16 02.0	Cathedral Juarez	6,929.1
B	31 47 11.43	106 32 37.31	....	....	....	....
C	31 46 37.15	106 30 38.00	308 19 54.6	128 20 48.8	Court-house	3,451.2
			311 42 46.5	131 43 33.1	Federal building	3,117.7
			330 33 25.7	150 34 14.8	Cathedral Juarez	4,995.4
Federal building	31 45 29.79	106 29 9.57	....	....	....	....
Court-house	31 45 27.64	106 28 55.13	....	....	....	....
Cathedral Juarez	31 44 15.90	106 29 4.73	....	....	....	....

TRIANGULATION AT SAN PEDRO RIVER.

A monument of dressed stone was found on the east bank of the San Pedro River, and the astronomical observations of the United States section were made near the monument, at Astronomical Station No. 10.

Afterwards another monument, consisting only of a pile of loose stones, was found on the west bank of the river and was recognized as the one erected by Emory. It was evident that the monument found on the east bank of the river was the one erected by Salazar, who did not find the one erected by Emory on the west bank. By an agreement of the joint commission (see pp. 37 and 38, Emory's report), the one erected by Emory on the west bank was to be recognized as the one marking the boundary.

A triangulation connecting these monuments was made by the United States section by means of a measured base line and a quadrilateral connecting Astronomical Station No. 10, near Salazar's monument, with Station A on tangent line near Emory's monument.

The difference of latitude between these stations was found to be + 30.08″, and between Salazar's monument and that of Emory + 29.67″, the latitude of Salazar's monument being 31° 19′ 35″ and Monument 20 of Emory being 31° 20′ 4.67″.

As the observations of the Mexican section were made directly at the monument of Emory, their result for its latitude (No. 98, new) of 31° 20′ 3.02″ ± 0.175″ was accepted in 1895 as the true latitude of Monument 98; the difference in station error in latitude accounting for the difference of the two results, = 1.65″.

TRIANGULATION AT NOGALES.

A base line, 724.96 meters long, was carefully measured on the railroad at Nogales, Mexico, and a triangulation made connecting the United States survey longitude station at Nogales, Ariz., with the azimuth station, Monument 122, and various buildings in Nogales on both sides of the boundary line.

This station was also occupied by both United States and Mexican sections for latitude observations.

This triangulation transfers the latitude and longitude of the astronomical station at Nogales, Ariz., to Monument 127 at the intersection of the parallel of 31° 20′ with the one hundred and eleventh meridian of longitude, as determined by Emory.

Points on the tangent through the azimuth station at Nogales, Ariz., were also determined, giving the lengths of portions of the tangent independent of the stadia measurements.

A sketch of the triangulation will be found at the end of this chapter, and a list of geographical positions follows:

Geographical positions of points in vicinity of Nogales, Ariz.

Stations.	Latitude.			Longitude.			Azimuth.			Back-azimuth.			To stations.	Distance.
	°	′	″	°	′	″	°	′	″	°	′	″		Meters.
Astronomical station	31	20	04.70	110	56	28.05								
Azimuth station	31	20	00.33	110	56	24.77	147	13	47.2	327	13	45.5	Astronomical △ station.	160.2
No. 1	31	19	51.73	110	56	57.14	242	32	28.2	62	32	43.3	do	866.7
							252	47	44.0	72	48	00.8	Azimuth station	895.9
No. 4	31	18	59.82	110	55	34.07	144	16	37.5	324	16	11.1	do	2,295.5
							126	03	17.4	306	02	34.2	No. 1	2,716.4
No. 2	31	19	26.55	110	57	01.45	289	36	11.4	109	36	56.8	No. 4	2,452.5
							188	21	14.7	8	21	16.9	No. 1	783.8
No. 3	31	19	56.00	110	55	41.24	66	51	02.4	246	50	20.7	No. 2	2,306.4
							86	15	27.2	266	14	47.7	No. 1	2,011.0
South base	31	19	27.41	110	56	47.81	85	47	07.4	265	47	00.3	No. 2	361.6
							161	46	04.6	341	45	59.7	No. 1	784.5
North base	31	19	50.79	110	56	44.57	6	47	50.7	186	47	49.0	South base	724.96
							30	52	51.8	210	52	43.0	No. 2	869.7

Geographical positions of points in vacinity of Nogales, Ariz.—Continued.

Stations.	Latitude.	Longitude.	Azimuth.	Back-aizmuth.	To stations.	Distance.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		*Meters.*
No. 5	31 20 11.52	110 59 19.42	274 43 15.2	94 45 08.6	No. 3	5,787.8
			290 19 08.0	110 21 05.1	No. 4	6,353.5
No. 6	31 18 35.01	110 59 27.06	183 52 54.3	3 52 58.3	No. 5	2,979.2
			247 18 36.3	67 20 33.7	No. 3	6,471.0
No. 7	31 21 40.55	111 05 16.86	286 09 23.9	106 12 29.9	No. 5	9,837.8
			301 41 11.5	121 44 13.4	No. 6	10,870.6
No. 8	31 19 38.66	111 04 35.25	163 40 16.6	343 39 55.0	No. 7	3,911.8
			283 30 08.8	103 32 49.0	No. 6	8,381.6
B	31 20 03.70	111 04 48.52	165 54 15.8	345 54 01.1	No. 7	3,075.5
			335 31 47.4	155 31 54.3	No. 8	847.1
Monument XIX*	31 20 03.85	111 04 48.36				
Corner Monument 127	31 19 59.28	111 04 34.46	110 07 10.9	290 07 03.6	B	395.7
			160 14 24.1	340 14 02.1	No. 7	3,314.2
Monument 122	31 20 00.73	110 56 34.53	272 43 41.5	92 43 46.6	Azimuth station	258.3
			65 07 07.4	245 06 55.7	No. 1	658.9
Levys store (flag pole)	31 20 02.20	110 56 32.58	63 35 21.3	243 35 68.5	do	725.0
			285 34 01.6	105 34 35.7	Azimuth station	214.3
Montezuma Hotel (flag pole)	31 20 06.17	110 56 29.83	313 47 19.9	133 47 20.8	Astronomical	65.2
			58 22 06.6	238 21 52.4	No. 1	848.0
Mexican custom-house (flag pole).	31 19 55.26	110 56 43.15	73 37 24.6	253 37 17.3	do	385.6
			233 54 47.8	53 54 55.6	Astronomical	493.9
Flag C	31 20 00.33	110 56 54.46		90 06 00.0	Azimuth station	785.0
Flag D	31 20 00.33	110 57 10.03		90 00 00.0	do	1,196.7
Flag E	31 20 00.32	110 57 47.23		90 00 00.0	do	2,180.0
Flag F	31 20 00.31	110 58 38.16		90 00 00.0	do	3,526.6
Flag G	31 20 00.30	110 59 13.87		90 00 00.0	do	4,470.4
Flag H	31 20 00.29	110 59 42.53		90 00 00.0	do	5,228.0
Flag I	31 20 00.26	111 00 30.69		90 00 00.0	do	6,501.2
Flag K	31 20 00.22	111 01 38.32		90 00 00.0	do	8,289.2
Flag M	31 20 00.08	111 04 26.00		90 00 00.0	do	12,722.2

*As numbered on Major Emory's map.

TRIANGULATION IN VICINITY OF YUMA, ARIZ.

A base 2,203 meters long was measured on the level mesa east of the town of Yuma, and an extensive system of triangulation made connecting the astronomical station in the corral of the United States Quartermaster's Department, occupied by the Coast and Geodetic Survey for longitude, and by both the United States and Mexican sections for latitude, with the azimuth station of the United States section, with Monuments No. 207, on the west side of the Colorado River, and No. 205, on the east side of the same river 20 miles below the junction of the Gila and Colorado. It was necessary to elevate the theodolite at Monument 205 about 25 feet by means of a tripod and scaffold to see the azimuth station.

Station No. XXXVII of Tangent A, on the west ridge of the Tinajas Mountains, was determined, thus measuring by triangulation the distance of this station from Monument 204, giving a valuable check on the same distance as measured by stadia.

Geographical positions of points in vicinity of Yuma, Ariz.

Stations.	Latitude.	Longitude.	Azimuth.	Back-azimuth.	To stations.	Distance.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″		*Meters.*
Latitude station	32 43 34.69	114 37 23.40	....	....	....	....
Azimuth station	32 42 39.54	114 37 07.44	166 15 07.8	....	Latitude station	1,748.9
			178 32 01.12	....	Azimuth mark	....
East base	32 41 45.85	114 36 34.94	152 53 39.8	332 53 22.2	Azimuth station	1,858.0
West base	32 41 55.23	114 37 58.78	224 24 37.4	44 25 05.1	....do	1,910.9
No. 9	32 39 13.49	114 38 07.41	182 34 51.2	2 34 55.8	West base	4,987.3
			207 09 59.1	27 10 49.0	East base	5,275.6
No. 10	32 39 10.36	114 35 27.58	91 20 12.8	271 18 46.6	No. 9	4,166.4
			158 01 12.6	338 00 18.7	Azimuth station	6,949.0
Pilot Knob	32 43 53.83	114 44 49.68	280 43 45.3	100 47 55.2	....do	12,253.0
			309 27 39.5	129 31 16.8	No. 9	13,578.9
No. 11	32 41 23.38	114 49 46.01	238 59 32.5	59 02 12.6	Pilot Knob	9,002.0
			280 19 00.8	100 26 44.2	No. 10	22,739.2
Monument 204	32 29 01.03	114 46 48.64	168 34 38.5	348 33 03.0	No. 11	23,330.5
			223 22 30.3	43 28 36.9	No. 10	25,844 4
Station XXXVII, line A, on Tinajas Mts.	32 15 39.70	114 02 56.80	130 36 15.6	310 18 48.1	No. 10	66,963.0
			109 55 52.2	289 32 23.1	Monument 204	73,095.5
B	32 43 28.35	114 37 14.78	352 45 05.8	172 45 09.8	Azimuth station	1,515.6
			93 49 32.5	273 45 26.6	Pilot Knob	11,871.3
Boundary post	32 43 29.54	114 36 56.61	349 58 35.2	169 58 46.9	East base	3,243.7
			10 22 39.2	190 22 33.3	Azimuth station	1,565.9
Indian school (flag pole)	32 43 53.49	114 37 04.85	1 41 55.1	181 41 53.7	....do	2,279.2
			90 05 02.4	270 00 51.1	Pilot Knob	12,193.5
Penitentiary (pole 1)	32 43 34.82	114 36 56.18	9 46 00.9	189 45 54.8	Azimuth station	1,728.0
			67 36 38.9	247 36 28.9	B	523.8
Penitentiary (pole 2)	32 43 35.46	114 36 56.05	9 46 00.8	189 45 54.6	Azimuth station	1,748.0
			92 39 42.8	272 35 26.7	Pilot Knob	12,345.8
Flag E	32 43 01.33	114 44 02.30	142 39 55.7	322 39 30.1	....do	2,034.0
			265 29 10.0	85 32 50.3	B	10,644.7
Monument 207	32 43 01.86	114 43 54.31	85 29 14.3	265 29 10.0	E	208.7
Flag F	32 42 55.69	114 45 26.81	208 21 36.8	28 21 56.9	Pilot Knob	2,035.2
			265 28 28.8	85 32 54.7	B	12,852.6
Flag G	32 42 49.78	114 46 54.91	265 27 36.7	85 32 50.3	B	15,154.4
			59 09 58.8	239 08 26.4	No. 11	5,190.6
Flag K	32 42 34.04	114 50 48.45	265 25 30.5	85 32 50.3	B	21,255.9
			323 13 27.3	143 14 01.0	No. 11	2,717.3

Electric light poles.

Appendix No. 1.

Report of Mr. E. L. Ingram, Assistant Engineer.

San Diego, Cal., *October 27, 1894.*

Following are the final reports on tangent and line work intrusted to my care during the progress of the present survey:

1. Report of tangent work, parallel 31° 47′ N.
2. Report of line work, meridian line.
3. Report of tangent work, parallel 31° 20′ N.
4. Report of line work, azimuth line, Colorado River to Pacific.
5. General report, common to all lines.

1. *Report of tangent work, parallel 31° 47′ N.*—Work in my charge: Parallel 31° 47′ was located by the tangent (to the prime vertical) and offset method. The duty assigned to me was to locate and mark in the field such tangents as were necessary for this purpose; to measure these tangents by chaining; to locate existing monuments with reference to tangents, and to make such other measurements and computations as were necessary and appropriate to the work in hand.

Size of camp: The camp was made up of my own party proper, together with several members of the topographical party, and the necessary help. The number of men varied more or less, but was about as follows: Tangent party—myself in charge—1 recorder, 2 chainmen, 4 targetmen; level party—1 levelman, 2 rodmen; stadia party—1 transitman, 2 rodmen; help—1 cook, 3 teamsters.

Transportation: This was also very variable, but was about as follows: One baggage wagon with 4 mules, 1 water-tank wagon with 6 mules, 1 spring wagon with 2 mules, 1 pack mule, 1 saddle horse.

Supplies: These were furnished by the quartermaster, usually without the help of the camp transportation.

Stations: Line stations were driven at each whole kilometer along each tangent, counting from its initial point, in addition to the main stations at the ends of the successive prolongations.

Rerunning of tangent No. 1: According to instructions, tangent No. 1 was run at all hours of the day over a burning mesa, regardless of all atmospheric conditions, in order to make quick time over a bad stretch of desert. In addition to this the average length of each prolongation was less than 3 miles, owing to the rolling nature of the country traversed. As a consequence of these and other unfavorable conditions tangent No. 1 deviated rapidly to the north, with a final azimuth error of 186.6″ at the meridian of Astronomical Station No. 2. Before commencing monument work I reran this tangent, for direction only, with a probable back-azimuth error of 1″, as well as it could be determined. In the actual location of monuments everything was referred to the original tangent, based on corrections derived from the new tangent. Between new Monuments Nos. 11 and 15 tangent No. 2 was used in place of No. 1.

Check tangents: Tangents Nos. 1, 2, 3, and 5 are the main tangents. New No. 1 and No. *3a* and No. 4 are check tangents, exerting their influence in the final location of the monument curve.

Dates: The work in my charge commenced February 12, 1892, and ended April 23, 1892.

2. *Report of meridian line.*—Work in my charge: Practically the same, except that a meridian line through the existing monuments was located in place of a series of tangents; chaining was abandoned, and stations were placed at probable monument sites in place of kilometer points; slightly reducing the size of the party, the size of camp and amount of transportation remaining about as before.

Dates: Meridian work was commenced April 29, 1892, and ended May 23, 1892.

Method of running line: This line was run practically as a single sight. A hill 2 miles south of and seeing Monument 40 and a hill one-third of a mile north of and seeing Monument 53 were found to be intervisible, and Monument 46 was found to be visible from the northern hill. Observations at the different points of view proved the three monuments to be truly in line with each other and on a true meridian. It was intended that the intermediate points located should also be on this line, but owing to the small transit used a deviation (1 decimeter) occurred in the lower part of the line and had to be corrected by offsets when the new monuments were located. At the upper corner a true meridian was established by the astronomical party, and the monument line was found to coincide therewith. At the lower corner it became necessary to use the Würdemann theodolite to connect with the azimuth station, making the result unreliable to at least 5″. The actual result obtained, if correct, would indicate a deviation of 3.4″ to the east in running northward.

3. *Report of tangent work, parallel 31° 20′ N.*—Work in my charge: The duties assigned to me on this parallel remained practically the same as before, with the addition of a small amount of topography in the vicinity of Nogales, Ariz. During my absence on monument work (August 15–November 5, 1892) one tangent (No. 12) was run entirely by J. F. Hayford, assistant astronomer. Mr. Hayford also ran tangent No. 15 while I was engaged on topographical work.

Camp and transportation: The size of the camp and amount of transportation was extremely variable, and were further modified by the topographical party, which was sometimes with my camp and sometimes detached.

Supplies: These continued to come through the quartermaster, depending partially on the camp transportation for their delivery.

Dates: Tangent work, May 26, 1892, to August 15, 1892, November 5, 1892, to December 6, 1892; absent on monument work, August 15, 1892, to November 5, 1892; engaged on topograpical work, December 7, 1892, to January 9, 1893.

4. *Report of line work, on azimuth line, Colorado River to Pacific.*—Work in my charge: All the work of this part of the survey, including line, level, and topographical work. This, of course, does not include the astronomical observations for azimuth, made at each end of the line by J. F. Hayford, assistant astronomer, nor the triangulation from Yuma to Monument 207, which was also in charge of Mr. Hayford.

Size of camp: The camp varied in size with the character of the country traversed, but for the greater part of the time was about as follows: Myself, in charge, 2 transitmen, 1 levelman, 10 rodmen, 2 packers, 1 guide, 4 teamsters, 1 cook, 1 cook's helper.

Transportation: Variable, but about as follows for the bulk of the time: Two baggage wagons with 4 mules each, 1 water-tank wagon with 6 mules, 1 spring wagon with 2 mules, 6 pack mules, 2 saddle horses.

Supplies: Up to May 10, 1893, all supplies were obtained from the quartermaster. From this date to September 20, 1893 (breaking up of camp), all supplies were purchased directly by myself as needed from time to time, and hauled by the camp transportation.

Level and topographical work: The methods established by J. L. Van Ornum, assistant engineer, were adhered to in this part of the work.

Line work: A broken line was run from the "Boundary post" in Yuma to the initial monument on the Pacific Coast. The line as actually marked in the field is best seen from the sketch given in the monument report, but may be described as follows:

Boundary post to Station 3 I (Coast Range) = prolongation of direction of line from boundary post to Monument 207.

Station 3 I—4 L (Mount Tecate) deviates 8′ 52″ to south from previous line.

Station 4 L—Monument 252 runs direct between these points.

Monument 252—old Monument II runs direct between these points.

Old Monument II—Monument 258 runs direct between these points.

Deviation at Station 4 L = 16′ 12.3″ north.

Deviation at Monument 252 = 8′ 22.9″ south.

Deviation at old Monument II = 0′ 38.2″ north.

The angles here given are computed values, and subject to correction for errors in distances and back-azimuth error.

The direction Station 3 I—4 L was also prolonged to the meridian of Monument 258 (passing 140.07 meters south) for the purpose of back-azimuth and latitude work, and furnished the basis for computing the angles above given, which could not be directly measured as easily with equal accuracy.

The object of the deviation at Station 3 I was to draw the located line closer to the actual monument line, but owing to the large station error between boundary post and Monument 258 this result was not achieved.

The main heliotrope stations, or points from which the successive prolongations were made, are Station K, Station 3 I, and Station 4 L, and an equal distribution of back-azimuth error (+23.8″) at these points is probably the best that can be done.

Dates: Line work commenced January 14, 1893, and ended September 20, 1893, when the camp was disbanded and I was ordered to San Diego for office work.

5. *General report.*—The following notes and remarks, applying to all the tangent and line work, are here grouped together to avoid unnecessary repetition.

All measurements are metric. All lines and tangents were run with Würdemann theodolite No. 85, which is an 8-inch repeater of the pillar pattern. In considering the results obtained it is but fair to remember that this instrument is extremely old, both in design and service, and capable of any use at all only with the greatest care. Fortunately it was possessed of a telescope of most unusual excellence.

In the early part of the work the lines were extended by sighting on wooden targets about 3 feet square, mounted with a sliding motion on wooden tripods. These targets were painted black and white, and various designs were experimented with without success, and finally the targets were given up entirely in favor of heliotropes. As far as visible (about 3 miles) a common range pole was capable of far more accurate alignment than any of the targets. Beyond 3 miles, in spite of their size, the targets were as hard to distinguish as a range pole. A similar experience occurred later in the work in a slightly different manner, and is considered of sufficient interest to be inserted here.

Observations for azimuth were taken at Monument 220, near New River, and the following morning the angle between the line and the azimuth box was sought to be measured. The azimuth box was less than 2 miles from the instrument, and the front of the box was divided into three equal stripes, the central one being white and the others black. Each stripe was 6 inches wide and 12 inches high. On top of the box was a white stick 1 inch in diameter and 12 inches high. Contrary to all expectations, the box appeared merely as a dim haze, even with the sun shining directly on it, and was entirely useless for sighting at with the intention of measuring an angle with any accuracy. The little stick, however, stood out with startling clearness and was bisected with ease and certainty.

The heliotropes which were used after the wooden targets were abandoned were simple little affairs without adjustments of any kind; were provided with mirrors 3 inches in diameter; at first mounted with a sliding motion, but finally attached rigidly to light wooden tripods. These little heliotropes were easily visible 30 miles to the naked eye, and could be seen 80 miles with the theodolite. The appearance of the heliotrope light varied greatly under different conditions. At sunrise and sunset the cross hair of the telescope was sufficient to obscure the whole light. Within an hour or less of those times the light appeared about three to five times the apparent width of the cross hair.. In the middle of the day the light grew to enormous proportions, covering as much as five minutes of arc. The angular width of the light remained about the same, regardless of distance. The light usually became more and more unsteady as it increased in size, in the middle of the day appearing to be in an intense state of vibration in all directions, and changing its size and shape with remarkable rapidity. In the middle of the day the light lost its dazzling appearance almost entirely and was frequently hard to distinguish from a white flag, even to the trained eye. This effect was also noticed when the light was not accurately pointed at the observer. When a strong wind was blowing the light apparently elongated in the direction of the wind, assuming an oval form, with the pointed part going with the wind. The pointed part then waved and fluttered just like the edge of a flag in a gale. It may here be observed that all these effects appeared in less degree in proportion as the light was more truly pointed at the observer (as judged by the brightness of the light), and it is the opinion of the writer that a heliotrope with telescopic line of sight and slow-motion mirrors would be worth many, many times the extra cost of manufacture. In this connection it may be mentioned that signals are hard to understand, and easily mistaken when the light is poor, as found on the 80-mile shot west of the Colorado River, where the signals failed repeatedly until the mirrors were provided with a rough attempt at slow motion by wooden levers about a foot long, held in place by light friction. With this new arrangement the signals were received at the 80-mile point with absolute certainty, and obeyed immediately and correctly.

If the mirror as ordinarily mounted is screwed so tight in its bearings as to safely resist the whirling effect of the wind it will move by fits and starts, even if moved in the most delicate way, which is by jarring it around with the tapping of a pencil. It is further believed that when the light is not truly pointed the visible image is not concentric with the center of the mirror, which is a very serious matter if true. If the light is directed incorrectly in a vertical direction there is little or no reason to expect that it makes any particular difference, except in the way of annoyance; but if it is swung slightly to one side or the other it seems not unreasonable that it may twist the line of sight. Unfortunately this point has never been determined without doubt, and my theodolite, having no micrometer eyepiece, was not well adapted to such a determination. A few experiments were made, however, when opportunity offered, and seemed to indicate that an east and west line had a tendency to turn northward from this cause. It will be noticed also from the line reports that nine out of eleven lines have a positive back-azimuth error, indicating that the successive prolongations have deviated northward.

After the completion of the meridian line a reconnoitering telescope, with heliotrope attachments (without slow motion), was added to the outfit and proved very valuable on account of its telescopic line of sight.

All level work in my charge was done with a Gurley wye level of the usual pattern, using the methods established by Mr. J. L. Van Ornum, assistant engineer.

All topographical work in my charge was done with a 6-inch Brandis engineer's transit, using the methods established by J. L. Van Ornum, assistant engineer.

The small instruments composing the balance of the outfit were such as are ordinarily used, the tapes, chains, level rods, etc., all being metric.

The stations marking the line differed somewhat at different times, but in general consisted of 2-inch by 3-inch stakes projecting from 6 to 18 inches above the ground and surrounded with stones for protection. A flag was usually left accurately on line near each station, for the benefit of the following parties. A small stake, usually 1 by 1 by 6 inches, was driven out of sight approximately south of each station at a distance of 1 meter, to be used as a witness if the main stake suffered any derangement. On the meridian line the witness stakes were put to the west. In point of fact, the main stakes were scarcely ever found disturbed, even after twelve or more months from time of placing. In the sand dunes, of course, a number of stakes disappeared, but in this case the witnesses were also gone.

The work on different parts of the boundary differed very much in theory, but the actual field work was practically the same in all cases, and consisted in establishing as nearly as possible a long, straight line over a given stretch of country by successive prolongations of a given initial direction. On parallels 31° 47′ and 31° 20′ the lines run were tangents to the prime vertical at or near the corresponding astronomical stations, the initial directions being jointly established by J. F. Hayford, assistant astronomer, and myself. The meridian line was run practically in a single sight. The azimuth line (Colorado River to Pacific) was run part way with the initial direction Boundary Post and Monument 207, and afterwards changed in direction, as explained in the detailed report thereon.

The object in every case was to obtain a straight line conveniently near existing monuments, and of such a nature that the actual boundary could readily be located by a series of easily computed offsets. The formulæ and constants pertaining to the work being more intimately related to the discussion of monument location are all given in the monument report and not repeated here.

The various straight lines were prolonged by myself personally, using the method of reversals. The instrument was set up over the last point established in any case, and carefully leveled with the striding level while pointing at the furthest visible point previously established. The telescope was then transited over and a new point lined in ahead as far as could be seen. This operation was repeated four times, the telescope being alternately direct and reversed to eliminate level and collimation errors, and the mean of the four new points thus located was considered to be the correct prolongation sought. Sometimes more or less than four points were used under peculiar conditions, but the general rule was the mean of four points. Each line was thus prolonged until it reached the meridian of the next succeeding astronomical station, where its back azimuth was determined and compared with the theoretical value. All the astronomical stations were located with reference to both the old and new tangents, so that the series of tangents formed a continuous chain throughout the work.

The theodolite used had no micrometer eyepiece, and hence the distance necessary for the forward heliotrope man to move to come into line could only be roughly estimated. The signals used were therefore of the simplest character. Long flashes (five seconds) of the heliotrope directed a movement to the north, and short flashes (one second) a movement to the south, the number of flashes giving a rude idea how far to move. When the forward heliotrope went out it meant it was being moved in response to the signal. When the light was judged to be on line a long, steady light (about thirty seconds) was shown, and responded to by three long flashes when understood, and the point thus established was marked on the ground. When the requisite number of points was located, and the mean established, the forward man kept a steady light while intermediate points were established at convenient places. A code of simple signals was also established for commencing and finishing work each day, going to lunch, etc., such as would naturally suggest themselves. Intermediate points were usually set with range poles, the instrument being moved forward from time to time as convenient.

It would hardly occur to anyone that there could be any difference between having the vertical hair of the telescope central with the heliotrope light and having the light central with the hair; but such proved to be the case. If the eye gives its chief attention to the light the hair soon becomes unsteady, apparently transparent, and uncertain in position, and the light, if good, shows dazzlingly bright. On the other hand, if the eye looks chiefly at the hair the light shows simply as a fairly bright background against which the hair appears densely opaque, black, sharp, and clear, and its position relative to the center of the light is unmistakable. No amount of focusing for parallax seems to prevent this result, which is acknowledged by every observer I have ever known to try it.

No table of results is given regarding the setting of new points ahead on the line for the reason that these results are very uniform in character, and seem to depend scarcely at all either on the length of the foresight or the backsight. Even on lines 30 miles in length independent settings with the telescope in the same direction seldom differed over a few inches, though in reversed positions they sometimes differed as much as 10 feet. The collimation error was very variable, owing to the jolting the instrument continually suffered in rough country. Curiously enough, in the longest shot of the whole survey, about 80 miles, the four settings agreed exactly. After the experience of the first tangent the foresights were made as long as possible, there seldom being more than two or three prolongations even in the longest tangents.

Appendix No. 2.

Report of Mr. E. L. Ingram, assistant engineer, on monument location.

San Diego, Cal., *October 31, 1894.*

General constants.—The following constants enter more or less into all the formulæ adapted to the work in hand, and are here grouped together for convenience of reference.

The geodetic constants conform to Clark's 1866 spheroid. Reference is made to the following publications: United States Coast and Geodetic Survey Card, 1886; United States Coast and Geodetic Survey, Appendix 7, 1884; United States Coast and Geodetic Survey, Appendix 9, 1885.

Major semi-axis $= a = 6378206.4$ meters; log. = 6.80469857

Minor semi-axis $= b = 6356583.8$ meters: log. = 6.80322378

$a : b = 294.98 : 293.98$.

Eccentricity $= \frac{a^2-b^2}{a^2} = e^2 = 0.006768658$; log. = $\bar{7}.83050257$

Sin. 1″		log. = $\bar{4}$.6855749
2 sin. 1″		log. = $\bar{4}$.9866049
Sin. 31° 47′		log. = 9.7215704
Sin. 31° 20′		log. = 9.7160168
1 meter	= 3.2808693 feet;	log. = 0.5159889
1 meter	= 39.3704316 inches;	log. = 1.5951702
1 kilometer	= 0.6213768 statute mile;	log. = 9.7933550
1 foot	= 0.30479727 meter;	log. = $\bar{9}$.4840111
1 statute mile	= 1609.3296 meters;	log. = 3.2066450
π	= 3.14159265;	log. = 0.4971499
$\frac{1}{2}$ sin. 1″		log. = $\bar{4}$.3845449
$a(1-e^2)$ 6335035;		log. = 6.80174898
$1-e^2$		log. = 9.9970504
$\frac{e^2 \sin.^2 1''}{6(1-e^2)}$		log. = 6.4264506
$\frac{e^2 \sin. 1''}{4(1-e^2)}$		log. = 1.9169670
$\frac{\sin.^2 1''}{12}$		log. = 8.2919685
Sin.² 1″		log. = 9.3711498

Radius of sphere with volume of Clark's spheroid = 6,370,991 meters.

Radius of sphere with surface of Clark's spheroid = 6,370,997 meters.

Length of meridian quadrant of Clark's spheroid = 10,001,887 meters.

Formulæ for tangents and parallels.—Parallels of latitude are most conveniently located in the field by the tangent (to prime vertical) and offset method. All necessary computations may be made by the formulæ and tables of United States Coast and Geodetic Survey, Appendix No 7, 1884, but the formulæ given below are better adapted to the purpose.

Let L = latitude of parallel and initial point of tangent.

l = latitude of any point on tangent.

M = longitude of initial point of parallel and tangent.

m = longitude of point on tangent whose latitude is l.

D = distance on tangent from initial point to point (m, l).

N = normal to ellipse (meridian section) to intersection with minor axis.

R = radius of curvature of ellipse (meridian section).

Z = azimuth (N. to E.) of tangent at point (m, l).

$90^\circ - Z$ = change of azimuth between initial and given points.

Then

$$R = \frac{a\,(1 - e^2)}{(1 - e^2 \sin.^2 L)^{3/2}} \qquad N = \frac{a}{(1 - e^2 \sin.^2 L)^{1/2}}$$

$$L - l = D^2 \frac{\tan. L\,(1 + e^2 \cos^2 L)}{N^2\, 2 \sin. 1''} \qquad m - M = D \frac{1}{N \sin. 1''} \frac{1}{\cos l}$$

$$90^\circ - Z = D \tan. l \frac{1}{N \sin. 1''} \text{ or, } 90^\circ - Z = (m - M) \sin. l$$

$L - l$ = meridian offset from tangent to parallel.

Argument (metric.)	For any parallel.	Constant for 31° 47′.	Constant for 31° 20′.
Log. N		6.8051867	6.8050964
Log. R		6.8029733	6.8029424
Log. $(L-l)''$ =	2 log. D	8.8025714	8.8101789
Log. $(L-l)$ meters =	2 log. D	7.3140232	7.3216616
Log. $(m-M)''$ =	log. D — log. cos l —	1.4906816	1.4906713
Log. $(90^\circ-Z)''$	log. $(m-M)$ + log. sin l.	....	....
$(90^\circ-Z)''$ per kilometer		20.02″	19.67″

Back-azimuth error.—The meridian lines for laying off the monument offsets are secured by turning off from the tangent line an angle depending on the theoretical azimuth at the given point and the assumed azimuth error at the same place. The shortness of the offsets and the smallness of the whole azimuth error to be distributed are always such that any reasonable assumption will give sensibly the same field location. When the azimuth error is large it is assumed to be constant between the heliotrope stations, since intermediate stations exert no influence on the prolongations of the line. When the azimuth error is small it is assumed to vary in direct ratio with distance from initial point of tangent, since other complications are much simplified without causing any practical error in the result. When the tangent error is known at one or more points along the line the azimuth error is distributed so as to be consistent therewith, at the same time keeping the assumed curvature of the tangent of the simplest possible character. Straight-line chords joining the heliotrope points are then considered to represent the tangent as run. The assumptions thus made with the various tangents appear in the tables in their proper places. By the curvature of the tangent is meant such a curve as will contain all the heliotrope points (or initia points of prolongation) and not the intermediate points which fill out the tangent. By instruction even the smallest azimuth errors were distributed on parallel 31° 47′, though later in the work anything under 10″ was ignored.

Tangent error.—By tangent error is meant the deviation of the line marked in the field from a true prolongation of the initial direction, as measured on the meridian at the given point. The tangent error and back azimuth error must harmonize with each other, the assumptions made for one controlling those made for the other. In some cases the tangent error was measured directly in the field; in other cases it had to be assumed, being directly computed in accordance with the distribution of azimuth error. In every case all the known errors were carefully considered and the simplest possible assumptions then made which would include and agree with observed facts.

The tables show in detail the assumptions made. When the azimuth error averages one-half second or less per mile it may safely be distributed in direct ratio with distance from initial point of tangent. In this case the tangent error will vary as square of same distance, and the offset formula may be conveniently modified so as to cover this correction. The direct ratio assumption for azimuth error distribution gives a smaller tangent error than when the error is divided entirely among the heliotrope points. This may be considered rather advantageous than otherwise, corresponding to the reasonable assumption that the tangent errors do not occur all one way. It may here be noticed that it is the *curvature* of the tangent as run (the successive deviation of successive prolongations) that modifies the computed offsets to the monument curve, and not the absolute value of the tangent error. Hence an incorrect assumption in regard to the value of the tangent error is a matter of much less importance than might at first appear.

Tangent data.

[Distances by chain and subject to correction; latitudes by J. F. Hayford, assistant astronomer.]

TANGENT NO. 1.

Station.		Offset N.	Latitude.	Back-azimuth error.		Tangent error.	
Name.	Distances along tangent.			Measured.	Assumed.	Measured. N.	Assumed. N.†
	Meters.		° ′ ″	″	″		
Magnetic	−(1,274.13)	1.035					
Astronomical No. 1	−(1,077.21)	1.03	31 46 59.40				
Monument No. 1	− (711.67)	1.02					
Monument No. 2	Zero.	1.00		0.0		0.00	
Monument No. 3	4,262.76	2.00			0.0		0.00
Heliotrope 6 A	6,226.20				+6.0		0.06
Heliotrope 10 A	10,934.20				+12.0		0.33
Heliotrope 11 A	11,834.85				+18.0		0.40
Heliotrope 16 A	16,212.00				+24.0		0.90
Heliotrope 19 A	19,388.55				+30.0	1.38	
Heliotrope 25 A	25,584.00				+59.9	3.18	
Mexican Astronomical No. 2	28,233.66	24.77		+75.0			4.14
Heliotrope 29 A	29,264.50				+75.0		4.52
Heliotrope 29 B	29,531.50				+79.0		4.62
Heliotrope 38 A	38,149.80				+83.0		8.09
Heliotrope 41 A	41,647.90				+87.0		9.57
Heliotrope 42 A	42,890.70				+93.0	10.13	
Heliotrope 43 A	43,392.30				+93.0		10.36
Heliotrope 50 A	50,602.62				+98.0		13.79
Heliotrope 51 A	51,130.35				+107.0		14.07
Heliotrope 52 A	52,639.50				+120.0		14.95
Heliotrope 55 A	55,277.80				+137.0		16.71
Monument No. 11	59,093.28	122.46			+159.0	19.66	
Heliotrope 59 A	59,137.18				+159.0	19.69	
Monument No. 15	79,058.47	240.10			+186.6	Replaced by tangent No. 2.	
Astronomical No. 2	79,061.88	235.98	31 47 0.21	186.6			

TANGENT NO. 2.

Monument No. 11	Zero.	22.91			0.0		0.00
Monument No. 15	19,970.39	4.14			0.0		0.00
Astronomical No. 2	19,973.80	zero.	31 47 0.21	0.0		0.00	

TANGENT NO. 3.

Monument No. 15	−3.41	4.14			*0.0		†0.00
Astronomical No. 2	Zero.	Zero.	31 47 0.21	0.0		0.00	
Heliotrode 1 A	1,672.65				0.0		0.00
Monument No. 21	21,470.77	27.05			+23.4	2.25	
Astronomical No. 3	34,658.32	58.40	31 46 58.00	+34.8			4.48
Monument No. 26	34,664.01	60.84			+34.8		4.48

* Assumed constant between given points.

† In direct ratio between given points.

Tangent data—Continued.

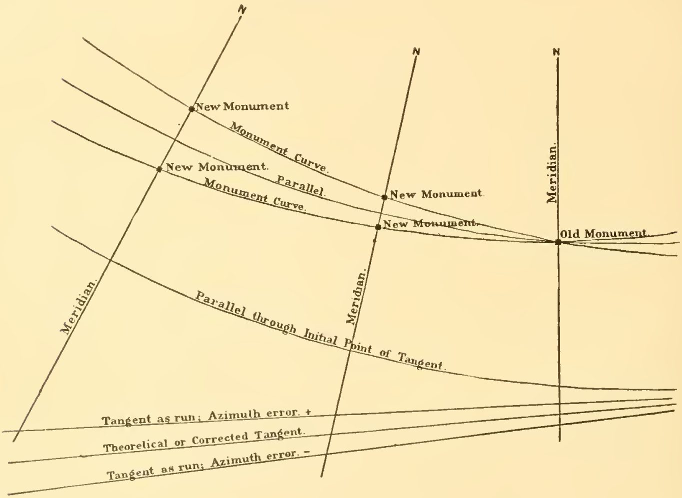
TANGENT NO. 5.

Station. Name.	Station. Number.	Offset N.	Latitude.	Back-azimuth error. Measured.	Back-azimuth error. Assumed.*	Tangent error. Measured. N.	Tangent error. Assumed. N.†
			° ′ ″	″	″		
Astronomical No. 3	Zero.	Zero.	31 46 58.00	0.0	....	0.00	....
Monument No. 26	5.69	2.44	....	....	0.0	....	0.00
Monument No. 32	20,463.36	22.79	....	....	+ 1.6	....	0.078
Monument No. 33	21,611.00	25.20	....	....	+ 1.7	....	0.086
Monument No. 40	41,415.14	98.97	....	....	+ 3.4	....	0.366
Astronomical No. 4	44,423.78	63.11	31 46 58.55	+ 3.4	....	....	0.366

* In direct ratio.

† As square of distance.

MONUMENT CURVE.



The diagram is intended to indicate the geometrical conditions governing the location of the monument curve joining any two consecutive existing (old) monuments, and is almost self-explanatory. The diagram, as will be seen, shows different conditions, all of which would not exist in any one case. The two tangents shown correspond to the two cases of error by which a tangent may be affected. The two monument curves represent two cases, depending on which terminal monument is farthest north. The computed offset from the tangent as run to the true parallel through one monument is increased or decreased by the distance between the monument curve and parallel at the given point, and the distance between the parallel and monument curve is assumed to vary in direct ratio as distance from monument at intersection of the curves.

Theoretical offset formulæ, parallel 31° 47′.

The offset from tangent as run to monument curve at any given point is made up of four parts, as follows:

1. Theoretical offset from a true tangent to a true parallel through initial point of tangent.
2. A correction for tangent error.
3. A constant of translation corresponding to true parallel through one monument.
4. A proportional part of the amount by which a true parallel through one monument passes north or south of the other monument.

The following table is formed from the data contained elsewhere in this report:

Tangent No.	Offset (by theoretical formulæ).
1	Theoretical — tangent error 1.12 — prop. part 28.45
2	Theoretical (no tangent error) + 4.14 — prop. part .59
3	Theoretical — tangent error + 4.14 prop. part 2.79
3	Theoretical — tangent error + 6.93 + prop. part .08
5	Theoretical — tangent error + 2.44 + prop. part .11
5	Theoretical — tangent error + 2.63 + prop. part .98

In these formulæ—

Log. theoret. = 2 log. sta. — 7.3140232, except for tangent 2, where substitute (sta.) the value (19973.80 — sta.). By sta. is meant distance from the initial point of the tangent.

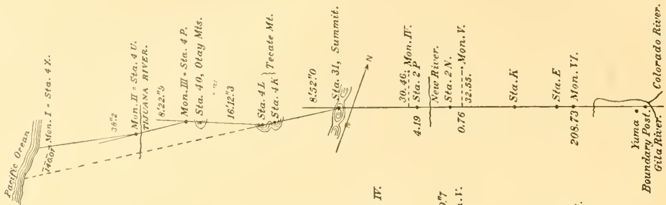
Tang. error (Mon. 3 to 15) = interpolate as directed in tangent data.
Tang. error (Mon. 15 to 21) = zero to sta. 1672.65 and then log.$^{-1}$ [log. (sta. — 1672.65) — 3.9414111].
Tang. error (Mon. 21 to 26) = log.$^{-1}$ [log. (sta. — 8134.68) — 3.7728459].
Tang. error (Mon. 26 to 40) = log.$^{-1}$ [2 log. sta. — 9.7315917].
Proportional part 28.45 = log.$^{-1}$ [log. (sta. — 4262.76) — 3.2849425].
Proportional part .59 = log.$^{-1}$ [log. (19970.39 — sta.) — 4.5295346].
Proportional part 2.79 = log.$^{-1}$ [log. (sta. + 3.41) — 3.8863124].
Proportional part .08 = log.$^{-1}$ [log. (sta. — 21470.77) — 5.2172615].
Proportional part .11 = log.$^{-1}$ [log. (sta. — 5.69) — 5.2694635].
Proportional part .98 = log.$^{-1}$ [log. (sta. — 21611.00) — 4.3667876].

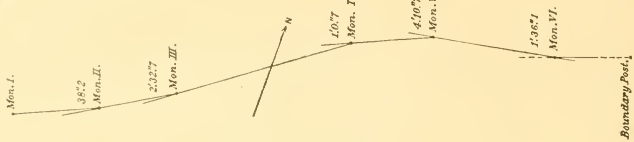
It will suggest itself to anyone that the above method of deriving an offset, while being the first and natural method, is exceedingly awkward and laborious. In nearly every case the monument site was selected in the field, and a simpler plan was a desideratum. The writer therefore devised by familiar methods the following empirical formulæ, which exactly represent the desired curve and will be found to be of exceptional simplicity when put in actual use. It will be noticed that only one new logarithm is involved for any given case, and in actual practice less than one minute served to determine the offset:

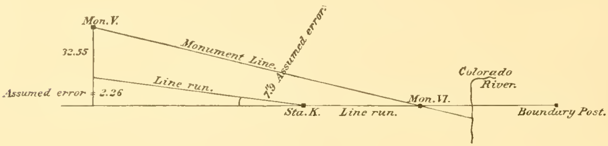
Tangent No.	Offset (by empirical formulæ).
1	log.$^{-1}$ (2 log. sta. — 7.3140232) — log.$^{-1}$ (log. sta. — 3.2849093) + 3.33 — tangent error;
2	log.$^{-1}$ [2 log. (19973.80 — sta.) — 7.3140232] — log.$^{-1}$ [log. (19973.80 — sta.) — 4.5303454] + 4.14;
3	E. of sta. 1672.65 — log.$^{-1}$ (2 log. sta. — 7.3140232) + log.$^{-1}$ (log. sta. — 3.8862434) + 4.14; W. of sta. 1672.65 — log.$^{-1}$ (2 log. sta. — 7.3140232) + log.$^{-1}$ (log. sta. — 4.7877796) + 4.33;
3	log.$^{-1}$ [2 log. (sta. — 1678.00) — 7.3140232] + 8.04;
5	log.$^{-1}$ [2 log. (sta. + 55.14) — 7.3156868] + 2.44.
5	log.$^{-1}$ (2 log. sta. — 7.3156868) + log.$^{-1}$ (log. sta. — 4.3645775) + 1.69.

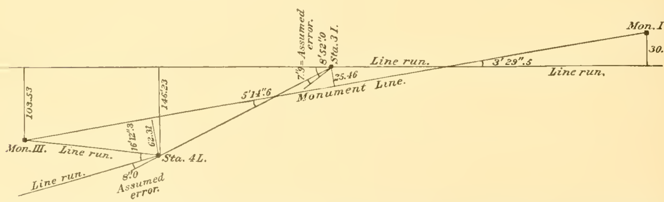
Angles in first and second sketches below subject to correction, depending on distribution of back azimuth error of $+23''.8$, and also for changes in distances due to remeasurements. The back azimuth error is assumed to have occurred in three equal parts at heliotrope stations (initial points of prolongations) K, 3 I, and 4 L.

SKETCHES ON AZIMUTH LINE.









The two sketches next above show the assumed distribution of azimuth error and the geometrical conditions governing the offset formulæ for the field location of the monument line.

FORMULÆ FOR AZIMUTH LINES.

The formulæ and tables of U. S. Coast and Geodetic Survey, Appendix No. 7, 1884, are very convenient for short lines and secondary triangulation, but give approximate results only with lines of great length, such as occur on this survey. The following formulæ give results of the greatest exactness even on lines of several hundred miles in length.

Given $\varphi =$ latitude of first point.

Given $\lambda =$ longitude of first point.

Given $\alpha =$ azimuth at first point toward second point.

Given s = distance from first to second point.

To find φ', λ', α^1, of second point:

$$\theta = \frac{s}{r \sin. 1''} + \frac{e^2 \theta^3 \sin.^2 1''}{6(1-e^2)} \cos.^2 \varphi \cos.^2 2\alpha$$

$$\zeta = \frac{e^2 \theta^2 \sin. 1''}{4(1-e^2)} \cos.^2 \varphi \sin. 2\alpha$$

$$\tan. \tfrac{1}{2}(\alpha^1 + \zeta - \triangle\lambda) = \frac{\sin. \frac{1}{2}(\gamma - \theta)}{\sin. \frac{1}{2}(\gamma - \theta)} \cot. \frac{\alpha}{2}$$

$$\tan. \tfrac{1}{2}(\alpha^2 + \zeta + \triangle\lambda) = \frac{\cos. \frac{1}{2}(\gamma - \theta)}{\cos. \frac{1}{2}(\gamma + \theta)} \cot. \frac{\alpha}{2}$$

$$\varphi^1 - \varphi = \frac{s}{\rho \sin. 1''} \frac{\sin. \frac{1}{2}(\alpha^1 + \zeta - \alpha)}{\sin. \frac{1}{2}(\alpha^1 + \zeta + \alpha)} \left[1 + \frac{\theta^2 \sin.^2 1''}{12} \cos.^2 1/2 (\alpha^1 - \alpha)\right]$$

The second term for θ is insensible except for very great values of s. ζ is always a very small angle, and is to be used with its algebraic sign. α and $\alpha^1 + \zeta$ are angles of polar triangle, and not azimuths from south point of meridian, as usually given.

ρ = radius of curvature of meridian at middle latitude.

r = normal (to minor axis) at first point.

θ = angle between terminal normals.

$\triangle\gamma = \lambda^1 - \lambda$; $\gamma = 90^\circ - \varphi$.

Eight places in logarithms give 3 correct in φ^1 and λ^1 and 9 give 4.

OFFSET FORMULÆ, COLORADA AND PACIFIC AZIMUTH LINE.

Colorado River to Monument 207: Offset (S.) = log.$^{-1}$ [log. (10910.62 — sta.) — 3.3026100].

Monument 207 to Station K: Offset (N.) = log.$^{-1}$ [log. (sta.— 10910.62) — 3.3026100].

Station K to Monument 220: Offset (N.) = log.$^{-1}$ [log. (sta. — 10012.20) — 3.3373516].

Monument 221 to Station 3 I: Offset (+ = N. — = S.) = log.$^{-1}$ [log. (113564.93 — sta.) + 7.0068280].

Station 3 I to 4 L: Offset (+ = N. — = S.) = log.$^{-1}$ [log. (sta. — 155321.41) + 7.1833113].

Station 4 L to Monument 252: Offset (N.) = log.$^{-1}$ [log. (215479.85 — sta.) + 7.5089256].

Monument 252 to Monument II and Monument II to Monument 258: Offset = zero throughout.

By "sta." in these formulæ is meant station number as given in tables of this report, but the reduction to mean sea level must be applied before using in the formulæ. These original distances were necessarily used because the remeasured values were not available at the time. Remarks on the derivation of these formulæ appear in another part of this report.

General remarks.—On parallel 31° 47′ and the meridian line the duties assigned to my care comprised the mathematical and field work of monument location, and the time so employed extended from August 15 to November 5, 1892.

On the azimuth line from Colorado River to Pacific Ocean the work intrusted to my care included the mathematical and field work of monument location and superintendence of monument erection. Operations on the azimuth line extended from March 20 to June 30, 1894.

The camp force varied somewhat, but averaged about as follows: Myself, in charge, 1 overseer and photographer, 1 wagon master, 1 rodman, 1 cook, 1 cook's helper, 2 packers, 3 teamsters, 1 blacksmith, 5 laborers.

The camp transportation averaged about as follows: Two baggage wagons, 2 water-tank wagons, 1 truck wagon for monuments, 1 spring wagon, 1 buckboard, 6 aparejos, 26 mules, and 3 saddle horses. An extra wagon with 4 mules was under camp control to April 23.

The formulæ for use with this line, which are in a certain measure empirical, are simply given as used, without going into their derivation, which can be readily studied out by anyone duly interested. The writer having personally run the line of reference, made the distribution of azimuth error according to his best judgment, and as shown in the sketches. All data not here given may be found in my report of tangent and line work, offset formulæ being based on original stadia measurements reduced to sea level.

The official limit for north and south difference of monument location between United States and Mexican points was placed at 2 meters, which was never reached. United States and Mexican distances between all monuments were compared in the field and subjected to remeasurement if differing over 1 in 500.

Throughout all monument work in my charge the most cordial and friendly relations existed between the United States and Mexican engineers and camps.

APPENDIX No. 3.

Report of Mr. B. A. Wood, assistant engineer, on monument location.

Before being assigned to duty with the monument party the location and erection of monuments along parallel 31° 47′ had been completed under charge of Mr. E. L. Ingram, assistant engineer, and the methods there employed having been found satisfactory the same general plan was followed with regard to monuments along parallel 31° 20′, as the problems here presented were practically the same.

The positions of the old monuments having been determined and their identity established, it became necessary to interpolate other monuments in a curved line conforming as nearly as possible to the parallel. In the calculation of these positions the formulæ for the computation of geodetic latitudes, longitudes, and azimuths, Appendix No. 7, Report of 1884 of the Coast and Geodetic Survey, were employed. By a combination of the quantities which affected each tangent it was possible to obtain a formula by which the latitude and azimuth for any given distance from the initial point of the tangent could be computed in the field in a few minutes, thus greatly simplifying and facilitating the work.

The question of the distribution of the azimuth error was one that received no little consideration, as an improper distribution would, in extreme cases, cause a greater discrepancy than the limit agreed upon by the joint commission. It was finally decided that such errors not greater than ten seconds should be neglected. When the error exceeded ten seconds, the circumstances of the tracing of each particular tangent were carefully considered and the distribution made at such points as seemed most liable to be in error by reason of wind, uncertain light, short backsight, etc.

By reference to the report of Mr. E. L. Ingram, assistant engineer, it will be seen that there were eight tangents traced along parallel 31° 20′, viz, 8, 9, 10, 11, 12, 13, 14, and 15. Of these, 8, 9, 10, and 11 were affected by back-azimuth errors of less than ten seconds, while the errors of 12, 13, and 14 were 12.6″, 32.3″, and 32.9″, respectively. That of 15 was not measured directly, but was obtained by triangulation and found to be less than ten seconds.

The errors of tangents 8, 9, 10, and 11, being less than ten seconds, were neglected; the error of tangent 12 was distributed equally at each azimuth station; the error of tangent 13 was distributed at three stations that seemed most liable to be in error, and the error of tangent 14 was distributed through the whole length of the tangent.

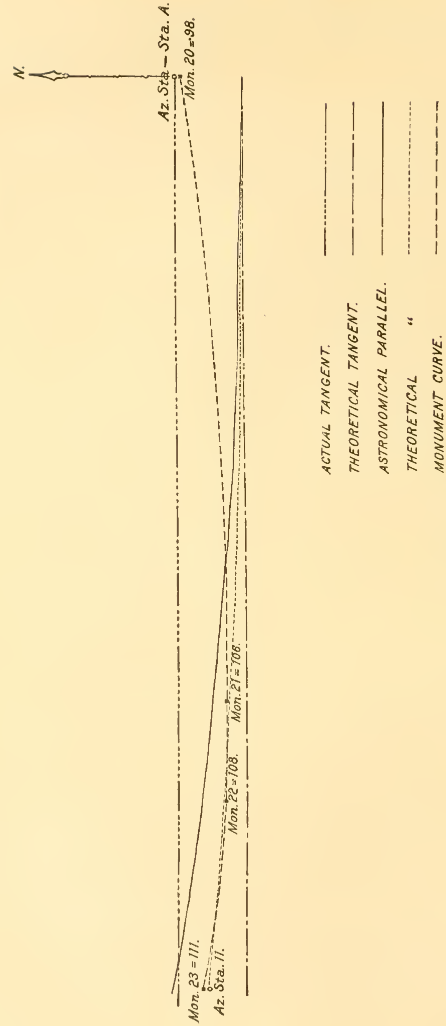
It may be interesting to follow the successive steps by which the final results were obtained. The following table shows the results along tangent 13, the data for which are given in the report of Mr. E. L. Ingram, referred to above. A sketch of tangent 13 is also given showing the relation of the monument curve to the astronomical parallel, etc.

United States tangent 13, parallel 31° 20′ N.

Measured distance from tangent to parallel		+14.51
Initial point of tangent north		151.53
		166.04
Computed offset for 42,149.68 meters	84.71	
Error of line to N	4.92	79.79
Difference of station error, north		86.25

Monument No. or station.	Distance from initial point of tangent.	Theoretical back-azimuth.	Observed back-azimuth.	Computed offset.	Constant.	Station error.	Line error.	Tangent to parallel.	Parallel to monument curve.	Tangent to monument curve.
		° ′ ″	° ′ ″							
Az. Sta. 10	0.00	90 00 00.0	...	+0.00	—151.53	0.00	—0.00	—151.53	...	...
98 (20E)	8.04	89 59 59.8	...	+ .00	—151.53	— .02	— .00	—151.51	+143.89	— 7.62
99	5,003.36	58 21.6	...	+ 1.19	—151.53	+10.24	— .00	—140.10	+109.48	— 30.62
100	9,865.43	56 45.9	89 56 56.7	+ 4.64	—151.53	+20.19	.00	—126.70	75.98	— 50.72
101	10,308.35	56 37.2	56 58.8	+ 5.07	—151.53	+21.09	— .02	—125.39	72.92	— 52.47
102	12,035.43	56 03.3	56 35.6	+ 6.91	—151.53	24.63	— .20	—120.19	+ 61.02	— 59.17
103	17,149.61	54 22.7	Add 32.3″ to the theoretical back-azimuth.	+14.02	—151.53	35.09	—1.02	—103.44	+ 25.79	— 77.65
104	19,505.10	53 36.3		+18.14	—151.53	+39.91	—1.37	— 94.85	9.47	— 85.38
105	22,292.57	52 41.5		+23.70	—151.53	+45.61	—1.81	84.03	— 9.64	— 93.67
106 (21E)	28,784.79	50 33.8		39.51	—151.53	58.90	2.83	55.95	— 54.38	—110.33
107	31,715.13	49 36.2		+47.96	—151.53	+64.89	—3.28	— 41.96	— 63.82	—105.78
108 (22E)	33,245.40	49 06.1		+52.70	—151.53	+68.03	—3.53	34.33	— 68.72	—103.05
109	36,804.55	47 56.1		+64.59	—151.53	+75.31	—4.08	— 15.71	— 71.03	— 86.74
110	40,134.56	46 50.5		+76.81	—151.53	+82.12	—4.60	2.80	— 73.06	— 70.26
111 (23E)	42,152.98	46 10.8		+84.72	—151.53	+86.25	—4.92	14.52	— 74.49	— 59.97
Az. Sta. 11	42,149.68	46 10.9	89 46 43.2	+84.71	—151.53	+86.25	—4.92	14.51	...	...

NOTE.—The azimuth error is supposed to be concentrated at 100, 101, and 102, and distributed directly as the distance.



Sketch of Tangent 13.
Scale N. and S., 1÷10000; scale E. and W., 1÷20000.

On June 14, 1893, the preliminary computations having been completed, I went to Nogales, Ariz., for the purpose of comparing the data with the engineers of the Mexican section. This duty completed, on June 16 the position of Monument No. 122 (old Monument No. 26), situated on the north side of International street, in the town of Nogales, was marked and its erection commenced. From this time until September 19 the erection of monuments along parallel 31° 20′ progressed continuously, during which time there were erected 74 monuments, consisting of 13 masonry, 14 sectional iron, and 47 solid iron, in eighty working days.

The average force employed for this work consisted of the following men and transportation, viz: 1 quartermaster, 1 photographer, 1 blacksmith, 1 stone mason, 2 rodmen, 5 teamsters, 5 laborers, 1 cook, and 2 helpers; 1 spring wagon, 1 buckboard, 2 water wagons, 3 baggage wagons, 1 truck, 5 horses, and 24 mules.

Parallel 31° 20′ having been marked, on September 21 I returned to Tucson, where preparations were commenced for the continuation of the erection of monuments along the azimuth line between the western extremity of parallel 31° 20′ north and the Colorado River. The wagon train traveled overland and did not reach Tucson until October 7.

On November 17, 1893, in accordance with instructions, I again went to Nogales, Ariz., for the purpose of comparing data with the engineers of the Mexican section and of entering into the final agreement which should govern the location and erection of monuments between Monument No. 127—the western extremity of parallel 31° 20′—and Monument No. 168 (old Monument No. IX), situated about 4 kilometers northwest of the town of Sonoyta. This agreement was afterwards extended so as to include the entire line to the Colorado River. This duty concluded, I went to the camp previously established in the Sierra de los Pajaritos, near the old mining camp of Warsaw, and on November 22 the work of erection was commenced.

The beginning of this work presented greater difficulties than any other portion of the entire line, situated as it is in mountains over which it was necessary to pack monuments and materials over rugged trails for a distance of about 18 miles. In order to give some idea of difficulties encountered in this particular section, there were consumed fifteen working days in erecting the 7 iron monuments included within the first 35 kilometers. No mention is here made of the 2 stone monuments in the above distance, as they were built by a special gang.

After these mountains were passed much greater progress was made, and 68 iron monuments were erected in seventy-seven working days, and for the whole line there were erected 10 masonry, 15 sectional iron, and 53 solid iron monuments in ninety-two working days.

The party as organized for this work consisted of the following men and transportation, viz: A quartermaster, photographer and overseer, wagon master, blacksmith, stone mason, rodman, 6 teamsters, 8 laborers, 2 cooks and 2 helpers; 2 spring wagons, 1 buckboard, 3 water wagons, 5 baggage wagons, 1 truck, 5 horses, and 36 mules.

From the above it will be seen that the force employed on the azimuth line was larger than that employed on parallel 31° 20′. This was rendered necessary on account of the greatly increased distance to points of supply of all necessaries, including materials, provisions, and water.

The erection of Monument No. 153, on Cerro de la Lesna, was attended with peculiar difficulties. The summit of this mountain is a sharp ridge of rock, which rises 36 meters in height, with almost perpendicular sides, over the top of which the line passed. Rodman Wheeler was the only man of the party who could scale the wall. He fastened a rope, by means of which others ascended and they pulled the materials for the monument up after them. To add to the difficulty the summit of the ridge was not of sufficient width to support the base of the monument, and had to be levelled by blasting. Five days were consumed in erecting this monument.

Other obstacles were encountered in the Sierra del Tule and the Sierra de las Tinajas Altas, in which places it was impossible to obtain practicable trails for mules, and the materials and tools had to be transported by hand over long and difficult ascents.

The engineering problem here presented was somewhat different from that affecting the two parallels, and resolved itself into simply interpolating new monuments in a straight line between old monuments, previously identified and located, and whose positions had been computed by Mr. John F. Hayford, assistant astronomer, who traced the line.

The limit of 2 meters, as fixed by the engineers in chief, was exceeded in two places, viz, on the Cerro de la Lesna and in the Sierra de las Tinajas Altas. With regard to the first, the difference disappeared when the line was retraced jointly by Captain Martinez, engineer in charge of the Mexican section of monument location party, and myself, a special report of which was submitted and approved. At the second point the limit was exceeded by only 4 centimeters, and after a long discussion of all the facts Captain Martinez and myself considered it to be to the interest of the work to accept the difference and proceed with the erection. Otherwise it would have been necessary to retrace nearly 163 kilometers of line, involving a delay of two or three weeks, in a locality where water was scarce and only a sufficient amount obtainable to complete the work without unnecessary delay.

Our position in this matter was further strengthened by a comparison of the results obtained by both sections. The angle at Monument No. 175 (old Monument No. VI), between the line of Monument No. 168 (old Monument No. IX) and Monument No. 175 produced, and the line of Monument No. 175–Monument No. 204 (old Monument No. II), as determined by the United States section, was 54′ 59.5″; as determined by the Mexican section it was 55′ 03″, or, briefly:

	′	″
Monument No. 204, north of line Monument No. 168 to Monument No. 175 produced	54	59.5
Monument No. 204, north of line Monument No. 168 to Monument No. 175 produced	55	03.0
Difference	00	03.5

From Monument No. 175 to the point in question the distance is 89,917 meters, from which we obtain:

$$\begin{aligned} \text{Log. } 89917 &= 4.9538418 \\ \text{Log. tan. } 1'' &= 4.6855749 \\ \text{Log. } 3.5 &= 0.5440680 \\ \hline &\quad 0.1834847 \end{aligned}$$

Which gives 1.53 meters as the amount of divergence between the two lines, which, from the discrepancy measured of 2.04 meters, leaves 0.51 as the amount of difference in tracing the line by the two parties.

In comparing the distances between monuments with the engineers of the Mexican section discrepancies were found to exist in the distances as determined by the two sections, amounting to 200 or 300 meters in some cases. This, of course, involved a remeasurement of a portion of the line. These remeasurements were made either directly, with a 50-meter steel tape, or by a small triangulation where the conditions were unfavorable for direct measurement.

In making remeasurements by triangulation small Brandis transits were used with verniers reading to twenty seconds. It was surprising to note with what accuracy angles could be measured with these instruments. From the results obtained we were convinced that with care and patience angles could be measured within an error not exceeding ten seconds.

On the line in question it gives me pleasure to state that only one error in excess of the limit was found in the distance as previously determined by the stadia measurement of the United States section.

The work on the above line was completed on March 14, 1894, and on the 15th camp was moved to Yuma, where preparations were commenced for the continuation of the work westward to the Pacific.

On March 20 I was relieved from duty with the monument party, and instructed to report for duty at the headquarters of the commission at San Diego.

The friendly relations established and maintained between the two sections for many months in the field rendered an otherwise arduous duty more than pleasant. To Capt. Gaspar Martinez Ceballos, Señor Gama, and Señor Bancalari the writer owes many thanks for their willingness to assist and share in many difficulties and hardships.

And in our own section much credit is due Mr. D. R. Payne, photographer and overseer, and Mr. M. E. Cunningham, wagon master for their zeal and efficiency in performing their respective duties and thus aiding no little in the successful completion of the above work.

APPENDIX No. 4.

Report of J. F. Hayford, assistant astronomer, on line determinations between Colorado River and Nogales, Ariz.

SAN DIEGO, CAL., *December 26, 1893.*

The party assigned to line work left Yuma, Ariz., for the field on March 14, 1893, and reached Tucson, Ariz., from the field on September 15, 1893. Between those dates 166 points were located on the boundary between Monuments Nos. 204 and 127, a distance of 373 kilometers. This portion of the boundary was already fixed upon the ground by 13 extant Emory monuments. The field work consisted of the location of intermediate points on the straight lines joining successive monuments, the measurement of the angle at each monument between adjacent monuments, and of establishing a connection at the beginning and end with the triangulation already executed near Yuma and near Nogales. When combined with the stadia measurements of distances along the line, as made by the topographical party under Mr. J. L. Van Ornum, assistant engineer, the work of the line party serves to determine the geographical coordinates of each of the old monuments as well as to locate the new intermediate points.

The line party proper consisted of myself as observer in charge of the party, 3 heliotropers (one usually acting as cook), and a driver. The line party was always with or near the topographical party, and the supplies and transportation were in common with that party.

The instrument used was Fauth repeating theodolite No. 725, which had previously been used for determinations of azimuth, and is described fully in that connection. The horizontal circle, 25 cm. (10 inches) in diameter, is graduated to five-minute spaces and is read by two opposite verniers to five seconds. The telescope has a focal length of 41 cm., and an objective 45 mm. in diameter. The eyepiece magnifies about 30 diameters. One turn of the eyepiece micrometer is 123.73″, or one division on the micrometer head is 1.24″.

Heliotropes were used as signals almost entirely, and also furnished a ready means of communication between the observer and the heliotropers.

The line was established in sections, each of as great length as possible, on which all points were established by running toward a fixed point. The front heliotroper having placed his heliotrope over a distant point on the line, and the instrument being at a known point, a second heliotroper placed himself approximately on line between the instrument and the front heliotroper, near the proposed site of a station, and showed a light to the instrument. The small angle between the two heliotropers was then measured with the eyepiece micrometer. The observer next telegraphed the result to the near heliotroper, using the Morse alphabet by long and short flashes from a heliotrope kept at the instrument for that purpose. The message as received by the heliotroper indicated to him how many divisions of micrometer he was from the line, and in what direction. Knowing that each division was equivalent to 6 mm. per kilometer of distance between himself and the instrument, he converted divisions of micrometer to linear measurement, using his best judgment as to his distance from the instrument. This measurement he made upon the ground with a 20-meter steel tape, and placed his heliotrope at the new position. The process of measuring the angle between the two heliotropers and telegraphing the result was then repeated.

The first offset, as measured by the heliotroper, necessarily corresponded to the difference on the micrometer indicated by the first and second messages from the observer, and therefore served to determine the distance from the heliotrope to the instrument. Using this known distance the heliotroper computed the offset necessary to place him on the line, and again placed his heliotrope by measurement. This process was repeated until the angle between the two heliotropes was apparently less than two divisions of the micrometer.

The final measurement of the angle by 27 pointings with eyepiece micrometer on the heliotrope ended the operations for that station. The pointings were taken in sets of three alternately on each light. As soon as the measurement was completed, "O. K." was sent to the near heliotroper, and he proceeded to mark the station and move on to the next.

Whenever convenient, as determined by the topography, position of camp, means of transportation, etc., the instrument was moved forward to some one of the newly determined points and the process of lining in points ahead was continued. In some cases the points, about 2 kilometers apart on an average, were lined in ahead from a single station for as much as 14 kilometers. In other cases the instrument was moved up at every station, so that it was never more than about 3 kilometers from the point being set.

In a few cases the instrument was lined in between two known points, one ahead and one behind, but this plan was avoided as much as possible because it was much slower than the usual method.

After the heliotroper first showed his light near a proposed station, the time required to place his heliotrope within two divisions (2.5″) of the line and to make the final measurement of the small angle by 27 micrometer pointings was usually from thirty minutes to one hour. Much more time was spent in traveling to and from stations than was required for the actual instrumental work.

The final measurements of the small angle between the two heliotropes made it possible, by the use of the distances afterwards determined by the topographical party, to compute the small offset from the station as placed to the true line. These small offsets were computed and furnished to the monument party.

The first extant monument from Monument No. II (204) near the Colorado was Monument No. VI (175), 163 kilometers to the eastward. Before the line party began its work, a reconnaissance party, under Mr. J. L. Van Ornum, assistant engineer, had, by the use of engineer's transits, placed a point on the Tinajas Atlas Mountains as nearly as possible on the straight line joining Monuments II (204) and VI (175). The front heliotroper was placed at this point, Station XXXVIII, and the line was run toward it from Monument No. II (204), a distance of 73 kilometers. With the instrument at Station XXXVIII, and with a heliotrope at Monument No. II (204) as a backsight, the line was produced by a single sight to the most distant visible point on the line, Station LII in the Tule Mountains, 25 kilometers ahead. The intermediate points were then located by running toward Station LII. From Station LII the most distant visible point on the line ahead was Station LIV, but 4 kilometers away, on the same range of mountains. From LIV again there was no chance to take a sight longer than 4 kilometers, to Station LVI, on the same range. At LII and LIV the original line was produced. At LVI the line was turned to run directly to Monument No. VI (175) as a foresight, and the small angle measured. In each of the cases in which the line is said to be produced there was in fact a small outstanding angle in the line which was measured with the micrometer. These five sections represent the longest sights possible in running the line, for in each case the forward sight was taken to a station which was against the actual sky line as seen from the preceding station.

The computation of offsets showed that Station XXXVIII was 0.87 meter north of the straight line joining Monument No. II (204) and Monument No. VI (175). The greatest offset from any station on the line as run to the straight line joining the monuments was 0.99 meter to the southward, at Station LV.

From Monument No. VI (175) to Monument No. 27 (127), with one exception, each monument was visible from the preceding one, and the line was located by running forward from each monument to a heliotrope placed on the next monument.

From Monument No. XII (160) the view to Monument No. XIII (150) was shut out by a sharp peak of the Lesna Mountains, about 33 kilometers from Monument No. XII (160) and 13 kilometers from Monument No. XIII (150). This peak, although not high, had faces so nearly vertical that it was difficult to climb. It was found on a preliminary investigation that at the point where the line crossed the peak the top was so narrow and so unsafe that it would be dangerous as well as extremely difficult to place the theodolite there. Accordingly the theodolite was placed successively at two points, which may be called A and B, about 10.5 meters apart on a rocky bench on the south side of the peak, and the angle at each point between Monument No. XII (160) and Monument No. XIII (150) was measured with the micrometer. The linear measurement between A and B, in connection with the angular measures, showed that the line was about 25 meters to the northward of the northern point, A. This measure was then made with considerable difficulty along the débris at the foot of the west vertical face of the peak, and Station XVI was established. Afterwards Station XVII was placed accurately on the line Monument No. XII (160) to Station XVI produced on the top of the peak, and Station XVIII was placed near the east foot of the peak accurately on the line Station XVII to Monument No. XIII (150).

All pointings upon Station XVII were made upon a short 1-inch pole held in position by hand, and the station was marked by a cross cut in the surface of the rock. The intermediate points were put in between Monument No. XII (160) and Station XVI and between Station XVIII and Monument No. XIII (150) in the usual way. The angles at Monument No. XII (160), between the back-sight (Monument No. X [162]) and each of the points Station XVI, A, and B, were measured with micrometer, and also the angles at Monument No. XIII (150), between the fore-sight (Monument No. XIV [146]) and each of the points Station XVIII, A, and B. These, measured, gave three of the four angles of each of the four-sided figures—Monument No. XII (160) to Station XVII, Monument No. XIII (150) to A, and Monument No. XII (160) to Station XVII, Monument No. XIII (150) to B—and therefore from each figure there was derived a value for the angle *at Station XVII* between Monument No. XII (160) and Monument No. XIII (150). These two vaules were 180° 21.5″ and 180° 19.2″. The mean, in connection with the stadia distance along the line, gave for the offset from Station XVII to the line joining Monument No. XII (160) and Monument No. XIII (150) 0.94 meter south.

This procedure gave a strong azimuth connection past the difficult point, and gave the different offsets independently of the rough linear measurement along the débris on the west face of the peak, which served for the first approximate location of the line. The computed value for the offset at Station XVII is probably as accurate as would have been obtained if that station had been occupied in the usual way.

If the lines Monument No. II (204) to Monument No. VI (175) and Monument No. XII to Monument No. XIII, which could not be run with a single foresight, be omitted, there are but 16 cases in which the computed offset from the station as set to the line joining adjacent monuments was greater than 0.10 meter, and the greatest offset was 0.31 meter.

The azimuth of the line Monument No. II (204) to Station XXXVII was determined by the Yuma triangulation. (See astronomical report.) All the angles in the line as run were measured with the micrometer, save the angle at Monument No. VI (175). That angle, being too large (55′) to measure with the micrometer, was measured with the theodolite used as a repeater. The instrumental line was finally connected with the line B to No. 7 of the Nogales triangulation (see astronomical report) by measuring with the theodolite used as a repeater the angle at B between Monument No. XVIII (129) and No. 7. The azimuth of the line B to Monument No. XVIII (129) as computed from the Yuma triangulation and the measurement of angles along the boundary was 6.7″ greater than the azimuth as given by the Nogales triangulation. This difference of 6.7″ arises from the errors in the Yuma and Nogales azimuth observations, the errors of the Yuma and Nogales triangulations, and the measurement of 16 angles along the line.

The computations of geographical positions were made as follows: The distance on the Clark spheroid between Monument No. II (204) and Monument No. 27 (127) was first computed from the latitudes and longitudes of those two points as given by the Yuma and Nogales triangulations. This distance as thus computed may properly be called the astronomical distance, as it depends ultimately upon astronomical observations at Yuma and Nogales. The distance from Monument No. II (204) to Station XXXVII on the Tinajas Mountains was determined by the Yuma triangulation. This being subtracted from the astronomical distance between Monument No. II (204) and Monument No. 27 (127) gave the astronomical distance from Station XXXVII to Monument No. 27 (127). The direct stadia measurement by the topographical party gave for the distance between Station XXXVII and Monument No. 27 (127) a value exceeding the astronomical distance by 301.85 meters, or one part in 994. The stadia distances on each separate section of the line between those points decreased in that ratio to agree with the astronomical distance were then taken as the true distances between the monuments.

Using these distances, the known latitude, longitude, and azimuth at Monument No. II (204) and the measured angles along the instrumental line, the geographical position of each monument, and the azimuths of each section of the instrumental line were computed. This computation developed the accumulated azimuth error of 6.7″ mentioned above. The error was distributed by applying a correction of 0.67″ to each of the ten angles at Monuments No. VI (175), IX (163), X (162), and XII (160) to XVIII (129), and the computation of geographical positions and azimuths made again with the corrected angles.

In these computations all lines except Monument No. II (204) to Monument No. VI (175) and Monument No. II (204) to Monument No. 27 (127) were computed by the formulæ and factors of Appendix No. 7, Coast and Geodetic Survey Report for 1884. The long lines named were computed by the more accurate formulæ of Appendix No. 9, Coast and Geodetic Survey Report for 1885.

Emory monuments.	Distance by stadia.	Corrected distance.	Azimuth.			Back azimuth.		
			°	′	″	°	′	″
II to VI	162,976.5	162,918.9	289	32	30	110	24	30
VI to IX	31,352.9	31,319.6	289	29	20	109	39	20
IX to X	23,435.2	23,409.9	289	41	00	109	48	20
X to XII	7,289.4	7,281.4	289	48	50	109	51	00
XII to XIII	46,601.5	46,550.2	289	50	50	110	05	20
XIII to XIV	19,881.6	19,859.0	290	08	30	110	14	40
XIV to XV	27,580.2	27,548.7	290	12	20	110	20	50
XV to XVI	14,759.3	14,741.8	290	20	00	110	24	30
XVI to XVII	4,236.8	4,231.8	290	25	00	110	26	20
XVII to XVIII	28,981.3	28,946.5	290	26	00	110	35	00
XVIII to XIX	5,647.3	5,640.3	290	37	10	110	39	00
XIX to 27	394.1	393.6	290	55	20	110	55	30

The latitude of Station B, as thus computed through the whole line, is 31° 19′ 59.24″, and from the Nogales triangulation is 31° 20′ 03.70″. The difference, 4.16″, represents the difference of station errors in latitude between Monument No. II (.04) and Station B.

The longitude of Station B, as computed through the line, differed from its longitude from the Nogales triangulation by 2.01″. This difference is the indirect effect of the latitude station error upon the computation, and not station error in longitude, for the measured distances had already been corrected to agree with the astronomical distance.

The latitude station error, 4.46″, and the longitude difference, 2.01″, were distributed proportionally to the distances of the various monuments from Monument No. II (204).

(NOTE.—The final results for the latitudes, longitudes, and azimuths of these old monuments computed from the mean of the measures of distances and angles, made by both United States and Mexican sections, and the latitudes corrected to conform to the *mean* latitude of the whole boundary, will be found in Report of Joint Commission, page 99.)

The offsets from each monument to the straight line joining Monument No. II (204) and Monument No. 27 (127) were then determined by computing the latitude and longitude of a point on said straight line opposite each monument. The offsets from the straight line to each monument, at right angles to the straight line, are as follows, all to the southward:

Monument No. VI (175)	1,413.2	Monument No. XV (141)	359.9
Monument No. IX (168)	1,183.6	Monument No. XVI (137)	259.4
Monument No. X (162)	1,023.8	Monument No. XVII (136)	231.1
Monument No. XII (160)	974.9	Monument No. XVIII (129)	35.1
Monument No. XIII (150)	657.7	Monument No. XIX	0.5
Monument No. XIV (146)	540.8		

On the whole line the work was pushed forward at all times without reference to favorable or unfavorable conditions for accurate observation. It was considered that such a procedure would give all needful accuracy, and that economic considerations would not justify any additional expenditure. Much of the observing was done under conditions that at first sight would seem likely to lead to large errors, and it is therefore more than usually desirable that the accuracy of the determinations should be put in evidence.

A study of the method of work and of the instrument leads one to the conclusion that the errors in the location of the various points on the ground arise almost entirely from two causes, first, instability of instrument during observations, and, second, errors of pointing.

Inasmuch as the instrument was simply mounted on its own tripod, and was without protection from sun or wind, it was subject to irregular movements due to its exposure. The routine of observation was especially designed to cancel out the effect of such movement upon the result. The mean time of the pointings on each of the two points concerned in any determination was made as nearly identical as possible and the pointings were taken in rapid succession. The 27 pointings constituting the final determination of a point were made in from ten to thirteen minutes. An idea of the magnitude of the errors arising from this cause can be gained by noting the average difference between each set of observations and the mean of the sets, as stated later in this report.

The value of one division of the striding level was 3.68.″ The level was applied so often, and the inclination of the line of sight was usually so small, that the errors from this source must be almost inappreciable.

By "errors of pointing," as used above, must be understood, not only the errors made in attempting to place the observing thread upon the brightest point of the heliotrope light as seen, but also the errors arising from the assumption that the apparent position of said brightest point coincides with the actual center of the heliotrope mirror from which the light issues.

From May 8 to the end of the work a record was kept during observations of the appearance of the heliotropes, of the temperature, and of the apparent diameter of the heliotrope light as measured in divisions of the eyepiece micrometer.

The temperatures were taken with a centigrade thermometer placed in the most extensive shade available in the vicinity of the instrument, which was usually the little shadow cast by the instrument box. There are but few cases in which the recorded temperature at observation is below 25° C. (77° F.). During June and July the greater number of the recorded temperatures were between 35° C. (95° F.) and 43° C. (109° F.). In a single case, on June 24, between 1 and 2 p. m., the temperature indicated by the thermometer hanging in the shade of the instrument box was 48° C. (118° F.).

The apparent diameter of the light of the heliotrope in divisions of micrometer (each 1.24″) varied from five or six divisions, in a few rare cases, either early in the morning or under a clouded sky, through the intermediate values to the other extreme, when the apparent diameter was 104 divisions. This last case occurred between 11 and 12 on a very hot July day on a line of sight about 2 kilometers long, which was within 3 meters of the almost bare sand. The average apparent diameter of the heliotrope lights for the season was twenty-five divisions (31″).

The diameter of light as measured includes only what might be called the *solid* part of the light, and excludes the rapidly changing rays and spots of light which sometimes formed a further irregular extension.

The principal mirror of the heliotrope, called in this report "R," was round, with a diameter of 10 centimeters, and that of the heliotrope called "C" was round, with a diameter of 7.5 centimeters. If the mirror itself were seen with the telescope, it would appear as an ellipse with the major axis equal to the diameter of the mirror. The measured angular diameter of the light as seen, taken in connection with the known distance to the heliotrope, shows that the mirror itself was visible only on very rare occasions even when the conditions were favorable. Usually the apparent width of the object upon which the pointings were made was many times that of the heliotrope mirror. For example, in the case in which the light appeared 104 divisions in diameter it corresponded to a target 1 meter in diameter, placed in the position of the heliotrope 1,600 meters from the instrument, although the diameter of the mirror was only 7.5 centimeters. On May 15, with the temperature in the shade 39° C. (102° F.), a heliotrope mirror 10 centimeters in diameter, 43 kilometers distant from the instrument, showed as a blaze of light 44 divisions (55″) in diameter, corresponding to a target, in the position of the heliotrope, 11.4 meters in diameter.

The characteristic appearance of the heliotrope light, as seen during the observations, over highly heated and nearly bare sand or rocks, was a bright blur of light with outline but poorly defined. Each separate portion of the outline seemed to be vibrating violently. Usually there was a part of the blur considerably brighter than the remaining portions, and the brightness increased gradually from the outline inward toward this region. In the most frequent case this bright region was in the center of the blur, and the extent of the vibration on all parts of the outline was about the same. It frequently occurred, however, that the outline was decidedly unsymmetrical with respect to the brightest region. In those cases the brightest region was always *to windward* of the center of the blur, and the leeward part of the outline vibrated more violently than the windward side, the whole appearance being much like that of flames blown sidewise by the wind.

In all cases the pointings were made upon the assumption that the actual position of the mirror was represented by *the brightest portion of the blur*, and not necessarily by the center of the blur.

As a rule, the violence of the vibration of the light increased with increase of apparent diameter. The size of the light and the violence with which its outline vibrated was apparently greater for lines which were near the ground than for high lines, and less during a steady breeze than when the wind blew in gusts and whirls, or when the air was still. Evidently there were various other unknown causes producing large and apparently accidental changes in the appearance of the light. This makes it necessary to base any reliable conclusions upon a considerable number of observations at various stations and on many different dates. Accordingly, in the investigation as to apparent diameter of light and accidental errors of pointing, of which the results are given below, all available observations from May 8 to the end of the work were used.

The pointings upon each heliotrope were made in sets of three pointings each, taken in quick succession. A convenient measure of the accidental errors of pointing is the mean of the differences between each of the pointings and the mean of the three. This mean difference may be called $\Delta 3$.

Variation of apparent diameter of light and of $\Delta 3$ with the time of day.

Hours.	Heliotrope R.				Hours.	Heliotrope C.			
	Diameter in divisions.	Number observations.	$\Delta 3$ divisions.	Number observations.		Diameter in divisions.	Number observations.	$\Delta 3$ divisions.	Number observations.
6–7	12	10	0.78	11	6–7	18	9	0.57	11
7–8	18	19	.90	21	7–8	28	23	.84	27
8–9	19	21	.73	24	8–9	25	37	.74	41
9–10	21	21	.94	26	9–10	27	38	.91	46
10–11	31	17	1.12	21	10–11	34	23	.85	27
11–12	35	8	1.08	8	11–12	31	18	1.00	18
12–1	42	1	1.40	1	12–1	22	3	.76	5
1–2	24	4	1.05	4	1–2	49	4	1.05	4
2–3	32	7	1.02	9	2–3	28	16	.88	16
3–4	27	8	.68	12	3–4	23	12	.69	14
4–5	21	5	.58	8	4–5	19	12	.68	14
5–6	16	5	.60	5	5–6	20	5	.47	6

The mean diameter of light for Heliotrope R was 23 divisions (29″) and for Heliotrope C 27 divisions (34″). The mean value of $\Delta 3$ was 0.88 division (1.09″) for "R," and 0.80 division (0.99″) for "C".

Very few of the observations were made within an hour of sunrise or of sunset. The table shows incidentally the hours most frequently used for observing.

Variation of apparent diameter of light for different distances between the theodolite and heliotrope.

Heliotrope R.			Heliotrope C.		
Distance.	Diameter in divisions.	Number observations.	Distance.	Diameter in divisions.	Number observations.
Kilometers.			*Kilometers.*		
2	19	3	1	41	7
3	23	1	2	37	44
4	13	2	3	31	22
5	24	2	4	24	15
6	19	3	5	23	21
7	27	5	6	26	16
8– 9	26	4	7	17	12
10	20	2	8	27	18
11–14	26	18	9	16	4
15–19	23	30	10	24	6
20–24	26	19	11–14	24	10
25–29	11	12	15–19	18	14
30–34	17	7	20–24	19	4
35–39	35	7	25–29	13	7
43	33	5	1– 2	37	51
56	13	6	3– 5	26	58
2–14	24	40	6– 9	24	50
15–24	24	49	10–29	20	41
25–56	20	37			

Variation of $\Delta 3$ for different diameters of light.

Heliotrope R.			Heliotrope C.		
Diameter in divisions.	$\Delta 3$ divisions.	Number observations.	Diameter in divisions.	$\Delta 3$ divisions.	Number observations.
0– 5	0.77	4	0– 5	0.37	4
6–10	.58	18	6– 8	.45	6
11–15	.70	20	9– 11	.62	6
16–18	.85	15	12– 14	.65	18
19–20	.95	4	15– 17	.64	19
21–22	.84	8	18– 20	.68	24
23–24	.66	5	21– 22	.90	10
25–26	.88	6	23– 25	.67	26
27–28	.92	8	26– 28	.69	20
29–30	1.15	11	29– 30	.70	5
31–32	.83	7	31– 32	.77	6
33–34	.90	2	33– 34	.63	4
35	.83	3	35– 37	.97	7
36–38	1.00	2	38– 40	.65	4
39–44	1.40	4	41– 44	1.20	9
45–49	1.12	4	45– 49	1.23	7
50–60	1.90	2	50– 60	1.54	11
61–67	1.70	3	61–104	1.29	10
0–15	.66	42	0– 20	.63	77
16–28	.85	46	21– 34	.71	71
29–67	1.15	38	35–104	1.22	48

The table shows that the accidental errors of pointing increase much more slowly than the apparent diameter of light, in spite of the fact that with increased diameter there is also increased vibration; and shows that, in so far as *accidental* errors were concerned, it was safe to observe even under the apparently abnormal conditions when the diameter of the light as seen was from 1′ to 2′.

$\Delta 3$ equal to 1.2 divisions corresponds to $\pm 2.7''$ for the probable error of a single pointing.

The final determination of each station lined in ahead of the instrument consisted of three sets of nine pointings each. A convenient measure of the accidental errors of the sets is the mean of the differences between the result from each set and the mean of the three results. This mean difference may be called Δ S. The actual relation between Δ S and Δ 3 is shown in the following table, in which the first column is the mean Δ 3 for the two heliotropes:

Δ 3 divisions.	Δ S divisions.	Number observations.	Δ 3 divisions.	Δ S divisions.	Number observations.
0 0-0.3	0.30	1	1.1	0.98	5
.4	.45	12	1.2	.87	3
.5	.80	2	1.3	1.32	4
.6	.70	20	1.4	.95	2
7	.54	7	1.5-1.6	1.05	2
.8	.83	15	1.7-2.2	.80	1
.9	.94	7	.0-.7	.60	42
1.0	.78	5	.8-2.2	.92	44

Δ S=0.92d corresponds to $\pm 2.1''$ for the probable error of a single set, and $\pm 1.2''$ for the probable error of the mean of the three sets.

Δ S is apparently proportional to Δ 3, but is about three times as large as would be accounted for by the influence of Δ 3 alone.

Only a limited time was available for experimental work in the field, but the following evidence in regard to the magnitude of the *constant* or *systematic* errors arising from the use of heliotropes was secured as opportunities presented themselves:

On May 8, in the Tule Mountains, a series of observations were made for the purpose of determining whether there was any apparent displacement of the light when the heliotrope was neglected, and also to determine whether the apparent position of the light coincides with the actual position of the heliotrope mirror. The line of sight passed from one high ridge to another high ridge, about 4 kilometers distant, over deep cañons and intervening ridges reaching nearly up to the line of sight. Pointings were made in quick succession upon a 1-inch pole carrying a flag and upon the heliotrope accurately in line with the pole and within 2 meters of it.

The mirrors of the heliotrope having been adjusted, the observations continued for fifteen to twenty-five minutes before the mirrors were again readjusted. During the observations the heliotrope light appeared to be from 4 to 15 divisions in diameter. The whole series of observations comprise 47 pointings on the pole and 195 upon the heliotrope, extending over a half hour in the forenoon and about two and a half hours in the afternoon. The mean result from all the observations is that the heliotrope light seemed to be 0.15 division = $0.19''$ = 4 mm. south of the pole. The observations do not show conclusively that there was any apparent change in the position of the light when the mirrors were neglected. If there was any such change it was masked by the accidental errors of observation. The accidental errors of pointing seemed to be slightly greater when the mirrors were first adjusted than later, when the light had become less bright and apparently smaller.

On June 7, at Station VI of Line B, 20 sets of observations of 12 pointings each, extending over four hours, were taken to ascertain the effect of reducing the mirror on Heliotrope C from 7.5 cm. in diameter to 2.5 cm. Heliotrope C was at Station IV, 5,800 meters to the westward of the instrument, and Heliotrope R was at Monument No. IX (168), 17,400 meters to the eastward. The average apparent diameter of the light from Heliotrope C was 25 divisions when the full size of the mirror was used, and 23 divisions when the light was reduced by passing through a hole 2.5 cm. in diameter. The reduced light seemed to be but slightly less bright than the full light. The accidental errors were as great with the reduced as with the full light. The mean of the 10 sets with the full light gave Station IV 2.8 divisions north of the line Monument No. IX (168) to Station VI produced, and the 10 sets with reduced light made it 3.1 divisions north. There was a remarkable difference between the forenoon observations and those made in the afternoon. The mean of all sets in the forenoon gave Station IV 5.9 divisions north of the line Monument No. IX (168) to Station VI produced, and the mean of all the sets in the afternoon made it but 1 division north.

The original determination of the position of Station VI from Station IV, on June 5, would make Station IV 0.2 division north of the line Monument No. IX (168) to Station VI produced. This extreme range of 5.7 divisions in the three values corresponds to a range of 0.20 centimeter in the position of Station IV.

This remarkably large range of results led to a special investigation at Monument No. IX (168), on June 15, to determine whether there was a systematic difference between forenoon and afternoon observations, and whether there was any systematic error due to the position of the back glass, which was used to reflect the sunlight to the main mirror of the heliotrope when the sun was behind the heliotrope from the observer. Eight sets of nine pointings each were taken in the forenoon, and fourteen sets in the afternoon. Heliotrope C was used at Station IX, Line B, 7,700 meters to the westward of the instrument and its position compared with that of two flag poles nearly on line at Stations X and XI. The apparent diameter of the light during observations was from 16 to 24 divisions. Taking the pointings upon the flag poles as a standard, the heliotrope appeared to be 0.6 division farther south in the forenoon than in the afternoon. During the forenoon observations the sun was to the northward of the line of sight, and during the afternoon observations to the southward. In the afternoon every alternate set was taken with the back glass to the southward of the line of sight, and the remaining sets with it to the northward. To exaggerate the effect, if any, the back mirror was purposely placed so that the line joining the centers of the two mirrors made a horizontal angle of about 50° with the line of sight from the instrument. The mean of seven sets with back mirror south agreed exactly with the mean of the seven sets with back mirror north.

For the purpose of detecting constant errors the line from Station IV, Line E, to Station XV, 25,800 meters long, was located independently both by lining in points ahead in the usual way, and by lining in the instrument between two known points, one ahead and one behind. Errors of pointing upon the forward heliotrope will affect both these locations alike. But errors in pointing upon the other heliotrope will have contrary effects in the two cases, making the located line too far north in the first case, and too far south in the second case if the heliotrope appears to be farther south than its true position. The greatest difference between the two locations at any of the ten intermediate stations was 32 centimeters, and the average difference was 17 centimeters. With one exception, all stations as located by the second method were farther south than by the first method. During the observations for these locations the heliotrope light appeared more than 30 divisions in diameter during a third of the time, and on one occasion appeared 104 divisions in diameter. The lines of sight were usually near the ground. There were several cases where the light appeared decidedly unsymmetrical, and the conditions generally were as unfavorable to accurate work as on any part of the whole line from the Colorado to Nogales.

As one more evidence of the reliability of the pointings upon the heliotrope, even under such unfavorable conditions as those encountered during the season, may be mentioned the azimuth error of 6.7″ as developed in connecting with the Nogales triangulation. The measurements of the various angles in the line as run were made upon heliotropes under conditions no more favorable than during the other portions of the work.

CHAPTER V.

TOPOGRAPHY.

For measuring the distance along the boundary line, three general methods were considered:

1. Triangulation.
2. Chaining.
3. Stadia measurement.

The method by triangulation is by far the most accurate, but it is slow and expensive, and in the present case would have added very greatly to the difficult problem of providing water and supplies for so many different parties. For these reasons, therefore, it was deemed impracticable.

The method of chaining is cheap and sufficiently rapid, and the work can be carried on under conditions of weather when triangulation and stadia work would have to be suspended. It has the disadvantage of requiring more cutting in a timbered country than does the method by stadia; of not being under the eye of an employe of a high grade of intelligence; of giving neither heights nor angles, and of being entirely impracticable in a rough, mountainous country, or in one badly cut up by cañons, which is the case with a considerable part of the country along the International Boundary Line, while even in hilly and rolling country it is less accurate than the stadia. On level ground and for distances of a few kilometers the chain is possibly the more accurate; but these limitations for greater accuracy practically debarred it from use in the case considered.

The method by stadia is cheap and rapid; requires less cutting than that by chain; is carried on under the eye of an instrument man, presumably of a high order of intelligence; gives heights and angles, and enables objects to be located from the line which is being measured; is ordinarily more accurate than the chain, and can be successfully used where the chain can not be, experience on this survey having shown that the stadia lines over mountains, hills, and cañons were more accurate than those on level plains and wide valleys.

It was conditionally decided, therefore, to measure the distances along the boundary line by stadia, and to take astronomical observations for latitude, longitude, and azimuth at or near the fixed extremities of each of the six sections of the boundary, which would serve the double purpose of locating these points and of checking the measured stadia distances between them. In addition, these measurements were also checked in several places by triangulation.

That there should be, however, no question as to the relative accuracy or adaptability of chain and stadia for this work, and as each would serve as a check on the other during the earlier stages of the survey, when all observers were inexperienced in working under the conditions then existing, it was decided to measure the entire distance along the boundary on parallel 31° 47′—159,193.4 meters—both by chain and stadia, and then from the experience so gained select the method best suited for the survey.

The distance thus measured was peculiarly favorable for chaining, being in general flat and destitute of trees. The greater part of this distance had been covered by a well planned triangulation made for the Mexican Government by Señores Molina and Contreras in 1855, and it is with their results, being unaffected by station error, that comparisons are made.

As it is believed that such a comparison of the relative values of the two methods of measurement, on so extensive a scale and under conditions so identically the same, has seldom been made, the results are given in detail in the following table:

Distances along parallel 31° 17′ determined by triangulation, stadia, and chain.

Triangulation.	Stadia.	Error of stadia.	Corrected chain.	Error of corrected chain.
Meters.	*Meters.*		*Meters.*	
19,971.1	19,970.4	1/28530	19,964.7	1/3120
21,500.7	21,472.6	1/765	21,474.2	1/811
13,192.9	13,170.9	1/600	13,193.2	1/43976
21,628.8	21,597.9	1/700	21,605.3	1/920
22,819.6	22,812.5	1/3214	22,804.1	1/1472
99,113.1	99,024.3	1/1116	99,041.5	1/1373

If, instead of averaging the errors of the stadia and chain on the above five sections, considered separately, these sections are taken as one continuous distance, the errors of the stadia and chain become 1/1116 and 1/1384, respectively, the very small change being due to the fact that practically all of the errors had the same sign.

From the preceding table alone it would appear that over country of this character the chain is more accurate than the stadia, but such was not really the case; for during the measurement of parallel 31° 47′ the stadia six times detected the dropping or addition of a chain length—20 meters. These have been corrected in the preceding table, but would have escaped notice entirely had not the chained distances been compared each night with the stadia distances, and remeasurements made whenever serious discrepancies between the two were discovered. In every such case it was found that the addition or omission of a chain length had caused the discrepancy.

The stadia having proved superior to the chain in a region peculiarly favorable to the latter, and there being no question as to its superiority in the mountainous region yet to be encountered, the use of the chain was thenceforth abandoned. The wisdom of this action became more fully confirmed with every day's progress of the work.

The measured distances along the boundary were used as bases in the topographic work. Locations were made principally by stadia, but in some cases by the method of intersections. Datum points for heights were given by a careful line of levels carried along the boundary from the Rio Grande to the Pacific.

Occasionally the topography was "filled in" from located points by aid of the prismatic compass, hand level, and sketching.

Between the Pozo Verde Mountains and the Colorado River—a distance of more than 323 kilometers—the region bordering the boundary line is difficult of access, remote from railroads, is practically uninhabited by Americans (there is but one American ranch within 30 kilometers of the boundary line on the United States side), and is a true desert, containing but five badly spaced permanent watering places in the entire distance.

Owing to these causes, and in order to expedite the work in this inhospitable region, it was decided that between the west end of parallel 31° 20′ and the Colorado River a topographic belt, 1 kilometer in width, adjacent to the boundary line, would be surveyed and plotted in the usual manner; but that the remainder of the 2½ mile belt of topography would be taken by placing flags on all of the prominent peaks, ridges, and other natural objects, to be located by the transit man engaged in measuring the boundary line. Another transit man would then occupy these positions and from them locate all flags in sight. Other important topographical features were then to be located either by stadia or by resection, and contoured sketches of the immediate vicinity made.

Subsequent events justified the wisdom of the plan adopted, for even with this more expeditious method there were times when the scarcity of the water supply threatened serious interruptions to the work, and slower progress would undoubtedly have been fatal to its continuous prosecution.

All heights, except those on the line of levels, were obtained by reading the vertical angles of the points located. For a time aneroid barometers were tried for obtaining heights, and the results were checked in each case by comparison with the line of levels. Although great care was used, and every possible precaution taken, the results obtained by the use of these barometers were found to be too unreliable, and their unavoidable errors too great, to admit of their use on a work where contour intervals were fixed at 20 meters.

From the commencement of field work in February, 1892, until its close in October, 1893, Mr. J. L. Van Ornum, assistant engineer, was in charge of the topographic party, which during that period operated between the Rio Grande and the Colorado rivers. From January 24, 1893, until September 20, 1893, another topographic party was put in the field under charge of Mr. E. L. Ingram, assistant engineer. This party operated between the Colorado River and the Pacific Ocean.

For the composition of these parties and interesting details of their work, see reports of Mr. J. L. Van Ornum (p. 166) and Mr. E. L. Ingram (p. 128), assistant engineers.

The topographic belt proper covered an area of 1,810 square miles, in which there were 39,266 locations in all—51 by triangulation, 2,523 by transit intersections, and 36,692 by stadia sights—each location giving both the position and elevation of the point.

In addition to those in the topographic belt, all prominent mountain ranges and peaks visible on either side of the line were located by intersections, giving 2,785 locations of this class.

The locations by intersections in the topographic belt averaged three sights each, while those outside of this belt averaged six sights each.

Of the area included within the limits of the topographic belt, 360 square miles are covered by mountains, 230 by hills, and 1,220 by valleys, mesas, and deserts.

The average number of locations per square mile for each of these classes is 60, 45, and 6, respectively; while the average for the entire topographic belt is a little less than 22 per square mile.

In explanation of these figures it should be stated that, as a whole, the mountains are extremely steep and rugged, necessitating, not unfrequently, sights the vertical angles of which varied from 40° to 60°. Some of the ranges between the Colorado River and Quitobaquita had such sharply defined and knife-like crests that it was with the greatest difficulty their summits could be reached, and with equal difficulty, owing to lack of room, that a transit could be set up on the crest and readings taken. The hills are much broken and cut up by innumerable cañons, and the valleys, mesas, and deserts unusually flat and very uniform in slope.

In all, 1,692 miles of stadia lines were run. These lines were of two classes:

1. "Main lines," i. e., straight lines run along the tangents or boundary line, and consequently free from azimuth errors.

2. "Side lines," i. e., ordinary stadia lines, in which both angles and distances are determined.

Of the first class 675 miles in all were run, of which five sections, aggregating 125 miles, were checked by triangulation, with an average error in distance of 1 in 1,218.

In addition, these lines were further checked by comparing the measured and computed lengths of all sections of the boundary except the Colorado River section, the data for the computations being furnished by the astronomical observations at or near the extremities of each of these sections. These comparisons are shown in the following table:

Table showing discrepancy between measured and computed distances along the boundary.

Sections.	Computed distance.	Stadia distance reduced to mean sea level.	Discrepancy add algebraically to stadia distance.	Discrepancy equals 1 in—
	Meters.	*Meters.*		
Monuments Nos. 1 to 40	159, 193. 4	158, 768. 4	+425. 0	375
Monuments Nos. 40 to 53	49, 830. 1	49, 846. 1	− 16. 0	3, 114
Monuments Nos. 53 to 127	272, 954. 2	273, 073. 4	−119. 2	2, 290
Monuments Nos. 127 to 204	372, 887. 3	373, 104. 6	−217. 3	1, 716
Monuments Nos. 207 to 258	225, 570. 2	225, 151. 7	+418. 5	539
TOTALS OF ABOVE DISTANCES FROM INITIAL MONUMENT ON RIO GRANDE.				
Monuments Nos. 1 to 40	159, 193. 4	158, 768. 4	+425. 0	375
Monuments Nos. 1 to 53	209, 023. 5	208, 614. 5	+409. 0	511
Monuments Nos. 1 to 127	481. 977. 7	481, 687. 9	+289. 8	1, 663
Monuments Nos. 1 to 204	854, 865. 0	854, 792. 5	+72. 5	11, 791
Monuments Nos. 1 to 258	1, 080, 435. 2	1, 079, 944. 2	+491. 0	2, 200

In the cases of the first and fifth sections of the table, the discrepancies between the measured and computed distances are doubtless greatly increased by the large local differences of station error which were found to exist both on the Rio Grande and the Pacific coast.

This was further indicated by the fact that there were three independent measurements of the first section by United States corrected chain, by United States stadia, and by Mexican stadia, the extremes of which differed less than 60 meters, while their mean differed about six and one-half times this amount from the computed distance.

There were two independent measurements of the fifth section, by United States stadia and by Mexican stadia, which differed by less than 25 meters, while their mean differed more than 400 meters from the computed distance.

It will be observed that some of the preceding distances differ slightly from those given in the tables of final distances between monuments. This is due to the fact that remeasurements were made of all distances, wherein serious discrepancies were discovered when the United States and Mexican distances were compared previous to the erection of monuments. In order to give a true idea of the accuracy of stadia work, the original measurements only, uncorrected by the remeasurements, are given in the preceding table, while the results of the remeasurements are included in the tables of final distances.

These results are of interest, as showing the accidental errors in stadia work, which occur in spite of all precautions. Inasmuch as the United States and Mexican measurements were made at different times, were totally independent of one another, and were generally not compared for months after they were made, it is fair to assume that the discrepancies shown by these comparisons included the greater number, if not all, of the accidental errors of the stadia measurements.

Two hundred and fifty-six distances, averaging 4,235.7 meters each, were compared, and remeasurements were made wherever serious discrepancies were shown. These remeasurements disclosed three cases in all where it was evident that the United States measurements contained accidental errors, either in reading the rod or in recording the readings. Two of the errors were about 100 meters each, and were probably due to errors in rod reading; the third was about 30 meters, and was probably due to a clerical error in recording.

As the total number of sights taken in measuring the compared distances was 5,059, and as it is extremely unlikely that two errors of this character, exactly equal in amount and with opposite signs (thus balancing one another), occurred in any single one of the 256 distances, when but three were found in all, it may be assumed that 3/5059 gives a fair idea of the probability of an accidental error of any considerable magnitude, where the observers are intelligent, careful, conscientious men, keep their own notes, and take foresights and backsights at each station. In all, four observers were engaged in measuring distances along the boundary line proper, and three of them had one accidental error each.

In this connection it is interesting to compare the relative effect of the accidental errors of the stadia with those of the chain.

In a distance of 153,841 meters, 7,692 chains of 20 meters each, 6 chains were either added or dropped accidentally, i. e., 1 chain in every 1,282, or an error from this cause of 1/1282.

The three accidental stadia errors before alluded to aggregated 247.46 meters in a total distance of 1,080,435 meters, or an error from this cause of 1/4366.

The preceding discussion has been entered into in detail because it is believed that seldom, if ever before, has it been possible to check in this manner work done on so extensive a scale, and thereby to determine, even approximately, the effect of errors the frequency of the probable recurrence of which is almost wholly unknown.

Of lines of the second class 1,017 miles were run, of which 118 lines, aggregating 514 miles, were closed on points on the main lines, by the method of latitudes and departures, with an average error in distance of 1 in 752. Twenty-five per cent of these lines showed an error in closing greater than 1 in 500; 31 per cent showed an error in closing between 1 in 500 and 1 in 1,000; 30 per cent showed an error in closing between 1 in 1,000 and 1 in 2,000, and 14 per cent showed an error in closing less than 1 in 2,000.

The following table was prepared to show the effect of the seasons on the accuracy of the work:

Season.	Aggregate length of lines.	Error in distance on closing equals 1 in—	Mean error on closing, per kilometer of line run.	
			In azimuth.	In elevation.
	Meters.		′ ″	*Meters.*
Spring	138, 702. 83	602	1 24	0. 103
Summer	298, 147. 87	728	0 45	. 141
Autumn	152, 325. 61	1, 090	1 01	. 101
Winter	237, 339. 65	742	1 07	. 128
	826, 515. 96	752	0 59. 6	. 123

Topographic field work was commenced in February, 1892, and carried on continuously until completed, in October, 1893; and in preparing this table the seasons, for convenience, were divided as follows:

Spring: March, April, May.

Summer: June, July, August.

Autumn: September, October, November.

Winter: December, January, February.

An inspection of this table shows that the least accurate work was done in spring, and the most accurate in autumn—a result which was due partly to inexperience on the part of the observers during the spring of 1892, but more especially to the effects of work done on the Yuma Desert in March, 1893, under conditions very unfavorable for accuracy.

The same lines were then grouped with reference to length of courses, in order to determine how their accuracy was affected thereby. This grouping is shown in the following table:

Number of lines.	Aggregate length of lines.	Average length of courses.	Average number of courses per line.	Average error in distance on closing equals 1 in—	Average error on closing, per kilometer of line run. In azimuth.	In elevation.
	Meters.	*Meters.*			′ ″	*Meters.*
29	111, 823. 2	253. 0	15. 2	553	1 55	0. 160
49	280, 706. 8	356. 7	16. 1	782	1 04	. 096
28	290, 633. 9	437. 7	23. 7	817	0 43	. 103
12	143, 352. 0	580. 4	20. 6	786	0 37	. 190
118	826, 515. 9	386. 2	18. 1	752	0 59. 6	. 123

From this table it would seem that there was little or no difference in accuracy in sights ranging from 300 to 600 meters in length, while for sights less than 300 meters a much smaller degree of accuracy was obtained. Such a conclusion, however, must be greatly modified by the fact that very long sights are taken only when all conditions are favorable, while short sights are necessary when much wind is blowing or when the air is "boiling," conditions which are both unfavorable for accuracy. The shortest average length of course in any closed line was 92.4 meters, and the greatest average length 704.6 meters. It is not likely, however, that sights as long as 500 or 600 meters could be taken advantageously anywhere except in atmosphere as clear as that of the Southwest.

With the idea of determining to what extent the accuracy of the work was increased by compensation of errors in the longer lines, the whole number of lines was divided, with reference to the number of courses in each line, into two classes, as shown in the following table:

Number of lines.	Aggregate length of lines.	Average number of courses per line.	Average length of course.	Average error in distance on closing equals 1 in—	Average error on closing, per kilometer of line run. In azimuth.	In elevation.
	Meters.		*Meters.*		′ ″	*Meters.*
71	238, 732. 2	9. 7	348. 0	683	1 28	0. 165
47	587, 783. 7	30. 9	404. 9	784	0 47	. 107
118	826, 515. 9	18. 1	386. 2	752	0 59. 6	. 123

This table shows that both the azimuth error and the error in elevation were more affected by the number of courses per line than was the error in distance, but that the accuracy of all increased with the number of courses per line.

Finally, to show how the character of the work was affected by practice on the part of the observers, the following table was arranged, comparing the lines run in 1892 with those run in 1893:

Year.	Number of lines.	Aggregate length of lines.	Average length of lines.	Average length of courses.	Average number of courses per line.	Average error in distance on closing equals 1 in—	Average error on closing, per kilometer of line run. In azimuth.	In elevation.
		Meters.	*Meters.*	*Meters.*			′ ″	*Meters.*
1892	81	449, 773. 9	5, 552. 8	341. 5	16. 3	697	1 18	0. 130
1893	37	376, 742. 0	10, 182. 2	457. 8	22. 2	829	0 35	. 116
	118	826, 515. 9	7, 004. 3	386. 2	18. 1	752	0 59. 6	. 123

Most of the work during the two years was done by the same observers, with the same instruments and rods, and under practically the same general conditions, consequently it is fair to assume that all differences in the character of the work during the two years were the direct result of practice and experience on the part of the observers. The table shows that both the average length of the lines and that of the courses was greatly increased in 1893, as was also the accuracy in distance, azimuth, and elevation—notably in azimuth.

A study of the preceding tables shows that the average azimuth error, on closing, per kilometer of line run, varied approximately inversely as the product of the square root of the average number of courses per line into the average length per course; or, denoting these quantities by e, N, and l, respectively, we have e varies as $1/l\sqrt{N}$, which is the theoretical law of variation, and becomes $1/\sqrt{N}$ when the courses are of equal length.

Theoretically this last ratio should also be true for the error in distance on closing; but in practice this was not found to be the case, the variation being much more gradual, indicating the existence of constant errors, which neutralized, to a considerable extent, the theoretical compensation.

Since the conclusion of the survey it has been shown by Mr. L. S. Smith, C. E., now assistant professor of topographical engineering in the University of Wisconsin, but in 1892–93 occupying the position of transitman on this survey, partly from observations taken during the progress of the survey and partly from others taken more recently (see Chapter X, Appendix, of the present report), that the constant error alluded to is very largely due to the effects of "differential refraction," i. e., the difference in the amount of refraction experienced by the upper and lower lines of sight, which difference varies with the season and with the hour of the day, and affects the accuracy of the interval determination, unless this determination is extended over a period sufficiently long to embrace the average conditions under which the proposed work is to be prosecuted.

Of the average error of all lines of the second class, 1/752=1.33 meters per kilometer, about 20 per cent, or 0.29 meter, was found to be due to azimuth error, leaving an error of 1.04 meters per kilometer = 1/962, as the average error due to the measurement of distance alone.

The line of levels carried from the Rio Grande to the Pacific afforded an exceptional opportunity for checking the accuracy of the elevations determined by stadia.

All lines of the second class have been arranged, with respect to their average vertical angles, as follows:

Number of lines.	Aggregate length of lines.	Sum of vertical components of courses.	Average vertical angle of lines.	Error in elevation on closing, per kilometer of line run.	Error in distance on closing equals 1 in—
	Meters.	*Meters.*	° ′	*Meter.*	
14	182, 960. 2	1, 262. 4	0 24	0. 053	
55	338, 132. 5	11, 706. 1	1 59	. 111	741
28	186, 426. 2	12, 139. 8	3 43	. 150	
17	112, 025. 4	11, 930. 6	6 05	. 181	824
4	6, 971. 6	1, 052. 0	8 35	. 492	
118	826, 515. 9	38, 090. 9	2 38	. 123	....

The angles in the fourth column of the table are obtained by dividing the numbers in the third column by the corresponding ones in the second column, the results being the tangents of these angles.

On examining this table it is seen that the error in elevation on closing increased very rapidly with an increase of the average vertical angle, while the error in distance actually decreased. The conditions for obtaining stadia elevations with accuracy in the region along the boundary were peculiarly unfavorable, owing to the great and sudden changes of refraction during the hours most favorable for field work, and it is therefore reasonable to suppose that with the same instruments and methods much greater accuracy would be obtained in a more favorable climate.

The lesser degree of accuracy, as regards distance, of the lines with small vertical angles is probably due largely, if not entirely, to "differential refraction," which is greatest on the flat valleys, mesas, and deserts where the lower line of sight passes closest to the surface throughout its entire length.

Including all classes of work, 60,971 sights were taken by the transit men, who at each sight read and recorded both the horizontal and vertical angles. The total time of the transit men was equivalent to one man for fifty-four months, which, excluding only Sundays and national holidays, gives an average of 44 sights per day for each transit man during the entire twenty months of the survey. In this connection it must be remembered that in addition to these sights the transit men took sketches covering the entire topographic belt and reduced the greater part of their notes in the field, and that more than half of the sights were taken in steep and rugged mountains, where much time was unavoidably consumed in getting from station to station and in traveling to and from work.

As an illustration of these delays, an instance mentioned by Mr. J. L. Van Ornum, assistant engineer, in charge of the topographical party, will be given:

A sight of about 2,000 feet was taken from one mountain ridge to the next, between which there was a ravine about 1,000 feet in depth. Before 10 o'clock the transit man began his descent from the ridge to cross the ravine and to climb to the point just observed, while he signaled the stadia man to cross from that point a second ravine to a third ridge for obtaining an advance sight. Approaching sunset forced them both to return to camp before they could reach the intended points.

The average length of the courses of the "main lines" was 214.3 meters; of the "side lines," 358.1 meters, and of the side sights from these lines, 346 meters. The shorter courses in the main lines were necessary in order to locate profile points on these lines.

The average distance to the points located, by intersections within the topographic belt, was 3,000 meters, and to those outside of this belt, 22,000 meters.

Since during the entire period of the survey the transit men each averaged about 31 locations per day, and since the average number of locations per square mile within the topographic belt was 22, it is evident that the rate of progress for each transit man during the duration of field work was 1.4 square miles per day.

It is seen also that had it been necessary to run only meander lines, without side sights, the transit men would each have averaged about 8 kilometers per day during the entire survey, excepting only Sundays and national holidays—a rate of progress which clearly shows the superiority of the stadia over the chain when the character of the country is considered, and when it is remembered that the stadia method gives both the horizontal and vertical angles, as well as the distance.

LINE OF LEVELS.

A line of levels, which, with its connections, aggregated 732 miles in length, was carried along the boundary from the Rio Grande to the Pacific Ocean, and connected at El Paso and Yuma with bench marks of the Southern Pacific Railway, and at San Diego with a bench mark established by the United States Coast and Geodetic Survey. To this line were referred all transit elevations, the datum plane being that of mean sea level of San Diego Bay.

Great care was taken in running this line; the rods were held on iron pins driven firmly in the ground; equal foresights and backsights were taken, and at each setting of the instrument both the backsight and foresight were read until two values of each were obtained, which did not differ more than 0.001 meter, the rod having been unclamped and reset after each reading. The mean of these two values was taken as the true reading.

In all, 9,663 instrument stations were occupied, each station representing four accepted rod readings on "turning points." In addition to these, 4,368 single readings were taken on points along the boundary.

Reducing the Southern Pacific bench marks at Yuma and El Paso to mean sea level of San Francisco Bay in order to check the line of levels, which is referred to mean sea level of San Diego Bay, the discrepancy was found to be -0.05 meter at Yuma and $+2.62$ meters at El Paso, the minus sign indicating that the Southern Pacific elevation is the lower of the two, and the plus sign that it is the higher.

Form San Francisco to Yuma the distance by the Southern Pacific Railway is 731 miles, and from San Diego, along the line of levels, the distance is 160 miles. To El Paso these distances are 1,294 and 728 miles, respectively.

The "boiling" of the air generally caused leveling to be suspended from about 10 a. m. to 3 p. m., thus rendering the progress of this work necessarily somewhat slow.

The time occupied in this work was equal to one level man for twenty-five and two-thirds months, which, excluding only Sundays and national holidays, gives an average of 14.8 for the number of instrument stations occupied per day, and 66 for the number of accepted rod readings per day for the entire time that the survey lasted. An idea of the rough character of the country can be formed from the fact that the average length of sights for the entire line of levels was but 61 meters.

In addition to numerous bench marks left on natural objects, which are fully described in the proper notebooks, the following table gives the elevation of the upper surface of the masonry base of each monument, together with the offset from the level line (along which the profile on the field maps is plotted) to the monument, thus enabling this line to be easily recovered at any time, should it ever become necessary:

Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.	Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.
	Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
1	1.02	1,131.9	....	21	27.05	1,213.1	....
2	1.00	1,303.8	....	22	31.11	1,212.9	....
3	2.00	1,255.7	....	23	34.53	1,219.4	....
4	3.77	1,247.9	....	24	45.645	1,259.3	....
5	10.77	1,245.5	....	25	56.65	1,297.7	+1.00
6	22.04	1,250.9	....	26	60.84	1,315.8	....
7	38.26	1,255.1	....	26	2.44	1,315.8	....
8	60.195	1,297.2	±1.00	27	2.935	1,294.8	....
9	64.31	1,288.7	±1.00	28	4.74	1,306.0	....
10	89.525	1,259.1	±1.00	29	7.90	1,272.6	± .50
11	122.46	1,248.1	....	30	12.62	1,271.7	....
11	22.91	1,248.1	....	31	18.085	1,433.5	±1.00
12	14.36	1,239.5	± .50	32	22.79	1,487.8	....
13	7.305	1,236.2	± .50	33	25.20	1,387.6	....
14	4.415	1,319.3	± .50	34	34.90	1,387.2	....
15	4.14	1,280.1	....	35	47.62	1,346.2	+ .50
15	4.14	1,280.1	....	36	59.37	1,347.2	....
16	4.48	1,269.7	+1.00	37	69.48	1,384.7	....
17	5.99	1,202.6	± .50	38	79.205	1,458.8	±2.00
18	9.35	1,205.6	....	39	90.605	1,518.4	+2.00
19	14.575	1,208.4	....	40	98.97	1,494.2	....
20	20.72	1,211.0	....				

On parallel 31° 47′ the monuments are all north of the tangents, and the offsets are measured in the meridian.

Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.	Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.
	Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
40	.00	1,494.2	....	47	.02E	1,294.8	....
41	.00	1,569.1	....	48	.03E	1,313.9	....
42	.00	1,404.2	....	49	.05E	1,326.8	....
43	.00	1,333.0	....	50	.07E	1,335.2	....
44	.00	1,279.6	....	51	.09E	1,344.1	....
45	.00	1,255.7	....	52	.10E	1,449.7	....
46	.00	1,270.8	....	53	.00	1,408.2	....

On the meridian section the offsets are perpendicular to the meridian. E $\hat{=}$ East.

Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.	Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.
	Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
53	− 6.49	1,408.2	....	91	− 23.10	1,476.1	....
54	− 5.87	1,396.0	....	92	11.87	1,399.1	+ .10
55	− 1.43	1,508.9	....	93	− 1.46	1,402.7	.10
56	+ .73	1,606.4	....	94	+ 6.01	1,399.7	.10
57	+ 5.54	1,643.0	.10	95	+ 16.12	1,375.9	....
58	+ 15.65	1,539.5	.20	96	+ 25.46	1,354.2	....
59	20.19	1,543.0	50	97	38.80	1,327.1	....
60	+ 36.55	1,413.5	.10	98	51.47	1,316.1	....
61	54.71	1,555.3	....	98	− 7.62	1,316.1	....
62	+ 63.10	1,619.3	....	99	− 30.76	1,426.6	.20
63	+ 4.44	1,535.1	....	100	− 51.18	1,839.9	+ 1.00
64	+ 5.75	1,619.7	....	101	− 52.77	1,848.6	5.00
65	−118.59	2,048.3	.50	102	− 59.67	1,800.4	+ 1.00
66	−101.01	1,576.9	....	103	− 78.10	1,611.0	+ .50
67	− 90.20	1,573.1	....	104	− 85.60	1,618.5	+ 1.00
67	+ 4.05	1,573.1	....	105	− 94.15	1,596.2	1.00
68	+ 6.34	1,584.1	....	106	−110.33	1,583.3	....
69	+ 11.63	1,609.0	....	107	−106.00	1,549.4	....
70	+ 16.90	1,662.2	....	108	−103.05	1,489.7	....
71	28.64	1,489.1	1.00	109	− 87.18	1,485.6	....
72	31.21	1,538.3	2.00	110	− 70.20	1,453.1	+ 1.00
73	37.51	1,266.8	....	111	− 59.97	1,409.8	....
74	84.84	1,322.0	+2.00	111	6.20	1,409.8	....
75	157.13	1,211.1	....	112	+ 16.40	1,451.0	....
76	+209.80	1,172.4	+1.00	113	42.09	1,659.3	....
77	+257.32	1,132.6	....	114	+ 50.82	1,750.5	1.00
77	− .73	1,132.6	....	115	65.76	1,672.3	+ 2.00
78	− .14	1,161.7	+ .10	116	85.405	1,292.9	+ .50
79	4.56	1,243.1	± .10	117	+108.28	1,192.4	+ .50
80	+ 9.85	1,465.1	± .50	118	+118.56	1,132.9	....
81	+ 12.62	1,479.4	....	119	66.67	1,248.3	+ 1.00
82	+ 15.80	1,374.2	....	120	42.16	1,272.1	+ 1.00
83	18.97	1,363.7	....	121	31.45	1,217.8	±1.00
84	+ 32.04	1,252.8	....	122	12.33	1,173.9	....
85	+ 42.68	1,203.8	....	123	6.08	1,248.7	± .50
86	56.72	1,204.2	± .10	124	− 3.63	1,330.6	....
87	79.15	1,248.6	....	125	− 12.70	1,381.3	± .50
88	− 31.23	1,315.8	.10	126	− 24.21	1,622.6	± .50
89	− 30.00	1,354.1	.30	127	− 24.63	1,592.05	....
90	− 27.41	1,390.3	.20				

On parallel 31° 20′ the offsets are measured in the meridian; those to the north of the tangent are "+," those south of the tangent are "—".

Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.	Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.
	Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
127	0.00	1,592.05	....	167	.00	421.65	....
128	—1.81	1,662.10	....	168	.00	565.27	....
129	.00	1,611.82	....	169	+ .02	395.33	....
130	.15	1,505.34	....	170	.07	369.37	....
131	+ .05	1,189.91	....	171	+ .20	379.12	....
132	+ .03	1,221.20	....	172	+ .10	334.00	....
133	+ .04	1,240.82	....	173	+ .11	308.20	....
134	.00	1,204.63	....	174	+ .07	313.93	....
135	.00	1,254.37	....	175	.00	365.40	....
136	.00	1,376.28	....	176	— .08	329.12	....
137	.00	1,147.74	....	177	— .04	261.88	....
138	.00	1,052.51	....	178	— .13	273.76	....
139	— .05	1,105.96	....	179	— .11	251.84	....
140	— .03	1,228.05	....	180	— .22	210.97	....
141	.00	1,327.74	....	181	— .51	245.49	....
142	— .10	926.06	....	182	— .43	278.72	....
143	.00	832.55	....	183	— .79	339.27	....
144	— .05	783.63	....	184	— .82	587.75	....
145	+ .02	801.97	....	185	— .56	614.35	....
146	.00	1,080.42	....	186	— .50	617.85	....
147	.03	817.24	....	187	— .50	479.68	....
148	.05	775.60	....	188	— .31	319.16	....
149	+ .13	749.49	....	189	— .12	547.73	....
150	.00	720.82	....	190	— .21	358.44	....
151	— .39	702.17	....	191	+ .15	644.34	....
152	— .27	690.56	....	192	+ .11	432.57	....
153	— .28	804.72	....	193	+ .10	242.34	....
154	— .55	542.67	....	194	+ .14	215.57	....
155	— .41	520.80	....	195	+ .08	200.93	....
156	— .29	511.75	....	196	+ .07	173.17	....
157	— .17	507.26	....	197	+ .04	140.81	....
158	— .16	529.66	....	198	+ .11	142.11	....
159	— .08	715.05	....	199	+ .11	81.45	....
160	.00	814.88	....	200	+ .06	51.01	....
161	.02	515.84	....	201	+ .13	47.00	....
162	.00	745.18	....	202	+ .08	48.92	....
163	+ .29	702.51	....	203	+ .06	44.92	....
164	+ .26	452.43	....	204	.00	41.42	....
165	+ .07	437.30	....	205	.00	26.60	±0.20
166	+ .01	421.24	....				

On the Sonora azimuth line offsets are measured perpendicular to the line as run; those measured to the north are marked "+", those measured to the south are marked "−."

Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.	Monuments.	Offset to monument as erected.	Elevation of top of masonry base above mean sea level.	Probable error of doubtful elevations.
	Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*
206	− 0.39	35.27	....	233	− 11.25	900.49	....
207	.00	47.59	....	234	− 4.99	1,063.05	....
208	+ 1.68	53.77	....	235	+ 2.68	1,151.83	....
209	+ 5.04	54.99	....	236	+ 8.16	1,121.13	....
210	+ 8.37	52.70	±0.20	237	+ 14.60	1,071.13	....
211	+ 10.72	45.23	....	238	+ 18.99	1,090.70	....
212	+ 12.62	41.47	....	239	+ 25.38	961.21	....
213	+ 14.41	39.10	....	240	+ 30.14	922.34	....
214	+ 17.20	33.96	....	241	+ 32.92	922.86	....
215	19.65	28.38	....	242	+ 40.33	785.97	....
216	+ 25.73	22.48	....	243	+ 48.00	635.33	....
217	+ 25.76	15.77	....	244	+ 50.50	571.20	....
218	+ 28.11	8.74	....	245	+ 56.10	579.51	....
219	+ 30.20	5.99	....	246	+ 60.79	1,041.55	....
220	+ 32.55	.55	....	247	+ 62.14	1,057.46	....
221	+ 30.46	− .56	....	248	+ 50.47	328.28	....
222	+ 23.29	−4.33	....	249	+ 40.41	249.14	....
223	+ 17.85	−4.37	....	250	+ 31.78	323.12	....
224	+ 11.12	83.54	....	251	+ 11.94	517.85	....
225	+ 9.18	114.63	....	252	.00	161.19	....
226	+ 4.68	64.17	....	253	.00	150.21	....
227	+ .52	100.09	....	254	.00	147.88	....
228	− 5.57	136.47	....	255	− .34	34.68	....
229	− 10.80	528.58	....	256	.00	137.41	....
230	− 18.53	674.43	....	257	.00	119.47	....
231	− 25.80	1,371.07	....	258	.00	*18.56	....
232	− 18.26	1,073.36	....				

* Top of granite base.

On the California azimuth line offsets are measured perpendicular to the line as run; those to the north are marked "+", and those to the south are marked "—".

Elevations below mean sea level are marked "—".

The figures in the second column give the offsets from the line actually run, and along which the profiles were taken, to the center of the monuments as erected. Offsets are in meters.

Those in the third column give the elevation (in meters) of the top surface of the masonry base of the monuments, referred to mean sea level of San Diego Bay, California.

Elevations unmarked by their probable errors in the next column are believed to be correct, with respect to the line of levels, to within less than 0.10 meter.

On parallels 31° 47′ and 31° 20′ it will be observed that the elevation is in many cases given as having a large probable error. This is due to the fact that the line of levels was run several months in advance of the erection of the monuments, and that on those parallels the elevations were not transferred to the monuments when the latter were erected, but afterwards in the office by the aid of photographs of each monument and the surface in its vicinity, elevations at or near the site of the monument, and such other notes as were available.

Whenever, owing to the distance of the nearest station of known elevation, the lack of necessary details in the photographs, or from any other cause, the elevation could not be transferred within 1 decimeter, the degree of approximation which it was believed could be safely relied upon is given as the probable error of the elevation in question.

The distances between the monuments in the preceding table are given on pages 34 and 35 of the Report of the Joint Commission.

MAGNETIC DECLINATION.

The known azimuths of the tangents and of the different sections of the boundary line furnished an easy method of determining, by means of the transit compass, the magnetic declination at various points along the boundary. In all, 534 compass readings were taken, at an average distance apart of 1.26 miles. The index error of the compass was determined and the readings checked by comparison with a full set of magnetic observations made in 1892 at San Diego, Cal.; Yuma, Ariz.; Nogales, Ariz., and El Paso, Tex., by the United States Coast and Geodetic Survey party which determined the latitude and longitude of those points, and also by comparisons with observations made with a magnetic theodolite by Mr. J. F. Hayford, assistant astronomer, at the 12 astronomical stations between the Rio Grande and the one hundred and eleventh meridian.

The period covered by the observations was from March 31, 1892, to October 16, 1893. The corrected observations have all been plotted, but owing to the uncertainty regarding the secular variation along the boundary no attempt to reduce them to any fixed epoch was made. Owing to this fact, and to the difficulty of reading the ordinary compass needle accurately, the curve of magnetic variations may at some points be several minutes in error, and is interesting principally as showing the distribution of magnetic declination and its local variations.

An examination of this curve shows that great local changes in declination invariably occurred when the line crossed over a lava-covered region, and that in one case this variation underwent a range of 5° 50′ in about 5 miles. In all, there were ten localities along the boundary where the declination underwent a change of from 1° 40′ to 5° 50′ in the course of a few miles. Four of these places were in lava-covered regions and six in mountains.

In no cases except in volcanic regions were large local variations of declination found on the deserts or in the valleys.

In order to judge fairly of the value of the stadia in topographical work, it is necessary to know the conditions under which stadia work was prosecuted on this survey.

The conditions favoring this work were the wonderful clearness of the atmosphere, the general absence of trees and thick undergrowth, the remarkable healthfulness of the region, its delightful winter climate, and the very few rainy days.

The unfavorable conditions were the intense heat on the deserts in summer, and the total absence of shade there; the scarcity and poor quality of the drinking water; the inability to procure fresh meat on the deserts, where most needed; the long haul for provisions, forage, and water; the violent sandstorms on the Colorado Desert, and the great atmospheric unsteadiness.

As to the temperature, it will be sufficient to state that on the deserts in summer the thermometer at times attained a maximum of 118° F. in the shade. This gives but little idea, however, of the temperature in which work was prosecuted; for of available shade for the working parties, even during the long noon intermission, there was absolutely none, and it was to sunshine temperature alone that they were exposed throughout the entire day. This temperature, during the month of June, 1893, generally varied from 130° to 140° F. at 8 to 9 a. m., 145° to 160° F. at 1 to 2 p. m., and fell below 130° F. at 5 to 7 p. m. In spite of this intense heat, work was vigorously prosecuted every day, and the general health of the party was excellent, owing, doubtless, to the fact that the extreme dryness of the atmosphere tempered the effect of the heat and caused rapid radiation, due to which the nights were in general cool and pleasant, however intense was the heat during the day.

While, owing to the causes above mentioned, such extreme heat is less debilitating than is the case where more moisture exists in the atmosphere, yet the bodily discomfort therefrom during the middle of the day is by no means so small as it is popularly supposed to be, and few who have once worked in such temperatures would care to repeat the experience.

The greatest obstacles to accuracy in the stadia measurements were, however, atmospheric unsteadiness and winds.

Under the term "atmospheric unsteadiness" are included certain peculiarities of atmospheric action—"differential refraction," refraction, and "boiling." The first has already been alluded to. The second is well known, but it should be stated that the daily variations in the amount of refraction and the suddenness of these variations are exceptionally great in this region.

The "vibration" or "boiling" of the atmosphere is familiar to everyone who has been engaged in field work, but occurs to a remarkable extent in the arid regions of the southwest, and was a subject of study on this survey by Mr. John F. Hayford, assistant astronomer, Messrs. J. L. Van Ornum and E. L. Ingram, assistant engineers, and Mr. L. S. Smith, transit man, from whose notes and reports the following facts were obtained:

The number of vibrations during consecutive minutes was very variable, being in some cases three times as great as in others, the most rapid vibrations occurring in the intervals when the breeze ceased.

When a steady breeze was blowing objects whose form was distorted and irregular from the atmospheric vibrations always suffered more distortion on the leeward than on the windward side, and their outline appeared actually to be blown with the wind like the flame of a candle.

The lateral component of the vibration was in general of less amplitude than the vertical component, and gave to the rod a sinuous appearance and a wave-like movement, always from the bottom toward the top. It was also observed that this component of the vibration was always greater at the bottom than at the top of the rod.

The lateral component of the vibration affects the accuracy of stadia work, as regards azimuth, to a greater extent than as regards distance.

The vertical component of the vibration was of a compound character, consisting of a primary vibration, upon which was superimposed a secondary vibration, more rapid but of smaller amplitude.

Atmospheric vibration was found to increase rapidly with length of sight; with difference of temperature between the air and earth; with the brightness of the sun, and with the absence of vegetation.

While the general effect of this vibration is to decrease the accuracy of a single sight, yet errors due to this cause alone are probably compensatory, balancing one another on an extended survey.

So far as atmospheric vibration alone was concerned, it was the general rule throughout the survey to continue work whenever the amplitude of the vertical component of this vibration appeared less than 1 centimeter at a distance of 200 meters, at which distance this vibration often reached 1½ and sometimes even 2 centimeters.

When wind alone was the disturbing element, work was continued as long as the stadia men were able to hold the rod up against it.

That stadia work was prosecuted under the adverse conditions mentioned in the two preceding paragraphs was not because it was supposed that accurate work could be done at such times, but because the great difficulty and expense of procuring water and supplies rendered it imperative that the work should proceed as rapidly as possible, even at a sacrifice in accuracy.

REPORT OF MR. J. L. VAN ORNUM, ASSISTANT ENGINEER.

SAN DIEGO, CAL., *April 6, 1891.*

As directed, at El Paso, Tex., I organized in February, 1892, the topographical party of the International Boundary Survey, to consist of two transitmen, each having three stadiamen, and one levelman, having two rodmen. This engineering force, with the necessary cooks, teamsters, packers, and laborers, formed the regular topographical camp in its work under my charge from the Rio Grande to the Colorado River.

At Yuma, in January, 1893, in accordance with the plan for two field parties for the survey of the deserts, one of the transitmen and the levelman were detached for topographical work on the California portion of the boundary. Filling their places, I proceeded with the survey to the eastward of the Colorado River and completed the fieldwork in October, 1893.

The transits used were of the usual description, manufactured by F. E. Brandis, Sons & Co., of New York City, having 6-inch horizontal circles reading to 20″, vertical circles reading to 1′ and 10½-inch telescopes magnifying 20 diamefers.

One of the levels used was made by W. & L. E. Gurley, of Troy, N. Y., and the other by F. E. Brandis, Sons & Co., of New York City. They were of the usual style manufactured by these firms, having 18-inch telescopes magnifying about 30 diameters.

PLATE I

Fig. 1. *Design of Stadia Rod used*

Fig. 2. *Target used for measuring vibration.*

The level rods were the regular New York form of rod, with metric divisions. Gurley's rod levels were used for securing a vertical position of the rod.

The stadia rods were designed by us. They were 4½ meters long, 1 decimeter wide, 20 millimeters thick at the middle and tapering to 15 millimeters thickness at the ends. The foot of each rod was shod with band iron. The face of the rod was divided into decimeters and centimeters, as shown:

As distinctive features of this rod will be noted the diamond form of decimeter division; their entire coloring on one side of the face of the rod for long distance readings, while at the other side they are divided into centimeters for short distance readings; the *red* centimeter divisions to distinguish every half-meter, and the red figure and diamonds, and the changing of the centimeter divisions to the opposite side of the face of the rod, to aid in distinguishing the meters.

This form of marking was adopted because of its simplicity, while at the same time it furnished the distinctive characteristics given to aid in readily reading the intervals. The twenty months of field service confirmed the expectation of their efficiency. Under fairly favorable conditions the centimeter divisions could be distinguished at a distance of 250 meters, and spaced by the eye of the observer into millimeter readings, while for secondary sights the decimeter divisions could be observed at a distance of 600 or 700 meters, and spaced in the same way into centimeters. While these long and accurate readings indicate the efficiency of the form of rod used, the clearness of the atmosphere also aided in securing this result.

For reconnoissances, and for aiding my work of sketching and planning operations, I at times made use of a prismatic azimuth compass and a Locke's hand level.

The essential work of the topographical party consisted in the measurement of the line; the securing of elevations of salient points upon it, and the detailed topography of a zone 4 kilometers (2½ miles) wide on the American side of the boundary. For obtaining these elevations a wye-level was used. For the measurement of the boundary within the limit of error desired the stadia furnished the best method, and the transit offered the lightest, most adaptable, and best instrument.

For topography the natural features and conditions of the country to be traversed led to the selection of the transit as the best field equipment. The frequent remoteness from supplies and water, and the great heat of summer, and other hardships to be encountered in an almost uninhabited region, necessitated as small a field party as practicable, and suggested the plotting of the notes away from the field. The topography, embracing a belt of country 4 kilometers in width, required a general onward movement, and a concentration of the work of all instrumentmen and instruments on topography as mountain ranges were encountered, all working to advantage in limited areas. The occasional remoteness of work from available camps, and excessively rugged character of some of the mountain ranges, called for the lightest equipment possible; while the necessity of utilizing even the frequent very windy days, and the precipitous mountains often requiring vertical angles as high as 60° and precluding the possibility of resections, confirmed the selection of the transit as the only practicable instrument for this work.

The level line, as a rule, followed the tangent lines of the boundary, taking elevations to secure a profile and to furnish reference points for elevations in topographical work. When difficult mountains were encountered the level line went around and joined the tangent again on the further side, a transit profile being taken over the mountain.

The level party was generally the first to quit work on account of the midday heat. The great heat and vibration of the atmosphere necessitated a cessation of work during the summer months from 10 a. m. to 3 p. m., and often longer.

Great care was taken to secure as accurate work as possible. Sights were ordinarily limited to 100 meters and were restricted to 250 meters. They averaged about 60 meters. The level adjustments were tested daily, and all possible care was taken to protect the bubble tube from the disturbing effects of the heat. Two independent readings were taken on each backsight and foresight; if these did not check within 1 millimeter, more settings of the target were made until such agreement was secured, the mean of the two being taken as correct. The levelman was required to check the final reading of the target on each sight. Each rodman kept a peg book for checking the levelman's computations. Each day's work was checked by a summation of backsights and foresights by both levelman and rodmen.

The level line as carried along the boundary gives the elevation at El Paso 2.67 meters less than the elevation assumed at starting. The assumed elevation was the mean of elevations given by the Southern Pacific Railway and the Atchison, Topeka and Santa Fe Railway, the former having been brought from San Francisco and the latter from St. Louis.

Further details of the level work are given in the Report of the Commissioners under the head of topography.

The measurement of the boundary line furnished monument distances, distances for the profile of the line, and points for the starting and closing of topographical lines. It was made by stadia for the whole distance. The length of sights varied from 100 to 300 meters, and averaged 214 meters. As a rule the length of sight was smallest toward midday, the vibration of the atmosphere already mentioned troubling during the summer for eight or nine hours of the day when on the plains, and stopping the work for four or five hours.

This vibration was the greatest on sandy plains having little vegetation. Though very aggravating, it was not so excessive as the temperature and character of the country would lead one to expect. The slight humidity of the atmosphere probably modified its amount.

Work would generaly stop when the amplitude of vibration reached 1 centimeter at a distance of 200 meters, while at midday this amplitude would often be as much as 1½ centimeters, and at times 2 centimeters at the distance mentioned. A peculiarity of the vibration of the air was its double character, or what might be called a primary and a secondary vibration. When this primary vibration had an amplitude of 4 centimeters and a rate of 30 per minute, at the same time would be remarked the secondary vibration, having an amplitude of 2 centimeters and a rate of 60 per minute.

A double measurement of each distance was made, first as a foresight and then as a backsight. Besides the profiles over mountains, profile points were often taken, in ravines or on ridges, by distance and vertical angle to assist the levelman. This measurement of the line used two of the rodmen. The third was occupied in giving topographical points for 200 meters on the Mexican side and adjacent points on the American side that could be taken to advantage.

Incidental to this work there were also taken from the tangent slope angles on the plains observations for magnetic declination at intervals of about 2 kilometers (for résumé of which see Report of the Commissioners under the head of topography), and intersections to and vertical angles on mountain peaks and ranges on each side of the zone of instrumental topography.

Great care was taken to secure a true and accurate interval factor. At first frequent determinations were made, and afterwards at intervals, to make sure that there had occurred no change of magnitude due to accident or to lapse of time. One determination was made after the transit had been exposed to the heat of the day to see if this appeared to affect its interval, but no difference was apparent.

The method usually followed in testing the interval was for two observers to take two readings, each at intervals of 40 meters, on a carefully measured base line (corrected for inclination and for the temperature of the tape) 400 meters in length. The transit was placed at a distance beyond the end of the base line equal to its focal distance plus the distance from center of instrument to the objective ($f + c$). Occasional obvious errors of reading were rejected, and the interval factor was determined for each distance. The mean of these was taken as the true factor, giving those of the observer who ordinarily used the transit double weight. After the first group of observations, when the newly determined factor differed but little from the previous ones (as was usually the case), the mean of the latter was given double the weight of the one just taken in obtaining the working factor. In all the determinations of the interval factor, made for the transit used in the measurement of the line, nearly 800 readings were taken, and the greatest deviation of any determination from the mean, during its twenty months of service, was less than 1/1000.

Tables of distances were made for the successive working interval factors in which the term $f+c$ entered, giving an easy and quick way of reducing the stadia reading to distance.

As before stated, the belt of topography taken was 4 kilometers wide on the American side of the line. The plan of work contemplated the instrumental location and determination of elevation of all topographical features that would appear on maps drawn on a scale of 1/30000, with contours at vertical intervals of 20 meters.

The tangent lines in their measured distances and established elevations were taken as the basis of the topography. From them stadia lines were run in a general northward direction, from the stations of which secondary sights (giving azimuth, distance, and vertical angle) were taken on salient points of the terrene, and, covering in this way an advantageous area, the main line turned southward, closing again on the tangent line.

Each main line was a true transit line, each station being occupied by the transit. The zero of the vernier was kept always north, and two sights for distance and elevation were taken on each course. To properly cover the terrene, spur lines were often run out from the main line, and where there was no indication of magnetic disturbance these spur lines were compass lines.

Special topographic books were ordered, to contain the reduced field notes as well as the original entries. The latter consisted of the stations, azimuths, and stadia readings, vertical angles and heights of instrument (above the station), with explanatory notes, and with sketches showing the configuration of the terrene, with the position of stations taken, and the location of all water, wood, grass, roads, trails, ranches, and towns.

Often when crossing a plain with the tangent, transit, and level line, the second transit man would form a detached camp with his men in the mountain range ahead or in the one just left, while in wide areas of mountains all the instrument men would work on topography to obviate too great a separation of camps. The vibration of the air interfering with observations much less in the mountains than on the plains, a greater accuracy and less interference with the hours of work were possible. It should be stated that the degree of accuracy of the work was reduced by the necessity of constant progress unless absolutely prevented by hard storms. It was the rule that field work should continue in storms as long as it was possible for the stadia men to hold up their rods in the wind.

The notes were reduced in the field, and then sent to the office for plotting. The reductions were made partly by a computer in the party and partly by the engineers on stormy days, during the midday cessation of instrument work, and evenings. Stadia readings were reduced to distances and these to horizontal and vertical components, elevations of instrument and elevations of all stations were obtained, and the latitudes and departures of all closed lines with the circuit of elevations were computed. The maximum allowable error of closing in distance was 1/300, and in elevation 1 decimeter per kilometer per degree of vertical angle; distances and elevations on the tangent lines were assumed correct in these computations.

For computing the elevation of stations on closed lines a formula was devised which, by taking advantage of the two readings on each course, eliminated the correction for curvature and refraction. The derivation of the formula is as follows:

Let the elevation of Station A (already known) be e, the H. I. there be a, and the vertical component of the reading on the next station be m. Let the elevation of this next station, B (to be determined), be x, its H. I. then be b, and the vertical component of the reading back to Station A be n. Represent the correction for curvature and refraction by c; m and n are positive or negative quantities according as B is higher or lower than A.

The following equations, then, are derived:

1. $x=e+a+m+c$ (by F. S. from A);
2. $x=e+n-c-b$ (by B. S. from B); whence:
3. $2x=2e+m+n+a-b$ (by adding 1 and 2); or:
4. $x=e+\frac{1}{2}(a+m+n-b)$.

Equation 4 gives the formula as used, from which the term c has disappeared. Errors due to the instrument being in not perfect adjustment, or to heat affecting the bubble tube or other portions of the transit (which is often quite troublesome), being both errors of a character similar to that due to curvature in their mathematical effects, are likewise eliminated. Consequently the only errors entering the result are those of observation, and nonvertical rod, and sudden changes in refraction, which the use of this formula reduces by half; or, if large, such errors are detected in the process of reduction, and the erroneous sight is corrected in the field by another observation on the course in question. The average error of closing before the adoption of the formula was more than half greater than after its use.

After completing the computation of the elevations of the stations on the closed line in this way the discrepancy in elevations on closing on the tangent was distributed uniformly backward along the line. Errors in closing of latitude and departure were also uniformly distributed.

The roads and trails of the country which this expedition followed were, outside of the zone of topography, and occasional short distances inside the zone, located by taking the azimuth of successive courses with a prismatic compass, and the distances by counting a horse's steps of known interval, both the initial and final points of the meander being instrumentally located.

In the Dog Spring, Guadalupe, and Perilla mountains the greater part of the topography was taken by intersections instead of by stadia. This method was used because it shortened the time of field work, and it was made practicable by the occurrence in these places of a few peaks commanding the whole region taken. Stations on these peaks were located by intersection from the tangent line and from each other, and at these stations transitmen had their positions.

An engineer with a flagman (both mounted whenever possible) would traverse an advantageous area, the flagman signaling at each salient point of the terrene, while the engineer made a contour sketch of the region, giving the located points, with their designating numbers, and recording the time of each signal. At the same time two transitmen occupied two advantageous positions on commanding peaks, and upon each signal from the flagman took simultaneous observations upon his vertical flag, recording the azimuth, vertical angle, and time of each observation. At the close of each day's work each recorded observation of each transitman was numbered to correspond to the engineer's record, the time entry serving as a check in numbering.

In the office each located point was plotted from the transitmen's stations according to the field record, and the distance from each station to each point was measured. From this distance and the corresponding vertical angle recorded the vertical component was computed; this, when corrected for curvature and refraction, was applied to the known elevation of the station, whence was derived the elevation of the located point. There being two observations on each point, comparison could be made. Eighty per cent of the points so located checked within less than 3 meters, even when the sights were 10 or 12 kilometers long. Of those not agreeing, the true elevation was indicated by reference to the contoured sketch.

It was the intention in such intersection work to use aneroid barometers for securing elevations if it was found that satisfactory results could be obtained. With this in view, one Cassella and two Queen & Co.'s compensated barometers were read on the intersection work in the Dog Mountains just described. One of them was placed at a transit station and ten-minute readings taken to show the atmospheric fluctuations during the day; the other two were carried by the engineer and read at each topographical point. The barometers were compared both before and after the work, and these readings also were recorded. The readings of each of the two observed barometers, as modified by these compared readings, were considered with reference to the readings of the stationary barometer; and the resulting differences (reduced by Guyot's Laplace's formula, as given by Williamson, to meters) gave the barometric differences of elevation. From these, knowing the elevation of the stationary barometer, the barometric elevations of the topographical points were determined.

All care was taken to obtain, if possible, satisfactory results; yet the two observed barometers at times differed from each other at the same station as much as 20 meters, and both differed often from the instrumentally determined elevations to a fatal degree, which at times amounted to 40 meters.

From the Colorado River eastward along the boundary for a distance of 300 kilometers the country is quite inaccessible, is almost uninhabited (having one ranch within 30 kilometers of the line on the American side), and is a true desert, having but five watering places, and some of these of limited capacity. This being such a wilderness, and offering many obstacles to the usual rate of progress, it was determined to modify the plans so as to further expedite field work.

The method followed in the field work was the same as on previous work in all particulars, except for the surface irregularities of the outer 3 kilometers of the topographical belt. In this area flags were placed on all the prominent peaks and ridges, and the location and elevation of these points were taken by the transit man from the boundary line. The second transit man occupied the positions of these flags, and took azimuths and vertical angles on all flags in sight, thus covering the terrene with a network of location angles. At the same time he located other important topographical points by resection, where possible, but more often by stadia, and made a contour sketch showing the details of the whole terrene, the located flags furnishing the accurate groundwork for the whole.

This method of field work suggests that followed in the mapping. The numerous flag locations furnished the salient points, the resections and stadia locations gave other accurately determined locations and elevations, and the minor details were filled in from the field sketches.

The results proved the wisdom of the plan. Less expeditious advancement would frequently have caused serious complications. At one time a threatened failure of water was only averted by an arduous and successful search for natural tanks in the Cerro Cabeza Prieta, and by good fortune in developing the supply of the Tule Wells. As it was, the survey was enabled to successfully cross the deserts and secure its topography in as great detail as the character of the county warrants.

The following table gives a general statement of the topographical work on this survey from the Rio Grande to the Pacific Ocean:

Section.	Boundary line.			Detached lines.							
				Transit.				Compass.			
	Number sights.	Distance measured.	Average length.	Number lines.	Number courses.	Length lines.	Average length courses.	Number lines.	Number courses.	Length lines.	Average length courses.
Rio Grande to one hundred and eleventh meridian...	2,388	481,963	201.83	133	714	210,499	295	51	523	181,537	347
One hundred and eleventh meridian to Colorado River....	1,882	377,426	200.55	104	487	134,316	276	24	399	141,233	354
Colorado River to Pacific Ocean....	798	226,467	283.79	29	137	64,200	469	16	171	78,759	461
Total	5,068	1,085,856	214.26	266	1,338	409,015	306	91	1,093	401,529	367

Section.	Closed lines.				Sights other than turning points.					
					Stadia.		Topographical intersection.		Mountain intersection.	
	Number lines.	Number courses.	Length lines.	Average length courses.	Number of sights.	Average length.	Points located.	Approximate average length.	Points located.	Approximate average length.
Rio Grande to one hundred and eleventh meridian	......	......	......	......	13,810	333	1,294	3,200	1,170	16,000
One hundred and eleventh meridian to Colorado River	......	......	......	......	8,743	346	1,190	2,800	1,200	25,000
Colorado to Pacific Ocean..	......	......	......	......	4,500	386	39	1,600	415	30,000
Total	118	2,140	826,516	386.22	27,053	346	2,523	3,000	2,785	22,000

SUMMATION.

Kind of location.	Number.	Average length.	Total length.
Stadia sights....	36,692	329	12,083,254
Topographical intersections	2,523	3,000	......
Mountain intersections	2,785	22,000	......
Total	42,000	......	......

On the closed lines the average error of azimuth per course is 23″. The average error in the closing by latitudes and departures is 1/752. A further discussion of the results obtained is found in the Report of the Commissioners under the head of topography.

Concerning the elevations on closed lines it is to be noted that the sum total of the vertical components on the aggregate length of lines of 826,516 meters is 38,091 meters, giving as the average vertical angle 2° 38′ 19″. The average error in closing in elevation is 1/374 of the vertical component, or 0.123 meters per kilometer of distance.

By grouping the lines according to their average vertical angle and plotting the corresponding errors in elevation of closing (expressed in meters per kilometer) I was enabled to draw the mean curve. If δ represents the average vertical angle expressed in degrees, the equation of this curve is $\frac{30\,(\delta \tan. \delta) + 8}{100}$.

Theoretically the error should vary as the tangent of the angle only. The presence of δ itself in the equation is due, I believe, to the fact that in practice rodmen will not hold the stadia rod vertical even with the aid of a plumb line, the tendency being to hold it perpendicular to the general slope, and so introducing an error varying with the inclination of the line of sight to the horizontal.

More favorable conditions in the field would change the constants of the equation and give a smaller probable error of elevation. These conditions would be secured by not working in very windy weather nor when the heat vibrations of the air are troublesome; by using transits whose vertical circles will read to a fraction of minute and whose stadia wires are as fine as possible and yet plainly visible.

A reconnoissance from Yuma eastward along the boundary, in February, 1893, developed the fact that eastward from old Monument No. II (204), near the Colorado River, there was no authentic mark on the line until old Monument No. VI (175), about 163 kilometers distant, was reached. As both these monuments are on plains, with three ranges of mountains between, it became necessary, before the survey could begin from the west, to establish a point on the westernmost range (the Tinajas Mountains) on a line connecting the two monuments just mentioned.

Preparation was made at Yuma for this expedition, which proved to be the most severe on the survey. Nearly half of the men deserted, when opportunity offered, on account of the arduous duties and forbidding prospect, and praise is due the engineers and those of the rodmen and teamsters who helped me to accomplish the purpose of the expedition and continued with the work.

All my party except one heliotropeman at Monument No. II (204) left Yuma by wagon train, following the Gila River eastward for 50 kilometers, then turning southward along the east foot of the Gila Range. The first water was reached at Tinajas Altas, 60 kilometers from the river. Seven kilometers southeast of this place two engineers with rodmen were left to occupy with their instruments stations on the Tinajas and Lechuguilla Mountains. With the wagon train I continued eastward 33 kilometers across the Lechuguilla Desert to the next water, at Tule Wells in the Tule Mountains, the easternmost of the three ranges. From this place I sent ahead by pack train a heliotropeman across the Tule Desert (73 kilometers) to the next water, at Agua Dulce, about 7 kilometers from Monument VI (175).

The plan followed for establishing this line was for the heliotropeman at Monument II (204) to show a constant light westward along the line, the engineers to work to the line by successive approximations. Fortunately the middle range (the Lechuguilla Mountains) proved to be so low at the line that observers could see over it, and the Tule and Tinajas Mountains were the only ranges it was necessary to occupy.

As an initiative I assumed a point on the Tule Mountains as near the line as I could guess, and from it showed a heliotrope to the Tinajas Mountains. There the engineer, by successive trials with his transit, lined in between my light and that at Monument No. II (204). Then he showed his heliotrope toward me and I lined in between him and Monument No. VI (175). By repeating this operation the line was continually approached.

The particular difficulty of the work will be realized when the character of the mountains in which these successive approximations were made is known. The Tinajas Mountains are a range excessively rugged and precipitous, about 4 kilometers wide, from 300 to 400 meters in elevation above the desert, and composed of numerous parallel ridges that had to be scaled in succession.

CAMP OF MEXICAN SECTION.
Near Lechuguilla Mountains.

CAMPAMENTO DE LA SECCIÓN MEXICANA.
Cerca de la Sierra de la Lechuguilla.

Old Monument No. I, on the Pacific.

Antiguo Monumento No. I, en el Pacífico.

The Tule Mountains are of much the same character, except that they are composed more of a succession of peaks than of ridges and are about 12 kilometers wide. Added to this there were numerous windstorms raising a dust that often obscured the heliotropes at the distance of about 70 kilometers, and clouds and thunderstorms further complicated operations.

The rodmen detailed to assist me in this work gave out after two or three days, leaving the engineers alone to make the observations and effect all the details of the work unaided. By unremitting effort and labor the purpose was finally accomplished, the successive camps called in, and the party returned to Yuma.

When on the regular survey this line was carried through with a Fauth theodolite and reduction made to the true line, it was found that the point set in the Tinajas Mountains was less than a meter (0.87) from the true line connecting the two monuments.

My first duty is last accomplished. With pleasure I commend the work of Mr. L. S. Smith, of Wisconsin, Mr. P. D. Cunningham, of Tennessee, Mr. James Page, of Maryland, and Mr. A. F. Woolley, jr., of Georgia, transitmen, and of Mr. P. D. Cunningham, of Tennessee, Mr. S. W. Speiermann, of Utah Territory, and Mr. Ernst Franke, of Colorado, levelmen. The courage, efficiency, and faithfulness of these engineers on the topographical work of this survey deserve especial mention.

CHAPTER VI.

OLD MONUMENTS.

Under the treaties of 1848 and 1853 the boundary was marked by monuments of stone and iron. In the process of their erection the line was divided into three sections, the monuments being numbered in each section independently. The numbers appeared only on the maps and were never placed on the monuments themselves. The first section comprised the Southern California boundary, extending from the Pacific Ocean to the Colorado River, a distance of about 141 miles, and was marked by 6 monuments. The second section was the azimuth line from the Colorado River to the one hundred and eleventh meridian—234.3 miles—with 19 monuments. The third section was the line from the Rio Grande to the one hundred and eleventh meridian, and includes the boundary along parallel 31° 47′, the meridian, and the parallel of 31° 20′. This section was marked with 27 monuments according to the maps of the American Commissioner, and 28 as shown on those of the Mexican.

In detail these old monuments were as follows:

Beginning at the initial point of the survey, at the Pacific Ocean, the first monument was located near the coast and, in accordance with the treaty, one marine league south of San Diego Bay. This was an elaborate structure of marble, made in New York and brought to this coast by a naval vessel, landed in the bay, and hauled on wagons to its destination. It consisted of a pedestal and shaft of white marble, the whole 16 feet high, and resting on a foundation of brick laid in mortar. The cutting and polishing, as well as the inscriptions, were finely executed. Its dimensions and inscriptions were as follows: Pedestal, including base, dado, and surbase, 5 feet 6 inches high; the dado 3 feet $2\frac{1}{4}$ inches square. The shaft was a pyramidal stone 10 feet 6 inches high, terminating in an acorn-shaped ornamental top. On the dado were inscriptions as follows: North side: "Direction of the line," with carved arrow above, "United States of America" on a raised shield, a laurel wreath below. On south side similar decorations, with inscription in Spanish, "Direcion de la Linea," "Republica Mexicana." On east side: "North latitude 32° 31′ 59.58,″ longitude $7^h\ 48^m\ 21.1^s$ west of Greenwich, as determined by Maj. Wm. H. Emory on the part of the United States and José Salazar Ylarregui on the part of Mexico." On the west side:

> Initial point of boundary between the United States and Mexico, established by the Joint Commission 10th October, A. D. 1849, agreeably to the treaty dated at the City of Guadalupe Hidalgo February 2, A. D. 1848. John B. Weller, U. S. Commissioner. Andrew B. Gray, U. S. Surveyor.

> Punto inicial de limite entre Mexico y los Estados Unidos, fijado por la Comision Unida 10 de Octubre, A. D. 1849, segun el Tratado concluida en la Ciudad de Guadalupe Hidalgo el 2 de Febrero, A. D. 1848. Pedro Garcia Conde, Comisionado Mexicana. Jose Salazar Ylarregui, Agrimensor Mexicana.

This monument had been so badly mutilated by visitors that some of the inscriptions had become illegible and the proportions of the stones seriously changed. Should the work of destruction have continued, the entire monument would eventually have disappeared.

The other 5 monuments of this section were of cast iron and composed of thin plates riveted together. They consisted of a base, an inverted shallow box of iron, 3 feet square, a shaft 2 feet square at base, 1 foot at top, 6 feet high, and terminating in a pyramid. The inscriptions found on the perfect monuments of this series were as follows: North side, "Direction of the Line," "United States of America," also an arrow and shield. South side, arrow and shield, "Direcion de la Linea," "Republica Mexicana." East face, "Boundary between the United States and Mexico agreeably to the treaty of Guadalupe Hidalgo of Feb. 2, A. D. 1848." West face, "Limite entre Mexico y los Estados Unidos conforme el tratado de Guadalupe Hidalgo del 2 de Febrero A. D. 1848."

These monuments were located, respectively, as follows:

No. II, about 5 miles east of the marble monument, in the valley of the Tijuana River, where the Mexican town of that name has since been built.

No. III, nearly 8 miles farther east, on Otay mesa, at the foot of the Coast Range.

A long interval, including the whole mountain region, occurs before reaching No. IV on the west side of New River, in the middle of the Colorado Desert, distant from No. III about 82.2 miles.

No. V on the east side of New River, 1.7 miles beyond No. IV.

No. VI on the mesa south of Pilot Knob Mountain, near the Colorado, 43.5 miles east of No. V.

Of the 5 iron monuments 3 had been destroyed, Nos. IV and V remaining in good condition, with the exception of their foundations, which were insecure. The latter apparently had been constructed of poles laid on the surface of the ground, and the monument fastened down by means of 4 iron rods passing through the base and anchored to pieces of wood embedded in the sand below. Had the sand been confined the method would have answered well. The sand had, however, drifted from beneath the bed of poles, and the monuments gradually settled, the ends of the bolts protruding several inches above the base.

The iron bases, somewhat broken, of the 3 destroyed monuments were found in their proper places. These were resting on masonry foundations, but the superstructures had entirely disappeared.

Of the 19 monuments shown on the maps of the second section, but 11 were found by our surveying parties; the other 8, if put up, had totally disappeared. All the monuments on this section, except No. II, located on the mesa east of the Colorado River Valley, were rude heaps of stone fragments, thrown together without mortar, and unprovided with inscription plates of any kind.

Monument No. I, of this section, was shown on the map to have been located near the river bank 20 miles south of the junction of the Gila and Colorado rivers, but no trace of it could be found.

No. II is an iron monument which formerly marked an important reference point near the junction of the Gila and Colorado rivers, but had been moved to the new line established to comply with the terms of the Gadsden treaty. This monument stands on the edge of the mesa overlooking the Colorado Valley, and 2.7 miles east of that river. It is pyramidal in shape, 8 feet high, 2 feet 6 inches square at bottom, 1 foot 3 inches square at top, with a base 4 feet square, and, like those on the southern California boundary, is composed of thin cast-iron plates riveted together. Its foundation, like the others, was found defective, and is now replaced by masonry.

Following the line eastward, Nos. III, IV, and V could not be found. It is possible they were never erected, as no trace of them exists, and it is hardly presumable that in this part of the desert, where a human being seldom passes, man's agency could have removed them.

No. VI, a rude pile of stones, was found 101.2 miles east of No. II.

Nos. VII and VIII, both originally located near the important Quito-ba-quita Springs, were also missing. These had undoubtedly been destroyed by unknown persons and for unknown reasons.

Old Monument No. II, California. Antiguo Monumento No. II, California.

Old Monument No. XII, on Sierra de la Nariz.

Antiguo Monumento No. XII, en Sierra de la Nariz.

OLD MONUMENT XVI, VIEW TO THE EAST. ANTIGUO MONUMENTO XVI, VISTA AL ESTE.

Nos. IX and X were found—IX, 19.5 miles east of No. VI, and near the present settlement of Sonoyta; No. X, 14.6 miles east of IX, on the western spur of the Nariz Mountains. No. XI was missing.

No. XII, on the eastern spur of the Nariz, was identified, and is 4.5 miles east of No. X.

No. XIII, 28.9 miles east of No. XII, located near the intersection of the road and boundary, and also near a precipitous rock, was so obscured by mesquite bushes that it was found with much difficulty.

No. XIV was situated in the Moreno Mountains, a considerable group of hills, 12.3 miles farther east.

No. XV, 17.1 miles eastward, where the line crosses the crest of the Pozo Verde Mountains, the southern extremity of the Baboquivari Range. This monument affords a conspicuous mark from both directions.

No. XVI, 9.2 miles beyond, occupies a position on a hill in the rolling country near the western slope of the Fresnal Mountain.

No. XVII, 2.6 miles from No. XVI, occupies the summit of the Fresnal and overlooks the adjoining country far to the east and west.

Eighteen miles beyond, on one of the most rugged of the Pajarito Mountains, No. XVIII was located, the last authentic monument found on this section of the boundary.

A small pile of rocks seemed to indicate the location of No. XIX on a high ridge near the angle at the Eastern end of this section, but was not accepted as a monument.

The remaining section of the boundary was marked, as shown by the official map on file at Washington, with 27 monuments, while upon the Mexican official map there are 28. The discrepancy occurs on that part of the line along parallel 31° 47′. The joint report of 1856 states that this line was marked by 10 monuments; the American copy of the map shows but 8, and the Mexican copy 9. Considerable confusion and uncertainty was occasioned by these differences. These monuments were numbered on the maps from the Rio Grande westward, the last number, 27, upon the American map, being at the intersection of parallel 31° 20′ with the azimuth line, at the one hundred and eleventh meridian as shown on that map.

The initial monument of this line stands on the west bank ot the Rio Grande, and at the date of our survey, 1892, was 172.6 meters from the center of the stream. When the location was made this distance was 71.04 meters, the channel of the river having moved 101.56 meters eastward since the location of the monument in 1855. The monument was built of cut stone, 12 feet high, 5 feet square at base, 2 feet 6 inches square at top, and was found in fair condition. The lower courses were somewhat disintegrated by the action of water, due to floods in the river or the wash from heavy rains pouring down the adjacent hillside. The following inscriptions were upon this monument:

On the north:	*On the south:*
U. S. Boundary according to the treaty of December 30 1853.	R. M. Limite conforme Al tratado 30 de Deciembre de 1853.
East side:	*West side:*
William Helmsley Emory American Commissioner.	Jose Salazar Ilarregui Comissionado Mexicana.

Nos. 2 and 3 were found in good condition. No. 2 was 711$\frac{3}{8}$ meters west of No. 1, and located on the highest point where the line crosses the Mulero Mountains. No. 3 was 3.2 miles from the river at the edge of the wide mesa, which extends westward beyond the range of vision. These two monuments were pyramidal in shape, 5 feet square at base, and built of rubble masonry, plastered on the surface with lime mortar, which had scaled off considerably. They were without inscriptions, but their height, 12 feet, and white color made them very conspicuous as boundary marks.

The next monument on this line was found 37.27 miles west of the river. It was much broken down, but from its shape and the several inscription stones found among the ruins it was undoubtedly erected as one of the marks of the boundary. It does not appear on the Emory map, but its approximate position is shown on the Mexican map, and accounts for the discrepancy in the number of monuments upon the two maps.

The next monument was about 50 miles from the river. (This, like the preceding, does not appear on the Emory map, but one, no trace of which was discovered, is shown about 4¼ miles to the east, on the summit of "Monument Mountain." The line falls to the south of this mountain, which, on account of its shape, we have called The Camel.) The monument was in bad condition, only about two-thirds of the original structure being in place. Plates of cut limestone, about 12 by 16 inches, contained the following inscriptions: On north side, the letters "U. S.;" on south side, "R. M.;" on east, "W. H. E." "A. C.;" on west, "J. S. I." "C. M.," all well cut and perfect. It was built of irregular and small fragments of stone laid partly in mud and partly in lime mortar. In dimensions it measured 5 feet 6 inches square at base, with a batter of about one in ten. Its height was originally 12 feet. From this point the wide valley westward, in which lie the Palomas lakes, is overlooked.

Thirteen and one-third miles farther west, and north of Lake Palomas, was found No. 5 of Emory's map. It was of the same general character as the former, including inscriptions, but in a more dilapidated condition.

The next monument—No. 6 of Emory's map—was found 8.2 miles west of No. 5, on the summit of the foothills south of the Tres Hermanas Mountains. It was of the same general character as the others and nearly demolished.

Thirteen and four-tenths miles farther west, and 2 miles south of the fine Carrizalillo Spring, Monument No. 7 of Emory's map was found. This was in a demolished condition, though the base was well defined and the usual inscriptions, with one exception, were present. It was located on low ground, but near an old road, now little used, running south from the spring.

East of this monument a distance of seven-tenths of a mile, and situated on a high ridge of the Carrizalillo Hills, was a square monument having vertical sides. This monument, being exactly on a line joining Nos. 6 and 7, was believed to be a boundary mark, and the one necessary to complete the full number of ten reported by the joint commission of 1856. It had not the ordinary characteristics of the other monuments and was without inscriptions.

No. 8 of Emory's map, or No. 9 of the Mexican map, and the tenth as actually found upon the line, marks the important point which terminates the boundary along parallel 31° 47′ and the beginning of the meridian section. It stands diagonally with reference to both lines, and is a fine cut-stone monument, in better preservation than the initial monument at the river. It was provided with the same inscriptions and was substantially of the same dimensions. With the exception of its base and one stone of the lower course it required no repairs.

Near the middle point of the meridian section, or about 15 miles south of the "corner," was found No. 9 of Emory's map. This had been originally well constructed of rough stone laid in mud mortar, but was found in bad condition, the mud plaster having scaled off and many of the stones loosened. It had inscription plates of stone containing the initials "U. S.," "R. M.," "W. H. E.," and "J. S. I."

At the south extremity of the meridian line and the beginning of the boundary on parallel 31° 20′ was an excellent cut-stone monument in nearly perfect condition. Its dimensions were the same as those of the monument at the upper corner, as were also the inscriptions.

The section of the boundary along parallel 31° 20′ was originally marked, according to the Emory maps, with 17 stone monuments, numbered from 11 to 27, inclusive. Piles of stones, some bearing monument characteristics, were found at fifteen points approximating to those given on the maps. Those corresponding to the positions of Nos. 11 and 24 were not found.

No. 12 was a rude pile of loose stones, 28.6 miles west of the corner monument, on the eastern foothills of the San Luis range.

No. 13, 3.8 miles farther west, marked the highest point where the line crosses this range, and the highest on the entire boundary.

No. 14, 3.4 miles beyond No. 13 and just west of the San Luis Mountains, was located near the important San Luis Springs.

OLD MONUMENT.
At south end of Meridian Section.

ANTIGUO MONUMENTO.
En el extremo sur de la Sección Meridiana.

Old Monument between New Mexico and Arizona.

Antiguo Monumento entre Nuevo México y Arizona.

No. 15, only 3 miles west of the latter, had been placed on a long, low ridge, which has every appearance of being an ancient artificial dam.

The next monument, No. 16, 13.3 miles beyond No. 15, was in the Guadalupe Canyon where the wagon road crosses the boundary.

No. 17 was on the flat west of and near the San Bernardino River. It had no characteristics of a boundary monument except its position.

Only 189 meters beyond, on the brow of the mesa, was No. 18. Though more distinctive than No. 17, it was badly dilapidated. Three of the old inscription plates, in a broken condition, were present.

The next monument, No. 19, 9.8 miles farther west, was found in a range of hills which extends west from the Perilla Mountains, and near a prominent feature of the landscape known as the "Niggerhead," a steep, rocky mountain, almost inaccessible.

Between this monument and the next one, No. 20, a distance of 42.8 miles intervenes. This stands near the west bank of the San Pedro River, and is the monument erected under Major Emory's direction. Near this river, and occupying a bold promontory on its eastern side, was found another monument. Its position was 25″ of arc, or about one-half mile south of the boundary. This monument was built by Señor Salazar, the Mexican commissioner, after failing to find the one previously erected by Major Emory, and which the present survey shows to have been placed about 3″ north of the true latitude. It was agreed between Major Emory and Señor Salazar, as expressed in their report, that in case both these monuments were found to exist, the one erected by the American commissioner would be adopted. The San Pedro River usually carries an insignificant amount of water, but during the rainy season is sometimes so swollen as to render it impassable.

Nearly 18 miles farther west, just beyond the Huachuca Mountains, a scattered pile of stones was found, which corresponded sufficiently well with the position of No. 21 to be accepted as the site of that monument. It was upon a broad, open mesa, which extends several miles along the boundary, and is intersected at frequent intervals by deep ravines.

Two and eight-tenths miles beyond No. 21, on the west side of a ravine through which flows during the rainy season one of the sources of the Santa Cruz River, was a pile of stones, which was decided to be monument No. 22. It had few characteristics to indicate its mission besides location, which was considered authentic.

No 23, 5½ miles farther west, was found on a ridge overlooking the main valley of the Santa Cruz on the east, and a fine, grassy region on the west, in which is located the small settlement of La Noria.

To the westward rise the sharp, rugged Patagonia Mountains, on the summit of which, some 5 miles distant, No. 24 is shown on Emory's map. No trace of this monument, however, could be found, the next one being No. 25, on the east side of the Santa Cruz River, where the boundary crosses this stream the second time after the latter has made its detour around the southern extremity of the Patagonia Mountains and taken a northerly course toward the Gila Valley. This monument was quite a large pile of stones, having regular form, but without inscriptions. It was distant from No. 23 14.7 miles.

Five and six-tenths miles farther on, in the broken country beyond the Santa Cruz, No. 26 was found. It was originally placed near the highway leading south into Mexico, which here runs through a beautiful, though narrow, valley containing good water near the surface.

In later years a railroad has been built through this valley from Benson to the Gulf of California, and the thriving town of Nogales has grown up here, spreading out on each side of the boundary. The old monument occupies about the middle point of the settlement. When found it was but a rude pile of stones, though its base seemed to have been carefully laid with square corners, and some attempts made toward shaping the structure in the form of a pyramid. Badly defaced inscription plates were present. A building on the American side covered one-half of this monument, the sidewalk and street being on Mexican soil.

In reference to this subject the commissioners made a special report to the Department, and as the matter is considered important a copy of that communication is inserted:

DEPARTMENT OF STATE,
INTERNATIONAL BOUNDARY COMMISSION,
UNITED STATES AND MEXICO,
Nogales, Ariz., November 29, 1892.

SIR: The American members of the International Boundary Commission beg respectfully to present for the consideration of the Department of State the following recommendation with regard to the boundary between the United States and Mexico west of the Rio Grande:

That a reservation not less than 50 feet be declared by the United States to extend along the entire length of the boundary on the American side, and that the Republic of Mexico be asked to declare a like reservation on the Mexican side, and that the erection of buildings on either side of the line, within these limits, be prohibited by law; provided, however, that such reservations may be used for public streets or highways.

The commissioners are deeply impressed with the importance of this measure, for the reason that the construction of private buildings near or upon the boundary affords most favorable conditions for carrying on smuggling operations, to the detriment of both countries.

At Nogales, on the American side, buildings have already been erected, and are occupied for business purposes, the south walls of which are on the line of the boundary, the old monument near the center of the town being half covered by one of these buildings. The Mexicans, with more generosity and modesty, have reserved a space about 50 feet wide south of the line, and which is now one of the principal streets of the town, business being carried on along this street by both countries.

At Columbus, a new town recently established about 60 miles west of the Rio Grande, no buildings have yet been built near the boundary, owing, it is said, to previous uncertainty as to its exact location; but now that the line is plainly marked, negotiations are on foot by interested parties to obtain ground on both sides and abutting on the boundary, for the purpose of erecting buildings that shall be located partly in each country. It is quite evident for what purpose buildings so erected are to be used.

It is proper to state further that at Nogales general public sentiment favors a measure of this character; and as the title to the ground on which the town is located is soon to be adjudicated by the courts, with a strong probability of a decision in favor of the Government's ownership, it would appear that private interests will not suffer; but should this be the case to any extent, it is believed that such interests can be reconciled by the people themselves, as the buildings located on the boundary are few and of an inexpensive character.

At Columbus the present proprietor of the lands on the boundary upon the American side is desirous of having a suitable reservation along the line devoted to a drive and park, and will offer no objection to a measure of the above character, provided the same width of land is set aside by the Mexican Government.

These two are the sole points where towns have been established.

The commissioners do not, of course, presume to suggest the method of arriving at the result desired, but simply as a matter of duty, and believing it to be a question of grave public interest, they desire to present it for the consideration of the proper department of the Government.

With the highest respect, your obedient servant,

J. W. BARLOW,
Lieutenant-Colonel of Engineers, U. S. A., Commissioner.

Hon. JOHN W. FOSTER,
Secretary of State, Washington, D. C.

Nearly 8 miles west of No. 26 was found the last of the monuments on this parallel. It was hidden away in one of the deep valleys of the Pajaritos Mountains, and was almost concealed by a dense growth of bushes. This monument, No. 27, had inscription plates and was built with more care than many of the others on this part of the line, as it marked the point where the boundary changes its direction at the one hundredth and eleventh meridian, as then determined, leaving the parallel and taking an oblique course toward a specified point on the Colorado River.

It appears from the foregoing description of the condition of the old monuments at the time of the present survey that the boundary, originally marked with an inadequate number of monuments, many of them unsubstantial and without distinctive features, had become almost obliterated. In one section the distance between authentic marks was over 100 miles, on another over 80, while intervals as great as 10, 15, and 20 miles were very frequent, giving rise to many disputes between miners, farmers, and herders, and permitting every facility and encouragement for smuggling.

Through the more settled regions, notably along the southern California line, an approximate boundary had been adopted and rights acquired which in some instances were found to be erroneous, entailing loss and dissatisfaction to citizens on both sides when the proper boundary became known. These cases, happily, were neither numerous nor very serious.

Old Monument No. 26, Nogales.

Antiguo Monumento No. 26, Nogales.

CHAPTER VII.

CONSTRUCTION AND ERECTION OF NEW MONUMENTS.

The convention of 1882 between the United States and Mexico, revived by the convention of 1889, contained provisions with respect to the erection of new monuments. A full copy of these conventions will be found in the joint report of this commission.

It was provided therein that the old monuments heretofore placed along the boundary should be restored in their original places; that new monuments should be set up at such points as might be necessary, and that the distance between two consecutive monuments should never exceed 8,000 meters; this distance to be reduced on those parts of the line which are inhabited or capable of habitation. It was also provided that the monuments might be of stone in some localities, and in others should be of iron, the latter to be 6 feet high, with suitable inscriptions; also that the engineers in chief should determine the scientific processes to be adopted in prosecuting the work.

In compliance with these provisions the two engineers in chief prepared a plan of operations for conducting the survey, and an agreement respecting the design, location, and erection of the necessary monuments to be placed upon old sites and upon new points to be selected. This plan of operations and the agreement are given in full in the joint report.

Provision was therein made for determining the authenticity of all the old monuments found and the method of connecting them by a line of new monuments placed at proper intervals.

The monuments which have been rebuilt on the old sites are generally of stone, exceptions being two old iron monuments on the California line and one, also of iron, east of the Colorado River. These being in good condition, were repaired and retained. Another exception is the new iron monument placed on the site of an old monument at Nogales.

The stone monuments were built in the form of an obelisk and are of the following dimensions: A shaft 10 feet high, 4 feet square at base and 2 feet at top, surmounted by a pyramid 1 foot high, a low foundation rising about 6 inches above the surface of the ground and 5 feet square. These monuments were built of such stone as could be found in the vicinity, the remains of the old monuments being generally used. Whenever stone of suitable quality could be obtained the fragments were roughly squared and made to conform to the batter of the structure, and when neatly pointed the monument presented a very good appearance. Where only rough, refractory bowlders could be had, the surface of the monument was covered with a stucco of Portland cement plaster. The mortar used in the body of the work was composed of lime, cement, and sand. In all cases the iron inscription plates described in the agreement were put on in addition to the old plates found at the site of the monument. The iron plates were painted white and the whole monument given a coat of whitewash.

The iron monuments are also obelisks, 6 feet 6 inches high, 12 inches square at base, and 9 inches at top. They are of two kinds: Those cast solid, for use on parts of the line which could be reached with wagons, and those cast in sections for convenience of pack transportation to less accessible positions. The weight in each case was 800 pounds, and the thickness of metal 2 centimeters. Inscriptions in English and Spanish, as agreed upon, were placed on the north and south sides, respectively, of the monuments, and sockets for a flag staff on the west side of each. Consecutive numbers were also added on the east side after the erection of the monuments. The monuments were each bolted securely to the natural rock or to artificial bases of concrete 3 feet square and 2 feet thick.

Two kinds of sectional monuments were used; the first, composed of a base, a cap, and 4 side pieces, answered very well, but as the side plates were rather long for pack-mule transportation, the design was changed for one composed of 7 pieces—a base plate and cap, such as in the other design, with 5 sections of shaft, the joints horizontal and rabbeted, each section 14 inches high, and made to fit over its neighbor below. The sections were held together by a wrought-iron bar 1 inch in diameter, connecting the base and top section. Above this was placed the pyramidal top, riveted to the section below, and concealing the bolt and nut.

This design was found to be much more convenient in every way than the other; the parts, being lighter and more compact, were easily handled and transported and were also assembled more readily, while the joints were so nicely fitted that the appearance of the monument when erected was practically the same as that of those which were cast solid.

The castings, including inscription plates and the necessary bolts, washers, numbers, etc., were all neatly prepared at El Paso, Tex., by the Foundry and Machine Company of that place, W. N. Small, president, and were in every way satisfactory. The iron was tough, resisting the rough handling incident to transportation by rail, wagon, and pack train without accidents, while the surfaces and the lettering, some of it very small, were as perfect as any work of a similar character turned out in more eastern establishments.

The cost of iron monuments, including inscription plates, numbers, bolts, washers, etc., ready for shipment, was about $40 each. Their transportation and erection, including cost of concrete bases, added from $100 to $110 to each monument, making the total cost in place about $150 each. The average cost of stone monuments was about the same.

The new monuments were located under the personal supervision of the engineers in chief. They were not placed at arbitrary intervals, but always upon the highest ridges, and at such distances apart that they are practically intervisible. To secure this result more perfectly each monument is provided with sockets, in which a high flagstaff can be inserted to show above small intervening obstacles.

1. Parallel 31° 47′ and the meridian section.

[130 miles, 53 monuments.]

The section of the boundary from the Rio Grande along the parallel of 31° 47′ and on the meridian to the parallel of 31° 20′ having been surveyed by the American and Mexican engineers, the results compared and accepted August 19, 1892, the work of preparation for the erection of monuments was immediately begun at El Paso.

The transportation for the monument-building party was detached from the main camp at San Bernardino, Ariz., August 6, 1892, and sent under charge of T. H. Logan, quartermaster, to El Paso, Tex., a distance by wagon road of about 240 miles. It followed the road via the Guadalupe Cañon, thence to Separ, on the Southern Pacific Railway, along which it continued to its destination, where it arrived on the 11th of the same month.

The train consisted of four baggage wagons, one water-tank wagon (capacity 400 gallons), and a light spring wagon for instruments; an additional spring wagon, with horses, was purchased at El Paso.

The organization of the American party consisted of one commissioner, one assistant engineer, one rodman and helper, which, with a similar Mexican party, was charged with the location of monuments. Each party had also a photographer to take views of monuments. The building party, wholly American, included a mason, a blacksmith, and several laborers, teamsters, cooks, etc., to perform the work of erecting monuments.

Monument No. 1, which is the old initial monument on parallel 31° 47′, stands on the west bank of the Rio Grande, 172.6 meters from the center of the channel. A description of this and all other old monuments has been given in the preceding chapter of this report.

The repairs upon this monument comprised the addition of a jacket of cement mortar, 4 feet high above the base, to protect the stones from further disintegration; repointing the joints with cement, and adding four small plates of marble, with inscriptions as follows:

On north side:	*On south side:*
Repaired by the	Renovado por la
Boundary Commission	Comision de Limites
Created by treaties of	Creada por los tratados de
1882–1889.	1882–1889.

On east and west sides the penalty notice, in English and Spanish, respectively. On the east side was also cut in one of the old stones of the shaft the number "1." These repairs were completed August 29, 1892.

Nos. 2 and 3 are also old monuments. They were originally covered with a lime coating, which had scaled off in places, and had also been much disfigured by visitors. These two monuments were repaired by removing as much as possible of the old plaster, recoating them with durable cement mortar, and placing on the north and south sides, respectively, the iron inscription plates in English and Spanish prescribed by Section III of the additional agreement dated March 9, 1892, subsequently modified by the addition of the penalty notice above referred to.

Similar cast-iron plates were placed on all masonry monuments, except No. 1, rebuilt or repaired by the present commission. Consecutive numbers were also placed on the east side of each monument, both old and new, from the Rio Grande to the Pacific Ocean, except along the meridian section, where these numbers were placed on the north side and the inscription plates on the east and west sides, respectively, and sockets for flagstaff on south side.

It having been agreed by the joint commission that the positions of old monuments after verification would be accepted and that new monuments should be placed on the proper connecting lines, the tangent parties of each section located their respective tangents, marking them at frequent intervals with substantial stakes. It remained, therefore, for the monument party to calculate and measure the necessary offsets from these tangents to the points selected for monuments and to compare the results. For formulæ and details of computation see Geodesy, Chapter IV, and its appendices.

When the two points so determined for each monument by the American and Mexican engineers differed in position more than 2 meters, remeasurements or recalculations were made until the error was discovered and the discrepancy reduced. The largest discrepancy which was allowed to remain on the parallel of 31° 47′ was 1.39 meters at Monument No. 10, the Mexican determination falling south of that of the United States. The average difference between the United States and Mexican locations for the new monuments on this line was 0.43 meter. On the meridian, the United States line, being considered perfect, was adopted by the Mexicans. In all cases the monument was placed midway of the two determinations.

On September 7, 1892, No. 4, the first new iron monument, was erected on the mesa 7,582 meters west of No. 3. The surrounding country is characteristic desert, being a succession of low sand hills carrying a scant growth of cactus, yucca, and greasewood, with an occasional mesquite bush.

The manner of setting the iron monuments in place when concrete bases were required was as follows, and was substantially the same along the whole line.

After the exact location had been determined by the engineers of the joint commission, and the necessary stakes driven to mark its position, the soil was excavated to a depth of 2 feet and the base box put in place. This consisted of four sides, inclosing a space 3 feet square and 2 feet deep. The box was carefully adjusted in position and accurately leveled. An iron template, containing four 1-inch holes, corresponding exactly with those in the base of the monument, was fastened by means of small bolts and nuts to the top of the box. The anchoring bolts were now placed in the box, their upper ends passing through the holes in the template. The box was then filled with concrete in layers thoroughly rammed. This mixture was formed of one cask (400 pounds) of Portland cement, a double quantity of the best sand obtainable, and a sufficient quanitity of gravel or broken stone to make up the required 18 cubic feet of material. About 30 gallons of water was necessary to give the requisite moisture. Allowing several hours for the concrete to harden, the template and box were removed and the monument put upon its base. The bolts passed easily through the four holes in the flange of the monument; the nuts, which were cylindrical, were screwed down with a pipe wrench, and the ends of the bolts riveted above them. A coat of paint had been given the monument before leaving the shop, and immediately after its erection and the attachment of the appropriate numbers another coat of white paint was added.

In moving out from El Paso the monument party encountered great difficulties, owing to the heavy loads to be carried over the soft, yielding sands of the desert. For 50 miles west of the river no water was found near the line, and a supply had to be sent out in advance, together with several monuments and casks of cement. This labor tasked the limited transportation appropriated to the monument work to its utmost capacity, the strain upon the animals being excessive.

It was not until the 14th of the month that the party was able to cut loose from the river and push out into the desert. It was then found that the provision for supplying water was inadequate, and an additional water tank was fortunately obtained by hire until another could be constructed at El Paso. With the aid of the second water wagon the work was pushed on without detention. The next water near the line, after leaving El Paso, is at Wragg's ranch, 50 miles distant, the vicinity of which was reached on the 27th instant, thirteen days after leaving the river at El Paso.

Monument No. 5, new iron, was erected on the 14th of September, 7,547 meters west of No. 4. The difference between the United States and Mexican offsets here was 1.36 meters, the United States determination falling south of the Mexican. The surrounding country at this monument is much the same as at No. 4, being a continuation of the desert mesa, with its characteristic vegetation.

Through this worthless region, where boundary disputes are not likely to occur, the distances between the monuments were made as nearly as possible to reach the limit of 8,000 meters provided by the convention, but in no case was this limit exceeded.

The sites of Nos. 6 and 7 were in all respects similar to those for 4 and 5, except that grama grass began to appear in sufficient quantities to afford some grazing for the animals when they could be spared from their work to take advantage of it.

No. 8 occupies a high, rocky, and sandy ridge, a spur from the Potrillo Mountains, which lie immediately north of this point, and No. 9, about 1,400 meters distant, was placed upon the crest of another high ridge beyond a deep ravine. It being desired to place the monuments so that they would be practically intervisible, it was necessary in this case to locate one on each of the two adjacent ridges.

On September 20 the monument party camped near an old monument (No. 1 of the Mexican map) and immediately established communication with Wragg's well, about 15 miles distant. The water question had become very serious. The two tanks now in use, and all available barrels, were kept moving between the line and the railroad, requiring journeys of from 10 to 20 miles over very difficult and sandy roads to keep the camp and its animals supplied with sufficient water. On some days the failure of a wagon to arrive on time would have resulted in a water famine that would have been disastrous.

The weather was extremely hot, and when short rations had to be enforced both men and mules seemed to require a double allowance. It was necessary to retain the camp at this place until the 24th to complete the unfinished work on iron Monuments Nos. 9 and 10, and to construct stone Monument No. 11, the latter to occupy the site of the old monument at this point.

No. 10 fell among sand hills and mesquite bushes near a wide ravine 7,027 meters west of No. 9, and 7,811 meters east of No. 11. The chief characteristic attending its erection was the heavy hauling through the sand hills.

After the return of the first water wagon sent to Wragg's well, which occurred on the evening of the 22d, and proved the practicability of obtaining water from that source, it was felt that the critical period had passed, and that work could go on without special anxiety on account of water.

The work of surveying this part of the line, performed during the preceding spring, was attended with much inconvenience on account of the scarcity of water; but with the monument party the conditions were even more trying, as the work was of a nature that required a large number of men and animals to be kept together to handle and transport the monuments, cement, etc., in addition to the usual supplies.

On the 24th, the work as far as No. 11 (stone monument) having been completed, a small force was left to finish the construction of this monument, and the camp moved 6 miles farther west and nearer the new water supply.

No. 12 was located on the mesa 3.2 miles west of No. 11, and No. 13, 4.3 miles beyond on the southern slope of a ridge near a high mountain called, from its shape, The Camel.

Camp was moved on the 27th west of this mountain and near the location of No. 14, which marks the crossing of the line over a high, sharp ridge about 3 miles west of No. 13. From this point, looking eastward just before sunset, the line as marked by seven or eight monuments is plainly visible, showing the curvature of the parallel for a distance of over 20 miles.

No. 15, 2 miles west of No. 14, was rebuilt of stone on the site of the old monument, and was finished on the 30th. From this monument a view to the west extends across a broad valley in which are located the shallow alkaline lakes known as Las Palomas, and near which the Mexican settlement of that name is situated.

Just north of these lakes, and adjoining the boundary, has been laid out on the American side the town of Columbus. Should the expectations of its founders in obtaining a railroad from the Southern Pacific line at Deming, the grading for which has been done, ever be realized no doubt a village of some importance may be built here, as the soil is fertile and, except in dry seasons, the grass is abundant. Beyond cattle raising, an industry badly crippled by the late droughts, no business is being carried on in this region.

Monument erection now continued rapidly across this plain. Iron Monument No. 16 was placed on a low ridge 1,660 meters west of No. 15, and Nos. 17, 18, 19, and 20 followed at intervals of about 4,000 meters each.

No. 21, occupying the site of old No. 5, was rebuilt of stone, its location being about 2 miles beyond No. 20. Nos. 22 and 23 were placed 1 mile apart, and where the section lines east and west of the town of Columbus, respectively, intersect the boundary. No. 24, 4,445 meters west of 23, was located on a rugged mal pais ridge, and No. 25, 3,826 meters beyond, was placed on the slope leading to the hills south of the Tres Hermanas Mountains.

On the summit of these hills, and 1,331 meters beyond No. 25, old No. 6 of Emory's map was rebuilt of stone in the usual manner and numbered 26. From this point another fine view is obtained, looking westward across the valley intervening between these hills and the Carrizalillo Mountains, a distance of about 11 miles.

Along the line crossing this plain were placed iron Monuments Nos. 27, 28, 29, and 30, at intervals of about 3,600 meters. This region is characterized by a soft, sandy soil yielding the ordinary desert vegetation, including greasewood and several varieties of cacti.

No. 31, upon the first ridge of the Carrizalillo Mountains, 3,436 meters west of No. 30, occupies a commanding position overlooking the valley to the eastward. The transportation of the monument to this elevated location was attended with considerable difficulty.

No. 32, 2,442 meters farther west, is a stone monument built on the site of what was considered one of the original monuments, and the eighth in order from the Rio Grande. It is situated on the highest point where the line crosses these mountains, and affords a magnificent view of mountain scenery in all directions.

In the valley, less than a mile west of this monument, is No. 33—also a stone monument—built on the site of old No. 7 of the Emory map. It was originally located near the wagon road, leading south from the Carrizalillo Springs, at one time much traveled, though during later years it has been but little used.

The erection of monuments was completed to this point October 17, 1892.

A plain about 10 miles in width and abounding in a heavy growth of mesquite extends westward to the Apache Mountains. Along this part of the line were erected iron Monuments Nos. 34, 35, 36, and 37, about 2½ miles apart.

On the most eastern ridge of the Sierra Rica Mountains No. 38 was located, 2,597 meters west of No. 37. This ridge slopes to the northward, and its steep, rocky scarp rendered the work of hauling the monument to its position very trying upon the animals and men.

No. 39 was placed on another sharp ridge sloping southward and 2,784 meters further west.

No. 40, marking the extremity of the boundary along parallel 31° 47′, and 2,060 meters from No. 39, is the old cut-stone Monument No. 8 of the Emory map. The present measurements and astronomical determinations show that this monument was originally located 54.38″ of longitude too far east, thereby causing this section of the boundary to be 1 mile less in length than was provided by the treaty.

This monument and Nos. 38 and 39 mark a part of the line which passes through what was once considered an important silver-mining region; many prospect holes on both sides of the boundary are still evidences of the work done here by miners, and some of the claims are yet considered valuable. No work, however, is now being carried on, and the general opinion is that the low grade of the ore precludes profitable working under the disadvantageous conditions that now exist.

From No. 40 the boundary runs due south about 31 miles, connecting the parallel of 31° 47′ with the parallel of 31° 20′. On this meridian section 11 iron monuments were placed at intervals of about 2½ miles. Old Monument No. 9, midway of the meridian, was afterwards rebuilt of masonry and numbered 46.

No. 41 was placed on the highest point where the meridian crosses the Sierra Rica, about 2 miles south of No. 40. It occupies a bold, rocky ridge, from which grand views to the north, south, and west are obtained. Northwest are the Hachita Mountains; west and southwest the vast range of the Sierra Hacha, including the "Big Hatchet," the most prominent mountain in this vicinity, while to the south the meridian line of the boundary is unobstructed almost to its southern extremity.

From No. 41 the line of monuments descends gradually about 12 miles, passing a mile west of the Mosquito Springs, a very valuable and important water source much used by travelers as a camping place; it also supplies large herds of cattle and horses with drinking water.

Iron Monuments Nos. 42, 43, 44, and 45 were placed along this part of the line. From 41 to 52 the intervals are between 2 and 3 miles.

Nos. 47, 48, 49, 50, 51, and 52 continued the line south over a comparatively level country, but much obstructed in places, especially in the vicinity of the Mosquito Springs, by a heavy growth of mesquite.

No. 52, the last of the iron monuments on this section, occupies the only ridge of importance south of No. 41, and was placed at 542 meters from the monument marking the south extremity of the meridian section.

The monument party completed the erection of monuments along the parallel of 31° 47′ on the 24th of October, and as the first iron monument was put up on the 7th of September, this line was marked in about forty working days, during which time 30 iron monuments were placed and 6 stone monuments built, being an average of one and one-third days for each iron monument and about seven days for each stone monument.

During the latter part of October and the beginning of November the weather was extremely unpleasant; rain and snow fell in unprecedented quantities, making the roads in places almost impassable, and seriously retarding the progress of the work. The 11 iron monuments along the meridian were all put up by the 10th of November, the average time per monument on this part of the boundary being about the same as on the parallel.

To add to the annoyance and inconvenience at this time, rumors of the near presence of the Apache "Kid" and his band were rife, and as the whole monument party with its escort was not large the men's anxiety on this account was not unreasonable.

Owing to these several difficulties it was decided to omit the rebuilding of the old monuments on the meridian until work should be resumed on parallel 31° 20′. The work on this parallel could not be taken up at this time owing to the fact that no agreement by the joint commission had then been reached in regard to its details.

Accordingly, on the 12th day of November the monument party, with its transportation, discontinued further work and moved westward along the boundary, joining the main camp two weeks later at La Noria, on the Santa Cruz River. The men and transportation were employed with this party in its operations westward until they were again required to take up monument work the following year.

During the entire progress of the work the photographer accompanied the working party, and made two or more views of each monument after it was erected.

The transportation was increased during the progress of the work by the addition of one baggage wagon and one water-tank wagon, the mules being supplied from the pack train sent from the main survey camp in September.

The boundary on parallel 31° 47′, 99 miles, is marked by 40 monuments, numbered 1 to 40 inclusive—30 solid iron, 6 new masonry on old sites, and 4 old monuments repaired; average distance apart, 2.5 miles; maximum, 7,948.3 meters; minimum, 713.4. The meridian section, 31 miles, is marked, in addition to No. 40 at the corner, by 13 monuments; 11 are solid iron, 1 new masonry, and 1 old masonry repaired; average distance apart, 2.4 miles; maximum, 4,772.91 meters; minimum, 542 meters.

The greatest difference between the United States and Mexican offsets occurred at No 10, the Mexican position falling 1.39 meters south of the American; and at No. 5, where the Mexican point fell 1.36 meters north of the American. On the meridian line the positions were identical, the American determinations having been adopted.

The organization of the monument party upon this work was as follows: Col. J. W. Barlow, commissioner, in general charge; E. L. Ingram, assistant engineer in charge of location; T. H. Logan, in charge of erection of monuments and transportation; D. R. Payne, photographer and general assistant; 1 rodman, 7 teamsters, 4 laborers, 1 blacksmith, 1 stone mason and 1 helper, 1 cook and 2 helpers.

The transportation consisted of 4 baggage wagons (afterwards 5), 1 water tank wagon (afterwards 2), 2 spring wagons, 1 buckboard, and 2 saddle horses; 15 pack mules were added and assigned to teams.

A hand truck and a sectional iron tripod, with differential pulleys, were provided for use in setting the iron monuments in position, but were soon abandoned, it being found more convenient and a saving of time to place them by hand.

The escort consisted of two mounted cavalrymen, for courier duty, and a guard of three noncommissioned officers and nine privates of the Twenty-fourth Infantry under the command of Sergeant Curtis. The escort was provided with one baggage wagon.

2. *Parallel 31° 20′.*

[170 miles, 74 monuments.]

Early in the spring of 1893 the joint commission came to an agreement with respect to the survey of the line along the parallel of 31° 20′. Preparations were then begun to take up the work of building monuments upon that part of the boundary. The boundary upon this parallel connects the southern extremity of the meridian section with the eastern end of the azimuth line at the one hundred and eleventh meridian, as established by Major Emory.

In May, 1893, a monument building party, similar in strength and equipment to that of the previous year, was detached from the main camp at Yuma and sent overland to Nogales, Ariz., where the final preparations for the work were effected, with the intention of working eastward from the one hundred and eleventh meridian to the meridian section.

This party consisted of one commissioner, Col. J. W. Barlow, in general charge, with Mr. B. A. Wood, assistant engineer, in charge of location, T. H. Logan in charge of erection of monuments, D. R. Payne, photographer, 2 rodmen, 1 blacksmith, 1 stone mason, 5 teamsters, 5 laborers, 1 cook, and 2 helpers. The transportation included 2 water-tank wagons, 3 baggage wagons, 2 spring wagons, 1 truck wagon, 5 horses, and 24 mules, which with some minor changes was maintained during the season. An escort of 10 men, Second Cavalry, and 16 men, Twenty-fourth Infantry, Second Lieut. George H. McMaster commanding, accompanied this party.

The truck wagon was specially prepared for hauling a single monument, with cement and water sufficient for its base, over almost any kind of country. The bed was hung beneath the axles near the ground, making the wagon so stable that it was frequently driven along rocky and steep mountain sides in places where mules could hardly find a footing.

From the careful profile and topography which had been made of this line it was possible to select all the positions for the location of monuments with such near approximation that the proper numbers could be placed upon them in advance without error, so that the work could be carried on from the west in the reverse order of the numbers.

Necessary preparations having been completed, the work was begun June 17, 1893. It was first carried westward along the parallel of 31° 20′ as far as the angle at the one hundred and eleventh meridian, a distance of about 8 miles, and then eastward along the parallel to the meridian section of the boundary, where the work terminated the previous year.

The time occupied in the work on the parallel of 31° 20′ was from the 16th of June until the 19th of September, 1893, when the most easterly monument on this parallel was erected.

The three old monuments which originally marked the meridian section, the repair of which had been deferred until the present season owing to inclement weather, were now rebuilt or repaired, and the entire work in this region was finished by the close of September, when the party and transportation were taken overland to Tucson, Ariz., to reorganize for the work of erecting monuments on the azimuth section of the boundary from the one hundred and eleventh meridian westward.

The monument party encountered this season an unprecedented rainy period. During the two preceding years hardly a drop of rain had fallen along this section of the boundary, and in consequence the country had a burned, barren appearance; nearly all the water courses had become dry; grass had disappeared; cattle by thousands had perished. This season the conditions were entirely changed; rain fell copiously and at very frequent intervals. The water courses were flooded, and the country took on a covering of green, in marked contrast to its former desert appearance. The few remaining cattle became fat and sleek, and grass soon grew in such quantities that vast fields were cut with machines, and hay soon became cheap and abundant.

The heavy rains, however, caused the monument party considerable inconvenience and somewhat retarded operations. The streams, which the previous year were dry ditches, now became at times impassable, and the former hard roads soft, bottomless quagmires. The weather was, however, generally cool and agreeable, so that men and animals thrived in spite of the hardship and exposure to which they were subjected.

Old Monument No. 8, at the northern extremity of the meridian section, was taken down and rebuilt in order to restore the injured foundation. The same stones were replaced in their original positions, leaving the external appearance but little changed. Iron inscription plates were added, and also the new number, 40, to conform to the present series.

Old No. 9, midway of the meridian section, was entirely rebuilt of masonry, in accordance with the adopted design for stone monuments. The material of the old monument was used, new inscription plates added, and the monument numbered 46. The monument at the south end of the meridian section was in such good condition that but minor repairs were necessary. It was repointed with cement mortar and inscription plates and the appropriate number, 53, added.

The first 10 monuments west of the lower corner on parallel 31° 20′ are of iron. No. 54, 2½ miles west of No. 53, and No. 55, 4¼ miles still farther west, were located on low ridges in a comparatively level area extending to the Dog Mountains. No. 56, 1¼ miles beyond, was placed on the first ridge of the Dog Mountains.

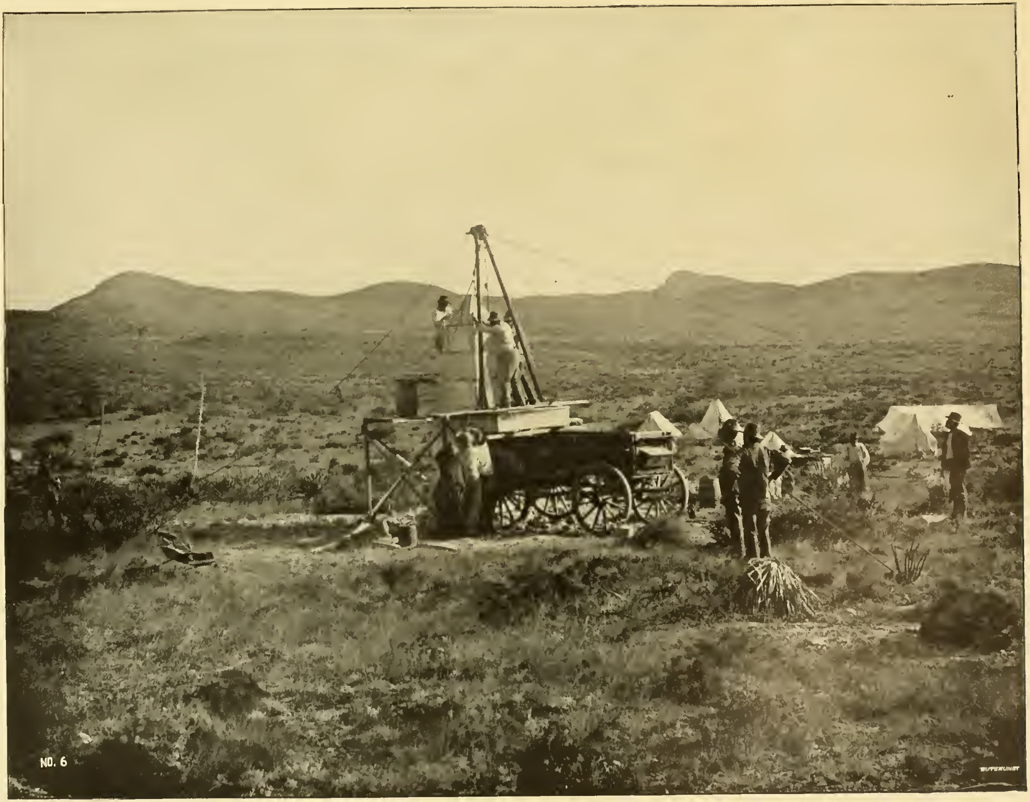
No. 57, a sectional monument, 2¼ miles distant from No. 56, marks the highest point of the line as it crosses these mountains. No. 58, 3½ miles beyond, was located on another prominent ridge, and No. 59, 1¼ miles still farther west, upon a third ridge at about the same elevation as No. 58.

In the Playas Valley, west of the Dog Mountains, and marking its lowest depression, No. 60 was placed, 4 miles distant from No. 59. No. 61, on a high ridge of the Whitewater Hills, 3½ miles west of No. 60, overlooks the Playas Valley to the eastward, and No. 62, 1¼ miles farther west, stands on the south slope of another prominent hill of the Whitewater group, and commands a fine view over the western arm of the Playas Valley. It is supposed that old No. 11 was located in this vicinity, but no trace of it could be found. No. 63 marks a point in the Playas Valley 2 miles west of No. 62.

No. 64, on the eastern slope of San Luis Mountains, 2½ miles beyond No. 63, was built of masonry on the site of old No. 12.

No. 65, a masonry monument, on the site of old No. 13, stands 3¾ miles west of No. 64 upon the summit of the San Luis range, and enjoys the distinction of being located on the highest point of the entire international boundary. This altitude is 2,048.3 meters, or over 6,700 feet, above sea level. From this point a magnificent view extends in all directions. Eastward, over the Whitewater and Dog mountains to the Boca Grande range, 50 miles distant; while westward the whole country as far as the Huachuca Mountains, 100 miles away, is spread out like a map. The mountains in the immediate vicinity are rough and broken and the ascent to the site of the monument steep and difficult.

No. 66, also a masonry monument, was built on the site of old No. 14, just beyond the western foot of this range, and 3½ miles west of No. 65. It stands south of the important San Luis Springs, which are extremely valuable to the ranchers in this region.



REBUILDING MONUMENT No. 40.
North end of Meridian Section.

RECONSTRUCCIÓN DEL MONUMENTO No. 40.
En el extremo norte de la Sección Meridiana.

OLD MONUMENT.
At San Bernardino Ranch, Arizona.

ANTIGUO MONUMENTO.
En el Rancho de San Bernardino, Arizona.

No. 67, still another masonry monument, marks the location of old No. 15. This is 3 miles west of No. 66 and stands about midway of Las Animas Valley on a low ridge, which is supposed to have been constructed as a dam by some prehistoric nation. Its height and great width required an amount of labor on the part of those ancient people which seems out of all proportion to the capacity of the country to support a large population.

The San Luis and Guadalupe ranges and adjacent valleys are favorite resorts for the few marauding Apache outlaws remaining in this country. Apache "Kid," whether justly or not, has been given a special notoriety as a desperate and dangerous bandit who habitually wanders between the San Carlos Reservation and certain strongholds in the Mexican Sierra Madre. Using these mountains as a highway, he has effectually eluded the many search parties that have been sent in pursuit of him. In traveling through the country he preys upon the ranchers, stealing horses and cattle and occasionally committing murder, when he finds it to his interest to do so.

Members of the monument party at different times believed this notorious character to be hovering in their vicinity, and on one or two occasions several Indians were seen whose suspicious actions gave rise to the conclusion that the veritable "Kid," with a few followers, was watching their movements with a view to an ambuscade. He gave us no trouble at any time, although the scattered condition of our parties afforded many excellent opportunities for an attack. It is believed that the "Kid" never incurs any personal risk, committing his depredations only under conditions which insure his own immunity.

Beyond No. 67 five iron monuments were placed in succession: No. 68 in Las Animas Valley, 2 miles beyond No. 67; No. 69, 3 miles further west, the latter near the foothills of the Guadalupe Mountains. Two miles west of No. 69 No. 70 was placed on a very high peak of the Guadalupe Mountains, from which a grand and interesting view of mountain scenery is obtained. The steep and rugged slope of this mountain rendered necessary the use of a sectional monument at this point, the pieces being carried to the site on pack mules. No. 71 was located at the point where the line between New Mexico and Arizona intersects the international boundary; it stands $3\frac{3}{4}$ miles west of No. 70, on the side of a high mountain and near the bottom of a deep ravine. This was also a sectional monument. No. 72, another sectional monument, was placed upon the summit of an extremely high, precipitous mountain, and about three-fourths of a mile west of No. 71. It occupies a site from which is visible a vast extent of broken, mountain country.

On the site of old No. 16, in the bottom of the Guadalupe Cañon, where the old road through this cañon crosses the boundary, Monument No. 73 was built of masonry. Its position is about $1\frac{1}{2}$ miles west of 72, and is near a high, rock bluff, around which the road curves in an easterly direction after passing the monument. The ranch house of Mr. Hall, an American who owned considerable property in this vicinity, was located in the cañon near this monument.

The Guadalupe Cañon is specially notable from the fact that it affords the only practicable pass for wagons within a distance of 50 miles to the north, and a much greater distance in the other direction; and as the boundary runs near the cañon it was of the utmost value in conducting the work of surveys and monument erection.

Nos. 74, 75, and 76, iron monuments, were placed on the mesa west of the Guadalupe Mountains at intervals of about 3 miles. The country here is rolling and the soil hard gravel and sand, yielding a moderate growth of grass beside the usual varieties of cacti.

No. 77, a masonry monument, stands on the mesa just west of the San Bernardino River and occupies the site of old No. 18. It was built of the fragments of that monument and provided with the usual inscriptions. Its altitude is less than that of any other monument on this parallel, being 1,132.6 meters above sea level; the river valley just east of it is somewhat lower. On this low ground near the river are the remains of old No. 17. This monument was not rebuilt.

The San Bernardino Valley at this place is flat and marshy, covered with grass, and has several springs of good water, also a number of quite large pools. At one time it was the site of a Mexican hacienda with flourishing ranches in its vicinity, nearly all now abandoned owing to the depredations of the Apache Indians and the malarial condition of the climate.

No. 78, an iron monument, was placed $1\frac{1}{4}$ miles west of No. 77 on a low ridge, and No. 79 $3\frac{3}{4}$ miles further west on one of the foothills of the Perilla Mountains. No. 80, a sectional iron monument, was located nearly 3 miles west of No. 79 upon a high, commanding ridge of these mountains. It overlooks the valley of San Bernardino and a large extent of country both to the northeast and southeast. The maximum difference in the offsets on this parallel between the United States and Mexican determinations occurred here, amounting to 1.6 meters, the Mexican position being south of the American.

No. 81, another sectional monument, was located less than 1 mile west of No. 80. It occupies the highest point of the line in crossing the Perilla Mountains and affords a superb view in all directions.

About 1 mile farther west, among the hills leading toward the Sulphur Spring Valley, No. 82 was rebuilt of masonry on the site of old No. 19. It stands near the road connecting the San Bernardino and San Pedro valleys. To the southeast of this monument is a conspicuous landmark known as the "Niggerhead," a tall, steep rock surmounting one of the highest mountains of this range. The Mexican name of this peak is Cerro Gallardo.

From the Perilla Mountains to the San Pedro River, a distance of about 42 miles, the line was marked with 15 solid iron monuments, at intervals varying from 1 to 4 miles, the average being about 3 miles.

The country along this part of the boundary is unobstructed by mountains or deep ravines, and but for the severe rains which occurred during the period of operations the transportation and erection of monuments would have been attended with little difficulty. The most serious obstructions were in the low valleys, especially at the Sulphur Spring bottom, where, owing to the almost constant rains, the roads were at times nearly impassable. The rich soil of these valleys, stimulated by the heat and unusual moisture, produced in a few days a growth of vegetation bordering upon the magical.

No. 98, near the western bank of the San Pedro River, was rebuilt on the site and from the remains of old No. 20.

The San Pedro River flows through an alluvial valley in which are located numerous ranches. About 7 miles south of the boundary is a small Mexican village, San Pedro, which until recently contained the Mexican custom-house, since moved to La Morita. The bed of the stream has been sunk by the attrition of the current 8 to 15 feet below the surface of the ground, and is from 30 to 60 feet in width. In ordinary seasons but little water is found in the stream, but during the operations of the monument party in this vicinity, heavy floods caused the river frequently to rise bank full, and as there are no bridges its depth at times seriously interrupted communication between opposite banks.

Three and one-half miles west of the river No. 99 was located on the ascending slope of the mesa toward the Huachuca Mountains. Nos. 100, 101, and 102 were placed high up on spurs of these mountains. They are all sectional, their parts having been carried to their locations on pack animals. They are specially notable on account of their high altitude and the rough and rugged nature of the adjacent country. No. 100 occupies the most easterly spur or ridge, at a distance of 3 miles west of No. 99, and is 1,840 meters above sea level, commanding an extensive view to the east as far as the Per.lla Mountains. No. 101, about one fourth of a mile farther west, occupies a still higher spur, being 1,848 meters above sea level, and marking the second highest point on the entire boundary. No. 102, a little more than a mile west of No. 101, stands upon a third high spur at an altitude slightly less than that of No. 100, overlooking a wide broken country westward across the Santa Cruz Valley as far as the Patagonia Mountains.

No. 103 was located about 3¼ miles farther west, in the foothills of the Huachucas, a well-wooded country much broken by ravines. No. 104, 1½ miles farther on, was located on a plain, and near the wagon road connecting the San Pedro Valley with that of the Santa Cruz. No. 105, about 1¾ miles beyond, stands on a high ridge west of a deep ravine. The latter contains a creek, in which flows at times an abundance of fine water. In locating this monument on the 17th of July the party encountered one of the severest rainstorms of the season, which flooded the entire country and filled the usually dry ravines with rushing torrents.

Four miles further west No. 106 was built of masonry on the site of old No. 21. Standing upon a wide, unobstructed plain, it presents a fine landmark.

About a kilometer east of this point is the dividing line between Pima and Cochise counties. A small, square, sheet-iron shaft, marking the southern extremity of this line, was found 5.11

Camp of Monument Party at Bisbee. Campamento de los Monumentos en Bisbee.

MAIN CAMP OF U. S. SECTION AT LA NORIA. CAMPAMENTO PRINCIPAL DE LA SECCIÓN DE LOS E. U. EN LA NORIA.

meters too far south. At the request of the county authorities it was moved north to its proper position on the boundary. One and three-fourths miles beyond No. 106 was placed iron Monument No. 107, also on a grassy plain and near the main wagon road.

No. 108, old No. 22, was rebuilt of masonry. It stands on the west bank of one of the tributaries of the Santa Cruz. This branch, ordinarily dry, was so flooded while the working party was camped in the valley that its crossing was several times interrupted. These floods would occur almost instantaneously, and, preceded by a loud roaring noise, a wall of water several feet high would suddenly come dashing along, carrying great quantities of drift, including sand, gravel, and stones of considerable magnitude.

No. 109, an iron monument, located about 2¼ miles west of No. 108, and No. 110, about 2 miles still farther west, occupy positions on ridges in a rolling country intersected by shallow ravines, which during the rainy reason carry the surplus water down from the Huachuca Mountains to the Santa Cruz River.

No. 111 was built from the débris of old No. 23, and occupies a low ridge just west of the Santa Cruz River, 1¼ miles from No. 110. It commands a fine view of the valley of the Santa Cruz to the east, with the Huachuca Mountains beyond, and overlooks the plain to the west on which is located the small settlement of La Noria, and beyond to the Patagonia Mountains.

In dry weather the head of the Santa Cruz River is but a short distance north of the boundary. The stream here flows south, skirts the southern limit of the Patagonia Mountains, then changes its direction to a northern course, and is again crossed by the boundary on the west side of this range. In the rainy season numerous ravines in the Huachuca Mountains pour their floods into the Santa Cruz both above and below its ordinary head. A long line of wire fence extends from the vicinity of La Noria eastward about 20 miles to the Huachuca Mountains. It was supposed to have been located on the boundary, but was placed several meters north of it.

About 1¾ miles west of No. 111, and immediately beyond La Noria, was located No. 112 on a small hill overlooking the town. No. 113, 3¾ miles west of No. 112, stands on the wooded slope of the Patagonia Mountains.

No. 114, probably near the site of old No. 24, which could not be found, was located 1¼ miles west of No. 113. It is 1,750 meters above sea level, and marks the highest point of the boundary on the Patagonia Mountains. This part of the boundary being inaccessible for wagons, they were compelled to make a detour south of the range, the work here being done by the aid of pack animals. From No. 114 a wide and magnificent view of mountain scenery is afforded, both toward the east and west.

No. 115 occupies a conspicuous place on a high, dark-colored mountain of volcanic rock nearly 2 miles west of No. 114. This and the preceding monument are of the sectional variety. No. 116, also sectional, is about 2½ miles beyond, and near the base of the Patagonia Mountains. No. 117 is located on the mesa which descends in a succession of ridges and valleys toward the second crossing of the Santa Cruz. It was placed 2½ miles west of No. 116.

No. 118, on the east bank of the Santa Cruz, was erected from the fragments of old No. 25. This monument stands at an elevation of 1,132.9 meters above sea level, and marks one of the lowest points on the parallel of 31° 20′, the elevation being practically the same as that of No. 77, at the San Bernardino River.

The Santa Cruz here flows north, after making a long detour around the southern limit of the Patagonia Mountains, and finally reaches the Gila Valley northwest of Tucson.

No. 119 was placed about 3¼ miles west of the river on one of the hills west of the valley and near a good wagon road leading to Nogales. No. 120 occupies a high, brown mountain 1½ miles west of No. 119. This monument marks the highest point of the boundary in the vicinity of Nogales, overlooking a wide extent of country in all directions. No. 121 was placed five-eighths of a mile west of No. 120 upon a sharp ridge which looks down upon the town of Nogales at its foot.

No. 122, located on the site of old No. 26, is an iron monument 256.8 meters west of No. 121. International street, lying wholly upon Mexican soil, passes this monument, the buildings upon the American side being so placed that their southern walls are exactly on the boundary. The old monument had been half covered by one of these buildings, making it necessary to have a portion of the front wall removed to enable the new monument to be placed in its proper location. No. 123 was erected on a low ridge about 1¼ miles west of No. 122.

Beyond Nogales the country gradually rises, and on approaching the Pajaritos Mountains becomes very rough and broken by deep, precipitous ravines; wagon transportation was impossible, and resort to pack animals was necessary.

Nos. 124 and 125, the latter sectional, at intervals of nearly 2 miles, were placed on prominent ridges of these mountains. No. 126, 2¾ miles west of No. 125, occupies one of the highest points of the boundary, being 1,622 meters above sea level. The monument, sectional iron, and all the materials for its base were carried to the site a number of miles on pack animals. The view from this position, especially eastward, is very fine and extensive.

No. 127, on the site of old No. 27, was built of masonry from the remains of that monument. It stands on the side of a mountain 231.8 meters west of No. 126 and near the bottom of a deep valley. It marks the western extremity of the boundary along parallel 31° 20′ and the change in direction to the azimuth line as determined by the original survey. According to the present survey, this point was determined to be 4½ miles west of the one hundred and eleventh meridian, differing in longitude from the original survey by 4′ 34.4″.

Exclusive of No. 53 at its eastern extremity, this section of the boundary is marked by 74 monuments; 13 are of masonry, located on sites of old monuments; 47 are new solid iron, and 14 new sectional iron. The average distance between monuments is 2.3 miles, the maximum being 6,769.3 meters and the minimum 231.8 meters.

The whole time consumed in their erection was from the 16th of June until September 19, 1893, a period of eighty working days, being an average of six days for each stone monument and for each iron monument one and three-tenths days.

The greatest differences between the United States and Mexican locations occurred at Monument No. 80, where the Mexican position fell 1.6 meters south of the American, and at No. 74, where the Mexican point fell 1.31 meters north of the American.

3. *Azimuth line between the one hundred and eleventh meridian and the Colorado River.*

[234½ miles, 78 monuments.]

The transfer of the men and transportation of the monument-building party from the meridian section of the boundary to Tucson, Ariz., was made early in October, 1893. The force was then reorganized and a number of improvements introduced. Monuments, cement, and other supplies were hauled from Tucson to the boundary and distributed between the one hundred and eleventh meridian and the Pozo Verde Mountains, a distance of about 30 miles.

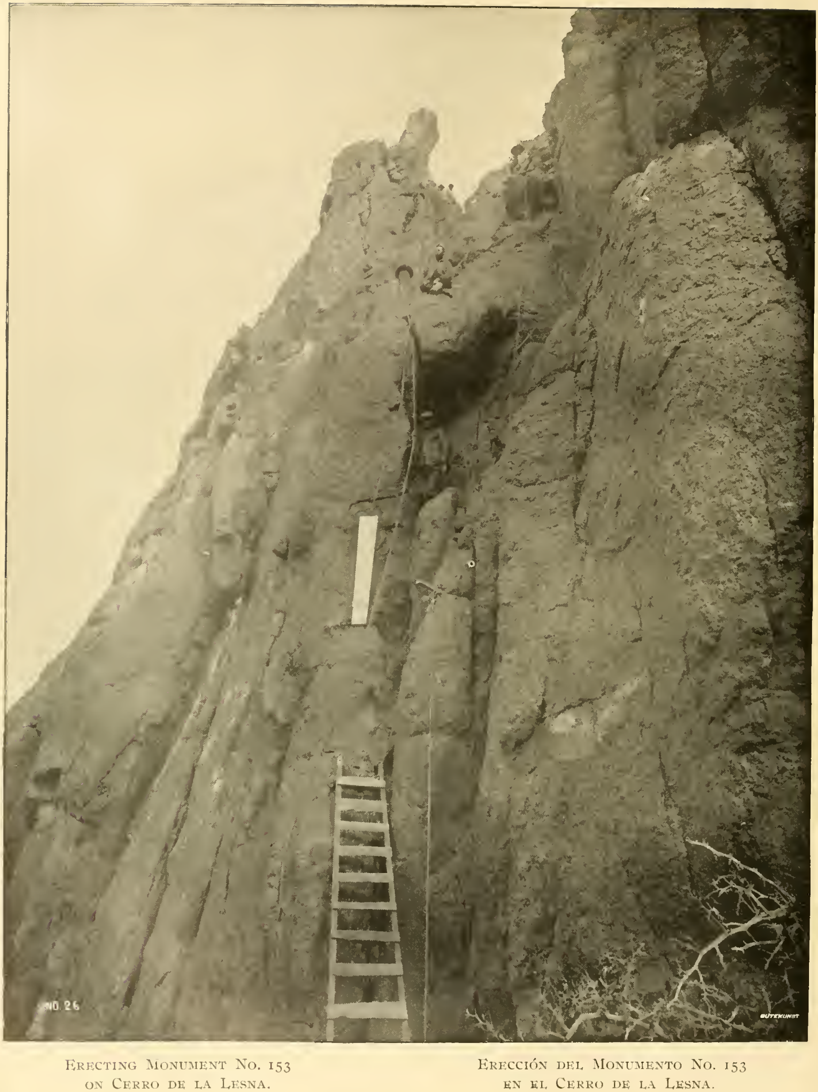
From the angle at the one hundred and eleventh meridan westward along the azimuth, the boundary passes for a distance of about 25 miles over the Pajaritos Mountains. This range has a high elevation (about 1,600 meters above the sea), and is so broken and cut up by deep, precipitous cañons that the work of erecting monuments was attended with more difficulties than were met in the same distance upon any other part of the boundary.

A supply camp was established near the Warsaw mining mill, from which all work along this section was carried on by means of pack animals, the distance by mountain trail to the several monuments ranging from a few miles to 22 miles in one instance.

These preparations were completed during November, and the work of setting monuments began at No. 128 on the 22d of that month.

Monument No. 128, sectional iron, was placed on a high ridge 394 meters westerly from the "angle" marked by No. 127. The monument on this ridge marks the highest point of the line through these mountains, being 1,662 meters above sea level. It stands near the site of old No. XIX, though the latter point was not identified. The pieces for this monument and the cement for its base were carried on pack mules 22 miles over very difficult mountain trails. The water for concrete was carried 9 miles and the sand 2 miles.

No. 129, a masonry monument, was built of dressed stone on the site of old No. XVIII. It occupies a high mountain ridge 3½ miles from No. 128. The sand. water, and cement for this work were packed several miles.



Erecting Monument No. 153
on Cerro de la Lesna.

Erección del Monumento No. 153
en el Cerro de la Lesna.

No. 130, a sectional iron monument, was located on a high mountain $2\frac{1}{4}$ miles beyond No. 129. The monument in sections, the sand and water, were carried on pack mules 10 miles. Its position commands a fine view of the surrounding mountains and cañons.

No. 131, also sectional, was carried 8 miles over mountain trails and placed on a high ridge $3\frac{1}{2}$ miles farther on.

No. 132 was located $3\frac{1}{4}$ miles beyond on another high hill, and required the use of pack animals, the monument in sections being carried about 6 miles.

No. 133 was placed $1\frac{1}{2}$ miles beyond No. 132; another sectional monument requiring the use of pack animals.

No. 134, about 2 miles farther on, and No. 135, $3\frac{3}{4}$ miles beyond the latter, are of solid iron, and occupy positions on a less broken part of the line, accessible for the monument wagon.

No. 136, built of masonry, and located on the site of old No. XVII, $1\frac{1}{2}$ miles beyond No. 135, stands upon the summit of the Fresnal Mountain, a high, rugged landmark which overlooks a large extent of surrounding country. This monument was well constructed of dressed stone found at the locality, but cement, water, and sand were carried several miles on pack mules.

No. 137, also a masonry monument, occupies the site of old No. XVI on a high, rocky hill, $2\frac{5}{8}$ miles west of No. 136.

Nos. 138, 139, and 140, solid iron monuments, mark the line over the rolling country between the Fresnal Mountain and the Pozo Verde range. They were placed on hills at intervals of about $2\frac{1}{2}$ miles. Near the latter is the thriving ranch known as La Osa.

No. 141 occupies a commanding position on the crest of the Pozo Verde Mountains $1\frac{1}{4}$ miles west of No. 140. This is a masonry monument built on the site of old No. XV. The difficulties here were such that the cement and water were carried by pack mules $2\frac{1}{2}$ miles. A magnificent view both east and west is afforded from this location.

Nos. 142, 143, 144, and 145 are solid iron monuments, marking the line at intervals of about $3\frac{1}{4}$ miles across the mesa country lying between the Pozo Verde and the Moreno mountains. This is an arid region, though occasional rains occur, and considerable grass is found on some of the plains, which, with the aid of a few pumping wells, supports a number of herds of horses and cattle.

No. 146, occupying the site of old No. XIV and 4 miles west of No. 145, marks the highest point where the boundary crosses the Moreno Mountains, the "Cerro de la Union" of the Emory survey. It is a masonry monument, and on account of the difficulties of the situation pack animals were necessary in conveying the material to the site.

No. 147, a solid iron monument, placed $4\frac{1}{2}$ miles west of No. 146; No. 148, about $2\frac{1}{2}$ miles beyond upon the same general declivity, and No. 149, nearly 3 miles farther on, mark the boundary between old Nos. XIV and XIII.

No. 150, on the site of old No. XIII and built of masonry, is $2\frac{1}{2}$ miles beyond No. 149. It stands near the crossing of the main road and also near a high, precipitous rock. It was well built of cut stone and provided with the usual inscriptions. The Indian village Cobota is located in this vicinity.

No. 151, $2\frac{1}{4}$ miles beyond No. 150, and No. 152, $3\frac{1}{4}$ miles still farther west, are solid iron monuments, marking slightly elevated points in the open and nearly level country.

No. 153, $2\frac{3}{4}$ miles west of No. 152, occupies the most remarkable position on the entire boundary. The line in crossing the Cerro de la Lesna rises abruptly from the plain below, a distance of about 500 feet, the upper 100 feet being a sheer precipice on both sides. To reach the summit of this ridge required a specially skillful and athletic climber to carry a rope, by means of which others were enabled to ascend and perform the work of erecting this monument. It is of the sectional iron type, the pieces and other materials being carried as far as possible on pack animals, and then hoisted by hand, with the aid of ropes, to the summit. The knife-edge crest was blasted off to give sufficient width for the base of the monument, which was then bolted to the solid rock. The erection of this monument proved to be the most difficult upon the entire boundary, requiring four days of excessive labor.

West of the Cerro de la Lesna a sandy, rolling plain extends to the Nariz Mountain, a distance of 18 miles, across which the boundary is marked by iron monuments Nos. 154, 155, 156, 157, and 158, at intervals varying from $2\frac{1}{2}$ to $3\frac{3}{4}$ miles.

No. 159, 2⅝ miles farther on, marks the crossing of the boundary over a rough, high, black lava ridge, the outlying spur of the Nariz Mountain. The truck wagon could not reach this site, and a sectional monument was placed here, the pieces being carried by pack train.

No. 160 is a monument of cut stone marking the point where the line crosses the summit of the Nariz Mountain and built on the site of old No. XII. Its location is 2½ miles west of No. 159 and its elevation about 1,000 feet above the valley on either side. It overlooks a wide extent of country to the eastward and the narrow valley to the west.

No. 161, an iron monument, stands in this valley, the Santa Rosa, 1¼ miles beyond No. 160. Old No. XI is supposed to have been located near this point, but was not found.

No. 162, a masonry monument on the site of old No. X, marks the crossing of the boundary over the Santa Rosa Mountains 3¼ miles beyond No. 161. These two ranges are about 5 miles apart where the boundary crosses.

The construction of this monument was attended with much difficulty, pack animals being necessary for transportation up the steep mountain slopes, and considerable work was expended upon the trail to make it passable for mules.

No. 163, a sectional iron monument, was placed on a sharp lava spur of the Nariz 1¼ miles west of No. 162. Its erection was also quite difficult.

The country beyond this point for a distance of about 13 miles is comparatively level, the most serious difficulty encountered being the lack of water, which had to be carried long distances.

Along this section of the line were erected iron monuments Nos. 164, 165, 166, and 167, at intervals of about 3 miles.

No. 168 occupies the site of old No. IX. It was built of masonry and stands upon a high hill 1½ miles beyond No. 167, and is near the Mexican settlement of Sonoyta.

Between this point and old Monument No. VI, a distance of 20 miles, the country is a rolling, hilly mesa, over which the boundary is marked by 6 iron monuments, Nos. 169, 170, 171, 172, 173, and 174, the intervals between them varying from 2 to 3½ miles. No. 172 was located at the old village of Quitobaquita, and near and south of the valuable springs of that name. Old Monuments Nos. VII and VIII had been located in this vicinity, but no trace of them could be found.

No. 175, a masonry monument, was built on the site of old No. VI, upon a high, rocky hill, about 9 miles west of the springs. It overlooks a large area of adjoining country to the eastward.

No. 176 was placed 2⅝ miles beyond on a narrow ridge extending southward from the Quitobaquita Mountains.

No. 177 was located upon the flat mesa 3¾ miles farther on.

No. 178, 4¾ miles beyond 177, was placed on a high, rough, lava hill, rendering it necessary to carry by hand the monument from the base of the hill to its position.

No. 179, about 3 miles farther west, was placed upon another sharp hill, though less difficult than the preceding.

Nos. 180, 181, 182, and 183 continued the marking of the line over the Tule Desert to the base of the Tule Mountains. They were usually placed on lava ridges at intervals of about 4¾ miles. The locations for Nos. 182 and 183 were such that the monuments were of necessity carried by hand short distances to their positions.

No. 184, a sectional iron monument, was placed on a very high mountain of the Tule group at a distance of 2⅝ miles from No. 183. It overlooks a vast extent of country eastward, the immediate neighborhood being a succession of rugged mountains, divided by deep, precipitous cañons. The steep, rocky sides of this mountain would not admit of even pack transportation, the pieces of the monument being carried by hand about 1¼ miles.

On a still higher and more rugged mountain 2¾ miles beyond was located No. 185. The work here was still more difficult. Pack animals were used in carrying the sections of the monument part way up the slope and the work completed by hand. This monument commands a magnificent view of rough and rugged mountain peaks rising in needle-like sharpness and separated by cañons whose sides are often vertical precipices.

No. 186 was placed where the boundary crosses the highest ridge of the Tule Mountains. It is 2¾ miles west of the preceding, and like the other its erection was attended with severe labor, requiring hand transportation a part of the way.

Monument No. 184. Monumento No. 184.

No. 187, on the most westerly ridge of the Tules, 2½ miles farther on, was erected also with great labor, as this ridge, though not as high as the others, was extremely rough. A solid monument had been provided for this point, and its transportation to the site was a difficult problem, effected by using one pair of the wheels of the truck wagon and trailing the monument upon a timber lashed beneath it.

No. 188 was placed about midway of the valley beyond and 4¾ miles west of No. 187.

No. 189, sectional, about 4 miles beyond No. 188, marks the crossing of the Lechuguilla Mountains, a high, rocky position which was barely accessible by pack mules.

Two and one-fourth miles distant from No. 189, upon a small hill, was located No. 190, near the foot of the Tinajas Altas Mountains. This range is one of the roughest and most precipitous encountered on the entire boundary, though the line in crossing it reaches an altitude above the sea of only 644 meters. The contrast between the valleys and steep mountains, whose sides are frequently vertical for many hundred feet, is more strongly marked than elsewhere along the boundary. The almost total absence of vegetation, sharp, rugged rocks only being visible, adds materially to the wild and desolate effect.

No. 191 was placed 2 miles beyond No. 190, and marks the point where the boundary reaches its highest elevation in crossing these mountains. In the immediate vicinity are many other high ridges, with intervening chasms several hundred feet in depth. The summits of these ridges are so narrow that men found great difficulty in retaining their positions while at work upon the survey. The monuments upon these rocky mountain tops were all of the sectional kind, and were bolted to the solid rock after the surface had been suitably leveled by blasting.

No. 192 was placed on a high ridge about 2 miles west of No. 191, and marks the last mountain point east of the Yuma Desert. This and the preceding were of the sectional variety.

From the foot of these mountains the desert has a gradual and nearly uniform descent to the Colorado River of about 250 meters in 70 kilometers. This gradual descent is only broken at one place, about midway of the slope, by a range of sand dunes bordered on the southwest, for a distance of about 1 mile, by a ridge of volcanic rock. The boundary crosses the northern end of this ridge, at which point No. 198 was placed and occupies a conspicuous position. The monuments on this desert as far as No. 204 are all of solid iron, resting on concrete bases. They are numbered from 193 to 203, inclusive, and were placed at intervals generally of about 6,000 meters.

No. 204, marking the westerly limit of the desert mesa and overlooking the Colorado bottom, is old No. II of the original line, repaired and provided with a new concrete foundation. The old monument was made of cast-iron plates resting upon a defective foundation, which had almost disappeared, permitting the structure to settle and become unstable. It was taken down, a heavy concrete foundation built on the exact site, and the monument carefully rebuilt, painted white, and provided with the new inscription plates. It now presents a very fine appearance.

The last monument on this section of the boundary is No. 205, which was placed in the river bottom 3,000 meters west of No. 204 and near the bank of the Colorado, in a heavy growth of cottonwoods and willows. No. I of the original survey was located near this point, but all trace of it has disappeared.

Of the 78 monuments now marking this section of the boundary, 53 are new iron, cast whole, 14 are new iron, in sections, 1 old iron, sectional, rebuilt, and 10 are of masonry upon the sites of old monuments. The average distance between monuments is 3 miles, the maximum being 7,898 meters and the minimum 393.5 meters.

The greatest difference between the United States and Mexican locations occurred at Monument No. 191, on the summit of the Tinajas Altas, being 2.04 meters, the Mexican position falling north of the United States. This difference is also the greatest on the entire boundary. In many cases the difference was inappreciable, while frequently the Mexican point fell south of the American.

Monument work on this section of the boundary commenced November 22, 1893, and continued until March 14, a period of ninety-four working days, the average time for erecting each iron monument being one and one-fourth days and for each of masonry three days.

The party as organized for this section was necessarily larger than heretofore, as the work was remote from railway transportation and required the maintenance of a special camp near the working party to afford the necessary supplies. These were at first hauled from Tucson, 70 to 150 miles, afterwards from Gila Bend, Adonde, and Yuma, as the work progressed westward.

The organization was as follows: Col. J. W. Barlow, commissioner, in general charge until disabled by an accident in December; Mr. B. A. Wood, assistant engineer, in charge of location, and in general charge after December; Mr. D. R. Payne, overseer and photographer; Mr. J. T. Amos, quartermaster and property clerk; Mr. M. E. Cunningham, wagon master; 1 rodman, 1 blacksmith, 1 stone mason, 9 teamsters, 9 laborers, 2 cooks, and 2 helpers, 2 spring wagons, 1 buckboard, 3 water wagons, 5 baggage wagons, 1 truck wagon, 5 horses, and 36 mules.

4. *The azimuth line from the Colorado River to the Pacific Ocean.*

[141 miles, 53 monuments.]

On reaching the Colorado River the monument party was reorganized and the force of men and teams reduced. This was possible by reason of better facilities for obtaining supplies, a special supply camp being no longer necessary.

After a short delay at Yuma the work on the southern California line was taken up, with the following organization: E. L. Ingram, assistant engineer, in charge; D. R. Payne, overseer and photographer; M. E. Cunningham, wagon master; 1 cook, 1 waiter, 2 packers, 3 teamsters, 1 blacksmith, 5 laborers, 2 baggage wagons, 2 water-tank wagons, 1 truck wagon, 1 spring wagon, 1 buckboard, 26 mules, 3 horses.

From the western extremity of the Arizona line the boundary follows the channel of the Colorado River northward about 24 miles to the boundary of California. This being a part of the water boundary between the United States and Mexico, the adjustment of which has been provided for under another convention, no monuments have been erected in connection therewith. This water boundary is held to extend to the point where the boundary between California and Mexico intersects the channel of this river, which is about 6 miles below the mouth of the Gila.

From this point the work of marking the boundary westward to the Pacific was taken up. Operations began on the 20th of March, 1894, by the erection of No. 206. This is an iron monument, and was placed 229 meters west of the center of the river channel, in a growth of willow and cottonwood trees.

No. 207, on the edge of the mesa, 810 meters from No. 206, and overlooking the river valley, was built of masonry. It stands at the south foot of Pilot Knob Mountain and replaces old No. VI, which was originally of cast iron but had been destroyed.

No. 208, an iron monument, was placed 2 miles beyond on the same mesa and near a line of heavy sand hills.

No. 209, about 4 miles farther west, stands among sand hills but upon firm ground.

No. 210, about 4¾ miles beyond No. 209, was placed on a soft, sandy plain which proved to be unstable, the wind cutting the sand from one side of the foundation and causing the monument to topple over. This unsafe condition was afterwards remedied by sinking the base lower and securing it by driving 8 iron pipes 12 feet into the ground, 2 at each corner of the base, and held in place at top by connecting iron bars. Should the sand drift away hereafter the monument would probably remain upright and settle vertically.

Through this part of the desert, composed of sand which moves in wave-like drifts, the monuments, 6 in number, were each provided with a hollow iron mast, 15 feet long, attached to the side of the monument near the top. These masts will probably remain visible in case the monuments shall become buried in sand drifts.

From the Colorado River westward the boundary, for a distance of about 10 miles, passes over a desert region composed of sand ridges almost totally devoid of vegetation. Adjacent and south of the line the valley of Salton River, frequently overflowed by the Colorado, and in which lies the old Yuma and San Diego wagon road, presents a marked contrast to this arid waste, having at times many pools of fair water left from the overflow of the Colorado River and an abundant growth of mesquite and other vegetation.

Monuments Nos. 211, 212, 213, 214, 215, 216, and 217 continue the marking of the boundary over this desert at intervals of about 3¼ miles.

No. 218, 3½ miles beyond 217, marks a point in the Salton Valley, which is here crossed by the boundary and trends in a northwest direction toward the Salton Lake.

No. 219, 3 miles farther on, is located in the same valley.

No. 220, 3⅜ miles beyond and just east of New River, is old No. V, repaired and placed upon a new concrete foundation.

No. 221 stands west of New River. It is old No. IV, 1¾ miles beyond No. 220, also repaired and given a new foundation of concrete. These foundations were made 3 feet square and 4 feet high, with 2 feet showing above the ground, and upon them were placed the usual iron inscription plates.

No. 222 marks a point in the New River Valley about 4½ miles beyond No. 221, and No. 223 was placed in the same valley 3¼ miles farther west.

The last four monuments mark the lowest depression on the entire boundary, No. 220 at the sea level, the others below it. No. 223 is 4.37 meters below sea level.

The vegetation here is similar to that in the Salton Valley and indicates a fine, rich soil, capable under irrigation of yielding abundant crops of grain and all the semitropical fruits. A comprehensive plan for bringing the Colorado water into this region, by means of a canal tapping the river about 12 miles above Yuma, has been under consideration for some time, extensive preliminary and locating surveys having been carried on during the winter of 1893–94.

No. 224, 4 miles beyond No. 223, marks the crossing of a considerable ridge, one of the spurs of Signal Mountain, a high detached peak just south of the line.

No. 225, about 1 mile beyond, marks a second spur of this mountain.

Nos. 226, 227, and 228 fall on the arid desert which now gradually ascends toward the Coast Range. These monuments were placed at intervals of about 3 miles. This region is as desolate and uninviting as can well be imagined; devoid of water, almost of vegetation, broken by sharp, rocky cañons, it has been the scene of many tragedies. The impression has prevailed that the precious metals are somewhere hidden away in the recesses of these gorges, and several prospectors, lured by the hope of finding rich deposits, have ventured too far from supplies and left their bones as witnesses of their rashness.

No. 229 marks the crossing of a high, detached ridge near the Coast Range. A sectional monument was packed to the point with great difficulty after expending considerable labor in preparing a trail up the rough, volcanic slope of the mountain. It stands 3 miles west of No. 228.

No. 230 was placed upon the crest of a still higher ridge, a part of the Coast Range proper, and 4¾ miles beyond the preceding, a sharp, rocky valley intervening. Much difficulty was here encountered. The preparation of a trail for the pack mules carrying the sections of the monument was necessary to reach a point within 100 meters of the location. Beyond this the mules could not proceed, and the pieces were thence carried by hand. The monument was bolted to the solid rock.

No. 231, sectional, about 4¾ miles beyond, was placed upon the summit of the range, its elevation being 1,371 meters above sea level. The approach to this monument is by way of the Mountain Spring Cañon, several miles to the north, through which passes the old Yuma and San Diego wagon road. When used by the overland stage line the road was kept in fine condition, but neglect on the part of the authorities and the earthquakes and storms of recent years had left it so bad that travel was attended with great labor and difficulty. The monument stands about 250 meters back from the extreme verge of the cliff, which here rises, an almost vertical wall of rock, from the rough, broken foothills below. The rim of this cliff marks a sudden and wonderful change in the character of the country. East of this line the great desert of the Colorado extends to the limit of vision dry and arid, with volcanic ridges and gorges in the foreground. Utterly destitute of vegetation, it is a region apparently without life. Westward the mountains are clothed in verdure; trees, bushes, and grass are everywhere; animals abound in great variety. The moisture from the ocean here prevails and is condensed into refreshing showers. To the east the hot air of the desert rises and forms a barrier through which mists seldom penetrate, being either rolled back by the desert winds or dissipated in the upper atmosphere.

No. 232, 3 miles west of No. 231, stands in a saddle of a high mountain ridge, very rough, but reached with the monument truck. Its site overlooks the beautiful Jacumba Valley to the west.

No. 233, nearly 3 miles farther west, stands on a low ridge three-quarters of a mile southwest of the Jacumba sulphur spring and at the foot of a very large bowlder, which renders it invisible from the road 300 meters to the north.

No. 234, 2½ miles beyond, was located on the south wall of Jacumba Cañon and near its top In placing this monument in position a long detour was necessary to reach the summit of the mountain with the pack train. The pieces of the monument by the aid of ropes were lowered down vertical cliffs to the site selected and the base bolted to solid rock.

No. 235, a sectional monument about 3 miles west, was bolted to the top of a huge bowlder upon an elevated ridge. This mountain region is much broken by hills and ridges, many of them being mountains rising several hundred meters above the valleys. The latter are frequently quite broad, affording fine water and excellent grazing. Others are but narrow, deep cañons with precipitous sides.

Nos. 236, 237, 238, 239, and 240 were placed on hills at distances apart varying from 1¾ to 2½ miles, No. 240 being just east of the main road leading south from Campo, the latter being 1¼ miles north of the line.

No. 241, a sectional monument, was placed on a high rocky ridge about 1 mile beyond 240 and west of a branch road leading to the Tijuana Valley.

No. 242, sectional, also upon a high ridge, was placed 3 miles west of No. 241, and No. 243, 3¼ miles farther west, upon the north slope of a conspicuous conical hill.

No. 244, about 1 mile west of No. 243, marks a point near the road leading to Potrero, 2¼ miles north.

No. 245 was placed on a low ridge in a valley near the east foot of Mount. Tecate, and 2¼ miles beyond No. 244. A portion of this valley is under cultivation, containing several improved ranches. Just west of this monument rises the bold scarp of Mount. Tecate, steep and rugged, nearly 500 meters above the valley up which in a zigzag course the pack train carried Monument No. 246 in sections, where it was placed about 2 miles distant from 245.

The crest of this mountain is a horseshoe ridge opening to the south, the two branches where the line crosses being about one-half mile apart. Upon the second of these No. 247, also a sectional monument, was placed. The pieces of this were carried up the mountain slope from the west side, the deep and rocky intervening cañon making it impracticable to cross directly from the east.

These monuments occupy positions from which the most magnificent scope of mountain country upon the whole boundary is visible. The Coast Range as far as the eye can reach is spread out to the east, south, and specially to the west, beyond which the Pacific Ocean is seen rolling its surf upon the beach, about 25 miles distant.

No. 248, also a sectional monument, was placed upon a sharp ridge west of Tecate Mountain, and 2¼ miles beyond No. 247. At the foot of this ridge the Tecate River flows through a narrow valley in a westerly direction, and, joining the Cottonwood about 2 miles beyond, the united streams form the Tijuana River.

No. 249 was placed on a low ridge in the Tijuana Valley one-half mile below the junction of Cottonwood and Tecate rivers.

No. 250, sectional iron, on a high ridge in the latter valley, was located 1⅝ miles beyond No. 249, overlooking the valley in both directions.

No. 251, a sectional monument, stands on the south slope of Otay Mountain, near the summit, and commands a fine view of the country west to the Pacific. It was located 4 miles west of No. 250.

No. 252, 2¼ miles farther west, is a masonry monument, built on the site of old No. III. It stands on the Otay mesa and near the foot of Otay Mountain.

Camp of Mexican Section.
At Hot Springs, Tijuana River.

Campamento de la Sección Mexicana.
En el Agua Caliente, Río de Tijuana.

Monument No. 255 (granite), view to the S. W.
Near Tijuana River.

Monumento No. 255 (granito), vista al S. O.
Cerca del Río de Tijuana.

No. 253, about 3½ miles farther west, and 254, about 2¼ miles beyond, continue the boundary across the mesa to the Tijuana Valley.

No. 255, in the Tijuana Valley, occupies a low bench of the plateau north of the river, and 1½ miles west of No. 254. This is a special monument, built of granite, of the same size as the other masonry monuments, but constructed with reference to the importance of the site. It is composed of but three pieces, resting on a foundation of concrete. The joints of the stones are all carefully cut; the exterior surfaces, with the exception of 4 panels on the respective sides and the faces of the pyramid at top, are left rough. The 4 panels bearing the inscriptions are polished, and the corners of the monument fine cut work. The whole effect is very satisfactory. Following are the inscriptions on the 4 panels:

On the north:

Boundary
of the
United States
Treaty of
1853
Re-established
by conventions of
1882–1889.

The destruction or
displacement of this
monument is a
misdemeanor
punishable by the
United States or
Mexico.

On the south:

Limite
de la
Republica
Mexicana
Tratado de 1853
Restablecido
por
Convenciones de
1882–1889.

La destruccion
o dislocacion de
este monumento es
un delito punible
por Mexico o los
Estados Unidos.

On the east:

255
Seccion Mexicana
de la
Comision Internacional
de Limites:
Jacobo Blanco,
Ingeniero en Jefe.
Valentin Gama,
Adjunto Astronomo.
Gaspar M. Ceballos,
Captain de E. M. E.,
Ingeniero Auxiliar

On the west:

255
United States
Commissioners:
Col. J. W. Barlow,
Corps of Engineers.
Lieut. D. D. Gaillard,
Corps of Engineers.
Asst. A. T. Mosman,
Coast and Geodetic Survey.

To protect this monument from injury by tourists a steel picket fence 7 feet high, inclosing an area 12 feet square, was built around it; the posts were embedded in granite blocks, and the interior space covered with a paving of artificial stone.

It was intended to perpetuate the site of old No. II, which was located at the crossing of the Tijuana River by the main highway leading to Mexico, and where the Mexican village of Tijuana has since been built. A monument of which the present 255 is a duplicate was erected at that point, but during the heavy floods of January, 1895, it was entirely destroyed and its fragments buried beyond recovery in the quicksands of the river. The bed of the stream was so changed that the site of old No. II lies in its mid channel. As the difficulty and expense of preparing a new foundation for a monument at the old point would be very great, and there being no real necessity for so doing, it was agreed between the engineers in chief to abandon the position and erect another monument, a duplicate of the one lost, on solid ground north of the river, and about 1,000 meters east of the old site. The village of Tijuana, badly damaged by the last flood and even more seriously injured by that of 1890, will now probably move many of its buildings to the vicinity of the new monument, where the custom-houses of both countries are to be located, and where the ground is high and entirely secure from future floods.

The boundary here crosses obliquely the Tijuana Valley and reaches the mesa again about 2½ miles west upon the crest of which No. 256 was located, a little more than 3 miles beyond No. 255.

No. 257, beyond two sharp ravines and upon a high ridge of the mesa, 1½ miles beyond No. 256, commands a fine view of the ocean and the city and harbor of San Diego.

No. 258 is the old initial monument of the original survey. It had become so mutilated by visitors that its outlines were nearly destroyed and its inscriptions partly obliterated. Chippings from the top and corners had been carried away, and so much of the base had been removed that the monument was becoming insecure on its foundation. It was decided to have it entirely remodeled. This work was done in San Diego, the monument being taken to the marble yard of Messrs. Simpson & Pirnie, where it was recut; its size reduced a few inches in all dimensions; it was then repolished and the original inscriptions restored as far as was deemed consistent. Including certain additions these inscriptions are now as follows:

On the north:

Boundary
of the
United States.

The destruction
or displacement
of this monument
is a misdemeanor
punishable by the
United States
or Mexico.

On the south:

Limite
de la
Republica
Mexicana.

La destruccion
o dislocacion
de este monumento
es un delito
punible por
Mexico o los
Estados Unidos.

On the west:

Initial point of Boundary between the United States and Mexico, established by the Joint Commission 10 October, A. D. 1849 Agreeably to the Treaty dated at the City of Guadalupe Hidalgo, February 2, A. D. 1848. John B. Weller, U. S. Commissioner. Andrew B. Gray, U. S. Surveyor.	Punto inicial del Limite entre Mexico y los Estados Unidos, fijado por la Comision Unida 10 de Octubre A. D. 1849 Segun el Tratado Concluida en la Ciudad de Guadalupe Hidalgo el 2 de Febrero A. D. 1848. Pedro Garcia Conde, Comisionado Mexicano. Jose Salazar Ylarregui, Agrimensor Mexicano.

On the east:

258

Reconstruido Agosto de 1894, por la Comision Internacional de Limites creada por los Convenciones de 1882 y 1889.	Reconstructed August, 1894, by the International Boundary Commission created by the Conventions of 1882 and 1889.

Marble not being readily obtainable, a granite base to replace that of marble destroyed by visitors was also provided. It was then returned to its site and reerected upon a new concrete foundation.

Two documents, one in English and one in Spanish, recording the names of the Commissioners and engineers employed on the present survey were engrossed upon parchment, encased in a copper tube, and embedded in the foundation. Following is a copy of the English document:

This paper was deposited in the foundation of Monument No. 258, October 3rd, 1894.

This monument was originally erected by Wm. H. Emory, United States Commissioner, and Don Jose Salazar y Larregui, Mexican Commissioner, on October 10th, 1849.

This monument was recut and re-erected under the direction of the International Boundary Commission, United States and Mexico, which has re-established the boundary line between the United States and Mexico, from the Rio Grande to the Pacific Ocean, under the conventions of July 29th, 1882, and February 18th, 1889, by the erection of 258 monuments under the Administrations of Presidents Benjamin Harrison and Grover Cleveland, James G. Blaine and Walter Q. Gresham their respective Secretaries of State.

United States Commissioners: J. W. Barlow, lieutenant colonel of Engineers, U. S. Army; D. D. Gaillard, 1st lieutenant of engineers, U. S. Army; A. T. Mosman, Assistant, U. S. Coast and Geodetic Survey.

Engineers employed on the survey: John F. Hayford, assistant astronomer; John L. Van Ornum, assistant engineer; Edward L. Ingram, assistant engineer; Bernard A. Wood, assistant engineer; and L. Seward Terry, Secretary of U. S. Commission.

A steel picket fence to protect the monument from injury, and an interior pavement were provided, as at No. 255. The pickets of these fences curve in at the top, making access to the inclosure extremely difficult.

The erection of this monument completed the marking of the southern California line and the entire boundary between the Rio Grande and the Pacific Ocean.

Of the 53 monuments on this section of the boundary 35 are of iron, cast solid; 12 are iron, sectional; 2 old sectional iron, repaired; 2 of masonry built on old sites; 1 granite; 1 marble, recut from old initial monument.

The average distance between monuments is 2.7 miles; the maximum 7,533 meters; the minimum 809 meters.

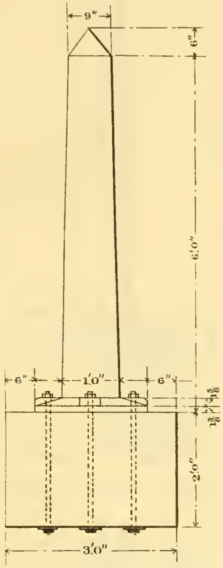
The work began on March 20 and continued until June 30, 1894, during a period of eighty-eight working days, in which the monuments, except the 2 built by contract, were erected; the average time per monument being about one and eight-tenths days.

Monument No. 258 (marble), view to the S. E.
Old initial monument, recut.

Monumento No. 258 (mármol), vista al S. E.
Antiguo monumento inícial, labrado de nuevo.

INTERNATIONAL BOUNDARY SURVEY

UNITED STATES AND MEXICO



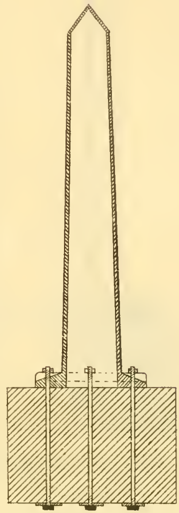
NOTE:

Thickness of Metal $\frac{13}{16}$"

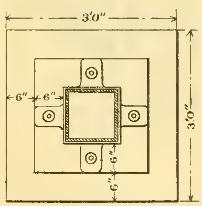
Bolts 2'.1" between Washers and 1" Diameter.

Nuts 2" round, $1\frac{9}{16}$ Hexagon Head. Washers 6" Diam. by $\frac{1}{2}$" thick

ELEVATION



SECTION

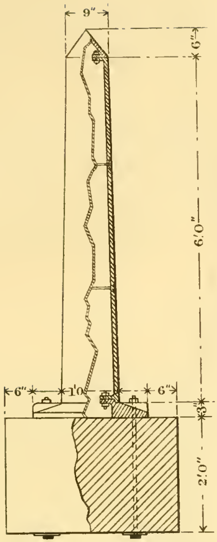


PLAN

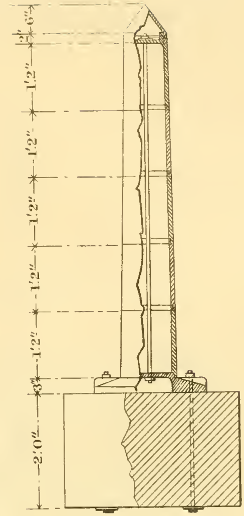
DESIGN FOR IRON MONUMENTS

ADOPTED NOVEMBER 1891

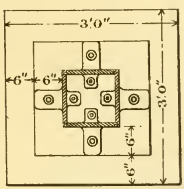
SCALE $\frac{1}{2}$" = 1'0"



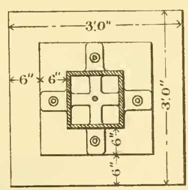
ELEVATION AND SECTION



ELEVATION AND SECTION



PLAN



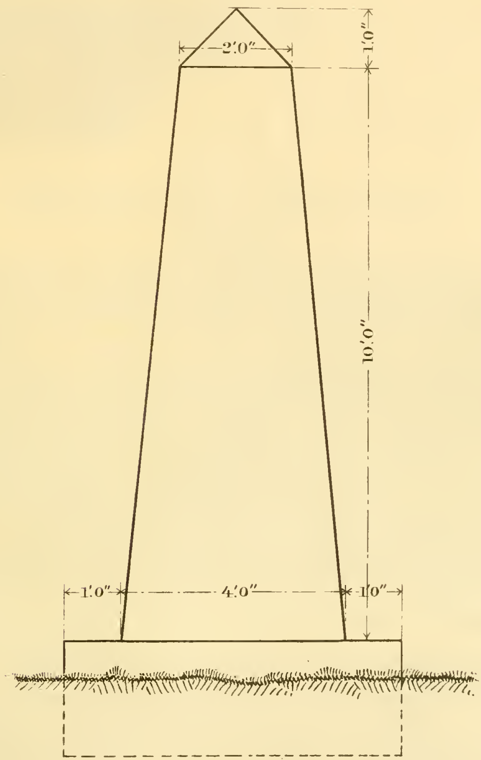
PLAN

DESIGNS FOR SECTIONAL IRON MONUMENTS

SCALE $\frac{1}{2}'' = 1'0''$

INTERNATIONAL BOUNDARY SURVEY

UNITED STATES AND MEXICO



DESIGN FOR STONE MONUMENTS

ADOPTED JUNE 3rd 1893

SCALE ½" = 1'.0"

The greatest difference between the United States and Mexican offsets, 1.48 meters, occurred at Monument No. 211, the Mexican point being north of the American.

The aggregate length of the several sections of the boundary now marked by monuments is 675 miles, the whole number of monuments being 258. The average distance apart is about 2.6 miles, and in no case has the limit of 8,000 meters been exceeded.

Summary.

Number of original monuments identified and repaired or replaced	43
Number of new points established and marked with iron monuments	215
Number of new solid iron monuments erected on new sites	175
Number of new sectional iron monuments erected on new sites	40
Number of new solid iron monuments erected on old sites	1
Number of old sectional iron monuments repaired	3
Number of old masonry monuments repaired	5
Number of old masonry monuments rebuilt	32
Number of new granite monuments built	1
Number of old marble monuments rebuilt	1

CHAPTER VIII.

PHOTOGRAPHY, BIOLOGY, AND FINANCIAL STATEMENT.

PHOTOGRAPHY.

The commission decided, as a part of its original plan of operations, to employ a photographer and to provide him with an outfit for taking such views along the line as would be useful in illustrating the character of the country, and also as an adjunct to the maps in fixing the locations of new monuments.

Mr. J. H. Wright, of Nashville, Tenn., was at first employed. He accompanied the main camp of the survey party along the parallel of 31° 47′ and photographed the old monuments upon this part of the boundary, but his work did not prove satisfactory and he was discharged.

Mr. M. J. Lemmon, of El Paso, Tex., was appointed in his place, continuing with the expedition as far as San Bernardino, on parallel 31° 20′, when his services were also discontinued.

In August, 1892, Mr. D. R. Payne, of Albuquerque, N. Mex., was engaged to succeed Mr. Lemmon. Mr. Payne proved to be an experienced and skillful photographer, and was continued in service until the completion of the photographic work in June, 1894.

The camera was of the portable type, with 8 by 10 inch glass plates, and was furnished with an excellent lens. The necessary plate-holders, printing frames, baths, a supply of chemicals, and a developing tent were also provided. The outfit was usually tranported in one of the spring wagons, but on portions of the line where wagons were impracticable Mr. Payne managed to carry the camera and other necessary articles on horse or mule back. The trails were frequently rough and sometimes dangerous, but happily no serious accident ever occurred to the camera or its belongings.

The plates were developed as frequently as practicable, and test prints made as a check upon the character of the work.

It was the intention to obtain one or more views of the old monuments to illustrate their condition at the time of the survey, and at least two of all the new monuments after their erection, as a help to the topography in identifying their locations. Where possible the monuments were photographed against a distinctive mountain or hill in the immediate vicinity.

The work done by Mr. Payne's predecessors not being entirely satisfactory, it was fortunate that he joined the monument party in El Paso at the beginning of its operations, thus permitting him to go over the entire line with this party and supply any previous deficiencies.

Photographs of 39 of the old monuments were obtained, which exhibit types of the previous structures employed, the rude heaps of loose stones on parallel 31° 20′ and the Sonora line, and the several cut-stone, masonry, and iron shafts which were found at other points.

The monuments, new and repaired, on the entire line, 258 in number, were photographed, one or more views being taken both by the American and Mexican photographers. These views will be of assistance in recovering the positions of monuments in case of their destruction.

Views characteristic of the country were taken in addition to those of the monuments. These show specially interesting natural scenery, such as settlements, public buildings in the vicinity of the boundary, also camps, ranches, etc.

At the close of the field work in June, 1894, the photographer was engaged at San Diego until December in preparing four copies of each view, which were mounted in albums and, with the negatives, transmitted to the Department.

When the commission assembled in Washington, in October, 1895, the question of obtaining plates from which to print copies of the photographs for publication with the report was considered. After quite an extensive investigation it was finally determined to adopt the method known as half-tone engraving, which, on account of its cheapness and accuracy, promised the most satisfactory results.

Accordingly a contract was entered into with the F. Gutekunst Company, of Philadelphia, for furnishing, on account of the joint commission, 300 half-tone plates of selected views. These selections comprise 260 views of new monuments, 8 views of old monuments, and 32 special subjects, as specified in the following list:

Views selected by the engineers in chief for illustrating the joint report of the International Boundary Commission, United States and Mexico.

Monument.	Kind of monument.	View to the—	Remarks.
No. 1	Stone	NE.	West bank Rio Grande.
No. 2	do	NW.	Summit of Mulero Mountains.
No. 3	do	SW.	Edge of mesa.
No. 4	Iron	SE.	On desert.
No. 5	do	NW.	Do.
No. 6	do	SW.	Do.
No. 7	do	NW.	Do.
No. 8	do	SE.	Do.
No. 9	do	NE.	Do
No. 10	do	NW.	Do.
No. 11	Stone	NE.	Site of old monument southwest of Potrillo Mountains.
No. 12	Iron	W.	On mesa.
No. 13	do	NW.	On south slope of ridge near The Camel.
No. 14	do	W.	On high, sharp ridge.
No. 15	Stone	NE.	Overlooking Las Palomas Valley.
No. 16	Iron	NE.	East of Las Palomas Valley.
No. 17	do	NW.	Las Palomas Valley.
No. 18	do	NW.	Do.
No. 19	do	NE.	Do.
No. 20	do	NE.	Do.
No. 21	Stone	NW.	North of Las Palomas Lakes.
No. 22	Iron	NW.	Las Palomas Valley, east of Columbus.
No. 23	do	NE.	Las Palomas Valley, west of Columbus.
No. 24	do	N.	On Mal Pais Ridge.
No. 25	do	N.	On slope of hill south of Tres Hermanas Mountains.
No. 26	Stone	NE.	On summit of hill south of Tres Hermanas Mountains.
No. 27	Iron	NW.	In valley southwest of Tres Hermanas Mountains.
No. 28	do	NW.	Do.
No. 29	do	NW.	Do.
No. 30	do	W.	Do.
No. 31	do	NW.	On first ridge of Carrizalillo Hills.
No. 32	Stone	NW.	On summit of Carrizalillo Hills.
No. 33	do	NW.	In valley south of Carrizalillo Spring.
No. 34	Iron	NE.	On plain west of Carrizalillo Spring.
No. 35	do	W.	Do.
No. 36	do	W.	Do.
No. 37	do	W.	Do.
No. 38	do	NW.	On eastern ridge of Sierra Rica.

Views selected by the engineers in chief for illustrating the joint report of the International Boundary Commission, United States and Mexico—Continued.

Monument.	Kind of monument.	View to the—	Remarks.
No. 39	Iron	NW.	On ridge of Apache Mountains.
No. 40	Stone	W.	At northwest corner, intersection of parallel and meridian.
No. 41	Iron	SE.	High ridge of Sierra Rica, meridian section.
No. 42	do	SW.	South slope Sierra Rica.
No. 43	do	SW.	Do.
No. 44	do	SE.	Do.
No. 45	do	SE.	Do.
No. 46	Stone	SW.	Near Mosquito Springs.
No. 47	Iron	SW.	On plain south of Mosquito Springs.
No. 48	do	SW.	Do.
No. 49	do	SW.	Do.
No. 50	do	SW.	Do.
No. 51	do	SE.	Do.
No. 52	do	NW.	On Rocky Ridge.
No. 53	Stone	N.	South end of line on meridian section.
No. 54	Iron	W.	On plain east of Dog Mountains.
No. 55	do	W.	Do.
No. 56	do	NW.	On first ridge of Dog Mountains.
No. 57	do	NW.	Summit of Dog Mountains.
No. 58	do	NW.	On Dog Mountains.
No. 59	do	W.	Do.
No. 60	do	W.	In Playas Valley.
No. 61	do	W.	In Whitewater Hills.
No. 62	do	E.	Do.
No. 63	do	SW.	In valley.
No. 64	Stone	E.	On slope of San Luis Mountains
No. 65	do	N.	On summit of San Luis Mountains.
No. 66	do	NE.	At west foot of San Luis Mountains.
No. 67	do	NW.	In valley on old dam.
No. 68	Iron	NW.	In Las Animas Valley.
No. 69	do	W.	Do.
No. 70	do	W.	On high peak of Guadalupe Mountains.
No. 71	do	W.	On Arizona and New Mexican Boundary.
No. 72	do	W.	On summit of High Mountain.
No. 73	Stone	NW.	In Guadalupe Cañon.
No. 74	Iron	NW.	On mesa west of Guadalupe Cañon.
No. 75	do	NW.	Do.
No. 76	do	W.	Do.
No. 77	Stone	SW.	West of San Bernardino River.
No. 78	Iron	W.	On low ridge.
No. 79	do	W.	On low ridge of Perilla Mountains.
No 80	do	NW.	On high ridge of Perilla Mountains.
No. 81	do	SW.	On summit of Perilla Mountains.
No. 82	Stone	SE.	In hills near Gallardo Mountain.
No. 83	Iron	SW.	On low ridge west of Gallardo Mountain.
No. 84	do	E.	On plain west of Gallardo Mountain.
No. 85	do	W.	Do.
No. 86	do	W.	Do.
No. 87	do	W.	Do.
No. 88	do	W.	Do.
No. 89	do	W.	On slope east of Mule Mountains.
No. 90	do	E.	On low hill of Mule Mountains.
No. 91	do	SE.	Do.
No. 92	do	W.	On plain west of Mule Mountains.
No. 93	do	E.	Do.
No. 94	do	W.	Do.
No. 95	do	SW.	On slope west of Mule Mountains.
No. 96	do	W.	Do.
No. 97	do	SW.	Do.
No. 98	Stone	W.	West of San Pedro River.
No. 99	Iron	E.	On mesa west of San Pedro River.
No. 100	do	NW.	On Huachuca Mountains.
No. 101	do	NW.	Do.

Views selected by the engineers in chief for illustrating the joint report of the International Boundary Commission, United States and Mexico—Continued.

Monument.	Kind of monument.	View to the—	Remarks.
No. 102	Iron	NW.	On Huachuca Mountains.
No. 103	do	W.	In west foothills of Huachuca Mountains.
No. 104	do	W.	Do.
No. 105	do	NE.	On high ridge.
No. 106	Stone	W.	On wide plain.
No. 107	Iron	SW.	Do.
No. 108	Stone	W.	Near Zorrillo Creek.
No. 109	Iron	W.	On ridge.
No. 110	do	E.	Do.
No. 111	Stone	NE.	West of Santa Cruz River.
No. 112	Iron	W.	On hill west of La Noria.
No. 113	do	W.	On east slope of Patagonia Mountains.
No. 114	do	W.	On high ridge of Patagonia Mountains.
No. 115	do	SW.	Do.
No. 116	do	W.	At west base of Patagonia Mountains.
No. 117	do	W.	On mesa west of Patagonia Mountains.
No. 118	Stone	W.	On east bank of Santa Cruz River.
No. 119	Iron	E.	On hill near wagon road.
No. 120	do	E.	On High Mountain.
No. 121	do	W.	On ridge east of Nogales.
No. 122	do	NW.	At Nogales.
No. 123	do	W.	On low ridge west of Nogales.
No. 124	do	W.	In Pajaritos Mountains.
No. 125	do	NE.	Do.
No. 126	do	NE.	Do.
No. 127	Stone	NE.	West end of line on parallel 31° 20′.
No. 128	Iron	NW.	On ridge of Pajaritos Mountains.
No. 129	Stone	E.	Do.
No. 130	Iron	NW.	Do.
No. 131	do	NW.	Do.
No. 132	do	NE.	Do.
No. 133	do	E.	Do.
No. 134	do	W.	On mesa.
No. 135	do	E.	Do.
No. 136	Stone	NW.	On Fresnal Mountain.
No. 137	do	NW.	On high, rocky hill.
No. 138	Iron	W.	On low hill.
No. 139	do	E.	Do.
No. 140	do	SW.	Do.
No. 141	Stone	W.	On crest of Pozo Verde Mountains.
No. 142	Iron	W.	On mesa west of Pozo Verde Mountains.
No. 143	do	NW.	Do.
No. 144	do	W.	Do.
No. 145	do	NW.	Do.
No. 146	Stone	NE.	On Moreno Mountains.
No. 147	Iron	E.	On west slope of Moreno Mountains.
No. 148	do	W.	Do.
No. 149	do	W.	Do.
No. 150	Stone	W.	Near road and high rock.
No. 151	Iron	NW.	Open level country.
No. 152	do	W.	Do.
No. 153	do	W.	On Lesna Mountain, very precipitous.
No. 154	do	W.	On rolling plain.
No. 155	do	NW.	Do.
No. 156	do	W.	Do.
No. 157	do	NW.	Do.
No. 158	do	W.	Do.
No. 159	do	NW.	On spur of Nariz Mountains.
No. 160	Stone	NW.	On crest of Nariz Mountains.
No. 161	Iron	SW.	In Santa Rosa Valley.
No. 162	Stone	NW.	On crest of Santa Rosa Mountains.
No. 163	Iron	NW.	On steep spur of Santa Rosa Mountains.
No. 164	do	SW.	In level country west of Santa Rosa Mountains.

Views selected by the engineers in chief for illustrating the joint report of the International Boundary Commission, United States and Mexico—Continued.

Monument.	Kind of monument.	View to the—	Remarks.
No. 165	Iron	W.	In level country west of Santa Rosa Mountains.
No. 166	do	E.	Do.
No. 167	do	NW.	Do.
No. 168	Stone	NW.	On high hill near Sonoyta.
No. 169	Iron	E.	On mesa west of Sonoyta.
No. 170	do	NW.	Do.
No. 171	do	NW.	On hill west of Sonoyta.
No. 172	do	W.	Near Quitobaquita Springs.
No. 173	do	NW.	On hilly mesa.
No. 174	do	W.	On plain.
No. 175	Stone	NW.	On high, rocky hill.
No. 176	Iron	N.	On ridge south of Quitobaquita Mountains.
No. 177	do	NW.	On mesa.
No. 178	do	NW.	On high, lava hill.
No. 179	do	E.	On high hill.
No. 180	do	NW.	On Tule Desert.
No. 181	do	W.	Do.
No. 182	do	N.	Do.
No. 183	do	W.	Do.
No. 184	do	NW.	On Tule Mountains.
No. 185	do	NW.	On high, rough peak of Tule Mountains.
No. 186	do	SW.	On crest of Tule Mountains.
No. 187	do	W.	On west ridge of Tule Mountains.
No. 188	do	NW.	In valley west of Tule Mountains.
No. 189	do	W.	On Lechuguilla Mountains.
No. 190	do	W.	Near east base of Tinajas Altas.
No. 191	do	W.	On crest of Tinajas Mountains.
No. 192	do	E.	On ridge west of Tinajas Mountains.
No. 193	do	W.	On Yuma Desert.
No. 194	do	E.	Do.
No. 195	do	E.	Do.
No. 196	do	E.	Do.
No. 197	do	W.	Do.
No. 198	do	E.	On Volcanic Ridge, Yuma Desert.
No. 199	do	W.	On Yuma Desert.
No. 200	do	W.	Do.
No. 201	do	E.	Do.
No. 202	do	W.	Do.
No. 203	do	W.	Do.
No. 204*	do	NW.	On mesa east of Colorado River.
No. 205	do	W.	In river bottom, east side Colorado.
No. 206	do	W.	In river bottom, west side Colorado.
No. 207	Stone	W.	On mesa near Pilot Knob.
No. 208	Iron	NW.	On mesa west of Pilot Knob.
No. 209	do	NW.	On sand hills west of Pilot Knob.
No. 210	do	W.	Do.
No. 211	do	SW.	On Colorado Desert.
No. 212	do	W.	Do.
No. 213	do	W.	Do.
No. 214	do	SW.	Do.
No. 215	do	NW.	Do.
No. 216	do	W.	Do.
No. 217	do	NE.	Do.
No. 218	do	W.	In Salton Valley.
No. 219	do	E.	Do.
No. 220*	do	NE.	East of New River.
No. 221*	do	NW.	West of New River.
No. 222	do	NE.	In New River Valley.
No. 223	do	W.	Lowest point on boundary.
No. 224	do	SW.	On spur of Signal Mountain.
No. 225	do	W.	Do.
No. 226	do	SW.	On Colorado Desert.
No. 227	do	E.	Do.

* Old iron monuments repaired.

Views selected by the engineers in chief for illustrating the joint report of the International Boundary Commission, United States and Mexico—Continued.

Monument.	Kind of monument.	View to the—	Remarks.
No. 228	Iron	NW.	On Colorado Desert.
No. 229	do	NW.	On high, rough ridge.
No. 230	do	S.	On high ridge of coast range.
No. 231	do	W.	On summit of coast range.
No. 232	do	W.	In saddle of high mountain.
No. 233	do	N.	On ridge near Jacumba Spring.
No. 234	do	W.	In Jacumba Cañon.
No. 235	do	S.	On bowlder.
No. 236	do	E.	On hill in Coast Range.
No. 237	do	NW.	Do.
No. 238	do	SE.	Do.
No. 239	do	NW.	Do.
No. 240	do	E.	Do.
No. 241	do	N.	On high ridge.
No. 242	do	SW.	Do.
No. 243	do	W.	On high hill.
No. 244	do	NW.	Near road south of Potrero.
No. 245	do	NW.	In valley east of Mount Tecate
No. 246	do	NW.	On east crest of Mount Tecate.
No. 247	do	N.	On west crest of Mount Tecate.
No. 248	do	SW.	On sharp ridge, west slope of Mount Tecate.
No. 249	do	SW.	On ridge west of Cottonwood Valley.
No. 250	do	W.	On ridge in Tijuana Valley.
No. 251	do	NW.	On south slope of Otay Mountain.
No. 252	Stone	NE.	On Otay Mesa.
No. 253	Iron	W.	Do.
No. 254	do	W.	Do.
No. 255	Granite	SW.	Near Tijuana River.
No. 255	do	SE.	Do.
No. 256	Iron	NW.	On mesa west of Tijuana River.
No. 257	do	NW.	On high mesa near Pacific Ocean
No. 258	Marble	NW	Old initial monument, recut.
No. 258	do	SE.	Do.

Old monuments and scenery.

United States custom-house, El Paso.
Parish church at Juarez.
Type of new monument, showing base.
Camp No. 1 of United States section on Rio Grande.
Old Monument No. XVI, East.
Rebuilding Monument No. 40, north end of meridian section.
Mosquito Spring.
Old monument at south end of meridian section.
Camp of United States section at Dog Spring, New Mexico.
Old Monument No. XII on Sierra de la Nariz.
Turkey Cañon, near Monument No. 66.
Old monument between New Mexico and Arizona.
Old monument at San Bernardino Ranch, Ariz.
Camp of Mexican section at San Bernardino, Ariz.
San Bernardino Springs.
Mexican custom-house, La Morita.
Camp of monument party at Bisboe.
Main camp of United States section at La Noria.
View on wagon road east of Nogales.
Old Monument No. 26, Nogales.
International street, Nogales.
Nogales, looking NE.
Mexican custom-house, Nogales, Sonora.
Mexican consulate, Nogales, Ariz.
Old mission, San Jose de Tumacacori.
Old mission, San Xavier del Bac.
Erecting Monument No. 153 on Cerro de la Lesna.
Giant cactus, near Tule Mountains.
Sonoyta River, Sonora.
Trail to site of Monument No. 184.
Monument No. 184.
Camp of Mexican section near Lechuguilla Mountains.
Las Tinajas Altas.
Observatory at Monument No. 204.
Old Monument No. II.
View of Yuma.
Barranca Verde Ranch, California.
Camp of Mexican section at Hot Springs, Tijuana River.
Astronomical Observatory, Tijuana.
Old Monument No. I on Pacific.

BIOLOGICAL WORK.

Capt. E. A. Mearns, assistant surgeon, U. S. A., was detailed by the War Department to act as medical officer for the commission, with the understanding that he would, in addition to his professional duties, make collections of natural history along the boundary for the benefit of science.

Barranca Verde Ranch, California.

Rancho de Barranca Verde, California.

Dr. Mearns proved himself to be a most efficient medical officer and an indefatigable and successful collector. His services with the commission extended from January, 1892, to September, 1894, excepting a few months during which he was assigned to duty at Fort Clark, Tex. This interruption did not, however, prevent him from covering the entire boundary line, as he was able, by joining the monument party at a later period, to take up his biological work at the exact point where he had left it on being ordered to Fort Clark. His researches along the whole line were therefore continuous.

During this period monthly reports of military and professional duties, in the capacity of surgeon of the party, were made by him to the War Department, and monthly reports on the biological and other collections, and facts relating thereto, were forwarded through the commission to the State Department.

The scientific work accomplished was of the nature of a biological survey of the Mexican boundary region, and agrees essentially with the plan which was submitted to the commission in January, 1892, before entering the field. Plants, vertebrate animals (mammals, birds, reptiles, batrachians, and fishes), molluscs, crustaceans, rocks, minerals, fossils, and a small amount of archæological and miscellaneous materials were embraced in the collections, which were deposited in the United States National Museum.

About 100 collecting stations were occupied during the course of the survey, which extended over a period of nearly three years, and covered an extent of 700 miles of the boundary. Dr. Mearns has been stationed at three military posts on the Rio Grande in Texas, and had previously served for more than four years in the Territories of Arizona and New Mexico. At each of these posts, as well as at each of the collecting stations on the boundary line, an effort was made to procure and preserve specimens of each vertebrate animal and flowering plant that could be found, in order that the collections might furnish indisputable evidence of the longitudinal dispersal and variation of as many species as possible.

It seemed important that the exceptional facilities afforded by this survey for studying the degree and manner in which plants and animals vary along a parallel, and if possible the laws which govern such variations, should be utilized as fully as possible. To this end much time was devoted by Dr. Mearns to gathering abundant material to show the distribution, and variation with locality, of the several species. The longitudinal ranges of the species and subspecies (geographic races) were carefully defined, and an approximately accurate knowledge of the character and extent of the faunal and floral tracts crossed by the boundary line was obtained.

The collections were made by Dr. Mearns, with the occasional voluntary assistance of other members of the party, and of Mr. F. X. Holzner, a collector employed at the doctor's request by the United States National Museum, and the American Museum of Natural History, in New York.

A detailed report upon these collections is now being prepared by several specialists to whom the materials of different classes have been distributed. A report upon the Mollusca, with illustrations, has been completed by Dr. W. H. Dall, and will soon be published. Miss Mary J. Rathbun has prepared an annotated list of the Crustacea collected, and more or less progress has been made upon the other groups. The Mammal report, by Dr. Mearns, is approaching completion, and a chapter on the birds, also by him, is expected to follow. The mammal collection aggregates about 4,000 specimens, and the bird collection nearly 8,000 specimens. The collections as a whole compare favorably with those made by any other Government scientific expedition, and number about 30,000 specimens, of which number about 10,000 are flowering plants, upon which Mr. F. V. Coville is engaged in preparing a special report.

Several preliminary papers containing descriptions of species new to science and based upon this material have been recently published.

FINANCIAL STATEMENT.

a. The field operations from February, 1892, to May, 1895.

Appropriations were made by Congress for the expenses of an International Boundary Commission, to survey and re-mark the existing frontier between the United States and Mexico, as follows:

By acts approved—		
March 3, 1885	$100, 000. 00	
September 30, 1890	75, 000. 00	
August 5, 1892	50, 000. 00	
		$225, 000. 00
In addition the following amounts disbursed on certain accounts have reverted to appropriation:		
From Mexican Government, being its share of cost of construction and erection of monuments	$20, 068. 64	
From sales of equipment and subsistence	6, 736. 08	
		26, 804. 72
Total		251, 804. 72

The field operations, which included the survey, the preparation of preliminary maps, the construction and erection of monuments, and photography, were carried on from February, 1892, until May, 1895. The principal objects to which the expenditures were applied, and their amounts in each case, are shown in the following list:

Astronomy:	
(1) Longitude party	$1, 560. 60
(2) Latitude and azimuth party	9, 447. 08
Tangent and monument locating parties	15, 198. 63
Topographical parties	51, 056. 71
Photography	5, 684. 96
Construction and erection of monuments	40, 501. 78
General office and commission expenses	58, 225. 97
Transportation	69, 424. 90
Balance on hand at close of field work	701. 90
Total	251, 801. 72

In this list the item "Construction and erection of monuments" includes transportation pertaining thereto, which sum, $16,591.06, is omitted from the item of general transportation, and should be added to obtain the gross amount, as shown in the next table.

The following is a combined table in which the columns show the cost of the different supplies as distributed among the general divisions of the work. These columns are added first in a line of totals without transportation, and finally with the approximate cost of transportation included:

General items.	Astronomy.		Running tangents and locating monuments.	Topography.	Photography.	Construction and erection of monuments.	General office and commission expenses.	Transportation.	Total.
	Longitude by telegraph.	Latitude and azimuth.							
Services	$320.42	$6,213.00	$11,232.96	$39,715.11	$3,988.08	$8,791.29	$52,941.55	$25,714.19	$148,916.60
Subsistence	958.00	720.00	2,852.65	8,617.67	400.80	1,563.63	1,879.25	5,903.52	22,895.52
Fuel		39.75	68.75	164.29			60.00		332.79
Forage								17,083.21	17,083.21
Water		38.59	163.24	367.31	21.68	165.82		1,024.00	1,720.64
Tentage		262.52	176.03	433.13	25.00		25.00	230.42	1,152.10
Photographic equipment and supplies					1,171.15				1,171.[illegible]5
Furniture and office supplies	1.25	53.65	79.20	227.36			1,878.36		2,239.82
Instruments	6.15	1,934.35	281.95	968.21					3,190.66
Repairs and appliances	194.20	169.72	254.15	458.05	35.25	287.75	86.72	3,481.43	4,967.27
Tools	1.10	15.50	89.70	165.58			12.25	284.12	568.25
Monuments and parts						11,559.38			11,559.38
Cement and lime						1,529.18	110.68		1,639.86
Rents and storage	2.65				43.00	17.67	1,158.90		1,222.22
Telegraph service	74.93						48.89		123.82
Postal service	1.90						24.37		26.27
Total	1,560.60	9,447.08	15,198.63	51,056.71	5,684.96	23,913.72	58,225.97	53,731.89	218,809.56
Maintenance of transportation		2,980.05	5,490.60	19,510.30	1,989.65	10,416.94	13,334.35	53,721.89	
Equipment for wagon and pack transportation		221.49	6,222.57	9,110.22	50.00			15,604.28	15,604.28
Wagon hire and ferriage	77.55		19.25	60.50	2.50	2,582.22	231.05	2,973.07	2,973.07
Transportation, rail	1,261.55	434.56	1,562.03	5,775.69	172.30	3,591.90	918.69	13,716.72	13,716.72
Total transportation								86,015.96	
Total	2,899.70	13,083.18	28,493.08	85,513.42	7,899.41	40,504.78	72,710.06		251,103.63

The final column of this table shows the total cost of each general article of supply, as services, subsistence, etc. To *accurately distribute* the cost of transportation so as to show the proportionate amount to each article of supply is impracticable, as the records were not kept with that view.

In the case of certain supplies, notably water, the purchase price represents but a minor part of the entire cost delivered at the camps, as in some instances water was hauled by rail and wagons over 100 miles, and frequently more than 40 miles by wagons alone.

A close estimate of the cost of transporting the water used by the United States section of the boundary survey can be obtained by computing the cost of maintaining the several water tank wagons used exclusively for supplying water.

Three of these wagons were used from the beginning to near the close of operations, and a fourth during a shorter period. The cost of maintaining each of these wagons averaged $105 per month; the number of months during which all the water wagons were in use was equal to 96 for one wagon, making cost of maintaining $10,080, to which should be added the original cost of the equipment less the amount received from its sale, giving $12,500 as the cost of transportation of water. If there be added the payments for water purchased, and a due proportion of the cost of supervision of transportation, the aggregate cost of water used would be shown to be about $16,000. The supply used by the escort was provided by its own tank wagon, and does not appear in the above computation.

In the same way it might be shown that the cost of forage, subsistence, etc., delivered at the camps was largely in excess of the first cost of those articles.

The column next to the final one shows the several items which make up the aggregate of the transportation. Its approximate distribution is shown under the different divisions of the work.

Although this entire sum of $86,015.96 was disbursed for transportation, it should be diminished by the net receipts on account of sales of equipment in order to show the exact cost to the appropriation. Likewise, from the aggregate sum of all the disbursements should be taken the amount received from the Mexican Government as a reimbursement, and the full amount received from sales, etc. This would leave $224,298.91 as the true amount applied from the original appropriations to the field work; if to this the balance of $701.09 be added, the result will equal the total appropriation, $225,000.

b. The office work, preparing reports and maps, from October, 1895, to November, 1896.

Balance remaining from previous appropriations		$701.09
Amount disallowed on previous accounts and refunded		1.57
Amount appropriated by act of Congress approved February 26, 1896		20,000.00
Total		20,702.66
Expended in compliance with the act, as follows:		
Salaries, draftsmen, preparing maps	$2,385.62	
Salaries, clerical, etc	1,735.95	
Engraving 20 copperplates, one-half cost	4,135.00	
Electrotyping same, one-half cost	1,000.00	
Preparing half-tone plates of 300 photographs and printing proofs	239.70	
Photolithographing, profiles	200.00	
Photolithographing, miscellaneous sheets	16.00	
Rent of office	1,052.50	
Furniture and office supplies	422.75	
Incidentals	255.64	
	13,543.16	
Balance on hand at completion of final report	7,159.50	
		20,702.66

CHAPTER IX.

DESCRIPTION OF MAPS, PROFILES, AND PLATES.

A map of the entire boundary line from the Rio Grande to the Pacific in 18 sheets, on a scale of 1÷60,000, accompanies this report. The sheets are each 1 meter long and show a belt of topography of 5 miles in width, 2½ miles on the north side of the line being drawn from the surveys of the United States section of the commission, and a width of 2½ miles on the south side of the line drawn from the surveys made by the Mexican section of the commission. Each monument is located in its true position on these sheets.

One additional sheet, making 19 sheets in all, shows the Rio Colorado where it forms part of the boundary. As this river was surveyed in March, 1893, by the United States section, and in February and March, 1894, by the Mexican section, the channel of the river is not the same, as determined by the two sections, and the two surveys are shown on one sheet by printing the maps of the two surveys in different colors.

Five sheets of profile of the boundary on a scale of 1÷60,000 horizontal and 1÷6,000 vertical are submitted. This profile is drawn from the levelings of the United States section, and gives the height of the masonry base of each monument above mean sea level of San Diego Bay.

An index map of the boundary line in 2 sheets, on a scale of 1÷600,000, is also submitted. This map shows the limits of each of the 19 sheets of the boundary, and also gives the location and the height of all the principal peaks in the vicinity of the boundary line as determined by the United States section of the commission, and also the roads, trails, springs, wells, and water holes as determined by the surveys of the United States section.

The railroads, roads, and settlements distant from the boundary line were compiled from the best maps available, including county maps of New Mexico, Arizona, and California, the United States Land-Office maps, those of the War Department, etc. The coast line of the Pacific north of the boundary was taken from the Coast and Geodetic Survey charts, and the coast of Lower California and the shore line of the Gulf of California from Hydrographic Office maps of the United States Navy Department.

The maps of the boundary submitted, including the index sheets, are prints from 22 copperplates, which are preserved for future use. These plates will admit of but a limited number of clear impressions (about 4,000 or 5,000); therefore, if a larger edition is required, the printing should be done either from electrotype copies of these plates or by photolithography.

The drawings of the profiles were not engraved; the 20 copies submitted were made by photholithography at the establishment of the Norris Peters Company, where other editions can be obtained from the photographs retained there.

CHAPTER X.—APPENDIX.

REPORT OF LEONARD SEWAL SMITH, ASSISTANT PROFESSOR, UNIVERSITY OF WISCONSIN, ON THE CAUSES OF SYSTEMATIC ERROR IN STADIA WORK.

[Mr. Smith served as transitman on this survey.]

AN EXPERIMENTAL STUDY OF FIELD METHODS WHICH WILL INSURE TO STADIA MEASUREMENTS GREATLY INCREASED ACCURACY.

I. Introduction.

The rapidly increasing interest in the subject of stadia measurements, due to its widening field of application, is bringing about a revolution in some of the established methods of field practice in this country. The superiority of the stadia, both in accuracy and in cost, over the chain in broken country is already firmly established, and late experience has shown equal merit in the measurements of long lines in flat regions.

The method is especially adapted for taking topography and hydrography,* with or without the control of a triangulation, for meandering roads and rivers, and for making preliminary railroad surveys.† The writer's conclusions, given in this report, show that the method has a much wider field of usefulness.

The collection of data for this report was begun during the field work of the International Boundary Survey, United States and Mexico, 1892–93, merely as a study of a certain atmospheric phenomenon, commonly called by engineers "boiling." In the summer of 1894 this work was continued in Wisconsin, but was also made to include an experimental study of the effect of this "boiling" of the air upon the accuracy of stadia measurements. During this latter work the all-important effect on such work, of what the writer has called differential refraction, was forced upon his attention and studied in detail. This part of the study, it is believed, furnishes the most valuable results of the whole investigation, for it is here shown that in this unsuspected phenomenon lies the reason that the accuracy of stadia measurements has in the past been limited to about 1/700.

It is well known among engineers that measurements made by the link chain, *as commonly used*, are subject to large systematic errors, principally due to wearing at its several hundred bearing surfaces, failure to hold it horizontally, expansion, and stretch.

On the other hand, since stadia measurements are subject theoretically only to compensatory errors, to insure superior results it should only be necessary to secure small probable errors of single sights. Practical results, however, have been uniformly disappointing, for, while the accidental errors of observation have always been within proper limits, *care has not been taken* to remove the causes of *systematic* errors, chief among which is what the writer has called *differential refraction*. That such systematic errors can be prevented or greatly modified by improved field methods the experimental work discussed by this paper seems clearly to have proved. This report gives the writer's results to date, but it is believed that the subject is worthy of continued study.

It is hoped that the method here used of investigating facts by extensive experiments rather than by purely theoretical considerations may appeal to the confidence of the practical field engineer. The writer's thanks for criticisms and suggestions upon the plan of the work are due

* For a description of such a survey see paper by J. L. Van Ornum in Journal of the Association of Engineering Societies, Vol. XIV, p. 219.

† See description of such a survey in Journal of the Association of Engineering Societies, Vol. XII, p. 411.

to Prof. J. B. Johnson and Mr. J. L. Van Ornum C. E., of Washington University; Prof. Wm. Raymond, of Rensselaer Polytechnic Institute; Prof. Ira O. Baker, of the University of Illinois; Mr. B. H. Colby, of St. Louis, and Mr. A. C. Schrader, C. E., of the Chicago sanitary district; but especially are his thanks due to Prof. George C. Comstock, of the University of Wisconsin, who, by reason of his long-continued and painstaking study of atmospheric refraction, has been able to make clear the significance of much experimental work.

II. STUDY OF ATMOSPHERIC UNSTEADINESS.

This report will deal with, first, the behavior of the air under various atmospheric conditions; second, the effect of such behavior in producing accumulative errors of stadia measurements, and, third, a discussion of the proper remedy. Experiments to determine the first point were made in the years 1892–93 while the writer was engaged as transit man and topographer on the International Boundary Survey between the United States and Mexico.

The whole line from El Paso to the Pacific Ocean, a distance of about 700 miles, was measured by the stadia method, and all accurate contour topography in a 2½-mile be t along nearly the whole distance was taken by the transit and stadia. The first 100 miles was also measured by chain,* and a former triangulation, and longitude determinations by the United States Coast and Geodetic Survey gave additional checks.

All connected with this work were early impressed by two facts, namely, the surprisingly high degree of accuracy and speed obtainable by the stadia, and the completeness with which this accuracy and speed were governed by the peculiar unsteadiness of the air, which engineers call "boiling" or "vibration."

With a view to discovering, if possible, the conditions governing this "boiling," a series of observations were recorded as fully as at first seemed necessary.† Only odd hours were at first given to the purpose; but later, while camped at the east base of the Tule Mountains, and near the middle of the Yuma Desert, a more extended and valuable series of observations was taken. The first observations were made on the New Mexico line, June 19, 1892, and the last on the Arizona line, July 25, 1893. This work has also been continued in Wisconsin.

(*a*) *Method of work.*—The first observations are lacking in data which afterwards were found to be very essential, namely, the temperature of the air when observations were taken, and the number of vibrations per minute of the recorded amplitude.

In these experiments 6-inch Brandis transits, weighing (including tripod) 25 pounds each, were used. The average focal length of these was 19 cm. and the constant *c* was 10 cm. The telescope magnified about 20 diameters and gave remarkably good definition. The rod was graduated in the metric system in the manner shown by fig. 1 (pl. 1). Its total length was 4.5 m., width 0.1 m., and thickness 2¼ cm. The characters were white and black, with red at the meter and half meter points in place of the black.

The target used was made by painting on the back of the stadia rod and at a distance of 2 m. from its foot black and white stripes of the width indicated in fig. 2 (pl. 1); but later, when paint became scarce, strips of black and white cloth were used instead.

The method of work was as follows: A rodman was sent in a given direction, with instructions to show the graduated face of his rod at every 100 or 150 paces, and to follow this, on signal, by the back containing the target. The first movement allowed the stadia to be read, and the second allowed the amplitude of the heat waves at that distance to be studied. This was continued for a distance never greater than 1,000 meters (five-eighths of a mile) and usually less than 800 meters (one-half mile). The limitation of distance was made for two reasons: first, beyond 800 m. the target became so irregular and indistinct that, except under very favorable circumstances, results were comparatively worthless, and, second, as in taking topography but few sights exceed 800 m., tests on longer distances were without interest.

In observing the middle horizontal cross wire was, by means of the gradienter screw, always put so as to bisect one of the stripes of the target, selecting for the experiment that stripe which was found would most nearly equal the amplitude of the vibration.

* In this first 100 miles the writer's stadia measurement detected six errors of 20 meters each (i. e., a whole chain). Both chain men were intelligent men and had had previous experience in similar Government work.

† This work was begun at the suggestion of Mr. J. L. Van Ornum, assistant engineer.

Later it seemed desirable to record the number of such vibrations per minute, and for ease in observing them the apparent swing of the wire from one edge of the stripe to the other was called *one vibration;* then back to its original position, *two vibrations.* The wire having a considerable thickness, doubtless introduced an error because of the difficulty in judging the coincidence of the middle point with the upper and lower limit of the target. This error, affecting all sights in nearly the same ratio, would not necessarily change their relative amounts, which was the important thing sought. Moreover, each experiment was usually repeated several times, and the mean result recorded. This was necessary, since, during the hours of greatest disturbance, the number of vibrations during consecutive minutes would frequently differ greatly. The number of vibrations would even group themselves sometimes so that 20 seconds would contain as many vibrations as the following 60. These periods of greatest activity appeared to come in the intervals between the slight breezes, when the air was still. During such intervals the effects of the heat waves seemed to accumulate until at times the vibrations became too numerous to count, only to be blown aside by the next breeze, and the process repeated.

(*b*) *Lateral vibration.*—If the breeze became a steady and not too violent one, the air had the appearance, when viewed through the transit, of a mighty river rushing madly along in the direction of the wind. The effect of this movement upon the appearance of the rod was marked. The different areas of color (diamond shaped) changed form rapidly, the distortion consisting in irregular tongues of color leaping laterally from the general line of the rod and dovetailing into the adjoining color, so that the rod appeared to be bounded by a constantly changing, irregular line (fig. 3). The leeward side of the rod was always more affected by this disfigurement than the windward side.

Fig. 3.
Effect of Vibration on Target.

Except in very windy weather this lateral vibration seemed to have a progressive wave movement along the rod, and always *from the bottom toward the top*, giving to the rod a peculiar snaky appearance. The lateral vibration was always considerably greater at the bottom than at the top of the rod, and frequently equaled in amplitude the vertical vibration observed at the same distance.*

While this lateral vibration is of vital importance to correct pointings in the measurements of horizontal angles, it is believed that it only indirectly affects the accuracy of a stadia measurement by decreasing the distinctness of the image.† It was accordingly less carefully studied than other phenomena.

(*c*) *Vertical vibration.*—In addition to the lateral vibration in nearly every observation, two distinct classes of *vertical* vibrations were observed, differing both in amplitude and period. One class consisted in a very quick and comparatively uniform amplitude,

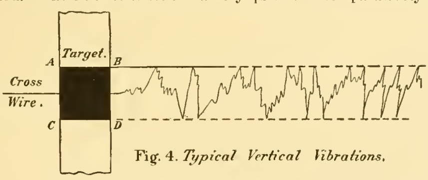


Fig. 4. *Typical Vertical Vibrations.*

and the second consisted in vibrations of much greater amplitude, but very much smaller in number per second. The latter will be called the *primary vibrations;* the former, the *secondary vibrations.*

*In making these experiments care was taken to guard against any movements of the transit, its parts all being firmly clamped. The tripod, too, was always firmly planted in the ground, and, when required to steady it, rocks were placed around the legs. It was early discovered that a stiff, gusty wind gave very irregular and unreliable results, in spite of all precaution, so that experiments were finally attempted only in favorable weather.

†This phase of the subject, with especial reference to pointings on heliotropes, has been very ably discussed by Mr. J. F. Hayford, assistant astronomer on the International Boundary Survey. See Appendix IV, Chapter IV, Report of the United States Section.

The manner in which these two systems would occur can be best shown by a diagram (fig. 4). Suppose the experiment was with the black stripe, A, B, C, D, one decimeter square. The middle cross wire was put so as to bisect the figure in the beginning, and was corrected anew whenever the amount of vibration above the middle line differed from that below the same line. If the cross wire could record its *apparent* motion in the same way that a vibrating tuning fork does when dragged along a smoked glass, it would describe a path like that in fig. 4. Thus, if B — D limits the extreme highest and lowest positions of the cross wire, i. e., the amplitude of the primary vibration, those positions will be reached only through the zigzag path constituting the secondary system of vibrations. In other words, the irregularities of the path may be considered due to the superimposed secondary vibration.

(*d*) *Vibration causes only accidental errors.*—In a general way, the primary vibrations seem to be less regular than the secondary, and, in the writer's judgment, affect to a greater extent the accuracy of a stadia measurement. This is true for the following reason: When a stadia measurement is made, the lower cross wire of the telescope is put on an even unit, and then the upper wire is instantly read. Now, if the only disturbance of the air was that due to the secondary vibration, the average position of either wire would remain nearly constant in position and could be readily found, so the intercept should be subject to but slight error.

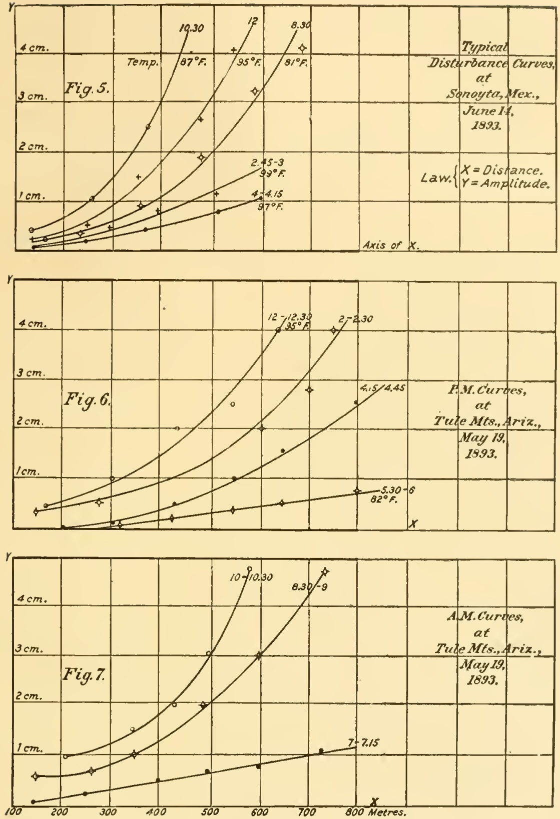
With both movements present, it is much more difficult to find the average position of the lower wire; and even when found, while the eye glances up to read the upper wire the irregular primary vibration may make the upper wire read seriously in error; nor can time be spared to study the average position of the upper wire, as was done with the lower one, because the telescope is constantly changing its position even when clamped, and though this movement occurs within small limits, it is large enough to make the previously determined position of the *lower* wire wrong, and so decrease the accuracy of the sight. When the vibration is excessive, this movement is sufficiently large to make any single reading seriously in error, but such errors are as likely to be *positive* as *negative*, and therefore follow the law of compensating errors. The cause of systematic error is evidently not here.

(*e*) *Typical curves.*—The manner in which the amount of this vibration is influenced by length of sight, hour of day, brightness of sun, and temperature can best be shown by typical curves representing actual observations. In fig. 5 the x abscissas of the curves are the lengths of sights in meters, and the y ordinates are the recorded amplitudes of the vertical swing of the cross wire. The time of greatest disturbance at the date and locality (Sonoyta, Mexico, June 14), represented by the curve, was 10.30 a. m.; and in general, all experiments in any season, show that the maximum unsteadiness of the air comes *not* during the hour when the air is at its maximum temperature, but during the hour when the *difference* in the temperature of the air and the earth is a maximum.* Thus, in figs. 5, 6, and 7 the maximum unsteadiness comes with a temperature of 87.6° F., and the minimum unsteadiness with a maximum temperature of 98.6° F., at 3 p. m. At 4 p. m. the falling temperature is followed by a decreased unsteadiness, and the fall is gradually accelerated until, at 6 o'clock, not the slightest glimmering is observable even at long distances.

In the summer a second maximum period of unsteadiness is observed just as the sun rises above the horizon, but it continues for only a half hour, after which interval the equilibrium of the air seems to be restored.†

* The unsteadiness of the air over the ice of Lake Mendota, Wisconsin, the present spring has been observed by the writer to be as great as it is in the middle of the Yuma Desert, with a temperature of 118° F. in the shade.

† The writer recalls one instance when his party began to determine the interval of transit before sunrise, but upon the appearance of the sun the increased unsteadiness compelled the postponement of the work. After a period of 30 or 40 minutes the air was quiet again and the work was completed without difficulty.



Figs. 5, 6, and 7.—Typical disturbance curves showing effect of hour of day and length of sight on the degree of unsteadiness. X = distance of sight. Y = amplitude of vibration.

The effect of both length of sight and hour of day is more clearly seen by reference to Fig. 8. Here the values of x are the hours of the day and those of y the amplitudes of the vibration of the line of sight. This curve may be said to be typical of sunny days during all except the cold winter months.

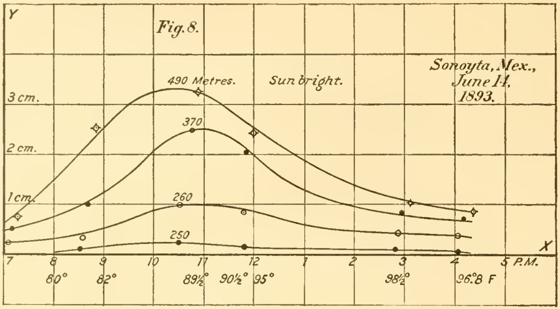


FIG. 8. Typical disturbance curves, showing the effect of time of day, temperature, and length of sight on degree of unsteadiness. X = time of day. Y = amplitude of vibration.

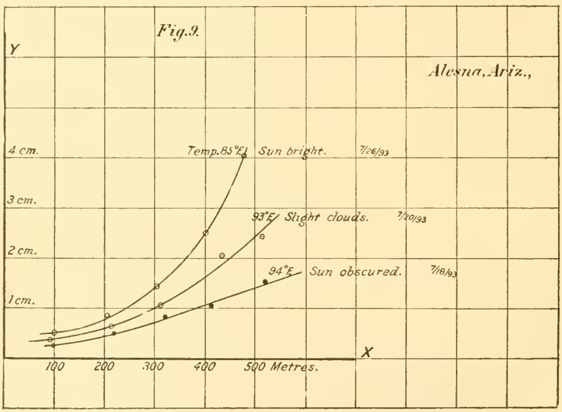


FIG. 9. Disturbance curves, showing effects of clouds on unsteadiness. X = distance of sight. Y = amplitude of vibration.

During a cloudy day, even with high temperature, but little unsteadiness is observed, and the curve representing the unsteadiness through the day would be a very flat one.

The effect of different amounts of clouds on this unsteadiness is clearly shown by fig. 9, which records a measurement of it at the same hour of different days, under almost exactly the same conditions (soil, vegetation, temperature, etc.), but differing in the amount of clouds present when the test was made. It will be seen that with the sun entirely obscured the curve is a straight line, with a bright sun an abrupt curve, and with the sun partly obscured the curve takes an intermediate position.

It is thought that the product of the number of vibrations per minute and their amplitude is a better measure of the amount of unsteadiness than either factor alone. Using this product for the values of y, and the hours of the day for values of x, the curves shown in figs. 10 and 11 are obtained, which very clearly indicate the hour of maximum unsteadiness, as well as the rate of change in the amount of unsteadiness as the length of sight is increased.*

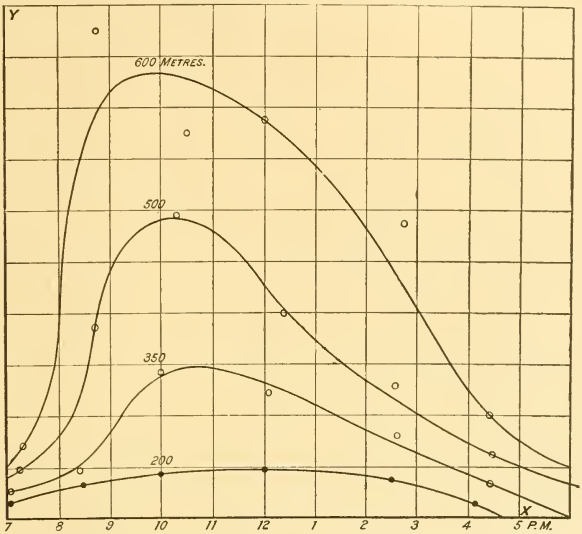


FIG. 10. Typical disturbance curves, showing effect of time of day and distance. Tule Mountains, Arizona. May 20, 1893. X Hour of observation. Y = Product of number of vibrations by their amplitude.

In fig. 12 the product of the number and the amplitude of the vibrations is used for the values of y and the *length of sight* for the values of x, giving a separate curve for *each hour* when tests were made. As in figs. 5, 6, and 7 a marked difference is seen in the curves representing the condition of the air three hours before noon from those representing its conditions three hours after noon, the latter indicating much less unsteadiness; and, in general, afternoon curves are flatter than forenoon curves, as is well shown in figs. 6 and 7. This probably means that, though the temperature of the air steadily increases up to 3 p. m., the temperature of the ground which, in the early morning had lagged behind that of the air, now increases *more rapidly* than the air, so that the actual *difference* in temperature of earth and air, which is the controlling cause of the unsteadiness, reaches a maximum by 11 o'clock, and then decreases as the day advances.

* The actual shape of the curves varies with a multitude of minor conditions besides those discussed, such as season, locality, vegetation, amount of moisture in air, soil, etc., but the curves given are selected from a large number as showing the average effect on unsteadiness of the conditions studied.

Another interesting example of the effect of clouds on the unsteadiness is illustrated in fig. 12. The field notes show that at about 10.45 a. m., and immediately after the test platted at M, the sun became obscured by a thick cloud. As a result the "boiling" at once decreased in amount, as

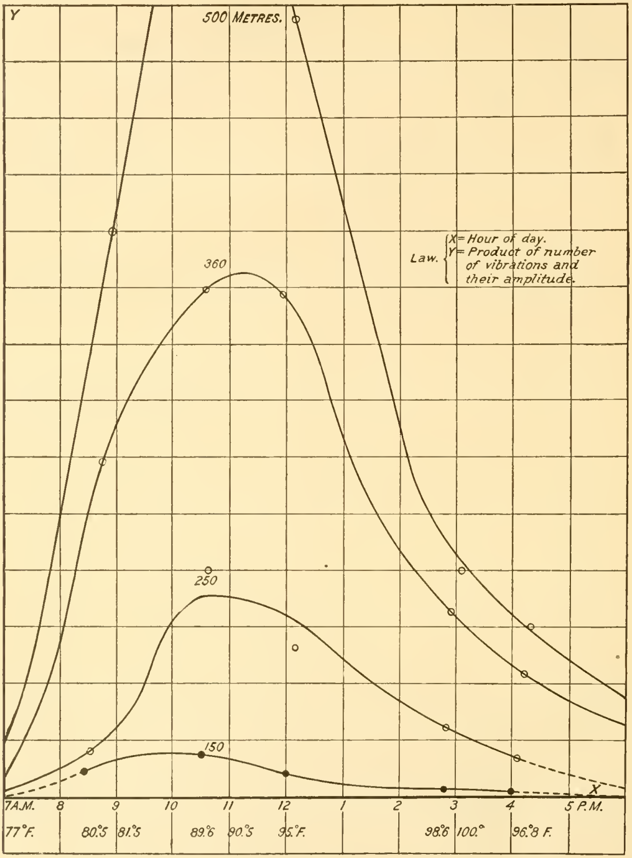


FIG. 11.—Disturbance curves, showing effect of hours and distance. Sonoyta, Mexico, June 14, 1893.

is shown by the abrupt descent of the curve from M M′. It was found that both the number and amplitude of the vibrations were increased when the sun shone on the rod, but the additional clearness of the image, because of better illumination, much more than compensated for the loss of same due to the increased unsteadiness of the air. Because of this, when making a test reading, the rodman was always sent in a direction which would allow the sun to shine on the rod, unless this was rendered impossible by the topogpaphy.

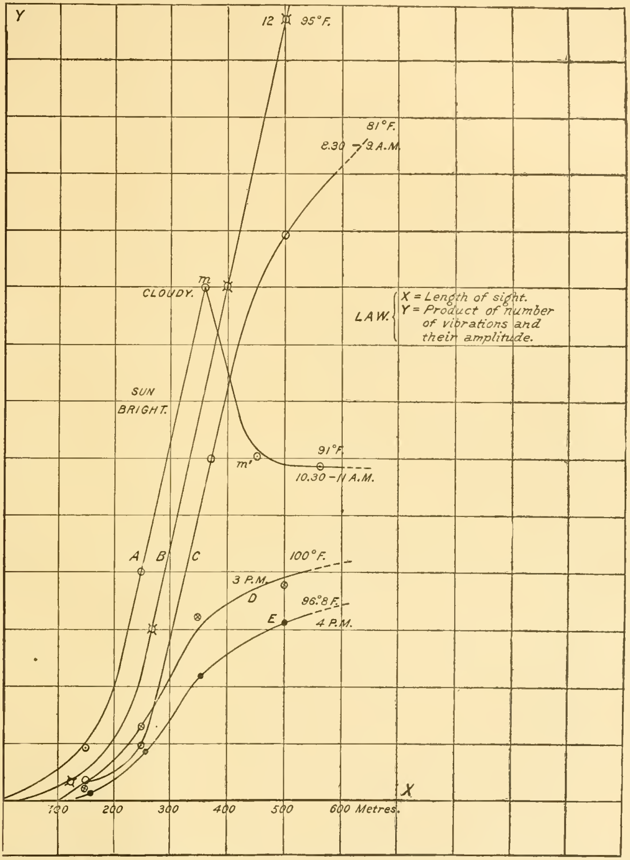


FIG. 12.—Disturbance curves showing effect of hour and distance, temperature and clouds, Sonoyta, Mex., June 14, 1893.

III. STUDY OF DIFFERENTIAL REFRACTION.

(*a*). *Relation between unsteadiness and refraction.*—It has been shown that the errors introduced into stadia work by the "boiling" or vibration of the air are *compensatory* in their nature; but, while engaged in studying such behavior of the air on a base line, in Wisconsin, during August, 1894, it was noticed that rod readings, made when such boiling was very marked, differed

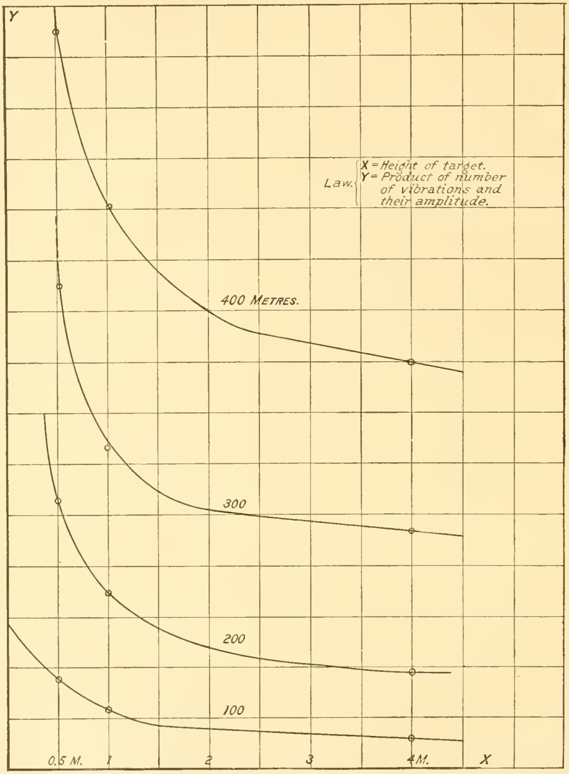


FIG. 13.—Disturbance curves, showing effect of height of line of sight. Temperature 95°–97° at 10 o'clock, Lesna Mountains, Ariz., July 25, 1893.

widely from those made under steady conditions of air. As this difference was found to be a *systematic* one, a careful study was made to determine its cause. It was soon apparent that this cause was what the writer, for want of a better name, has called "*differential refraction.*" As used in this paper, the term "differential refraction" expresses the difference in the amounts by which the two lines of sight, upper and lower, are refracted by the air.

It is known that in the morning, before the earth and air receive heat from the sun, the density of the air is greatest at the surface of the earth, and decreases upward. Rays of light in the stratum nearest the ground are refracted downward, i. e., positively. But later on, in a sunny

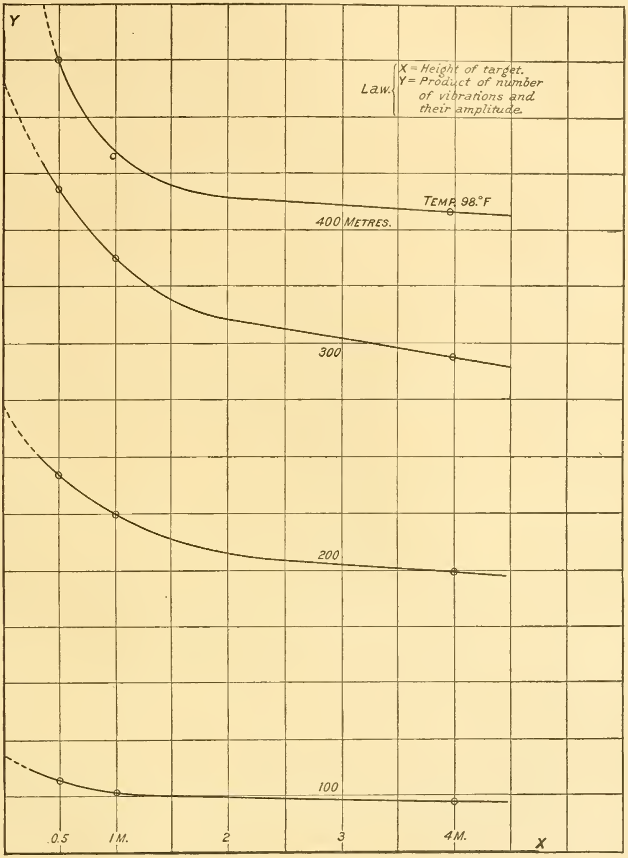


FIG. 14.—Disturbance curves, showing effect of height of line of sight at 12 o'clock July 25, 1893.

day, the temperature of the stratum of air in contact with the earth becomes highly heated by the radiation of heat from the earth. This increased temperature causes a rarefaction, which, within a short distance from the ground, makes the density of the air *increase with the distance from the* *surface.* Rays of light traversing this portion of the air are bent upward, i. e., negatively, in accordance with the general law that refraction bends a ray of light toward the denser part of the medium through which the ray passes.

A great many experiments were attempted to determine the depth of this abnormal stratum, some of which gave interesting results. It seems certain that, while the total depth of this stratum varies at different hours and seasons, still, the depth of the portion of it in which the change in density is most rapid is seldom more than 3 or 4 feet. If the lower line of sight of a reading traverses this lower stratum, it suffers a much greater refraction than the upper line of sight. If both happen to be refracted in the same direction, the error in the rod reading is the difference of the refractions. If the two lines of sight be refracted in opposite directions, the error in the rod reading is evidently the sum of the refractions.

In the summer of 1893, while camped near the Cerro de la Lesna, a careful series of experiments was made to determine the relative amounts of unsteadiness in the strata of air from ½ meter to 4 meters above the ground. These experiments, repeated in Wisconsin the past summer, gave similar results, which are shown in a graphical form in the curves, figs. 13 and 14. The x abscissa in these curves is the distance of the target above the ground, the y ordinate is the product of the amplitude of vibrations and their number per minute.

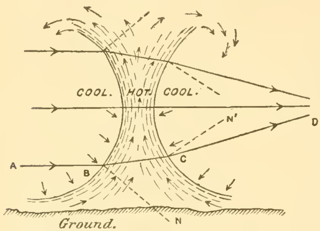


Fig. 15.—Showing typical shape of air currents and effect on refraction.

In every experiment it was found that the amounts of unsteadiness in strata between 4 m. and 1 m. above the ground increased only *slowly* as the strata tested neared the ground, while between 1 m. and ½ m. this unsteadiness increased *very rapidly* as the strata neared the ground. For example, at 10 a. m., July 25, 1893, with the temperature 95° F., and with the target 200 meters distant, the amounts of unsteadiness at 4, 1, and ½ meters above the ground were to each other as 5 : 6 : 9; that is, the rate of change of disturbance between ½ and 1 meter was 18 times that between 1 meter and 4 meters (fig. 13). The average ratio, with tests at 100, 200, 300, and 400 meters distant, at the same hour was 7 : 11 : 15½; that is, the average rate of change in amounts of disturbance between strata ½ and 1 meter above the ground was 5 times the rate in strata between 1 meter and 4 meters above the ground.*

(*b*) *A probable explanation.*—A probable explanation† of this remarkable fact may be found in the peculiar funnel shape of the ascending currents of air caused by the radiation of heat from the various materials of the ground along the line of sight. Such currents (fig. 15) have been observed to rapidly contract as they rise, owing to the pressure of cooler air, but, becoming cooled by contact with the surrounding cooler air, they finally spread out laterally and, mixing with cool air, return again to the surface of the ground, thus completing a cycle.‡ It is probable that the lateral spreading of the column of air does not take place within the limits affecting stadia work, viz, 15 feet.

Such a rarified current of air acts like a great lens, but one whose shape constantly changes with every little breeze or is completely destroyed by a strong wind. When the rays of light traverse such a lens nearly at right angles to its axis, those rays which are near the ground suffer the greatest refraction. This is illustrated by the following experiment: A 4-inch oil burner was put just below the line of sight between the transit and a target, and the refraction was measured; then the distance of the line of sight above the burner was increased, upon which the refraction diminished.

An experiment was performed to determine the effect of making the opposite sides of the ascending column of air as nearly parallel as possible by entirely inclosing it with shutters, hung from

* Unless otherwise stated, the height of target is 2 m. above the ground.

† It should be noted that the final conclusions of this paper do not depend upon this hypothesis.

‡ No such definite line as shown in the figure separates the ascending current from the surrounding cooler air, but the effect on refraction is the same as though such were the case.

the ceiling, excepting at a narrow aperture left to allow the transmission of the line of sight to the target; but even when the line of sight was as nearly as possible perpendicular to the parallel surfaces, refraction was still evident, though in less degree. These experiments were performed in the basement of Science Hall, University of Wisconsin, where the strata of air were known to be horizontal. When performed in the open air similar results were obtained, but the refraction was less steady in amount and direction, owing to the changing form of the refracting medium. The distance between the target and the transit remaining constant, it was found that the amount of refraction was increased as the burner approached the transit.

A perfectly homogeneous soil, or soil covering, is seldom found in nature. Each exposed belt of sand, clay, loam, gravel, or rock, each mantle of vegetation, will absorb from the sun and give off heat to the superimposed air according to its own rate of absorption and radiation. This gives rise to ascending air currents of different densities, and corresponding indices of refraction. The almost infinite variety of ways in which a ray of light traverses the large number of such currents, when influenced by every gust of wind, great and small, gives rise to the peculiar fluctuations of the line of sight, which have been called primary and secondary vibrations; the former due to air currents near the transit, and the latter due to currents near the rod. It was found impractical to test the strata of air lower than one-half meter above the ground, because of the unevenness of the surface, but during several years of field work, both in the Southern and Northern States, it has been a matter of almost daily experience that a line of sight, passing tangent to the ground, even at but *one point*, always suffered an extraordinary disturbance. A longer path in such a stratum would naturally be expected to augment the disturbance. On the other hand, if the line of sight passes over a valley so as to remove the line of sight from the ground, little or no disturbance is ever noticed, even on extremely long sights.

(*c*) *Experimental evidence of differential refraction.*—Additional evidence of the increased refraction in the stratum next to the ground is furnished by some careful experiments * made in Wisconsin during the past summer, a record of which is shown in Table 1.

TABLE 1.

August 23, 1894, 11 a. m. Temperature. { In sun, 102° F., slight wind. In shade, 89° F., sun unobscured.

High line of sight.		Low line of sight.		True distance.
Stadia distance.	Error of stadia.	Stadia distance.	Error of stadia.	
Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
487.48	—0.27	484.46	— 3.29	487.75
458.57	1.31	455.57	— 1.69	457.26
427.49	0.71	424.70	— 2.08	426.78
396.80	+0.51	395.01	— 1.28	396.29
366.42	0 61	365.02	— 0.79	365.81
335.04	—0.29	332.69	— 2.64	335.33
304.66	—0.18	302.97	— 1.87	304.84
2776.46	2.40	2760.42	—13.64	2774.06
$+\frac{1}{1155}$ = error.		$-\frac{1}{166}$ = error.		

After reading the stadia every 100 feet between station 304.84 m. (1,000 feet) and station 487.75 m. (1,600 feet) with the *usual* height of instrument (1.4 m.), the same distances were read with the transit *on the ground* (i. e., H. I. = 0.25 m.). It will be seen that the latter readings show a very much larger error, all in the same direction (systematic), whose sum is the total distance so measured as 1 : 166, while the uncompensated errors with the instrument at its ordinary height were not of the same sign (i. e., not systematic), and their algebraic sum is to the distance as 1 : 1155. It should be noticed that the readings with the least height of instrument gave such uniformly large systematic errors as to entirely cover up the accidental ones, while with the normal height of instrument, the upper and clearer portions of the rod being used, the presence of about

* In justice to these experiments it should be stated that at the time they were made the writer had such erroneous ideas on this subject that the results of the experiments were a complete surprise to him.

an equal number of plus and minus errors shows that the cause for systematic errors was no longer present.

The reason for this marked change will be understood when it is remembered that the lower line of sight in the first case traveled its whole length in a rapidly varying stratum of maximum disturbance, while the upper line of sight traveled the larger part of its length in strata of comparatively little and uniform disturbance. This is well illustrated in figs. 16 and 17. In fig. 16 both lines of sight would be refracted in the same direction—B to B′, A to A′; that is, the concavity of their paths would be turned toward the denser air. This would make both readings too large, and if both lines were refracted equal amounts no error in the intercept

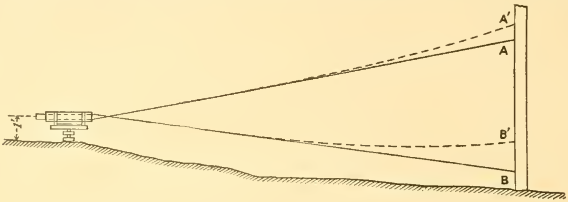


Fig. 16.—Showing increased differential refraction with low height of instrument.

would result. However, such is not the case. Under such conditions the distance BB′ always exceeds AA′, and the resulting error is AA′−BB′. This explains the uniform minus error with low height of instrument. The normal height of the instrument taken (represented by fig. 17) brings the lower line of sight entirely above the stratum of greatest disturbance, while that of the upper line of sight traverses strata which it has been shown differ but slightly from that traversed by the lower line of sight. Both lines are, as in the previous cases, refracted in the same direction, but in very nearly equal amounts; hence the intercept suffers but a slight error.

The fact that the sum of the two half interval readings on the upper and clearer portion of the rod almost invariably exceeded the full interval reading had been repeatedly noticed in the

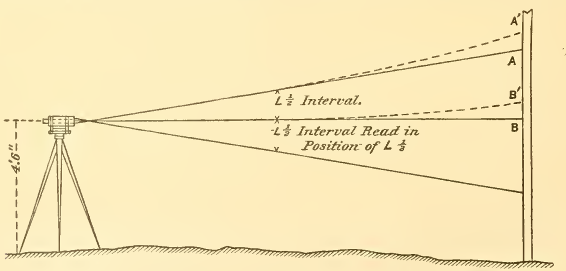


Fig. 17.—Showing small differential refraction with high height of instrument, and reading on upper portion of rod.

field work of the International Boundary Survey, but not until the results of this experimental work were studied was the cause for the disagreement made clear.

A very interesting illustration of differential refraction on a large scale (which, in fact, is the only illustration the writer has ever seen on the subject outside of his own experiments) has recently been brought to his attention. This is found in Appendix 3, Vol. II, of Colonel Walker's report of the Great Trigonometrical Survey of India. Because of the inaccessibility of this report, the main facts on this point are here given.

The engineers were operating in a very level country, where the rays of light from the stations under observation grazed the surface of the ground. The differential refraction was first noticed between two stations called Nár and Jeto, the former being on a slightly elevated table-land between two river valleys, the latter being 13 miles distant in the valley bottom. It was feared that the ordinary heliotrope would not be visible, so a second heliotrope was mounted on a tripod about 16 feet vertically above the ordinary heliotrope.

Colonel Walker says:

The line between the instrument at Nár and the ordinary heliotrope at Jeto was not an air line at all, but passed through the ground for a distance of more than 3 miles, while the line between the instrument and the upper heliotrope could not have been more than 5.3 feet above the ground at the point of nearest approach. At Jeto both the auxiliary and the ordinary heliotropes were generally visible for about an hour after sunrise and before sunset, but in the middle of the day the lower one was always invisible, being below the apparent horizon. Here I noticed with surprise, one evening, that the two heliotropes were apparently very much closer together than it was possible they could be in reality. Measuring the angle subtended I found it to be only 16.5 seconds, whereas the true subtense was 49.5 seconds. Three days afterwards, in the morning, about an hour after sunrise, I found the apparent subtense to be as much as 97.7 seconds. Thus its magnitude had varied from one-third to twice that of the true subtense, attaining a maximum value six times greater than its minimum value. This clearly showed that the amounts by which the rays of light proceeding from the two heliotropes were respectively affected by refraction must have varied materially at different hours of the day. The observations were only differential and did not give the absolute values of refraction, but it seems highly probable that the lower ray was very much more refracted than the upper in the evening and very much less in the morning.

This remarkable phenomenon led to a systematic study of both absolute and differential refraction, the details of which are given in the volume mentioned.

It will be sufficient to state that numerous instances of negative as well as positive refraction were found, ranging between the extreme values of -0.09 and $+1.21$ of the contained arc. Negative refraction was met with only between the hours of 1 to 3.30 p. m., and positive refraction between 3.30 p. m and 10 a. m. After 10 a. m. signals were generally below the horizon, so no observations were possible.

In the case of observations on differential refraction it was found "that the refraction was sometimes greater in the upper ray and sometimes in the lower, but that the range from lowest to highest value at each station was always *greater for the lower than for the higher ray.*

Between the hours of 1 and 3.30 p. m., whenever the sun was shining brightly, the apparent subtense was greater than the true and the refraction was lower in the lower ray than in the upper; but at the same time in cloudy weather the converse occasionally happened. On the other hand, between 3.30 p. m. and sunset the apparent subtense was always less than the true, and the refraction was higher in the lower ray than in the upper. These variations in subtense were evidently due to the coexistence of a lowering refractive power in the strata of the atmosphere nearest the ground with a raising refractive power in the strata immediately above during the hours when the radiation of the heat of the sun from the ground was considerable, and to the converse condition of a greater raising power in the lower than in the upper strata when there was little or no radiation and consequestly greater density in the lower than in the upper strata of the atmosphere.

The application of the above record to the subject of stadia measurements is easy to see, and it will be noted that the explanation given is essentially the same as that advanced by the writer, based upon observed stadia readings at different hours of the day. The only difference in the data is the relatively long distance of the sight from Nár to Jeto, it being 13 miles instead of the few hundred feet which necessarily limit the length of a stadia reading. But even on so short a stadia sight as 1,000 feet the writer has seen the rod intercept change by 0.19 of a foot (equals 40 seconds of arc) during different hours of the same day. Such large differences in rod readings can be understood when it is noted that if in the first case (see fig. 18) the upper line of sight be refracted negatively more than the lower, or if the upper line of sight be refracted negatively and the lower line of sight positively, then the observed intercept $a' b'$ will be larger than the true in tercept $a b$. Again, if, as in fig. 19, the upper line of sight be refracted downward (positively) and the lower line of sight upward (negatively) the observed intercept $c' d'$ will be smaller than the true intercept $c d$. It will be seen that the difference in the observed rod readings, namely,

$a' b'$ (fig. 18) — $c' d'$ (fig. 19) is about four times as large as any single refraction. Hence a small absolute refraction may be the cause of a large differential refraction.

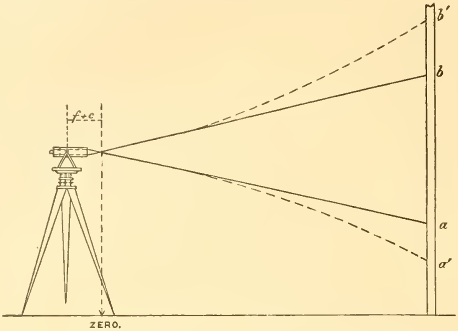


Fig. 18.—Differential refraction causing too large rod readings.

A good illustration of this fact was recently sent the writer by one of the topographers of the Chicago Drainage Canal. The topographer was taking a stadia reading over a rise of ground when he noticed that, in reading from the top of the rod downward the distance read was 725 feet,

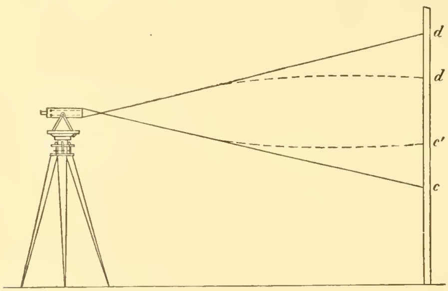


Fig. 19.—Differential refraction causing too small rod readings.

while in reading from a point near the ground upward the distance was shortened to 715 feet. For the reasons given above the former reading was more likely correct, though the manner in which the stadia interval was determined has a governing influence on this point.

TABLE 2

(A) RECORD OF EXPERIMENTS FROM 8 TO 9 A. M. AND 2.30 TO 7 P. M., STADIA MEASUREMENTS AGGREGATING 43.3 MILES.

Errors of the stadia on distances of 200 to [illegible] feet

Date	Time	Temperature	Condition of air	Sun	Wind	200 feet 60.97 m		300 feet 91.45 m		400 feet 121.938 m.		500 feet 152.423 m		600 feet 182.907 m		700 feet 213.390 m	
Good conditions for work.																	
August 4	5-5.30 p. m.	90° sun; 80° shade	No vibration even close to ground	Clear	No wind	0.14				0.03				0.32			
August 6	2.30-4 p. m.	86° shade	Only vibration a glimmering	Cloudy	do	.04		0.24		13		0.03		.42		0.32	
Do	5-5.30 p. m.	84° sun; 82 shade	do	do	do	04				13				32			
August 15	do	80° shade	Rod distinct, no vibration	do	do	.04			0.06	13			0.02	.37		.42	
Do	5.30-6 p. m.	65° shade	do	Partly cloudy	do	.04			01	.03			.07	.12		22	
August 20	8-8.30 a. m.	72 shade	Slight vibration		Slight breeze	.04			.01	.13		.03		.74		32	
August 21	do	67 shade	No vibration even at 2,000 feet	Clear	do	.04			.01			.08		.17		22	
Do	8.30-9 a. m.	78 sun; 67 shade	Air dusty; little vibration	do	do		0.06		06				.07	.07		.07	
Do	5-5.30 p. m.	79° sun; 72° shade	do	do	Still		.01		.06			.03		.12		.12	
Do	5.30-6 p. m.	72 sun; 66 shade	No vibration even at 2,000 feet, rod distinct.	do	do	.04			.01			.03		.12		07	
August 23	2.45-3.30 p. m.	120° sun; 96° shade	Slight vibration, rod distinct			.08			.06	.13		.13		22			0.08
Do	3.30-4 p. m.	92 shade	Very slight vibration	Hazy	Still	.09		.04		.13		.03		.37		.12	
Do	4-4.30 p. m.	91° shade	No vibration, rod distinct	Cloudy	do	.04		.04		.13		.13		.57		.12	
July 5	8-9 a. m.	70 shade	Rod can not be read after 426 m.	Clear	Slight		.06		.11	.13			.37		0.18		.47
Sum of errors on each length sight						0.64	0.13	0.32	0.39	1.10	0.00	0.49	0.53	3.93	0.18	2.00	0.55
Average error of single sight on each distance						1/1104		1/1515		1/1106		1/1703		1/623		1/1004	
Errors of closing total distance on each length sight						1/1071		−1/15080		1/1106		1/34120		1/682		1/1566	
Sum of distance measured with each length sight						,853.58 m		1,097.40 m.		1,219.38 m.		1,829.04 m.		2,560.70 m		2,560.68 m.	
Poor conditions for work.																	
July 5	9-10 a. m.	72-74° F. shade	Very bad	Bright	Slight breeze		0.06		0.16	0.13		0.03			0.18		1.07
Do	10-11 a. m.	74-76 shade	do	do	do	0.04			.16		0.16		0.37		.18		0.37
Do	11-12 a. m.	76-78 shade	do	do	do	.04			.16	.13			.17	0.32			1.17
Do	2-3 p. m.	80-80 shade	do	do	do	.14			.16		.16	.03		.32			0.48
August 4	10-10.30 a. m.	86 sun; 76° shade	100 vibration of 0.01 per minute	do	do		.06				.26			.32			
Do	12 m-12.30 p. m.	117 sun; 78 shade	Rod indistinct at 1,000 feet, and can not be read after 1,600 feet.	Few clouds			.16				.16			.28			
Do	2-2.30 p. m.	82 shade	Last four readings easily made	do	No wind		.06			.63				1.11			
August 13	10-10.30 a. m.	96 sun; 83 shade	Vibration at 1,100 feet 0.01 m	Few fleecy clouds	do	.04			.16	.13			.17	0.12			.37
Do	2-2.30 p. m.	92 sun; 90° shade	Vibration at 426 m. 0.02 m. very fast	Half cloudy, hazy	Slight breeze	.04			.16	.13			.27	.22		0.22	
August 16	10-10.30 a. m.	100 sun; 76 shade	Vibration very bad rod indistinct	Clear	do	.04		.02		.03			.17	.12		.12	
August 17	9-9.30 a. m.	80° sun; 75 shade	do	Cloudy	Slight	.04			.16	.13			.07	.22		.12	
August 23	11-11.30 a. m.	102 sun; 89° shade	Vibration of 0.005 at 122 m	Clear	do		.01	.04		.13						.32	
Do	2-2.30 p. m.	120° sun; 98 shade	At 61 m. vibration 0.008; at 97 m. vibration 0.000, at 121 m vibration 0.01; at 152 m. vibration 0.015 m.	do	None	.04			.16		.16		.37	.12			.38
Sum of errors on each length sight						0.42	0.35	0.06	1.28	1.44	0.90	0.06	1.59	3.15	0.36	0.78	3.84
Average error of a single sight on each distance						1/1938		1/582		1/517		1/531		1/585		1/482	
Errors of closing total distance on each length sight						1/1153		1/718		+1/2031		−1/867		1/73		−1/857	
Sum of distance measured with each length sight						792.61 m.		914.50 m.		1,585.10 m.		1,371.81 m		2,194.88 m.		2,133.90 m.	
Total uncompensated error of both sets, (A) and (B)						+1/3636		1/1144		1/1		−1/3019		1/738		−1/2616	
Grand total of distances measured with each length sight						1,646.19 m.		2,011.90 m.		2,804.49 m.		3,200.85 m.		4,755.58 m.		4,694.58 m.	

Date	Time	800 feet 243.874 m.		900 feet 274.358 m		1,000 feet 301.842 m		1,100 feet 335.326 m		1,200 feet 365.810 m		1,300 feet 396.294 m		1,400 feet 426.779 m		1,500 feet 457.2[illegible]
Good conditions for work.																
August 4	5-5.30 p. m.	0.02					0.68			0.21					0.09	
August 6	2.30-4 p. m.	32			0.28		48		0.09		0.68		0.48	0.21		
Do	5-5.30 p. m.	12				0.62				21				91		
August 15	do	.02		0.42		82		1.10		61		0.71		31		
Do	5.30-6 p. m.		0.10		.28		.18		44		38		98		29	
August 20	8-8.30 a. m.		00					0.21		41						
August 21	do		00		.08		18	.51		.41		51		69		0.11
Do	8.30-9 a. m.		00		08	42			09	21		51		01		1
Do	5-5.30 p. m.		.00		12	.12		01		11		61		21		01
Do	5.30-6 p. m.		00		08		.08	21		51		81		31		1
August 23	2.45-3.30 p. m.		.10		08		.18	11		51		51			09	11
Do	3.30-4 p. m.		00	22		.12		21		61		1.11		91		
Do	4-4.30 p. m.	.10		92		.32		01		.41		0.81		41		31
July 5	8-9 a. m.		.18		.58											
Sum of errors on each length sight		0.58	0.38	1.56	1.58	2.42	1.78	2.17	0.62	4.41	1.06	5.78	1.36	3.97	0.47	2.06
Average error of single sight on each distance		1/3288		1/961		1/420		[illegible]		[illegible]		[illegible]		[illegible]		
Errors of closing total distance on each length sight		1/1071		1/150806		1/8715		[illegible]		[illegible]		[illegible]		[illegible]		
Sum of distance measured with each length sight		3,414.24 m.		3,017.94 m.		3,658.10 m.		3,688.59 m.		4,755.53 m		3,962.04 m		5,121.15 m		4,11[illegible]
Poor conditions for work.																
July 5	9-10 a. m.		0.48		2.27		0.68		1.29		0.58		1.08		2.48	
Do	10-11 a. m.		.67		1.08		5.16		1.99		2.68		1.88		0.99	
Do	11-12 a. m.		.28		0.68		4.66		1.69		2.18		3.08		3.78	
Do	2-3 p. m.		.18		.28		0.68		0.69		1.38		1.48		1.09	
August 4	10-10.30 a. m.	0.02					.88				4.37		2.58		.07	
Do	12 m-12.30 p. m.		.18				.68				3.87				2.58	
Do	2-2.30 p. m.	.02					2.67		1.30		1.38				1.09	
August 13	10-10.30 a. m.	.02			58		0.68		0.59		2.58				3.08	
Do	2-2.30 p. m.	.12			08	0.32		0.21		0.41					0.99	
August 16	10-10.30 a. m.		48		2.07	82			29		1.88		5.47		2.58	
August 17	9-9.30 a. m.		.10		0.18		68		19		0.38	0.21			1.09	
August 23	11-11.30 a. m.						18		.29	61		51		0.71		1.31
Do	2-2.30 p. m.		10		.08		20		29		.59		1.48		2.58	
Sum of errors on each length sight		0.18	2.47	0.00	7.30	1.14	17.1	0.21	9.10	0.92	1.47	0.72	17.65	0.71	26.80	1.1
Average error of a single sight on each distance		1/1104		1/[illegible]		1/214		1/38		[illegible]		1/16		1/12		
Errors of closing total distance on each length sight		−1/1275		[illegible]		1/24		−1/141		−1/98		−1/41		1/9		
Sum of distance measured with each length sight		2,920.49 m.		2,469.22 m.		[illegible],962.95 m.		[illegible],688.57 m.		4,755.53 m.		3,566.64 m.		5,548.13 m.		[illegible]
Total uncompensated error of both sets, (A) and (B)		1/3633		−1/784		−1/482		1/18		1/81		1/1		1/41		
Grand total of distances measured with each length sight		6,340.73 m		5,487.16 m		7,021.05 m		7,377.14 m		9,[illegible]11.06 m.		7,529.58 m		10,660.48 m.		9,145[illegible]

(B) RECORD OF EXPERIMENTS FROM 9 A. M. TO 2.30 P. M., STADIA MEASUREMENTS AGGREGATING 11.3 MILES.

(*A*) I

Error					
300 feet.		400 feet.			.
91.45 m.		121.938 m.		1	in otal ce.
			—		
....	....	0.03	....	...	$\frac{1}{2423}$
0.24	......	.13	......	0	$\frac{1}{3425}$
......	......	.13	......	...	$\frac{1}{2312}$
....	0.06	.13	....	...	$\frac{1}{521}$
......	.01	.03	....	...	$\frac{1}{1154}$
......	.01	.13	....		$\frac{1}{945}$
......	.01	....	....		$\frac{1}{1147}$
......	.06	....	....	...	$\frac{1}{3377}$
......	.06	....	....		$\frac{1}{2808}$
......	.01	....	....		$\frac{1}{1453}$
	.06	.13	....		$\frac{1}{2308}$
.04	....	.13	....		$\frac{1}{881}$
.04	....	.13	....		$\frac{1}{1067}$
....	.11	.13	....	...	$\frac{1}{737}$
0.32	0.39	1.10	0.00	0	$\frac{1}{1938}$
$\frac{1}{1545}$		$\frac{1}{1106}$			
$-\frac{1}{15686}$		$+\frac{1}{1108}$			
1,097.40 m.		1,219.38 m.		1	
....	0.16	0.13	....	0	$\frac{1}{185}$
....	.16	....	0.16	...	$\frac{1}{189}$
....	.16	.13	....	...	$\frac{1}{184}$
....	.16	....	.16		$\frac{1}{254}$
....	....	....	.26	...	$\frac{1}{132}$
....	....	....	.16	...	$\frac{1}{162}$
....	....	.63	....	...	$\frac{1}{458}$
....	.16	.13	....	...	$\frac{1}{208}$
....	.16	.13	....	...	$\frac{1}{945}$
.02	....	.03	....	...	$\frac{1}{286}$
....	.16	.13	....	...	$\frac{1}{482}$
.04	....	.13	....	...	$\frac{1}{114}$
....	.16	....	.16	...	$\frac{1}{411}$
0.06	1.28	1.44	0.90	0	$\frac{1}{257}$
$\frac{1}{882}$		$\frac{1}{817}$			
$-\frac{1}{750}$		$+\frac{1}{2933}$			is- eas
914.50 m.		1,585.19 m.		1	both nd hts.
$-\frac{1}{1559}$		$+\frac{1}{1710}$			
2,011.90 m.		2,804.49 m.		3	3 m les)

(*d*) *Effect of length of sight and hour of day on refraction.*—A study of over 420 independent test stadia sights, aggregating 85 miles in length, made on an accurately measured base line,* during the months of July and August, under the variety of conditions found in usual working hours, gives undoubted proof of this refraction error.

Table 2 is a record of the conditions of field work (such as date, time of day, temperature of air in sun and shade, the amount of sun and wind, and the unsteadiness of the air), and the resulting accuracy of sights differing in length from 60.77 meters (200 feet) to 609.684 meters (2,000 feet).

This work naturally divides itself into two classes; first, stadia readings, varying from 60.97 meters (200 feet) to 304.842 meters (1,000 feet) in length, made with full intervals; and, second, readings with half intervals, on distances varying from 335.326 meters (1,100 feet) to 609.684 meters (2,000 feet). For the purpose of a comparative study it has also seemed wise to divide all the work again into two divisions: (*A*) Work done in the morning and evening hours (i. e., before 9 a. m. and after 2.30 p. m.); and (*B*) work done in the remainder of the day, 9 a. m. to 2.30 p. m.

At the top of each column in the table is the true length of sight,† and the actual error of each sight for that length is placed in the proper column with proper sign (+ or —) indicated. At the foot of each column this work is summed so as to show: (*a*) The "average error" ‡ of a single sight of each length; (*b*) the sum of the distances of each set of observations on any distance; (*c*) the actual accumulated error for each of such summations. This treatment is repeated for work in both divisions of the day, and at the bottom of the table, division (*B*), the two results are averaged together. A somewhat similar summation is made across the sheet from left to right.

A study of these data discloses the significant fact that at *all* hours of the day, using the 304.842 meters (1,000 feet) sight, both the average errors and the uncompensated errors greatly exceeded the errors existing when the sight was either 100 feet longer or 100 feet shorter. The reason for this is plain. The length of the stadia rod was such as to make it necessary in reading 304.84 meters to put the lower cross wire near the foot of the rod, and the lower line of sight suffered an excessive refraction compared with that of the upper line of sight. This excessive refraction in the cooler hours of the day resulted in too large a rod reading, and during the middle hours of the day in too small a rod reading. When the sight was 100 feet shorter the lower line of sight rose above the stratum of maximum refraction, and a decreased *difference* in the amounts of refraction suffered by the two lines of sight resulted, giving a correspondingly decreased error. Again, the 335.326 meters sight was read by half intervals on the upper and clearer portions of the rod. This allowed both lines of sight to traverse a nearly uniform stratum of air, thereby giving to each nearly equal amounts of refraction, and decreasing the error of this reading, compared with the one which was 100 feet shorter. It should also be noticed that the errors at 304 meters, 274 meters, and 243+ meters show a gradual decrease as the line of sight recedes from the ground.

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*This base line was measured with a carefully standardized 100-foot steel tape, and was 2,216.888 meters (7.273.236 feet) long. The base was located on four streets, forming a quadrilateral, in the village of East Troy, Wis., about 20 miles from the Illinois boundary. The situation was selected for several reasons; first, it was over very level ground; second, the completion of a circuit left the observer right where he began, thus saving the time which would otherwise have been required for walking to and from work; third, the four directions gave the average conditions of sun on rod met with in the field; fourth, on three of these streets the sun shone all day uninterrupted by shade trees, while on the other, trees on either side partially shaded the ground. This furnished opportunity of observing the effect of sun or shade alone, or alternate belts of both at the same time.

The ground had been brought nearly to true grade. Tacks were set in stakes placed every 100 feet and lined in with transit. A spring balance was used to measure the proper pull on the tape and the temperature of the air was recorded at frequent intervals. A scratch on the tack heads recorded each tape length. A line of levels was also run over the line, and the distance on each street computed, making the usual corrections for tape length and grade. As the assistant was a competent engineer, the precautions taken should insure an accuracy of not less than 1/25000.

† Determined by the base line measurement. The writer has presented so much detailed evidence of *differential refraction* and its effect upon stadia accuracy, because he believes this paper to be the first exposition of its quantitative measurement and application to stadia work. It seemed but just, therefore, that the reader should be shown the data upon which the conclusions are based.

‡ Deduced from the recorded errors of 10 to 14 observations.

For convenience in comparison the totals of Table 2 have been brought together in Table 3. A glance at the individual sights recorded in Table 2, or at the summations in Table 3, discloses the fact that in morning and evening work the bulk of the errors are positive (the readings are too large), while midday work with even greater uniformity shows negative errors (the readings are too small). The reason for this is that in the reduction of the field notes an average interval factor was used, as will be explained below. On account of the influence of refraction on such an interval determination, the average interval would be *exact* for only a small portion of the field day. Midday work computed with such an interval would give negative errors; while morning and evening work would, for the same reason, give positive errors.

In Table 3 is shown the percentage of both positive and negative errors in each separate class of work. Thus, in the morning and evening work, 66 per cent of the errors were positive, 30 per cent negative, and 4 per cent were zero errors; while in the midday work this proportion was about reversed, i. e., 76 per cent of the errors were negative and 24 per cent positive. These proportions do not, however, correctly express the relative *amounts* of positive and negative errors, for during morning and evening hours of work the negative errors are much smaller numerically than the positive errors, and vice versa during midday hours of work. The actual *amount* of the positive error during morning and evening hours is 75 per cent of the total; while during midday hours the positive errors amount to but 4 per cent of the total error, though constituting 24 per cent of the whole *number* of errors. The reason for the small amount of positive and large amount of negative errors in work executed in the midday hours will appear in the discussion of the interval determination.

TABLE 3.

Work done 7–9 a. m. and 2.30–7 p. m.

Short sights.				Long sights.			
Length of sight.	Sum of distances.	Accumulated error.	Average error of single sight.	Length of sight.	Sum of distances.	Accumulated error.	Average error of single sight.
Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*	
60.97	853.58	+0.51	$\frac{1}{1106}$	335.33	3,688.57	+1.55	$\frac{1}{1322}$
91.45	1,097.40	−0.07	$\frac{1}{1545}$	365.81	4,755.53	+3.35	$\frac{1}{866}$
121.94	1,219.30	+1.10	$\frac{1}{1108}$	396.29	3,962.94	+4.12	$\frac{1}{583}$
152.42	1,829.04	−0.04	$\frac{1}{1793}$	426.78	5,121.35	+3.50	$\frac{1}{1157}$
182.91	2,560.70	+3.75	$\frac{1}{623}$	457.26	4,115.37	+0.40	$\frac{1}{1166}$
213.39	2,560.68	+1.45	$\frac{1}{1664}$	487.75	5,852.98	+0.16	$\frac{1}{1134}$
243.87	3,414.24	+0.20	$\frac{1}{3556}$	518.23	5,182.32	+7.49	$\frac{1}{674}$
274.36	3,017.94	−0.02	$\frac{1}{961}$	548.72	6,035.89	+3.30	$\frac{1}{1262}$
304.84	3,658.10	+0.64	$\frac{1}{876}$	579.20	5,212.80	2.68	$\frac{1}{951}$
....	....	....	....	609.68	5,487.15	1.85	$\frac{1}{878}$
Average length of sight.	Total distance.	+7.52	Average error single sight.	Average length of sight.	Total distance.	+28.40	....
182 m.	20,210.98 m.	$\frac{1}{2685}$	$\frac{1}{1088}$	466 m.	49,414.90 m.	+ $\frac{1}{1741}$	$\frac{1}{536}$
(600 feet.)	(12.6 miles.)			(1,528 feet.)	(30.9 miles.)		

111 sights: 6 zero errors, 6 per cent; 69 plus errors, 62 per cent; 36 minus errors, 32 per cent.

106 sights: 2 zero errors, 2 per cent; 74 plus errors, 70 per cent; 30 minus errors, 28 per cent.

Total: 217 sights: 143 plus errors, 66 per cent; 66 minus errors, 30 per cent; 8 zero errors, 4 per cent.

TABLE 3—Continued.

Work done 9 a. m.–2.30 p. m.

Short sights.				Long sights.			
Length of sight.	Sum of distances.	Accumulated error.	Average error of single sight.	Length of sight.	Sum of distances.	Accumulated error.	Average error of single sight.
Meters.	*Meters.*	*Meters.*		*Meters.*	*Meters.*	*Meters.*	
60.97	792.61	+ 0.07	$\frac{1}{1025}$	335.33	3,688.57	— 8.89	$\frac{1}{396}$
91.45	914.50	— 1.22	$\frac{1}{682}$	365.81	4,755.53	— 20.96	$\frac{1}{259}$
121.94	1,585.19	+ 0.54	$\frac{1}{577}$	396.29	3,566.64	— 16.93	$\frac{1}{194}$
152.42	1,371.81	— 1.53	$\frac{1}{831}$	426.78	5,548.13	— 26.09	$\frac{1}{202}$
182.91	2,194.88	+ 2.79	$\frac{1}{628}$	457.26	5,029.89	— 18.65	$\frac{1}{236}$
213.39	2,133.90	— 3.06	$\frac{1}{462}$	487.75	5,852.98	— 30.43	$\frac{1}{184}$
243.87	2,926.49	— 2.29	$\frac{1}{1164}$	518.23	4,664.09	— 21.58	$\frac{1}{212}$
274.36	2,469.22	— 7.30	$\frac{1}{338}$	548.72	6,035.89	— 29.49	$\frac{1}{204}$
304.84	3,962.95	—16.01	$\frac{1}{216}$	579.20	4,054.40	— 23.74	$\frac{1}{171}$
....	....	....	....	609.68	4,877.47	— 33.03	$\frac{1}{448}$
Average length of sight.	Total distance.	—28.01		Average length of sight.	Total distance.	—229.78	
182 + m	18,351.53 m.	— $\frac{1}{655}$	$\frac{1}{432}$	462 m.	48,073.60 m.	— $\frac{1}{209}$	$\frac{1}{201}$
(600 + feet.)	(11.4 miles.)			(1,515 + feet.)	(30 miles.)		
101 sights {61 minus errors, 60 per cent. 40 plus errors, 40 per cent.				104 sights {96 minus errors, 92 per cent. 8 plus errors, 8 per cent.			

Total: 205 sights {157 minus errors, 77 per cent.
48 plus errors, 23 per cent.

Summation: 422 sights {191 plus errors, 45 per cent; but 13 per cent of total amount of error.
223 minus errors, 53 per cent; but 87 per cent of total amount of error.
8 zero errors, 2 per cent.

In the column of Table 3 headed "Average error of single sights" may be found what is really the average error (or the probable error) of the readings at different distances. An average error* of each class of work is found by dividing the average error of a single sight by the average length of sight. Thus, in morning and evening work, using short sights (200 to 1,000 feet), the average sight was 182.9 meters (600 feet),† and the average error of a single sight was the total error (18.56 meters), divided by the number of sights (111) or 0.167 meters; and 0.167/182.9=1/1095, which is the average error of the average length sight. Using long sights (1,100 to 2,000 feet), the work done in the same morning and evening hours shows an average error of a single sight of 1/935 (average length of sight 466 meters, or 1,528 feet). The average error of an average length sight on work done in midday shows a marked increase, as compared with the rest of the day. Thus, on short sights it is 1/432, and on long sights 1/201.

* This average error corresponds to the probable errors of observation on an unknown length, but, as in this case, the *real* distance is known, the average error is more trustworty than any probable error computed on a limited number of observations.

† The United States official relation between standard measures is 1 foot=0.304801 meter.

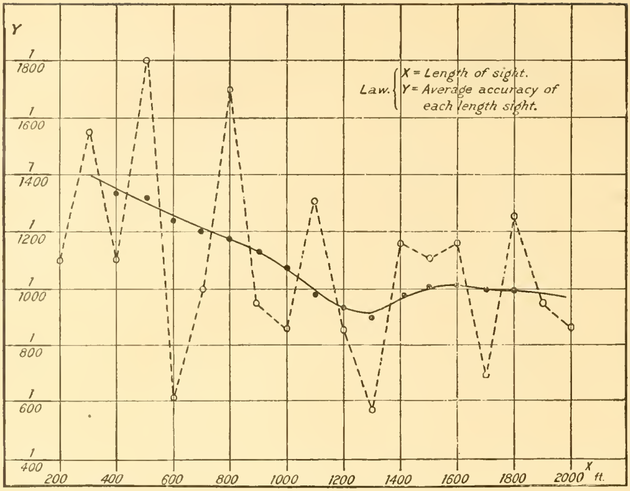

FIG. 20.—Error curve for morning and evening work, 217 test sights: 43.5 miles.

The manner in which the average error of a single observation is affected by the length of sight is shown by the curves in figs. 20 and 21. In both curves the x coordinates are the lengths of sight expressed in feet, while the y coordinates represent the average errors of the readings of

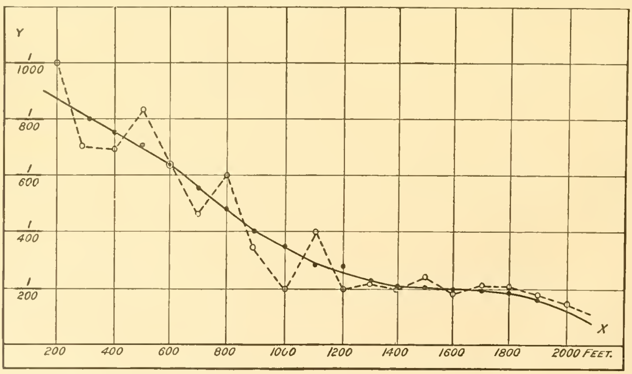

FIG. 21.—Error curve for midday work (9 a. m–2.30 p. m.), 204 test sights, aggregating 41.3 miles, on a base line, using sights of 200–2,000 feet in length.

East Troy, Wis., 1894. X and Y are same as in fig. 20.

the different lengths (10–14 observations each). The coordinates of the heavy regular curve are similar except that the ordinates represent the averages of the three adjacent ordinates of the broken curve, hence it is an average curve. It will be seen that this regular curve (fig. 20), representing results of work in the morning and evening hours, does not vary widely from an accuracy of 1/1000, even on the very long sights; while the marked irregularities of the corresponding broken curve indicate the presence of the usual accidental errors of observation, first positive and then negative.

Summation of results.

Time.	Short sights.	Long sights.	Total.
Morning and evening work.	Average error single sight on 12.6 miles — + $\frac{1}{1088}$.	Average error single sight on 30.9 miles — + $\frac{1}{935}$.	43.5 miles + $\frac{1}{1755}$.
Midday work	Average error single sight on 11.4 miles — − $\frac{1}{655}$.	Average error single sight on 30 miles — − $\frac{1}{209}$.	41.4 miles − $\frac{1}{257}$.

The curve (fig. 21) represents the errors of work done in the middle of the day, and is in striking contrast to fig. 20; for, during the first half of its length, the error curve descends quite rapidly and uniformly from an error of 1/1029 at 200 feet to 1/216 at 1,000 feet, from which last point the curve descends very much more slowly to the longest sight (2,000 feet). The rapid descent in the first half of the curve is due principally to the increasing differential refraction, as the lower line of sight approaches the ground, as has been previously explained. The rapid descent of the curve is arrested at the 1,100-foot point, because the reading of the remaining distances (1,100–2,000 feet) by half intervals, raised the lower line of sight out of the stratum of maximum refraction. In fact, the upward movement of both lines of sight put both in strata of nearly equal refracting power, and the rod intercept was, accordingly, subject to less error. But after 1,800 feet the lower line of sight was again forced into the maximum refracting stratum, and the curve takes an increased descent as a result.

The fact that such large errors result from a lack of uniformity in the amount of refraction of light rays, when obliged to traverse strata of different densities, suggests the advantage of placing the stadia rod in a horizontal position instead of in a vertical position when making a reading for distance. The practical difficulties of such a method, while great, are perhaps not insurmountable.*

(*e*) *Effect of refraction on accumulating errors.*—Not less interesting is the manner in which the errors of these 85 miles of measurements accumulated. Twelve miles of stadia measurements, made with short sights (average length 600 feet), in the *morning* and *evening* hours, show an accuracy of + 1/2685, while the same distance, measured by sights of the same length in *midday*, show an accuracy of but — 1/655. Again, 30 miles of measurements made in the morning and evening hours, using long sights (1,100–2,000 feet), show an accumulated error of but + 1/741, while the same distance, measured in the same way but in *midday* hours, developed an accumulated error of — 1/209.

The practical deductions to be made from this work are therefore, first, do not attempt accurate stadia work in hours not represented in your interval determination; and, second, in midday do not make long readings which require the lower stadia wire to be put nearer than 3 or 4 feet from the bottom of the rod. If such long readings can not be avoided, take the readings by half intervals on the upper and clearer portions of the rod. If this method had been followed in the work shown in table 3, the resulting accuracy of the work would have been greatly increased. Thus the accumulated error in 12.6 miles, measured by short sights (average length 182 meters, or 600 feet), in morning and evening hours, is + 7.52 meters, while that of the midday work, omitting the 900 and 1,000 feet sights, is — 4.70 meters in a distance of 7.4 miles. The accumulated error of the total measurement (20 miles) is + 2.82 or + 1/11,400. That such a nice balancing of errors is always possible in actual field work, the writer does not for a moment

* The writer has recently begun a series of experiments, using this method, the results of which may be published later.

suppose; but that a careful *planning* of any proposed field work will give results far superior to those obtained without such study seems too apparent to need further discussion.

Unfortunately for the interests of the stadia method, the effect of refraction in producing accumulative errors and the proper methods for preventing such errors are only partially appreciated or understood by stadia engineers. For instance, one prominent engineer of wide experience with the stadia argues that the best time for determining the stadia interval is during the middle of the day. He bases his reasoning on two well-known facts: First, that during the middle hours of the day the atmospheric refraction of light rays is at a minimum, and he cites many authentic cases on record where this was the observed fact; second, that during the middle hours of the day the amount of refraction changes but slowly, while at morning and evening this change is rapid. This engineer makes an error, however, because he is treating his patient for the *wrong* disease—for *absolute* refraction instead of *differential* refraction. It would be just as sensible for the physician to give the usual remedies for pneumonia to a patient suffering from consumption. This is not quibbling over a name, but it is a serious question of the proper remedy. In the present case the wrong name for the disease has determined the wrong remedy, and therefore the name is important.

IV. The Proper Remedy for Systematic Errors.

(*a*) *The correct statement of the problem.*—The error of the engineer referred to above is such a common and natural one that it is worth while to make it perfectly evident. In making a stadia reading you are concerned with the *relative* behavior of *two* lines of sight which traverse widely diverging portions of the atmosphere; while in making any other kind of pointing, as in reading a vertical angle on a distant signal, you are concerned with the behavior of but *one* line of sight. Conditions which may cause a minimum amount of refraction for such a single line of sight may or may not be such as to cause a minimum *difference* of refraction in a stadia reading. They are quite independent phenomena, and there is no simple relation between the two cases. In the first case an observer is concerned with the absolute refraction of a ray of light passing through the air, and it is known that the refraction increases with the density of the air—i. e., refraction varies inversely with the temperature.* In the second case the observer is concerned, not with the absolute amount of refraction, but with the relative amounts suffered by the *two* lines of sight. Obviously, that condition will be the best for stadia observations which causes both lines of sight to be bent either *not at all*, or bent the *same amount* in the same direction. As far as refraction affects the accuracy of stadia work, one of these conditions is as favorable as the other. Now, it happens that during the middle of the day, 10.30 a. m. to 2 p. m., the *absolute* refraction of light rays is small and changes but little, but the *differential* refraction during this time is excessive, as has been shown experimentally; moreover, it is well known that during these midday hours "seeing conditions" are very unfavorable to accurate work. The rod appears both unsteady and indistinct, giving large accidental errors.† The argument, then, that the middle of the day is the best time for determining the stadia interval, even without experimental proof to the contrary, is at best a mere assumption; and in the light of that proof the assumption is shown to be false.

If an engineer determines his interval under the conditions which obtain in midday, conditions which are the very farthest removed from the average conditions of the working day, his work done during midday would certainly be expected to be more accurate than that done during the remainder of the day. But unless he intends to confine his work exclusively to midday, which is of course absurd, he would be inviting systematic errors by choosing midday for the interval determination.

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* This branch of the subject has been very carefully studied by the United States Coast and Geodetic Survey. See reports of same for 1871, pp. 154–170; 1876, pp. 355–367; 1883, pp. 281–321; 1884, pp. 391–405. The minimum amount of absolute refraction comes at about 3 p. m., the hour of highest temperature, and the maximum amount of absolute refraction comes twelve hours later, with the lowest temperature.

† In the field work of the Mexican Boundary Survey accurate stadia measurements were not attempted during the middle of the day, if the unsteadiness was marked, and in the more desert region accurate work was sometimes suspended from 8 a. m. to 3 p. m. During such time work was done on side lines, in "filling in" togography, where there was little chance for accumulating errors.

(*b*) *The case applied to the recent survey of St Louis.*—That this is not mere theorizing will be abundantly proved by a glance at the results of the recent survey of St. Louis, a survey which, in most respects, is the equal of any municipal survey of recent times. The report* of this survey states that "stadia distances were always read too long; that of the hundreds of stadia lines run, the coordinates of whose stations are upon record, there is not a single exception to the fact that, in lines run north and south, the latitude is always more in error than the longitude, and that, in lines run east and west, the longitude is always more in error than the latitude." The report also gives a tabulation of a stadia line run around the city, the length of which was 40.4 miles, and which frequently was checked on triangulation stations. Near the southern-most point, 22 miles from the beginning point, the errors had accumulated to +38 meters in latitude, +14 meters in longitude, or +1 877; but when the line had returned to the point of beginning, the constant error, continuing, canceled itself, so that the closing error of the circuit was 1 6332. These, and other facts, prove that distances on this survey were always over-read †

In order to understand the reason for the systematic errors it will only be necessary to inquire into the method of the interval determination. The engineer in charge gives out the following facts: The interval of the single transit used in the stadia work was determined by a single observer, and was made to depend upon ten observations taken at some certain half-hour (not recorded) of a July day, over ground and in weather that are admitted to differ widely from the average conditions met during the three years of field work. As previously stated, the engineer in charge states in his report that the proper time to determine the interval is in the *middle* of the day, so that it is safe to assume that in his work he followed his own advice.

The experiments discussed in this paper show that in the hot months, at least in July and August, the intercept on a stadia rod reaches a minimum at about 11 o'clock a. m., and changes very slowly for several hours. This small rod intercept would result in too large a stadia interval. That is, in the common formula $D=Ks$, the value of $K=\left(\frac{D}{s}\right)$ determined by midday observations would be too large, since the observed values of s would be the *minimum* instead of the average for the field hours. It would, therefore, be expected that measurements covering the usual field hours of every month in the year should be excessive. Such was actually the case at St. Louis.‡

(*c*) *The accurate way of determining the interval.*—Had the stadia interval been determined early in the day or late in the afternoon, the results would have still shown systematic errors, but of opposite sign. However, had the interval determination extended over all of the field hours of several days so as to get average conditions, such systematic errors would have been changed into compensating ones, and the longer the line the greater would be its relative accuracy. Even in this case, as a matter of caution, it would be wise to redetermine the interval whenever the conditions of field work had, for any reason, become greatly different from those attending the original interval determination, e. g., an interval determined in the hot summer months should not be used in the cold winter months without testing it by another independent determination. In every such determination let every condition affecting it be, as near as may be, equal to the average conditions to be met in the field. If the survey is to be over ordinary soil, do not determine the interval on a stone curbing; if the rodman is not to be aided by a plumb bob in the field, do not suffer such aids in holding the rod for the determination, and above all let each man

* See Journal of the Association of Engineering Societies, Vol. XII, p. 1.

† Because of this fact the engineer, in his report, advises setting the transit 43 centimeters back of the initial point on the base line, in determining the stadia interval, so as to virtually subtract that amount from each rod reading. While this would be correct in his work it certainly would not be correct when generally applied to stadia work. For instance, the engineer in charge of the stadia survey of the Chicago Drainage Canal, the surveys of which already cover 50 square miles, states that all his stadia distances, as compared with those obtained by steel tape and triangulation, show a *minus* error (too short) of about one-half the amount on the former work. In the writers's own experience, the measurement on the Mexican boundary line, of 45 miles of level mesa, across that part of the Yuma Desert between the Colorado River and the Tinajas Altas Mountains, showed a minus error of 39 meters as compared with the triangulation determination of the same distance. In short, whether the accumulated errors are positive or negative depends almost entirely on the method of interval determination, and especially upon the hours of day used in such interval determination. This point is made clear in the following discussion.

‡ Experiments made the past winter *indicate* that rod readings made in the middle hours of a winter day are much greater than those made in the corresponding hours of summer days. This fact, if it proves to be true, would cause all winter work of the St. Louis survey to show positive systematic errors.

who is to use a transit determine an interval for his own use. In this way his personal equation will be eliminated. A careful examination of the field records of twenty-four interval determinations made on the International Boundary Survey proves conclusively the truth of the above statement. A few of the typical curves of these intervals may be of interest.

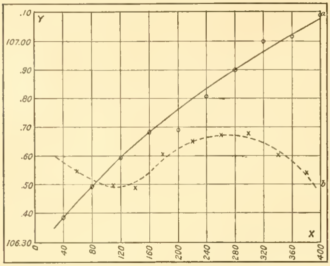

FIG. 22.—Showing the interval determinations of Brandis Transit, 1586. July 8–9, 1893. Nacho Guero Valley, California. X = length of sights in meters. Y = the corresponding interval.

Fig. 22 represents two stadia interval determinations made at Nacho Guero Valley, Lower California, during consecutive days and on the same base line with same instruments, rod, and observers. One interval was taken during the hours 6 to 7.30 a. m., the other from 4 to 5.30 p. m. Unfortunately the notes do not record which was morning and which afternoon, but the full line curve closely resembles the normal afternoon curve.

The first thing to note is that the average ordinate [106.76] in curve (*a*), namely, the average value of K differs from that of curve (*b*) [106.55] by 1/500. The interval used until this time was 106.98, which differs from (*a*) by 1/486, and from (*b*) by 1/250. The writer believes this to be a very unusual disagreement, and one explained by the position of base line, which lay along a small valley with trees so distributed that the line of sight traversed alternate strips of sun and shade, the former largely predominating. An abnormal refraction resulted, causing both determinations to differ widely from the average of several previous ones.

The extremes in temperature at this place in early morning and afternoon were very pronounced. Ice would nearly form in morning, while during the afternoon the temperature would rise to 98° F. The result of such a marked difference in conditions explains the large difference in the resulting intervals. The fact that the choice of an improperly located base line could cause so large an accumulative error as 1/486 would seem to justify more care in such selection than topographers have been accustomed to think necessary.

The point that should not be lost sight of in selecting the base line is that condition of soil, vegetation, etc., shall not differ widely from the corresponding conditions expected in the field.

The necessity of testing for a change of interval with a decided change in season is emphasized by fig. 23. Curves *a* and *b* represent respectively the interval determinations of March 20 and July 10, 1893, of Brandis transit No. 1573, made at same morning hour. It will be seen that both curves are parallel to axis of X for a considerable distance, but on sights greater than 200 meters the platted ordinates [values of K] differ widely and systematically, as is seen by the rapidly diverging curves. The average value of the ordinates in curve *a* is 106.85, while that of curve *b* is 106.53. That is, if the former value represented the average conditions of winter and the latter of summer, a systematic error of 1/333 would be made in all stadia measurements executed during the summer by continuing the use of the winter value of K instead of its actual or true value at such a time.

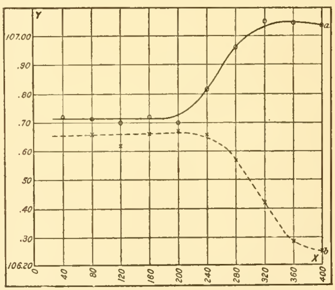

FIG. 23.—Showing the effect of season upon value of intervals. X = length of sight on base line. Y = value of interval, K.

In view of this proof of the inevitable change in the value of the interval, th common practice of painting a rod to correspond with the stadia interval of a certain hour and day and then continuing the use of such rod unchecked and unchanged during the widely different seasons of this country—oftentimes, in fact, for many years at a time—is seen to be inviting the large systematic error which almost without exception characterizes such work. If this evidence be taken to prove the fact that even so-called fixed stadia wires actually change their relative positions, or, what amounts to the same thing, appear to change on account of the influence of differential refraction at different seasons, then the present method of painting the rod to correspond with the determined interval is objectionable because of the cost of regraduating and repainting the rod to correspond to such change in interval. A method entirely free from this objection of cost, and one which the writer has found to stand every test during several years of field use, is that which uses rods divided into true units of feet, yards, or meters and employs an interval factor in the computation of distances. With this system a change in the interval simply means the loss of an hour's time in the preparation of a new table for reduced or true distances corresponding to any rod reading.

Few experienced topographers will deny the fact that many observers have a decided personal equation* in reading a stadia rod. The more experienced the observer the more pronounced the personal equation. It seems to be due to a bias of judgment in making the bisections and in estimating the position of center of stadia wire. The following fact will illustrate this point: On the International Boundary Survey each transit man was instructed to observe the interval of his transit in conjunction with one other engineer.† An examination of the field notes discovers that some engineers had the same personal equation, while others differed quite radically, as is seen in the following table of the first four interval determinations of Brandis transit No. 1584:

Brandis transit, 1584.

Date.	Interval determined by—		Number of transit.
	Mr. S.	Mr. O.	
April 11	104.61	104.57	B. No. 1584
April 28	104.82	104.61	B. No. 1584
April 29	104.83	104.63	B. No. 1584
May 7	104.51	104.41	B. No. 1584
Average	104.69	104.55	Diff. 1—750

This transit measured the boundary line from El Paso to the Colorado River. Opposite each date will be found the separate interval determined by each of the two observers. It will be seen that all of Mr. O.'s determination of K are, without exception, smaller than the writer's, and that the average discrepancy would cause an accumulative error in measuring 1,040 feet of 1.4 feet, or of 1 in 750. The size of this error, though serious enough, is not so objectionable as the fact that from its nature it must be systematic. The custom of having the chief of the party determine the working value of the interval, while his assistants do the observing, is thus seen to be wrong in both theory and practice. The better way would be to let the user of the transit determine the stadia interval himself, or if several engineers were using the same instrument let each determine his own interval.

An example of the case of two observers with very much smaller difference in personal equations is seen in the following table, taken from the records of the same survey:

Date.	Locality.	Interval determined by—		Number of transit.
		Mr. S.	Mr. C.	
July 26, 1892	Lang's Ranch, N. Mex	104.62	104.57	B. No. 1586
Jan. 18, 1893	Yuma, Ariz	97.59	97.50	B. No. 1097
Jan. 19, 1893	do	104.53	104.47	B. No. 1584
Jan. 20, 1893	do	106.88	106.77	B. No. 1573
	Average	103.40	103.34	Dif. — 1 — 1722

* The engineer in charge of the St. Louis survey states that "there was a higher degree of accuracy noticed in the stadia work of the engineer who determined the wire interval;" also, that "a uniform difference in the accuracy of work done by the several observers was shown by the computation of the coordinates of stadia stations," thus indicating a different personal equation for each observer. It should be noted that only the experienced observer can be said to have a personal equation, and this personal equation would be more and more constant and important with increasing experience.

† In computing the average or working interval on this survey double weight was given to the observer who used the transit. Doubling the number of observers doubled the time necessary for the determination without any compensatory gain in accuracy. For this reason a single observer is preferable.

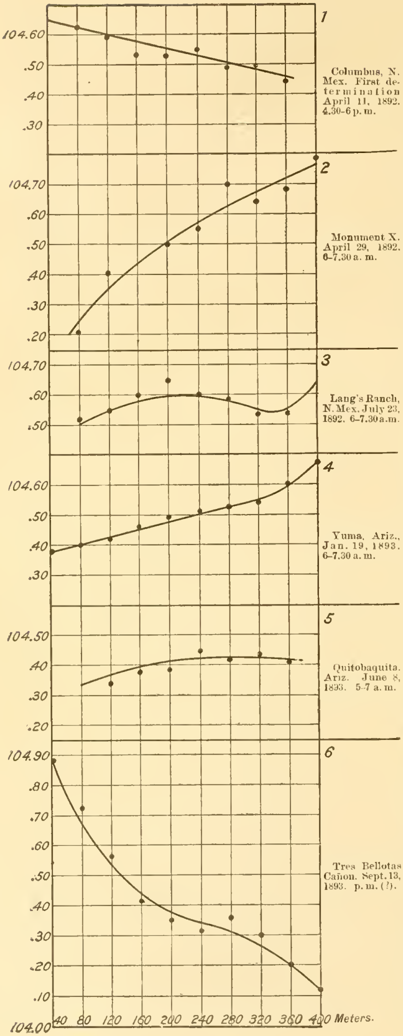

FIG. 24.—Interval of Brandis # 1584.

In this case, as in the one given above, the difference between the observed intervals is seen to have a constant sign, namely, each of Mr. C.'s values are less than the writer's, though the difference is small, being 1 in 1,722.

The last, but by no means the least, potent cause of systematic error in the stadia measurement of the Mexican boundary line remains to be discussed; but first a few words of explanation.

If, in determining the stadia interval, the transit be centered a distance f + c back of the zero of the base line (see fig. 18), the angle formed by the upper and lower line of sight, constituting the stadia reading, will have its apex directly above the zero of the base line. Now, if it were not for the influence of differential refraction, the intercept on the stadia rod held at any point on the base line ought to be proportional to the distance from the rod to the zero of base line. In other words, if we substitute in the usual stadia formula $D = KS$, the several rod readings S_1, S_2, S_3, etc., and also the corresponding exactly determined base-line distances to the rod, D_1, D_2, D_3, etc., we will have an equal number of observation equations containing only one unknown quantity, namely, K, the stadia interval, and solving for K we should expect a series of values affected only by accidental errors. So much for theory. When put in practice this method almost invariably gives a series of values of K differing systematically from each other, the best possible proof of the existence of differential refraction. Obviously this disturbing agency is the factor which determines the accuracy of stadia measurements.

The graphical method is well adapted for bringing out more clearly this point. If a curve be constructed whose abscissæ are the lengths of sight [varying from 80 meters to 400 meters], as determined by the base-line measurements, and whose ordinates are the corresponding values of K, as determined above, such a curve should be theoretically a straight line parallel to the axis of X. Instead, with rare exception, it is found to be a curve cutting the axis of X. An illustration of this fact will be seen in the curves shown in fig. 24, and which represent all the interval determinations of Brandis transit No. 1584.

In the interval determinations, made in the afternoon, it will be noted that the values of K decrease quite uniformly as the length of sight on the base line increases, shown by the descending curve; while in the morning determinations just the opposite is true—i. e., the values of the interval increase with increased length of sight on base line, shown by the ascending curves.

As a rule, the extreme values of K (i. e., those determined at the 80 and 400 meter distance) will be found to differ greatly, as, for example, in one case, 1 in 174 (see curve 2, fig 24). Now the working conditions from El Paso to Yuma were such, that the average length of sight on this section of the boundary line was 215 meters and of the 4,000 stadia sights along this 540 miles of line less than 10 per cent were of more than 270 meters in length. But, as stated in the report of Mr. J. L. Van Ornnum, assistant engineer, the method of finding the true or working value of the interval was to take the average of all the individual values constituting a determination including those from 80 to 400 meters. On account of the systematic differences in these intervals this method would be correct only in case the stadia readings of the field measurements were approximately equally distributed over the same range in distance as those of the interval determination.

A good illustration of this point is found in the stadia measurements, between monuments, along the boundary line from Monument No. 43 to Monument No. 66. Nineteen of these measurements were afterwards checked by a triangulation and by careful steel tape measurements with the result shown in the following table:

TABLE 4.

Between monuments.	K — 104.60 U. S. stadia.	Triangulation and steel tape.	Error of stadia.	K — 104.44 U. S. stadia.	Error of stadia.
	Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
43–44	3,691.74	3,690.14	+ 1.60	3,686.10	— 4.04
46–47	4,779.95	4,773.91	+ 6.04	4,772.70	— 1.21
48–49	4,445.93	4,443.17	+ 2.76	4,439.0	— 4.17
49–50	4,399.24	4,382.20	+ 17.04	4,392.60	+ 9.60
60–61	5,793.63	5,774.95	+ 18.68	5,784.70	+ 10.25
62–63	3,340.28	3,334.02	+ 6.26	3,335.20	+ 1.18
69–70	3,332.65	3,324.18	+ 8.47	3,327.50	+ 3.32
78–79	5,992.19	5,987.53	+ 4.66	5,983.0	— 4.53
83–84	6,067.67	6,060.42	+ 7.25	6,058.4	2.02
86–87	6,332.40	6,325.51	+ 6.89	6,322.9	— 2.61
87–88	6,698.31	6,685.18	+ 13.13	6,688.18	+ 3.00
91–92	5,698.71	5,693.35	+ 5.36	5,690.10	— 3.25
92–93	4,465.20	4,462.58	+ 2.62	4,458.4	4.18
93–94	3,310.40	3,308.87	+ 1.53	3,305.4	— 3.47
94–95	3,478.41	3,475.07	+ 3.34	3,473.17	— 1.90
95–96	3,074.85	3,073.61	+ 1.24	3,070.18	— 3.43
96–97	3,627.78	3,623.94	+ 3.84	3,622.3	— 1.64
107–108	1,530.27	1,527.33	+ 2.94	1,528.0	— 0.67
119–120	2,475.42	2,471.31	+ 4.11	2,471.70	+ 0.39
Total	82,535.03	82,417.27	117.76	82,409.23	— 8.04

It will be noticed in this table that *every one* of the 19 checks shows a systematic error—i. e., every one of these stadia measurements was too long, the average error being 1 in 700. This shows that the interval factor (K), used in the computation of distances, was too large. This value of K was 101.60. As the stadia sights of the field measurements were practically limited to those less than 270 meters in length, the computation of the interval should have been restricted to the same limit of sight on the base line.* Had this been done, the resulting value of K would have been 104.44.

* In explanation of why this method was not employed, it should be stated that at the time the field work was done the causes of systematic errors in stadia measurements were nowhere thoroughly understood. A careful study of methods and results of topographic surveys made in the United States and elsewhere convinces the writer that the field methods used in the topographic work of the United States Boundary Survey were the most carefully and judiciously planned and executed of any topographic survey with which he is acquainted.

Computed with this value of K, the distance between monuments given in Table 4 would have been less by 1 in 650. In the last two columns of Table 4 will be found each separate distance between monuments computed on this basis, and also the resulting error (with proper sign) of the determination. It is interesting to note that, unlike the first set of errors, these latter errors are not systematic, and that their absolute values, with only four exceptions, are less than the actual errors computed with the adopted interval (104.60); and finally that the accumulated error of these 82,417 meters of stadia measurement is only 8 meters, or an error of 1 in 10,000, instead of the original 117.76 meters of error (1 in 700). Nor is this explanation true of only the interval under discussion. A glance at fig. 24 will show that the same reasoning applies equally well to all the other morning determinations of transit 1584, and the writer will add that it also applies to 13 out of 15 morning determinations of other transits used on the survey.*

Of the 24 interval determinations made on this survey only three were made in the afternoon, although as many measurements were made in the afternoon as forenoon. This fact in itself may have been one cause of the systematic error shown in Table 4, as experience shows that the values of the interval determined in the afternoon are less than the corresponding values determined in the morning. This fact is illustrated by fig. 25, which shows 2 curves, the upper being the

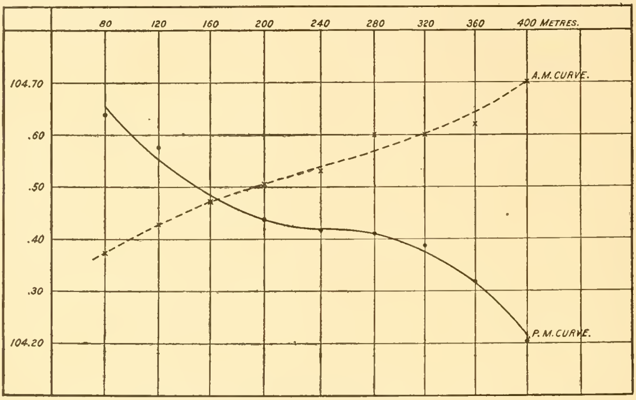

FIG. 25.—Showing characteristic interval curves of morning and afternoon.

average curve of the four morning intervals shown in fig. 24, while the lower curve is the average of the only two afternoon determinations (shown in same figure). A glance will show that the average ordinate of the morning curve—i. e., the average value of the interval factor—is larger than that of the afternoon curve. That is, distances computed with afternoon intervals would be shorter than if computed with morning intervals.

From the foregoing data this generalization can be drawn: Test the stadia interval only on distances and at hours that will be *frequently employed* in the field measurements. In the class of surveys the writer has in mind, viz, those extending over a considerable length of time, this caution can easily be employed.

* The two exceptions noted above furnish internal evidence of being abnormal. In one case this was so clear that the determination was entirely disregarded by the Commission.

TABLE 5.

Results of 18 miles of stadia measurements, showing the compensation of errors.

East Troy, Wis.		Weather.				Average length of sight.	A street (319.157 m.). Errors.		B street (775.446 m.). Errors.		C street (325.731 m.). Errors.		D street (796.555 m.). Errors.		Fractional error in closing on—				Total distance measured from beginning.	Fractional error in this circuit.	Total uncompensated error from beginning.	Uncompensated error of this circuit.		Uncompensated error from beginning.
Date.	Time.	Temperature.	Sun.	Wind.	Amplitude of vibration.		+	−	+	−	+	−	+	−	A street.	B street.	C street.	D street.				+	−	
1894.						*M.*													*Meters.*					
Aug. 4	8-9 a. m.	60°-68° F.	Bright.			139	0.09	.....	.....	0.41	0.15	.....	.....	0.89	$+\frac{1}{3546}$	$-\frac{1}{1891}$	$+\frac{1}{2172}$	$-\frac{1}{894}$	2, 216. 888	$-\frac{1}{2091}$	$-\frac{1}{2091}$	....	1.06	−1.06 a. m.
Aug. 5	6-7 p. m.	68° in shade.	Cloudy ½ time. Bright ½ time.	Still	None	170	.....	0.04	.....	.12	.....	0.05	.....	.69	$-\frac{1}{7979}$	$-\frac{1}{6462}$	$-\frac{1}{6514}$	$-\frac{1}{1154}$	4, 433. 777	$-\frac{1}{2463}$	$-\frac{1}{2262}$	....	0.90	−1.96 a. m.
Aug. 6	9-10 a. m.	98° in sun. 80-86° in shade	Cloudy ¾ time. Sun ¼ time.	Slight, but increasing	0.01 at 180 m. (80 vibrations).	170	.....	.04	.....	.33	.15	.....	.....	.78	$-\frac{1}{7979}$	$-\frac{1}{2350}$	$+\frac{1}{2170}$	$-\frac{1}{1021}$	6, 650. 666	$-\frac{1}{2217}$	$-\frac{1}{2247}$	....	1.00	−2.96 a. m.
Aug. 6	10-12 a. m.	98° in sun. 86° in shade.	Sun obscured by thin clouds.	In gusts. Shakes transit.	0.008 at 140 m.	170	.24	.....	0.39	.....	.35	.....	.....	1.08	$+\frac{1}{1330}$	$+\frac{1}{1988}$	$+\frac{1}{931}$	$-\frac{1}{738}$	8, 867. 555	$+\frac{1}{22168}$	$-\frac{1}{6568}$	1.71	....	−1.35 a. m.
Aug. 6	5.30-6.30 p. m.	80° in shade.	Bright.	Slight	Very slight.	277	.09	.....	.68	.....	.34	.....	0.60	.....	$+\frac{1}{3546}$	$+\frac{1}{1140}$	$+\frac{1}{958}$	$+\frac{1}{1327}$	11, 084. 443	$-\frac{1}{1298}$	$-\frac{1}{8210}$	...	0.13	−1.48 p. m.
Aug. 7	1.30-2.30 p. m.	97° in shade.	Partly cloudy.	In gusts.	0.007 at 198 m.	222	.....	.16	.....	.12	.....	.05	.20	.....	$-\frac{1}{1995}$	$-\frac{1}{6462}$	$-\frac{1}{6514}$	$+\frac{1}{3982}$	13, 301. 332	$-\frac{1}{17053}$	$-\frac{1}{8987}$	....	.10	−3.06 p. m.
Aug. 13	8-9 a. m.	76° in shade.	Hazy	None	0.005 at 320 m.	277	.....	.06	.....	.22	.....	.05	.....	0.69	$-\frac{1}{5319}$	$-\frac{1}{3525}$	$-\frac{1}{6514}$	$-\frac{1}{1154}$	15, 518. 221	$-\frac{1}{2173}$	$-\frac{1}{6207}$	....	1.02	−2.50 a. m.
Aug. 13	11-12 a. m.	96° in sun. 82° in shade.	Hazy	Slight	0.01 at 300 m.	277	.....	.26	1.07	.....	.....	.35	.10	.....	$-\frac{1}{1227}$	$+\frac{1}{725}$	$-\frac{1}{931}$	$+\frac{1}{7965}$	17, 735. 109	$+\frac{1}{3958}$	$-\frac{1}{9143}$	0.56	....	−1.94 a. m.
Aug. 14	6-7 p. m.	82° in shade.	Bright.	None	None	277	.09	.....	.....	.32	.25	.....	.....	.00	$+\frac{1}{3546}$	$-\frac{1}{2423}$	$-\frac{1}{1303}$	0	19, 551. 998	$-\frac{1}{4618}$	$-\frac{1}{8079}$	....	0.48	−2.42 p. m.
Aug. 16	9-10 a. m.	86° in sun. 79° in shade.	Few clouds.	None	0.01 Fast at 195 m.	201	.06	.....	.....	.32	.....	.06	1.20	.....	$+\frac{1}{5319}$	$-\frac{1}{2423}$	$-\frac{1}{5429}$	$+\frac{1}{664}$	22, 168. 887	$+\frac{1}{2519}$	$-\frac{1}{14395}$	.88	....	−1.54 a. m.
Aug. 16	5-6 p. m.	70° in shade.	Bright.	Slight	None	369	.04	.....	0.18	.....	.....	.15	1.80	.....	$+\frac{1}{7979}$	$+\frac{1}{4308}$	$-\frac{1}{2171}$	$+\frac{1}{443}$	24, 385. 775	$+\frac{1}{1185}$	$+\frac{1}{73898}$	1.87	....	0.33 p. m.
Aug. 17	8.30-9 a. m.	68° in shade.	Cloudy	None	None	369	.....	.06	.....	.72	.05	.....	.....	2.04	$-\frac{1}{5319}$	$-\frac{1}{1077}$	$+\frac{1}{6511}$	$-\frac{1}{390}$	26, 602. 664	$-\frac{1}{800}$	$-\frac{1}{10903}$	....	2.77	−2.44 a. m.
Aug. 20	10-12 a. m.	92° in sun. 82° in shade.	Sun ¼ time. Cloudy ¾ time.	Slight	Violent when sun shines.	139	.....	.01	.....	.22	.....	.05	.....	0.05	$-\frac{1}{31916}$	$-\frac{1}{3525}$	$-\frac{1}{6511}$	$-\frac{1}{15931}$	28, 819. 553	$-\frac{1}{6718}$	$-\frac{1}{10401}$	..	0.33	−2.77 a. m.
							0.61	0.63	2.32	2.78	1.04	1.01	3.90	6.22	......	......	......	......	......	......	......	5.02	7.79	......
Total accumulated error of 13 measurements							$-\frac{1}{207450}$		$-\frac{1}{21914}$		$+\frac{1}{141150}$		$-\frac{1}{4483}$											
Aggregate distance measured on each street							4, 149.04 m.		10,080. 80 m.		4,234. 50 m.		10,355. 21 m.											
Average accumulated error of a single measurement							$\frac{1}{3346}$		$\frac{1}{1977}$		$\frac{1}{2665}$		$\frac{1}{1623}$											

Average fractional error in closing on a single measurement of the four streets is the

Average error $\left[\frac{5.02 + 7.79}{13}\right]$: 2216.88 = $\frac{1}{2256}$ or $2\frac{1}{3}$ feet per mile.

(*d*) *Experimental work showing the compensation of errors.*—In order to discover to what extent errors would accumulate, in making a long stadia measurement under actual field conditions, thirteen independent stadia measurements of the base line* were made on the several days and under the conditions of weather and length of sight recorded in Table 5. The method adopted in making these measurements insured the determinations of each distance being entirely independent of any knowledge of what such readings should be. In nearly every sight the transit was set up at undetermined points on the line, so that though the rod was always held on the hundred-foot stations its distance from the transit could never be known by the observer. Moreover, the rod was graduated in meters and the base line in feet. As only one rod of the kind adopted was available, only a single stadia line was in any case measured. There can be no doubt that the accuracy actually obtained could have been improved by taking both a foresight and a backsight on each distance, but with one rodman† this wasted too much time in walking. When the wind blew the rod was provided with a plumb line for aid in holding the rod plumb.

Table 5 is a record of the conditions affecting the work and the results of the work. This record includes (*a*) the actual error made on each street, expressed in meters; (*b*) the corresponding fractional error of each street measurement, and of each complete circuit‡ of 2,216.888 meters; (*c*) each circuit is also summed up from the beginning, and the corresponding accumulated error is given. This varies from 1/2091 on the first circuit to 1/10404 at the end of the thirteenth circuit.

Of the thirteen measurements given in the table, 8 were in the forenoon and 5 in the afternoon, and the work covered every hour of the day from 8 a. m. to 7 p. m., and employed sights varying from 139 to 369 meters in length. The average length of sight used in the morning work was 218 meters (715 feet), while that of the afternoon work was 263 meters (863 feet), or 20 per cent longer than morning sights. The average error of the morning determination of the circuit length was −0.85 meter, or −1/1901, while that of the afternoon determinations was +0.66 meter, or +1/3185. The average uncompensated error of the forenoon work was −0.38 meter, or 1/5834, while that of the afternoon work was +0.05 meter, or 1/42630. This remarkably small error of afternoon work is, of course, accidental, but it is the writer's experience that seeing conditions of the air are much better in the afternoon than in the forenoon, both for stadia work and for pointings in measuring horizontal angles.

The largest error in morning work was when half-interval sights of 369 meters in length were employed, at 9 o'clock. This gave an error of −2.77 meters, or −1/800. Full-interval measurements using shorter sights at the same morning hour, and under less favorable circumstances, gave very much better results. Thus, one using 139 meter sights gave accuracy of 1/2091; one using 201 meter sights gave accuracy of 1/2519; one using 222 meter sights gave accuracy of 1/2217; one using 277 meter sights gave accuracy of 1/2170. This uniformly small error indicates the greater reliability of the shorter length sight, which fact has also appeared from the previous discussion.

The largest error of the afternoon determinations was the one using the same long half-interval reading of 369 meters, which at this time, 5 to 6 p. m., gave an error of +1.80 meters, or 1/1185.

As previously stated, the sun was unobstructed on all the streets except D street. This street, until about 8.30 a. m., was completely shaded. After that time the sun struck the ground at frequent spots, increasing in number and area, till at 11 a. m. the whole street was exposed to the sun. After 2 p. m. the sun shone upon it only in spots, and after 4 p. m. the direct sunlight was entirely cut off by the trees.

The result of the thirteen different measurements of this street is in striking contrast to those obtained on the other three streets. Thus, while the average error of a single measurement on A, B, and C streets was 1/3346, 1/1977, and 1/2065, respectively, the average error on D street was

* See description of this base line in footnote, p. 427.

† In this work four different and totally inexperienced rodmen were employed at different times. With one exception they were not over 15 years of age, and though they were shown how to hold the rod, before trusting them with it, doubtless more experienced rodmen would have insured better results.

‡ It should be noted that the computation of stadia measurements of these circuits was the same as though made in *a straight line* of length equal to the sum of lengths of the four streets forming the circuit. Computations were not made by *latitudes and departures*.

twice as large (1/1023). As every condition affecting the measurement of all four streets was exactly the same, excepting this one matter of alternate belts of sun and shade on D street, the greatly increased error in measurement of this street seems justly attributable to this peculiar condition.

At the time the field work was done the effect of the shade was expected to lend greater accuracy to the measurements, but later study has shown that alternate belts of sun and shade give rise to air columns of different temperatures and hence of different densities. Such a condition of the air causes indistinct images, together with increased refraction of the rays of light. The first effect causes large accidental errors, and the latter large systematic errors.

The total time spent in measuring the thirteen circuits, a total of 18 miles, was fourteen hours, making the rate of about 13 miles per day of ten hours. A double stadia line, i. e., one with both foresight and backsight readings on each distance, could, with two rodmen, be measured in nearly as short a time.

V. SUMMARY OF CONCLUSIONS.

The above experimental data lead to the following conclusions:

First. Unsteadiness of a terrestrial line of sight is made up of both vertical and horizontal vibrations.

Second. The vertical vibrations are made up of two systems, one of large amplitude and slow movement and the other of short amplitude and relatively fast movement.

Third. This vertical vibration may seriously affect the accuracy of any single stadia reading, but from its nature it must cause a compensating error, and therefore is of only secondary importance.

Fourth. The time of maximum vibration is about the middle of the forenoon, or when the maximum difference of temperature between ground and air occurs.

Fifth. Long sights (i. e., those whose intercepts about equal the length of the rod) should either not be read in the hot parts of the day, or else should be read by half intervals on the upper part of the rod.

Sixth. The vertical vibration is accompanied by an abnormal refraction in the stratum of air within 3 or 4 feet of the ground, which in all past work has caused large accumulating errors, thus limiting the accuracy of stadia work to about 1/700.

Seventh. The engineer who is to execute the field measurements should himself determine the stadia interval in order to avoid the systematic error due to his personal equation.

Eighth. In determining the interval, the length of sight on base line should be limited to the most common ones employed in the field work.

A somewhat wide correspondence with experienced stadia engineers establishes the fact that at present scarcely two engineers agree as to the proper time of determining the interval. One writes, "determine it in midday;" another, "determine it in the morning;" another, "during a cloudy day," etc. If the conclusions of this paper are correct, all are individually wrong, and yet collectively right. The only correct way is to *determine the interval during many hours, and select such hours as will approximate as closely as possible to average field conditions.* The degree of accuracy which will result in the field measurements will correspond closely to the degree of such approximation.

The writer is aware that some experienced topographers will refuse to follow his suggestions, for the reason that in their opinion stadia measurements are sufficiently accurate already. For many purposes this is doubtless true, but these engineers certainly do fail to see the widening field of usefulness that would properly belong to the stadia method, when once its accumulative errors had been brought within proper limits. A large amount of expensive control, now rendered indispensable by present careless methods, could be advantageously omitted as unnecessary.

The stadia method is such a convenient and economical one to use that it would seem a step in the direction of progress to give the method increased accuracy, especially as this can be done at so little expense.

The chief objections to the added care which is required in the original interval determination, and also to any subsequent determination made necessary by a decided change in field conditions, will doubtless be the cost of repainting the rods in the latter case and the cost of additional care in both cases. The first objection will be entirely removed by not incorporating the interval in the rod, as is at present so generally done, but instead, using rods divided into standard units of length, and then computing true distance by means of an *interval factor*. By means of a table such computations can be made very quickly. All the measurements discussed in this paper were thus computed. This point is very ably discussed by Mr. J. L. Van Ornum, of Washington University, in a paper on stadia work read before the American Society of Civil Engineers at its summer convention of 1895. He names the following as some of the disadvantages of the present method as compared with the method in which an interval factor is employed:

First. Subsequent tests of interval can not be made without the expense of repainting and regraduating the rod.

Second. Rods can not be interchanged among transits.

Third. Old rods can not be used with new transits.

Fourth. Rods can not be used in leveling without computing the necessary correction.

Fifth. Leveling rods can not be used in stadia work.

Sixth. Observers with different personal equations can not use the same rods without causing systematic errors in the work.

The disadvantages of the present system seem so evident that the adoption of the *interval factor* system seems only a question of the time necessary to "teach old dogs new tricks."

The second objection to using proper care in determining the stadia interval is more apparent than real. Increased accuracy of any work usually involves increased expenditure of care or money, or perhaps both. The real question is, Will the results of such increased care justify the increased cost? It has been seen that such care prevents, in a great measure, the large systematic errors which up to the present time have confined the use of the stadia method within narrow limits. On some surveys with which the writer is acquainted the cost of the steel tapes worn out in making measurements where the stadia method might have been employed has exceeded either the cost of repainting rods or of the increased care of interval determinations. Again, it should be noted that in surveys extending over a year or more, and furnishing frequent triangulation or steel-tape checks on the stadia measurements, each check may be used as an interval determination, and the average of a number of such determinations would give the very best value for the interval to be used in future, without the expense of an extra dollar or of an extra hour of time.

The foregoing report is hereby attested by the signatures of the members of the United States section of the International Boundary Commission.

Signed November 25, 1896: J. W. BARLOW,
Colonel of Engineers, U. S. A.

Signed October 1, 1896: A. T. MOSMAN,
Assistant, Coast and Geodetic Survey.

Signed November 25, 1896: D. D. GAILLARD,
Captain of Engineers, U. S. A.