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DEPARTMENT OF STATE.

REPORTS

UPON THE

SURVEY OF THE BOUNDARY

BETWEEN THE

TERRITORY OF THE UNITED STATES

AND THE

POSSESSIONS OF GREAT BRITAIN

FROM THE

LAKE OF THE WOODS TO THE SUMMIT OF THE ROCKY MOUNTAINS,

AUTHORIZED BY

AN ACT OF CONGRESS APPROVED MARCH 19, 1872.

ARCHIBALD CAMPBELL, Esq.,
COMMISSIONER.

Captain W. J. TWINING,
CORPS OF ENGINEERS, BREVET MAJOR U. S. A., CHIEF ASTRONOMER.

PUBLISHED IN ACCORDANCE WITH AN ACT OF CONGRESS
APPROVED MARCH 3, 1877.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1878.

[44TH CONGRESS, 2D SESSION. SENATE EX. DOC. No. 41.]

MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES,

COMMUNICATING

INFORMATION IN RELATION TO THE BOUNDARY-LINE BETWEEN THE UNITED STATES AND THE POSSESSIONS OF GREAT BRITAIN,

FROM THE

NORTHWEST ANGLE OF THE LAKE OF THE WOODS TO THE SUMMIT OF THE ROCKY MOUNTAINS.

FEBRUARY 23, 1877.—Read, ordered to lie on the table and be printed.

To the Senate and House of Representatives:

I transmit herewith a report from the Secretary of State bearing date the 20th instant, with its accompaniments, being the report of the commissioner of the United States and of the officers of engineers attached to the commission appointed to determine the boundary-line between the United States and the possessions of Great Britain, from the northwest angle of the Lake of the Woods to the summit of the Rocky Mountains. These reports announce the completion of the labors of this commission, whereby the entire boundary-line between the United States and the possessions of Great Britain is marked and determined, except as to that part of the territory of the United States which was ceded by Russia under the treaty of 1867.

U. S. GRANT.

WASHINGTON, *February* 23, 1877.

DEPARTMENT OF STATE,
Washington, February 23, 1877.

By the act of March 19, 1872, entitled "An act authorizing the survey and marking of the boundary between the territory of the United States and the possessions of Great Britain, from the Lake of the Woods to the summit of the Rocky Mountains," the President was authorized to co-operate with the Government of Great Britain in the appointment of a joint commission for determining such boundary-line between these points.

This boundary to be determined was that defined in the second article of the convention between the United States and Great Britain of October 20, 1818, whereby it was provided "that a line drawn from the most north-

REPORTS

OF THE

COMMISSIONER AND OF THE CHIEF ASTRONOMER

OF THE

NORTHERN BOUNDARY.

UNITED STATES NORTHERN BOUNDARY COMMISSION,
Washington, July 3, 1876.

SIR: I have the honor to transmit herewith the original of the final agreement of the commissioners, the original "List of astronomical stations observed," the original official "List of monuments marking the international boundary-line," and the maps, records, and reports relating to the northern boundary commission, as enumerated in the accompanying letter of the chief astronomer.

I would also respectfully report that with the exception of a few expenditures necessary in closing the office, not included in my accounts for the quarter ended June 30, 1876, but for which vouchers will be rendered in a few days, all office-expenses have ceased.

I have the honor to be, very respectfully, your obedient servant,

ARCHIBALD CAMPBELL,
Commissioner Northern Boundary Survey.

Hon. HAMILTON FISH,
Secretary of State.

UNITED STATES NORTHERN BOUNDARY COMMISSION,
Washington, D. C., June 30, 1876.

SIR: I respectfully transmit the following official records and documents relating to this survey:

First. Portfolio containing originals of preliminary maps of the survey.

Second. Portfolio containing the joint maps signed by the commissioners and chief astronomers.

Third. Two boxes marked "U. S. Northern Boundary Commission, 1872–1876. Under convention of London, Oct. 20, 1818."

(First.) "Book records."

(Second.) "Map records."

The contents are marked on the cover of each box, and all indexed and referred to in detail in the accompanying paper, marked "Appendix F to the report of Capt. W. J. Twining, Corps of Engineers, chief astronomer."

Fourth. Appendix A to report of chief astronomer, being the report of Capt. J. F. Gregory, assistant astronomer.

Fifth. Appendix B, being the report of Lieut. F. V. Greene, assistant.

Sixth. Appendix C, hypsometry.

Seventh. Appendix D, being a bound copy of the astronomical and geodetic results of the survey, accompanied by a descriptive memoir by Capt. W. J. Twining, chief astronomer.

Eighth. Appendix E, giving the complete details of the monuments marking the boundary, including the calculated azimuths from each.

Ninth. Appendix F, index to maps, showing the record by pages on which each map is based.

Tenth. Appendix G, giving the latitude-observations on which the reconnaissance-maps are based, parts 1 and 2.

I also transmit the following maps and diagrams:

1. Reconnaissance-maps, 6 sheets.
2. Profile, 1 sheet.
3. Diagram to illustrate the relative errors of astronomical stations in latitude, resulting from local deflections of the plumb-line.
4. Diagram showing method of tracing parallel.
5. Sketch showing triangulation of Chief Mountain Lake.
6. Map of the vicinity of the northwest point of the Lake of the Woods; scale, 6 inches=1 mile.
7. Magnetic chart.
8. Drawings of instrument-stands.
9. Drawings of targets.
10. Fifty sets photolithographs of preliminary maps

The portions of my report not yet complete are as follows:

1. Appendix H, by Mr. Lewis Boss, on the standard declinations of the stars used in the latitude work.

This important appendix is to be completed, without further expense to the commission, by Mr. Boss, with the assistance of Professor Newcomb, of the Naval Observatory, and the Nautical Almanac Office.

2. Text of report of chief astronomer, in hands of copying-clerk, and waiting completion of Appendix H.

I am, very respectfully, your obedient servant,

W. J. TWINING,

Captain Engineers, Chief Astronomer.

ARCHIBALD CAMPBELL, Esq.,

Commissioner Northern Boundary.

UNITED STATES NORTHERN BOUNDARY COMMISSION.

REPORT OF COMMISSIONER ARCHIBALD CAMPBELL.

1872-1876.

REPORT.

UNITED STATES NORTHERN BOUNDARY COMMISSION,
Washington.

SIR: In compliance with instructions received from the Department upon my appointment as "commissioner on the part of the United States to determine and mark the boundary-line between the United States and British possessions, as defined in the second article of the convention between the United States and Great Britain of October 20, 1818," I have the honor herewith to report generally the results of the labors of the commission, and to transmit the detailed report of the same by Maj. W. J. Twining, United States Engineers, chief astronomer, as far as completed.

The second article of the convention of 1818, above referred to, is as follows:

ARTICLE 2. It is agreed that a line drawn from the most northwestern point of the Lake of the Woods, along the forty-ninth parallel of north latitude, or, if the said point shall not be in the forty-ninth parallel of north latitude, then that a line drawn from the said point due north or south as the case may be, until the said line shall intersect the said parallel of north latitude, and from the point of such intersection due west along and with the said parallel, shall be the line of demarkation between the territories of the United States, and those of His Britannic Majesty, and that the said line shall form the northern boundary of the said territories of the United States, and the southern boundary of the territories of His Britannic Majesty, from the Lake of the Woods to the Stony Mountains.

The immediate cause of the authorization by Congress of the determination and demarkation of this portion of the boundary-line between the United States and British possessions is stated by the President in his annual message to Congress, dated December 5, 1870, third session of Forty-first Congress, as follows:

In April last, while engaged in locating a military reservation near Pembina, a corps of United States engineers discovered that the commonly-received boundary-line between the United States and the British possessions at that place is about forty-seven hundred feet south of the true position of the forty-ninth parallel, and that the line, when run on what is now supposed to be the true position of the forty-ninth parallel, would leave the fort of the Hudson Bay Company, at Pembina, within the territory of the United States. This information being communicated to the British Government, I was requested to consent, and did consent, that the British occupation of the fort of the Hudson Bay Company should continue for the present. I deem it important, however, that this part of the boundary-line should be definitely fixed by a joint commission of the two governments, and I submit herewith estimates of the expense of such a commission on the part of the United States, and recommend that an appropriation be made for that purpose. The land-boundary has already been fixed and marked from the summit of the Rocky Mountains to the Georgian Bay. It should now be in like manner marked from the Lake of the Woods to the summit of the Rocky Mountains.

The President's message is accompanied by a correspondence between the State, Treasury, and War Departments, and between the State Department and British minister, in relation to the difficulties on the frontier arising from the uncertainty as to the true position of the boundary; and also by an estimate of the probable cost of a commission for surveying and marking the boundary between the United States and British possessions, made by General Humphreys, Chief of Engineers, in compliance with the request of the State Department. The following is a copy of the letter transmitting the estimate:

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., November 23, 1870.

SIR: In reply to the communication of the 7th instant from the Department of State asking for an estimate of the probable cost of surveying and marking the boundary between the United States and the British possessions, from the Lake of the Woods to the Rocky Mountains, I beg to reply that a properly-organized commission, with two sets of astronomical and surveying parties to expedite the work, would require, from the estimate hereunto annexed, an expenditure of about $100,000 yearly while actually engaged upon field-duties.

But it is not possible to state with certainty the length of time required to trace and mark the whole line, as the progress that would be made depends upon the nature of the country to be passed over.

The line is about eight hundred and sixty miles long. The season for working to advantage is short, and although the country is generally an open one, the number of astronomical stations to be occupied, upon which the rate of progress mainly rests, depends so much upon the distance of prominent points of elevation from each other, that they cannot be estimated.

From one month to six weeks would, no doubt, making due allowance for bad weather, be required to establish astronomically a point on the parallel, to trace its connection with a preceding one, and to move the party to the next. Should these points average fifty miles apart, there would be some seventeen stations, or, say, eight stations for each astronomical party to occupy, which would consume from eight to twelve months' actual field-duty for the completion of the line.

It is not probable that the parties can be kept in the field continuously for this length of time, but that the work would have to run through two seasons at least, if not longer.

The services of the officers and the greater part of the assistants would be required for another year on office-work to complete the records of the survey, so that the probable expense which would be incurred for completing the work might be set down at $325,000.

Officers of engineers have been frequently assigned to perform such duties as these, and if the demarkation of this boundary should be confided to them, the estimate should be modified.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. W. W. BELKNAP,
Secretary of War.

In compliance with the recommendation of the President, a joint resolution appropriating $100,000 for the survey of the boundary-line between the United States and the British possessions, from the Lake of the Woods to the Rocky Mountains, was introduced into and passed the House of Representatives, but, from want of time or other cause, it failed to pass the Senate. At the succeeding session of Congress, 1871–'72, the following act passed both houses and became a law, viz:

AN ACT authorizing the survey and marking the boundary between the territory of the United States and the possessions of Great Britain, from the Lake of the Woods to the summit of the Rocky Mountains.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the President of the United States, by and with the advice and consent of the Senate, be, and he is hereby, authorized to co-operate with the Government of Great Britain in the appointment of a joint commission, in accordance with the plan and estimates of Brig. Gen. A. A. Humphreys, Chief of Engineers, submitted November twenty-third, eighteen hundred and seventy, for determining the boundary-line between the United States and the British possessions, between the Lake of the Woods and the Rocky Mountains: *Provided, however,* That engineers in the regular service of the United States shall be employed exclusively as engineers in the performance of the duties contemplated by this act, without any additional salary, and the Secretary of War is hereby directed to make the necessary detail of engineers for that purpose.

SEC. 2. That fifty thousand dollars, or so much thereof as may be required, be, and the same is hereby, appropriated, out of any money in the Treasury not otherwise appropriated, to carry into effect the object of said joint commission.

Approved March 19, 1872.

The amount of the appropriation for one year, according to the estimate of General Humphreys, should have been $100,000, but it was reduced by Congress to $50,000, a sum insufficient for a vigorous and economical prosecution of the work, particularly during the first year, as many purchases had to be made for an outfit. In consequence of this reduction, the organization of the commission was deferred by the Department until the month of June, when I received the appointment of commissioner, with instructions to organize a party for the survey of the boundary, in accordance with the means provided by Congress.

In compliance with the terms of the act creating the commission, the Chief of Engineers, by direction of the Secretary of War, detailed the following engineer officers for duty with the commission, viz: Capt. and Bvt. Lieut. Col. F. U. Farquhar, Capt. and Bvt. Maj. W. J. Twining, Capt. (then Lieut.) James F. Gregory, and Lieut. F. V. Greene.

An office was temporarily rented in Washington for the necessary preparations for the survey. Early in July, Colonel Farquhar, with the engineer officers and civil assistants attached to the commission, left Washington for Saint Paul, Minn., and there organized a party for field operations.

Previously to leaving Washington, upon a request made to the Secretary of War, the Quartermaster-General was directed to furnish the commission with the necessary means of transportation for the field-work of the survey, with the understanding that the mules, wagons, &c., furnished were to be returned in good condition at the close of the work in the field. The train was directed to assemble at Fort Abercrombie, on Red River, there to await the arrival of the commission.

On my arrival in Saint Paul, Second Lieut. O. D. Ladley, Twenty-second Infantry, who had been detailed by Maj. Gen. W. S. Hancock, then in command of the Department of Dakota, to act as quartermaster and commissary to the commission, reported to me in person and was directed to proceed to Fort Abercrombie in advance of the commission, to put the train in readiness for the march to Fort Pembina, near the forty-ninth parallel.

The purchase of supplies for the season's work being made, and the employés required being secured, the commission left Saint Paul for Fort

Abercrombie, and on the 29th of August, with the train, started thence northward for Fort Pembina, and reached that post on the 5th of September. Capt. Loyd Wheaton, of the Twentieth Infantry, the officer in command of that post, rendered the commission efficient assistance and facilitated its operations. General Hancock, having detailed Capt. A. A. Harbach's company, K, Twentieth Infantry, as escort to the commission, I found them there in readiness to enter upon the duties assigned them.

The encampment of the commission was at once established in the vicinity of the forty-ninth parallel, near the post erected by Colonel Long in the year 1823, by direction of the government, to mark a point on the boundary-line between the United States and British possessions. Colonel Long at that time was engaged in an expedition to the source of Saint Peter's River, Lake of the Woods, &c. In the narrative published in 1824, compiled from his notes, he makes the following statement:

> The main object of the party in visiting this place (Pembina) being the determination of the forty-ninth degree of latitude, Mr. Calhoun lost no time in taking observations. The first one which he made was near Mr. Nolen's house, and, although not very satisfactory, yet it showed that we were near to the boundary-line, as it indicated 48° 59′ 27″. We then pitched our camp a little farther down on the bank of the river, and, as near as we could judge, to the boundary-line. A large skin-lodge, which was lent to us, sheltered the gentlemen of the party during our stay there. Our tent-flies were pitched around it for the use of the soldiers. In honor of the President of the United States, this place received the name of Camp Monroe. A flag-staff was planted, which, after a series of observations made during four days, was determined to be in latitude 48° 59′ 27″ north. The magnetic meridian having been ascertained to be 13° 17′ 25″ east, the distance to the boundary-line was measured off, and an oak post fixed on it, bearing on the north side the letters G. B., and on the south side, U. S. On the 8th of August at noon the flag was hoisted on the staff, which bore south 44° 25′ west of the post at a distance of 207½ feet. A national salute was fired at the time, and a proclamation made by Colonel Long that, by virtue of the authority vested in him by the President of the United States, the country situated upon Red River above that point was declared to be comprehended within the territory of the United States. (pp. 46 and 47, Long's Narrative of an Expedition to the Source of Saint Peter's River, Lake Winnepeg, Lake of the Woods, &c., performed in the year 1823, by order of the Hon. John C. Calhoun, Secretary of War.)

When astronomical observations and surveys to determine the boundary-line were commenced by the commission, the season had reached the middle of September, leaving a comparatively short period of time for field-work in this high latitude. The British commissioner, Capt. D. R. Cameron, R. A., and the British chief astronomer, Capt. S. Anderson, R. E., reached Pembina on the 16th and 18th of September. On the latter day the first meeting of the joint commission took place, and a general plan of operations was agreed upon for the remainder of the season.

The mode of surveying and marking the boundary was discussed, and it was agreed that a point on the forty-ninth parallel of north latitude, close to the western bank of Red River, should be the point of the boundary first to be ascertained.

It was also agreed that when the last-named point had been ascertained, the part of the boundary-line to the east of Red River should be determined, and, if practicable, the survey of it completed during the first working season, so as to enable the joint commission to commence the survey of the line westward of the point ascertained near Red River, at the opening of the next year's operations in the field.

It was also agreed that such portions of the boundary-line eastward of Red River as may be through wooded country, should be cleared for a breadth of thirty feet, under the direction of the British commissioner, during the winter season, at the joint expense of the two commissions.

The manner of permanently marking the line was left for future consideration, in order that it might be ascertained by inspection of the country what would be the most desirable and economical material for its demarkation.

On the 1st of October Colonel Farquhar, United States chief astronomer, left the camp for the Lake of the Woods, to meet the chief astronomer of the British commission, for the purpose of jointly ascertaining the position of the "northwesternmost point of the Lake of the Woods," the initial point of the boundary-line; and from that point to determine the boundary-line due south, according to the terms of the treaty, until it reaches the forty-ninth parallel.

On the 11th of October, accompanied by Captain Cameron, I took the steamer from Pembina down Red River to Fort Garry, on the way to the northwesternmost point of the Lake of the Woods. On the 14th we started from Fort Garry for the Lake of the Woods, and on the 19th reached the vicinity of the northwesternmost point, where we found Colonel Farquhar and Captain Anderson, with their respective parties. After their arrival at the lake they had, with the assistance of native Indians of that region, discovered the remains of the reference monument erected by the United States and British commissioners (Messrs. Porter and Barclay), appointed under the sixth and seventh articles of the treaty of Ghent; from which monument, by a series of courses and distances laid down in their joint report to their governments, the position of the northwesternmost point of the lake was to be ascertained. The northwesternmost point not being on firm ground, could not be marked by a monument.

From this report of the chief astronomers I was satisfied with the northwesternmost point of the lake, as ascertained by them and recommended for our acceptance, but Captain Cameron was not disposed to accept the result of their examinations and search for the reference monument, it being his policy in the interest of the Canadian Government, if not the result of instructions, to leave the question of the northwesternmost point of the lake unsettled, because the meridian boundary-line from that point southerly to its intersection with the forty-ninth parallel would cut off from the mainland and leave to the United States a portion of territory, projecting into the lake, of great importance, and almost indispensable to the province of Manitoba as a means of communication with Canada. Upon this territory a depot and steamboat-landing at the terminus of the Fort Garry road had been established for some time previously to the authorization of the joint commission to determine the boundary.

The British commissioner, while declining to agree officially to the northwesternmost point of the lake as determined by the chief astronomers, expressed his willingness to cut a sight-line from that point southerly through the timber along the meridian boundary until it strikes the shore of the lake, without, however, at that time agreeing to it as a part of the boundary-line. His object doubtless was to leave the question in abeyance, in the hope that before the boundary was completed to the summit of the Rocky Mountains, or subsequently, some arrangement might be made between the two governments whereby this small but much-coveted and important piece of territory would become a part of the North West Territory.

Having completed the object of our visit to the Lake of the Woods, we started to Fort Garry on the 25th of October, and reached it on the 29th. In consequence of rainy weather we remained there several days. On the 6th of November we returned to Pembina. By that time the parties generally had closed field operations, and those of the United States commission were on their way to Fort Abercrombie, where the wagon-train was to be left during the winter season. From there the employés were taken to Saint Paul and discharged for the winter. The last party in the field, under Major Twining, did not reach Saint Paul until the 23d of November, by which time it had become quite cold.

The Department having designated Detroit as the place for establishing the office of the commission during the winter, the employés who were no longer required were discharged at Saint Paul. The chief astronomer, with his assistants, repaired to Detroit, where they remained until the opening of the season for field-work in the ensuing spring.

Congress, during the session of 1872–'73, appropriated $125,000 for the operations of the ensuing fiscal year, making it available upon the passage of the act, as the amount of the previous appropriation was nearly exhausted.

Before the resumption of field-work for the year 1873, Colonel Farquhar, United States chief astronomer, applied to the Engineer Department to be relieved from duty with the boundary commission, preferring his legitimate duties in the Engineer Corps. His request was granted, and Maj. W. J. Twining, the engineer officer next in rank on duty with the commission, became chief astronomer.

At the earliest moment practicable, in the year 1873, Major Twining was in the field with his parties. The survey was commenced at the astronomical station which had, during the previous year, been determined and marked on the western bank of Red River. Major Twining commenced operations with the intention of completing four hundred miles of the survey during the season, and he accomplished his object. The boundary was marked at intervals of one mile between the United States and the province of Manitoba, and farther west at average intervals of three miles. These monuments were built of earth, or stone where it could be found. Those separating Manitoba from the United States have been replaced by monuments of iron.

The climate of the country in the vicinity of the boundary cannot be surpassed. The days, though sometimes warm, are always more or less tempered by a pleasant breeze, and the nights in midsummer are cool and refreshing, and sometimes exceedingly cool, even to the freezing-point. The surface of the earth in this region is generally a rolling prairie, gradually but almost imperceptibly rising from Red River to the base of the Rocky Mountains.

After crossing Pembina River, thirty-five miles west of Red River, there is a considerable rise in the land. This elevation is called Pembina Mountain, though in reality it is only an elevated plateau. The boundary farther to the west crosses Turtle Mountain, a rough and rugged elevation covered with timber, through the whole extent of which along the boundary a vista of fifteen feet in width was cut. The distance from the east to the west base of the mountain is about thirty-four and one-half miles. By far the larger part of Turtle Mountain falls upon the southern side of the line, and, in consequence of the great scarcity of timber in that latitude, it is a fortunate acquisition.

At the close of the season's work in October Major Twining withdrew all his parties from the field, with the exception of Lieutenant Greene's, and moved southwardly to Jamestown, Dak., in order to strike the Northern Pacific Railroad at that point, and from there continued his journey to Saint Paul, where the employés for the season's work were discharged, and the officers and assistants repaired to Detroit to bring up the office-work during the winter. Lieutenant Greene with his party remained in the field during the winter, in order to complete the survey of the line between the Lake of the Woods and Red River, it being impracticable to perform that work during the summer season on account of the swampy character of the country.

In consequence of delay in the passage of the appropriation for the boundary commission for the year 1874, it was late before I was able to join the parties in the field. On my arrival at Fort Buford, on the Missouri, the military post at which Major Twining laid in his supplies for the season, I found he had a short time previously started northwardly, to strike the forty-ninth parallel at the point where the survey terminated at the close of the previous season. As soon as my small train was in readiness, I moved toward the boundary-line, accompanied by a small escort of infantry, five companies of which had been detailed by General Terry as escort to the commission, together with two companies of cavalry. As the commission were moving through a country far from civilization, occupied by Blackfeet and other warlike Indians, this large escort was considered necessary to its safety and exemption from molestation.

After steadily traveling for seventeen days, on the 2d of August we reached the camp of the cavalry escort. The country over which we passed, following the Missouri and its tributaries, is monotonous and uninteresting.

The cavalry camp was near the Three Buttes or Sweet Grass Hills, three prominent peaks which rise to a great height over the surrounding country, and present a most agreeable relief to the eye in contrast with the tameness of the country over which we had recently passed. We here found delicious, cold, spring water, a great luxury after the unpalatable and unwholesome water we had been obliged to drink on the route when not near the Missouri River.

From the summit of these peaks on a clear day a fine view of the crest of the Rocky Mountains is obtained. After remaining a day at the cavalry camp, we left for Major Twining's camp, which we reached after a journey of thirty miles. Captain Gregory and Lieutenant Greene, engineer officers attached to the commission, were encamped in its vicinity. It created quite a variety in our wilderness life to find such an assemblage of parties in this attractive neighborhood.

From Major Twining I learned that two hundred and forty miles of the remainder of the boundary left unfinished last year had already been completed since he reached the boundary, and in a little less time than six weeks.

On the 8th of August, a clear, cool, and bright day, accompanied by Lieutenant Greene, I rode to the summit of the westernmost of the Three

Buttes, a distance of about six miles from the camp. The ascent was steep toward the summit, but practicable. From that elevated point the Rocky Mountains in all their grandeur were in full view, while beneath us it required but little imagination to convert the rolling prairie into an ocean. The summit of the butte is about 1,700 feet above the level of the prairie.

On the 12th of August, accompanied by Major Twining, I left the Three Buttes for the Rocky Mountains, the distance being about one hundred and ten miles. We encamped for the night in a very fine position, giving a full view of the group of buttes composing the Sweet-Grass Hills; for each of the three principal buttes is composed of one chief butte, surrounded by others of inferior size, the whole of them covering a considerable extent of territory.

The next morning we moved westward, traveled about twenty-eight miles, and encamped on Milk River. From our camp we had fine views of the Rocky Mountains, the summit being still partially covered with snow. On our journey this day we passed through the country of the Blackfeet Indians, during which time it was deemed prudent to keep closer together and nearer to the escort than usual, but we were not molested. The Indians, knowing that we were well protected by troops, gave us no trouble during the whole survey.

Toward the evening of this day, the 13th of August, Captain Cameron, the British commissioner, unexpectedly made his appearance among us, having just returned from the summit of the Rocky Mountains, where the survey was rapidly progressing to a conclusion. As this was the last opportunity before the parties would be withdrawn from the field, we held a meeting of the joint commission at our camp. Captain Cameron stated that he was now prepared to agree to the northwesternmost point of the Lake of the Woods, as determined by the chief astronomers of the United States and British commissions, his government having directed him to acknowledge the reference-monument pointed out to the chief astronomers by Indians residing in the vicinity.

He also agreed to adopt the astronomical parallel as the true boundary instead of the mean parallel, which he had hitherto strongly urged, and which would have been a great additional expense without any corresponding benefit.

These points of difference being settled, the joint commission adjourned to meet on some future day, after the completion of the office-work, for the purpose of comparing the records of the survey and the final maps of the boundary, preparatory to their signature by the commissioners.

The day after the meeting of the joint commission, we continued our journey toward the Rocky Mountains over a soft, rolling, grassy prairie. During the journey the mountains were constantly in view. No description can do justice to the magnificence of this mountain scenery. As we approached it day by day, the Chief Mountain, near the forty-ninth parallel, stood pre-eminent in distinctness and grandeur, resembling a gigantic obelisk broken off at the summit. There is an infinite variety in the mountain range near the parallel. It requires but little aid of the imagination to see a city in ruins, in which fortifications, pyramids, and other familiar objects present themselves to the eye.

On the 17th of August we reached Chief Mountain Lake, near the base of Chief Mountain, and encamped in its vicinity. On the 20th, with a pack-train, we started westward over the Rocky Mountains, taking two days in crossing to its western base, and two days in returning. We found the United States and British parties approaching the termination of the line, and searching for the monument erected on the summit of the mountains at the terminus of the boundary between the United States and British possessions authorized by the treaty of 1846. The monument was at length discovered in a spot very difficult of access, and therefore the better adapted to preserve it from being disturbed. The survey was carried to the monument, and the line was thus completed from the northwesternmost point of the Lake of the Woods to the summit of the Rocky Mountains.

The weather had been so fine during the whole season that there was no interruption to the progress of the survey. The nights were clear, and the astronomical work was rapid and accurate. Being so remote from settlements, and in a latitude where winter commences very early, it was most fortunate that the parties were able to leave the field while it was still comparatively mild.

Arrangements had been made by Major Twining early in the season for the construction of Mackinac boats at Fort Benton, on the Missouri, for the purpose of transporting the party down the Missouri River to Bismarck, the western terminus of the Northern Pacific Railroad, and thence to Saint Paul by railroad, to be discharged, with the exception of the assistants who were required to do the office-work of the commission.

By the 12th of September, the various parties in the field having assembled at Fort Benton, the fleet of six Mackinac boats started down the river. Major Twining and his assistants accompanied the expedition. At night the boats were fastened to the shore, and the whole party, including officers, bivouacked. They reached Bismarck in eighteen days.

On the 13th of September I left Fort Benton for Fort Shaw, on Sun River, in Montana, accompanied by General Gibbon, United States Army, who had left his post for Fort Benton, to visit the officers of the commission before their departure for the East. He had been directed by the commanding general of the Department of Dakota (General Terry) to furnish the commission any additional escort that might be required when it reached the neighborhood of the Rocky Mountains, and he had promptly informed me of his readiness to respond to my requisition for troops, if they should be needed.

We reached Fort Shaw, in Montana, a distance of sixty-three miles, in about eight hours, traveling in a spring-wagon over the natural surface of the ground, which was of a similar character to that over which we had passed on our way to the Rocky Mountains.

I remained two days at Fort Shaw. The post was garrisoned by four companies of infantry. It had a very neat and highly military appearance, the houses being mainly of adobe and very warm and comfortable. General Gibbon took much pride in exhibiting his fine gardens filled with vegetables for the troops. The soil is very fertile, and, although the warm season is brief, vegetables come to maturity rapidly and are of a very fine quality.

On the 16th of September I left Fort Shaw for Helena, a distance of eighty miles, and with a relay reached it in twelve hours. On the succeeding day I attended a fair, at which the various products of Montana, mineral, animal, and vegetable, were exhibited. Notwithstanding the high latitude of Montana, the winters are comparatively mild. The cattle are left at large during that season, and keep in good condition by picking up nutritious grass of that region, which remains on the ground throughout the winter covered by snow of a moderate depth. Montana being protected from westerly winds by the Rocky Mountains, the climate is much milder in winter than might naturally be supposed.

The next day I started from Helena in a Concord stage, and after traveling steadily four days and three nights I reached Ogden, on Salt Lake, and there took the Union Pacific Railroad for the East.

After the chief astronomer and his assistants reached Washington, an office was rented for the purpose of working out the results of the survey, and constructing the maps for the illustration of the boundary-line and the country adjacent thereto.

The British commission, at the close of the field-work of the survey, returned to London and there executed their office-work. In the month of March last Maj. D. R. Cameron, R. A., Her Britannic Majesty's commissioner, announced to me by letter that early in April the work of the British commission would be completed and ready for the final meeting of the joint commission preparatory to closing its proceedings, and requested, if convenient, that I would meet him for that purpose in London. Having submitted the proposition to the Department, I received authority to comply with it. Accordingly, with the assent of the Department, I left the United States on the 1st of April, in advance of the chief astronomer, who followed on the 19th. On his arrival at London the United States and British chief astronomers compared the records and maps of the respective commissions, and having reported that the latter were ready for the signature of the commissioners, they were duly signed on the 29th of May, with a protocol of the final proceedings of the commission, of which the following is a copy, viz:

Record of proceedings at a meeting of the commissioners appointed respectively by the President of the United States of America, and by Her Britannic Majesty, to ascertain and mark the boundary-line between the respective territories of the United States and of Her Majesty, the said line being that defined by the second article of the convention of London, signed October 20, 1818.

PRESENT.

Donald R. Cameron, major Royal Artillery, commissioner on the part of Her Britannic Majesty.

S. Anderson, captain Royal Engineers, chief astronomer to Her Majesty's commission.

A. C. Ward, captain Royal Engineers, secretary to Her Majesty's commission.

Archibald Campbell, commissioner on the part of the United States of America.

W. J. Twining, captain of the Corps of Engineers of the United States Army, chief astronomer to the United States commission.

1. The chief astronomers submit the following documents and maps:

a. A detailed list in duplicate of forty astronomical stations, in addition to one for the location of the most northwestern point of the Lake of the Woods, at which observations were taken under their superintendence, to determine the line described in the second article of the convention of London (signed October 20, 1818) between the terminal points, viz, the most northwestern point of the Lake of the Woods and the eastern end of the international boundary-line previously marked between Akamina, in the Rocky Mountains, and the western coast of North America.

b. A descriptive list in duplicate of three hundred and eighty-eight (388) monuments and marks placed on the boundary-line, as derived from the astronomical stations enumerated in the list referred to in section *a* of this paragraph.

c. A duplicate set of twenty-four (24) maps on a scale of $\frac{1}{126720}$, or 1 inch to 2 miles, illustrating the topography of the country through which the boundary-line runs, and indicating the relative positions of the various monuments and marks referred to in section *b* of this paragraph.

2. The second article of the convention of London, signed 20th October, 1818, is read, as follows:

"It is agreed that a line drawn from the most northwestern point of the Lake of the Woods, along the forty-ninth parallel of north latitude, or if the said point shall not be in the forty-ninth parallel of north latitude, then that a line drawn from the said point due north or south, as the case may be, until the said line shall intersect the said parallel of north latitude, and from the point of such intersection due west, along and with the said parallel, shall be the line of demarkation between the territories of His Britannic Majesty and those of the United States, and that the said line shall form the southern boundary of the said territories of His Britannic Majesty, and the northern boundary of the territories of the United States, from the Lake of the Woods to the Stony Mountains."

The duplicate documents and maps enumerated in paragraph numbered one (1)—one set for each of the respective governments—having been examined and compared, are authenticated by the signatures of the commissioners, who agree as follows:

1. The three hundred and eighty-eight (388) monuments detailed in the list referred to in section *b* of paragraph numbered one, are on and mark the astronomical lines stipu-

lated by the second article of the convention of London (signed October 20, 1818) to be the line of boundary between the territories of Her Britannic Majesty and of the United States of America, from the Lake of the Woods to the Stony (*i. e.*, Rocky) Mountains.

2. In the intervals between the monuments along the parallel of latitude, it is agreed that the line has the curvature of a parallel of 49° north latitude; and that such characteristic shall determine all questions that may hereafter arise with reference to the position of the boundary at any point between neighboring monuments.

3. It is further agreed that, in the event of any of the said three hundred and eighty-eight (388) monuments or marks being obliterated beyond the power of recognition, the lost site or sites shall be recovered by their recorded position relatively to the next neighboring unobliterated mark or marks.

ARCHIBALD CAMPBELL,
United States Commissioner, London, May 29, 1876.
D. R. CAMERON,
Major R. A., Her Britannic Majesty's Commissioner, London, May 29, 1876.

The proceedings of the joint commission having thus been brought to a conclusion, it adjourned *sine die*.

In accordance with an estimate of the chief astronomer of the United States commission, made immediately preceding the opening session of the present Congress, the Department was informed that the office-work of the commission would be completed at the close of the present fiscal year, and that a balance of the appropriation, amounting to $15,000, would probably remain unexpended. This contemplated result is now accomplished, and is in a great measure due to the ability and careful management of Major Twining, who has had immediate charge of the survey of the boundary-line, and to his assistants, Captain Gregory and Lieutenant Greene, United States Engineers, who have most efficiently and zealously discharged the duties which devolved upon them.

Mr. James E. Bangs, the secretary of the commission, who has been immediately under my charge, has performed with fidelity and accuracy the various duties pertaining to his position, and particularly those connected with the disbursement of the funds appropriated for the expenses of the commission.

In conclusion, I would respectfully call the attention of the Department to the report of Dr. Elliott Coues, the surgeon and naturalist of the commission, whose eminent ability in the latter position has placed him among the most distinguished of those who have devoted themselves to this branch of science.

I have the honor to be, very respectfully, your obedient servant,

ARCHIBALD CAMPBELL,

Commissioner Northern Boundary Survey.

Hon. HAMILTON FISH,

Secretary of State.

LIST OF THE ASTRONOMICAL STATIONS OBSERVED BY THE JOINT COMMISSION FOR THE DETERMINATION OF THE INTERNATIONAL BOUNDARY-LINE FROM THE NORTHWEST ANGLE OF THE LAKE OF THE WOODS TO THE ROCKY MOUNTAINS.

No.	Name of the astronomical station.	Distance from Lake of the Woods station.		Longitude west of Greenwich.			Remarks.
		Miles.	*Links.*	°	′	″	
	Northwest angle			95	08	39.7	Lat. 49° 22′ 19″.137.
1	Lake of the Woods (joint)	0	0		16	55.3	
2	Pine River	31	7205		59	01.1	
3	West Rosean Ridge	68	1283	96	46	51.9	
4	Red River (joint)	88	4936	97	13	51.5	
5	Point de Michel (joint)	108	5962		40	25.2	
6	Pembina Mountain, east (joint)	121	0002	98	00	33.0	
7	Pembina Mountain, west	135	6307		16	06.3	
8	Long River	165	1305		54	52.1	
9	Sleepy Hollow	183	3911	99	19	02.4	
10	Turtle Mountain, east	203	7729		46	04.3	
11	Turtle Mountain, west	238	1510	100	31	13.9	
12	First Souris (or Mouse River)	258	0744		57	29.8	
13	South Antler	281	1973	101	28	03.0	
14	Second Souris (or Mouse River)	303	7150		57	56.1	
15	United States No. 8 Astronomical Station	325	3846	102	26	25.2	
16	Short Creek	343	2892		50	00.9	
17	Third Mouse River	359	3254	103	11	11.3	
18	Grand Coteau	377	2977		34	53.7	
19	Mid Coteau	400	4925	104	05	31.0	
20	Big Muddy	426	5035		39	53.6	
21	Bully Spring	451	1841	105	12	21.4	
22	Poplar River	473	3454		41	39.2	
23	West Poplar	496	6906	106	12	31.1	
24	Little Rocky	522	4742		46	31.5	
25	Frenchman's Creek	550	6740	107	23	18.2	
26	Cottonwood Coulé	567	3881		45	45.9	
27	Pool on Prairie	588	1931	108	13	09.2	
28	Near Goose Lake	615	3202		48	59.6	
29	East Fork	642	0218	109	21	27.8	
30	West Fork	655	2357		41	38.2	
31	Milk River Lake	677	0281	110	10	19.5	
32	Milk River	702	3023		43	46.1	
33	East Butte	723	0383	111	11	02.5	
34	West Butte	739	5770		33	02.6	
35	Red Creek	760	3160	112	00	19.5	
36	Second Milk River (or south branch)	785	0279		32	50.3	
37	North branch Milk River	804	3361		58	25.2	
38	Rocky Mountains	825	6138	113	26	35.3	
39	Belly River	836	3385		40	39.0	
40	Chief Mountain Lake	846	0240		53	19.7	
41	Akamina	853	2529	114	02	56.5	Observed by the joint commission, 1861.

W. J. TWINING,
Captain of Engineers, United States Chief Astronomer.

ARCHIBALD CAMPBELL,
United States Commissioner, May 29, 1876.

S. ANDERSON,
Captain Royal Engineers, British Chief Astronomer.

D. R. CAMERON,
Major Royal Artillery, Her Britannic Majesty's Commissioner, May 29, 1876.

LIST OF MONUMENTS MARKING THE INTERNATIONAL BOUNDARY-LINE FROM THE NORTHWEST ANGLE OF THE LAKE OF THE WOODS TO THE ROCKY MOUNTAINS.

NOTE.—The azimuths given in this table are calculated, and do not form a part of the official agreement of the commissioners.

MONUMENTS MARKING DUE SOUTH LINE.

Number of mound.	Distance south of northwest point.	Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles. Links		° ′ ″	° ′		° ′		
....	0 0	Not marked..........	95 08 57.7	....	.....	....	.....	Northwest point in swamp. Latitude 49° 23′ 50″.3.
1	1 3071	Iron pillar	95 08 57.7	00 00	0	180 00	2	Latitude 49° 22′ 38″.2.
2	1 7001	......do	95 08 57.7	00	1	00	3	Latitude 49° 22′ 12″.6 north of Dawson road.
3	2 2797	......do	95 08 57.7	00	2	00	4	Latitude 49° 21′ 47″.8.
4	3 3626	......do	95 08 57.7	00	3	00	5	Latitude 49° 20′ 50″.4.
5	5 0945	......do	95 08 57.7	00	4	00	6	Latitude 49° 19′ 23″.6.
6	6 1882	Granite cairn	95 08 57.7	00	5	00	7	Latitude 49° 18′ 25″.4.
7	7 4351	Iron pillar	95 08 57.7	00	6	180 00	8	Latitude 49° 17′ 17″.2.

MONUMENTS FROM LAKE OF THE WOODS WESTWARD.

Number of mound.	Distance from Lake of the Woods.	Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles Links		° ′ ″	° ′		° ′		
1	0 0	Stone cairn, 7½′ × 8′	95 16 55.3	....	.....	270 09	2	Lake of the Woods astronomical station.
2	3 0	Earth mound, 7′ × 14′ ..	20 52.8	90 06	1	09	3	
3	5 0	......do	23 31.1	07	2	10	4	
4	9 0	Iron pillar	28 47.8	06	3	09	5	
5	12 0	Earth mound, 7′ × 14′ ..	32 45.4	06	4	09	6	
6	15 0	......do	36 42.9	06	5	09	7	
7	17 0	Iron pillar	39 21.2	07	6	08	8	East of northeast Roseau crossing.
8	18 2080	Earth mound, 7′ × 14′ ..	41 01.0	08	7	09	9	
9	21	Iron pillar	44 37.9	07	8	09	10	
10	24 1548	Earth mound, 7′ × 14′ ..	48 50.8	06	9	09	11	
11	25 6804	Iron pillar.............	51 02.0	07	10	09	12	On Ridge.
12	29	Earth mound, 7′ × 14′ ..	55 11.3	07	11	09	13	At Pine River.
13	30	......do	56 30.5	07	12	07	14	
14	32 5154	......do	96 00 00	05	13	01	15	Marking eastern boundary of Manitoba.
15	33 4936	Earth-mound, 10′ × 6′ ..	01 16.9	00	14	01	16	
16	34 4936	Timber	02 26.0	00	15	01	17	In Great Roseau Swamp
17	35 4936	......do	03 55.2	00	16	01	18	Do.
18	36 4936	......do	05 14.4	00	17	01	19	Do.
19	37 4936	......do	06 33.6	00	18	01	20	Do.
20	38 4936	......do	07 52.7	00	19	01	21	Do.
21	39 4936	......do	09 11.9	00	20	01	22	Do.
22	40 4936	......do	10 31.1	00	21	01	23	Do.
23	41 4936	......do	11 50.2	00	22	01	24	Do.
24	42 5519	Iron pillar	13 15.2	00	23	01	25	
25	43 4936	Earth mound, 10′ × 6′ ..	14 28.5	00	24	02	26	
26	44 5519	Iron pillar.............	15 53.6	89 59	25	01	27	
27	45 4936	Earth mound, 10′ × 6′ ..	17 06.9	59	26	02	28	
28	46 5519	Iron pillar.............	18 31.9	59	27	02	29	
29	47 4936	Earth mound, 10′ × 6′ ..	19 45.3	90 00	28	01	30	
30	48 5519	Iron pillar.............	21 10.3	00	29	02	31	Near 40-Mile station.
31	49 4936	Earth mound, 10′ × 6′ ..	22 23.6	01	30	02	32	
32	50 5519	Iron pillar	23 48.6	01	31	02	33	
33	51 4936	Earth mound, 10′ × 6′ ..	25 02.0	01	32	02	34	
34	52 5519	Iron pillar	26 27.0	01	33	02	35	
35	53 4936	Earth mound, 10′ × 6′ ..	27 40.3	01	34	02	36	
36	54 5519	Iron pillar.............	29 05.3	01	35	02	37	Fast of Pointo d'Ormo.
37	55 5519	......do	30 21.5	01	36	02	38	West of Point d'Orme. Between 37 and 38 the Roseau River at Pointe d'Ormo crosses the line three times.
38	56 5519	......do	31 43.7	01	37	02	39	
39	57 5519	......do	33 02.8	01	38	02	40	
40	58 5519	......do	31 22.0	01	39	02	41	
41	59 5519	......do	35 41.2	01	40	02	42	
42	60 5519	......do	37 00.4	01	41	02	43	
43	61 5519	......do	38 19.5	01	42	02	44	
44	62 5519	......do	39 38.7	01	43	02	45	

List of the monuments marking the international boundary-line, &c.—Continued.

Number of mound.	Distance from Lake of the Woods.		Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles.	*Links.*		° ′ ″	° ′		° ′		
45	63	5519	Iron pillar	96 40 57.9	90 01	44	270 02	46	
46	64	5519	do	42 17.1	01	45	02	47	
47	65	5519	do	43 36.2	01	46	02	48	
48	66	5519	do	44 55.4	01	47	02	49	
49	67	5519	do	46 14.6	01	48	05	50	East of Roseau Ridge.
50	68	5519	do	47 33.8	04	49	05	51	West of Roseau Ridge.
51	69	5519	do	48 52.9	04	50	05	52	
52	70	5519	do	50 12.1	04	51	04	53	
53	71	5519	do	51 31.3	03	52	05	54	
54	72	5519	do	52 50.5	04	53	05	55	
55	73	5519	do	54 09.6	04	54	05	56	
56	74	5519	do	55 28.8	04	55	05	57	
57	75	5519	do	56 48.0	04	56	05	58	
58	76	5519	do	58 07.2	04	57	05	59	
59	77	5919	do	59 26.3	04	58	05	60	
60	78	5519	do	97 00 45.5	04	59	05	61	
61	79	5519	do	02 04.7	04	60	04	62	
62	80	5519	do	03 23.9	03	61	05	63	
63	81	5519	do	04 43.0	04	62	05	64	
64	82	5519	do	06 02.2	04	63	05	65	
65	83	5519	do	07 21.4	04	64	05	66	
66	84	5519	do	08 40.6	04	65	05	67	West bank of Joe River.
67	85	5519	do	09 59.7	04	66	05	68	
68	86	5519	do	11 18.9	04	67	05	69	
69	87	5519	do	12 38.1	04	68	05	70	East of Red River.
70	88	4936	do	13 51.5	02	69	00	71	Red River astronomical station.
71	88	5519	do	13 57.3	00	70	01	72	
72	89	5519	do	15 16.4	00	71	01	73	
73	90	5519	do	16 35.6	00	72	01	74	
74	91	5519	do	17 54.8	00	73	01	75	
75	92	5919	do	19 14.0	00	74	01	76	
76	93	5519	do	20 33.1	00	75	01	77	
77	94	5519	do	21 52.3	00	76	01	78	
78	95	5519	do	23 11.5	00	77	01	79	Marais River.
79	96	5519	do	24 30.7	00	78	01	80	
80	97	5519	do	25 49.8	00	79	01	81	
81	98	5519	do	27 09.0	00	80	01	82	Manitoba principal meridian.
82	99	5519	do	28 28.2	00	81	01	83	
83	100	5519	do	29 47.4	00	82	01	84	
84	101	5519	do	31 06.5	00	83	01	85	
85	102	5519	do	32 25.7	00	84	01	86	
86	103	5519	do	33 44.9	00	85	01	87	
87	104	5519	do	35 04.1	00	86	01	88	
88	105	5519	do	36 23.2	00	87	01	89	
89	106	5519	do	37 42.4	00	88	01	90	
90	107	5519	do	39 01.6	00	89	01	91	
91	108	5519	do	40 20.8	00	90	269 58	92	Grant's, or Pointe Michel.
92	109	5519	do	41 39.9	89 57	91	58	93	
93	110	5519	do	42 59.1	57	92	58	94	
94	111	5519	do	44 18.3	57	93	58	95	
95	112	5519	do	45 37.5	57	94	58	96	
96	113	5519	do	46 56.6	57	95	58	97	
97	114	6319	do	48 23.7	57	96	58	98	
98	115	5519	do	49 35.0	57	97	58	99	
99	116	5519	do	50 54.1	57	98	58	100	
100	117	5519	do	52 13.3	57	99	58	101	
101	118	5519	do	53 32.5	57	100	58	102	
102	119	5519	do	54 51.7	57	101	58	103	
103	120	5519	do	56 10.9	57	102	57	104	
104	121	5519	do	57 30.0	56	103	57	105	
105	122	5519	do	58 49.2	56	104	57	106	
106	123	5519	do	98 00 08.4	56	105	58	107	Base of Pembina Mountain.
107	124	5519	do	01 27.6	58	106	55	108	
108	125	5519	do	02 46.7	54	107	55	109	
109	126	5519	do	04 05.9	54	108	55	110	
110	127	5519	do	05 25.1	53	109	55	111	
111	128	5519	do	06 41.3	51	110	51	112	
112	129	5519	do	08 03.4	54	111	54	113	
113	130	5519	do	09 22.6	54	112	54	114	
114	131	5519	do	10 41.8	53	113	55	115	
115	132	6065	do	12 06.5	54	114	270 00	116	Near west bank of Pembina River.
116	134	2307	do	14 07.5	90 00	115	00	117	Top of ridge west of Pembina River.
117	134	5519	do	14 39.3	00	116	00	118	
118	135	5519	do	15 58.5	00	117	269 59	119	Near United States astronomical station No. 4.
119	136	5519	do	17 17.6	89 58	118	58	120	

List of the monuments marking the international boundary-line, &c.—Continued.

Number of mound.	Distance from Lake of the Woods.		Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth	To mound number—	Remarks.
	Miles.	*Links.*		° ′ ″	° ′		° ′		
120	137	5519	Iron pillar	98 18 36.8	89 57	119	269 58	121	
121	138	5519	......do	19 56.0	57	120	59	122	
122	139	5519	......do	21 15.2	58	121	58	123	
123	140	5519	......do	22 34.4	57	122	58	124	
124	141	5519	......do	23 53.5	57	123	58	125	
125	142	5519	......do	25 12.7	57	124	58	126	
126	143	5519	......do	26 31.9	57	125	58	127	
127	144	5519	......do	27 51.1	57	126	58	128	
128	145	5519	......do	29 10.2	57	127	58	129	
129	146	5519	......do	30 29.4	57	128	58	130	
130	147	5519	......do	31 48.6	57	129	58	131	
131	148	5519	......do	33 07.8	57	130	58	132	
132	149	5519	......do	34 26.9	57	131	58	133	East bank of large coulé.
133	150	5519	......do	35 46.1	57	132	58	134	
134	151	5519	......do	37 05.3	57	133	58	135	
135	152	5519	......do	38 24.5	57	134	58	136	
136	153	5519	......do	39 43.6	57	135	58	137	Near coulé, east bank.
137	154	5519	......do	41 02.8	57	136	58	138	
138	155	5519	......do	42 22.0	57	137	58	139	
139	156	5519	......do	43 41.1	57	138	58	140	
140	157	5519	......do	45 00.3	57	139	58	141	
141	158	5519	......do	46 19.5	57	140	58	142	Near crossing of Half-Breed trail.
142	159	5519	......do	47 38.7	57	141	58	143	
143	160	5519	......do	48 57.9	57	142	58	144	
144	161	5519	......do	50 17.0	57	143	58	145	
145	162	5519	......do	51 36.2	57	144	59	146	
146	163	5519	......do	52 55.4	58	145	58	147	
147	164	5519	......do	54 14.6	57	146	57	148	
148	165	5519	......do	55 33.7	54	147	55	149	
149	166	5519	......do	56 52.9	54	148	55	150	
150	167	5519	......do	58 12.1	54	149	55	151	
151	168	5519	......do	59 31.3	54	150	55	152	
152	169	0420	......do	99 00 00.0	54	151	54	153	Western boundary of Manitoba.
153	169	5519	......do	00 50.4	54	152	55	154	
154	170	5519	......do	02 09.6	54	153	55	155	
155	170	6998	Stone cairn, 13′ × 7′*	02 24.2	54	154	55	156	
156	172	7154	......do*	05 04.2	54	155	55	157	
157	175	7662	......do*	09 06.7	52	156	54	158	
158	176	5485	Stone cairn, 10′ × 6′*	10 04.3	53	157	56	159	
159	178	6527	Earth mound, 16′ × 7′*	12 53.0	54	158	55	160	
160	180	7412	......do′	15 40.1	53	159	55	161	
161	183	1414	Earth mound, 10′ × 5′*	18 38.3	53	160	54	162	
162	183	3911	Earth mound, 9′ × 6′*	19 03.0	53	161	56	163	Sleepy Hollow astronomical station.
163	186	3911	......do*	23 00.5	54	162	56	164	
164	189	1228	......do*	26 31.5	54	163	56	165	
165	191	5717	......do*	29 54.2	54	164	57	166	
166	195	1272	......do*	34 27.0	53	165	57	167	
167	198	3911	......do*	38 50.6	53	166	57	168	
168	201	7911	......do*	43 27.7	53	167	56	169	
169	203	7729	Earth mound, 14′ × 6′*	46 04.2	54	168	270 04	170	Turtle Mountain, east, astronomical station.
170	206	7729	......do*	50 01.8	90 01	169	04	171	
171	209	5582	......do*	53 38.0	01	170	04	172	
172	212	7729	......do*	57 56.8	01	171	04	173	
173	215	1996	......do*	100 00 57.6	02	172	05	174	
174	218	7729	......do*	05 51.9	01	173	04	175	
175	221	7248	......do*	09 44.6	01	174	04	176	
176	224	7729	......do*	13 46.9	01	175	04	177	
177	227	6470	......do*	17 32.0	01	176	04	178	
178	229	7245	......do.	20 18.0	01	177	03	179	East shore of Boundary Lake.
179	233	3787	Earth mound, 9′ × 6′*	25 05.5	00	178	03	180	High ridge east of Summit Lake.
180	235	2660	......do*	27 27.7	01	179	03	181	On slope of Turtle Mountain, and outside of timber.
181	237	6968	Stone cairn, 16′ × 7′*	30 48.7	01	180	05	182	East of Turtle Mountain, west, astronomical station.
182	243	1114	......do*	37 45.8	01	181	05	183	
183	247	0649	......do*	42 57.9	01	182	04	184	
184	249	3036	......do*	45 59.9	01	183	04	185	
185	252	5896	......do*	50 25.7	01	184	04	186	
186	255	2940	Earth mound, 8′ × 5′*	53 54.0	02	185	03	187	
187	256	3880	Stone, 16′ × 7′*	55 22.4	02	186	03	188	
188	258	0744	Earth mound, 5′ × 8′*	57 29.8	02	187	00	189	First crossing of Mouse River on west bank, astronomical station
189	261	0744	......do*	101 01 27.3	89 57	188	00	190	
190	264	0744	......do*	05 24.8	57	189	01	191	
191	267	0744	......do*	09 22.3	58	190	00	192	
192	270	0744	......do*	13 19.9	57	191	00	193	Right bank of South Antler Creek
193	273	0744	......do*	17 17.4	57	192	00	194	Left bank of South Antler Creek.

List of the monuments marking the international boundary-line, &c.—Continued.

Number of mound.	Distance from Lake of the Woods.		Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles.	*Links.*		° ′ ″	° ′		° ′		
194	276	0744	Earth mound, 5′ × 8′*	101 21 14.9	89 57	193	270 00	195	
195	279	0744	......do*	25 12.4	57	194	270 00	196	
196	281	1973	Stone cairn, 10′ × 5′*	28 02.9	58	195	269 55	197	On prairie near South Antler Creek
197	283	2146	Stone cairn, 15′ × 6′*	30 52.9	52	196	54	198	
198	286	0448	......do*	34 23.7	52	197	55	199	
199	288	5976	Earth mound, 15′ × 6′*	37 58.8	52	198	55	200	
200	291	0514	Stone cairn, 15′ × 6′*	41 00.2	52	199	55	201	
201	294	7699	Earth mound, 12′ × 6′*	46 08.9	52	200	55	202	
202	297	2521	......do*	49 15.1	52	201	56	203	
203	300	1250	Stone cairn, 12′ × 6′*	53 00.1	51	202	56	204	
204	301	5152	......do*	54 57.9	51	203	49	205	East bank of Mouse River, near road.
205	303	7150	Earth mound, 5′ × 8′*	57 56.0	47	204	270 01	206	Second crossing Mouse River astronomical station.
206	306	7150	......do*	102 01 53.6	58	205	01	207	
207	309	7150	......do*	05 51.1	58	206	01	208	
208	312	7678	......do*	09 53.8	58	207	01	209	East of Rivière des Lacs.
209	315	7150	......do*	13 46.1	57	208	01	210	West of Rivière des Lacs.
210	319	0398	......do*	17 56.0	57	209	00	211	
211	321	7150	......do*	21 41.2	57	210	01	212	
212	325	3846	Earth mound, 14′ × 6′*	26 25.2	57	211	08	213	Astronomical station.
213	329	7294	Stone, 8′ × 6′*	32 16.0	90 01	212	08	214	
214	331	5986	Earth mound, 14′ × 6′*	34 41.4	06	213	08	215	
215	334	5167	Stone, 8′ × 6′*	38 30.8	05	214	08	216	
216	337	1260	Earth mound, 10′ × 5′*	41 49.7	05	215	08	217	
217	340	1291	Stone, 10′ × 5′*	45 47.5	05	216	08	218	East bank of coulé.
218	342	2814	Earth mound, 13′ × 6′*	48 40.9	06	217	07	219	East bank Short Creek.
219	343	2892	Earth mound, 9′ × 6′*	50 00.9	06	218	03	220	British astronomical station, Short Creek, west bank.
220	346	0472	Earth mound, 12′ × 6′*	53 34.4	00	219	03	221	
221	349	2410	......do*	57 51.1	00	220	03	222	
222	352	4392	......do*	103 02 08.3	00	221	03	223	Near Half-Breed road, east bank of Mouse River.
223	356	0770	......do*	06 49.1	89 59	222	03	224	West of Mouse River.
224	359	3254	Stone, 12′ × 5′*	11 11.2	59	223	269 59	225	Third Mouse astronomical station.
225	361	7908	Earth mound, 18′ × 8′*	14 35.7	56	224	269 59	226	
226	364	3606	......do*	17 51.2	57	225	270 00	227	East of Mouse River.
227	369	0336	Earth mound, 16′ × 6′*	23 54.1	55	226	270 00	228	West of Mouse River.
228	372	4136	......do*	28 29.3	56	227	269 59	229	
229	374	5825	Stone, 12′ × 7′*	31 21.3	57	228	269 59	230	
230	377	2977	Earth mound, 12′ × 6′*	34 53.7	56	229	270 09	231	Grand Coteau astronomical station, base of Coteau.
231	379	7417	......do	38 16.0	90 06	230	09	232	
232	382	4013	......do	41 39.8	06	231	09	233	
233	385	1896	......do	45 16.4	06	232	09	234	
234	388	6377	......do	49 58.2	06	233	09	235	
235	392	4139	......do	51 52.8	06	234	09	236	
236	395	4462	......do	58 53.5	06	235	09	237	
237	398	6241	......do	104 03 08.6	06	236	08	238	
238	400	4925	Earth mound, 10′ × 5′	05 31.0	07	237	269 52	239	Mid Coteau astronomical station.
239	403	2392	......do	09 06.4	89 49	238	52	240	
240	405	5407	Stone, 10′ × 5′	12 14.6	49	239	52	241	
241	407	6966	......do	15 08.4	49	240	52	242	East side of large coulé.
242	410	4899	Earth, 10′ × 5′	18 45.5	49	241	52	243	West side of large coulé.
243	413	3675	......do	22 30.9	49	242	52	244	
244	417	2411	......do	27 35.0	49	243	52	245	
245	421	2177	Stone, 10′ × 5′	32 49.4	49	244	52	246	
246	424	0941	......do	36 34.7	49	245	52	247	
247	426	5035	Earth, 14′ × 6′	39 53.6	49	246	270 05	248	Big Muddy astronomical station.
248	429	4938	......do	43 50.2	90 02	247	05	249	
249	432	1370	Earth mound, 14′ × 6′	47 12.4	02	248	05	250	East of Pyramid Creek.
250	435	3035	......do	51 26.4	02	249	04	251	On west bluff Pyramid Creek.
251	437	1489	......do	53 49.4	02	250	05	252	
252	440	7152	......do	58 43.0	01	251	04	253	East of Big Muddy River.
253	444	5081	......do	105 03 39.2	00	252	03	254	West of Big Muddy River.
254	447	5311	Stone, 12′ × 6′	07 39.0	00	253	03	255	
255	451	1841	Stone, 10′ × 5′	12 21.4	00	254	06	256	Bully Spring, United States astronomical station No. 11.
256	451	4321	......do	12 45.9	05	255	07	257	
257	454	4541	Earth mound, 10′ × 5′	16 45.6	04	256	07	258	
258	457	5874	......do	20 56.3	04	257	07	259	
259	460	5841	......do	24 53.5	04	258	07	260	In a broad valley.
260	464	4632	......do	29 58.3	03	259	07	261	
261	467	4826	......do	33 55.7	04	260	07	262	
262	472	0732	......do	39 53.1	03	261	06	263	In valley of Poplar River
263	473	3451	Earth mound, 14′ × 6′	41 39.2	04	262	269 57	264	Poplar River astronomical station
264	476	3471	......do	45 36.7	89 54	263	57	265	
265	479	3332	......do	49 33.0	54	264	57	266	

List of the monuments marking the international boundary-line, &c.—Continued.

Number of mound.	Distance from Lake of the Woods.	Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles. Links.		° ′ ″	° ′		° ′		
266	482 3454	Earth mound, 14′ × 6′ ..	105 53 31.8	89 54	265	269 57	267	
267	485 3454	......do	57 29.3	54	266	57	268	
268	488 3454	......do	106 01 26.8	54	267	56	269	
269	491 2054	......do	05 10.5	54	268	57	270	
270	494 3454	......do	09 21.8	54	269	56	271	
271	496 6906	Stone, 15′ × 6′*	12 34.3	54	270	270 07	272	West Poplar River astronomical station.
272	498 6821	Earth mound, 12′ × 7′* .	15 11.9	90 05	271	07	273	
273	501 1299	......do*	18 14.7	05	272	07	274	
274	502 7391	......do*	20 34.2	05	273	07	275	On edge of west branch Poplar River.
275	505 0356	......do*	23 22.1	05	274	08	276	
276	510 0170	......do*	29 56.1	04	275	07	277	
277	511 1061	Stone, 10′ × 6′*	31 24.1	05	276	08	278	
278	514 1239	......do*	35 23.4	05	277	08	279	
279	518 3641	Earth mound, 12′ × 7′*	41 03.9	04	278	07	280	
280	520 7605	Stone, 10′ × 6′*	44 21.5	05	279	07	281	East of Little Rocky Creek.
281	522 4742	Earth mound, 14′ × 6′* .	46 31.5	05	280	02	282	Little Rocky Creek astronomical station; west of creek.
282	525 3103	Stone, 10′ × 6′*	50 12.8	00	281	02	283	
283	528 0764	......do*	53 47.2	00	282	03	284	
284	531 2323	......do*	58 00.1	00	283	03	285	
285	534 7642	......do*	107 02 50.3	89 59	284	02	286	
286	537 1010	......do*	05 42.2	90 00	285	03	287	
287	541 7704	......do*	12 05.1	89 59	286	03	288	On east bluff of Frenchman's Creek.
288	544 7513	Earth mound, 12′ × 6′* .	16 00.8	90 00	287	03	289	
289	548 3375	Stone, 10′ × 6′*	20 36.5	00	288	02	290	On west bluff of Frenchman's Creek.
290	550 6740	......do*	23 48.2	00	289	07	291	Frenchman's Creek astronomical station.
291	553 1607	......do*	26 54.9	04	290	08	292	Near lake.
292	557 2460	......do*	32 20.0	04	291	07	293	
293	560 3708	......do*	36 29.9	04	292	07	294	
294	563 2270	...... do*	40 13.2	04	293	07	295	
295	565 2322	......do*	42 52.1	05	294	07	296	
296	567 3881	Stone, 12′ × 6′*	45 45.8	05	295	00	297	Cottonwood coulé astronomical station.
297	570 3881	......do*†	49 43.4	89 57	296	00	298	
298	573 3881	Stone, 10′ × 6′*	53 40.9	57	297	00	299	
299	576 3881	......do*†	57 38.4	57	298	00	300	On west bank of Cottonwood coulé.
300	579 3881	......do*	108 01 35.9	57	299	00	301	
301	582 3881	......do*†	05 33.5	57	300	00	302	
302	585 3881	......do*†	09 31.0	57	301	00	303	
303	588 1931	......do*	13 09.2	57	302	269 58	304	Pool on Prairie astronomical station.
304	591 6187	......do*	17 48.8	55	303	59	305	
305	596 5787	......do*	21 20.8	54	304	58	306	
306	599 0228	......do*	27 23.3	55	305	58	307	
307	601 2182	......do*	30 21.0	55	306	59	308	
308	605 6789	......do*	36 23.3	54	307	58	309	
309	608 6593	......do*	40 18.9	55	308	58	310	
310	613 0378	......do*	45 53.2	54	309	58	311	
311	615 3202	Stone, 12′ × 6′*	48 59.5	55	310	270 11	312	Near Goose Lake astronomical station.
312	618 3202	Stone, 10′ × 6′*	52 57.0	90 08	311	11	313	
313	621 1085	......do*	56 33.6	08	312	11	314	
314	624 2737	......do*	109 00 47.5	08	313	11	315	
315	627 0571	......do*	04 23.6	08	314	11	316	
316	630 4402	......do*	08 59.0	08	315	10	317	
317	632 4005	......do*	11 33.4	08	316	11	318	
318	635 4459	Stone and earth mound, 10′ × 6′*.	15 35.5	08	317	11	319	
319	639 4147	Stone, 10′ × 6′*	20 49.1	08	318	11	320	
320	642 0218	......do*	24 07.7	08	319	269 53	321	East Fork astronomical station, in river bottom.
321	643 6856	......do*	26 32.6	89 51	320	53	322	
322	646 2395	......do*	29 46.0	51	321	53	323	
323	649 2001	......do*	33 39.6	50	322	53	324	
324	651 1113	Earth mound, 12′ × 7′* .	36 09.2	51	323	54	325	
325	655 2357	Stone, 10′ × 6′*†	41 38.2	50	324	57	326	West Fork, astronomical station, in river bottom.
326	658 2357	......do*†	45 35.7	51	325	55	327	
327	661 2357	......do*†	49 33.2	52	326	55	328	
328	664 2357	...... do*†	53 30.7	52	327	55	329	
329	667 2357	......do*	57 28.2	52	328	55	330	
330	670 2357	......do*†	110 01 25.8	52	329	55	331	
331	673 2357	......do*†	05 23.3	52	330	55	332	
332	677 0281	Stone, 10′ × 8′*	10 19.5	52	331	51	333	Milk River Lake astronomical station.

List of the monuments marking the international boundary-line, &c.—**Continued.**

Number of mound.	Distance from Lake of the Woods.	Nature of monument.	Longitude west of Greenwich.	Azimuth.	To mound number—	Azimuth.	To mound number—	Remarks.
	Miles. Links.		° ′ ″	° ′		° ′		
333	680 0497	Earth and stone mound, 10′ × 6′*	110 14 19.1	89 51	332	269 54	334	
334	683 1144	......do*	18 23.1	51	333	54	335	
335	685 5545	Stone, 10′ × 6′*	21 45.0	51	334	55	336	
336	699 3677	..... do*	39 54.9	50	335	57	337	
337	702 3023	Stone, 12′ × 6′*	43 46.0	49	336	46	338	West of Milk River astronomical station.
338	705 7527	Stone, 10′ × 6′*	48 28.1	43	337	46	339	
339	708 3204	......do*	51 42.8	43	338	46	340	On west bank large coulé.
340	711 3444	......do*	55 42.7	43	339	46	341	
341	714 2412	......do*	59 30.0	43	340	46	342	
342	717 7848	......do*	111 04 21.3	43	341	46	343	
343	720 5550	......do*	07 56.1	43	342	51	344	On crest of spur.
344	723 0383	......do*	11 02.5	50	343	51	345	Mound on west slope of spur of East Butte.
345	726 4094	......do*	15 36.8	48	344	51	346	
346	730 0573	......do*	20 18.6	48	345	51	347	
347	734 0724	Stone, 10′ × 7′*	25 36.8	48	346	52	348	
348	738 5383	Stone, 14′ × 8′*	31 39.6	48	347	50	349	East of West Butte.
349	740 0197	Stone, 10′ × 6′*†	33 26.6	49	348	270 25	350	West of West Butte.
350	742 6392	......do*†.............	37 06.3	90 22	349	25	351	
351	745 6377	......do*†.............	41 03.7	22	350	25	352	
352	748 6766	......do*†.............	45 05.1	22	351	25	353	Near Creek.
353	751 5770	......do*†.............	48 52.7	22	352	25	354	
354	754 5770	......do*†.............	52 50.2	22	353	25	355	
355	757 7524	......do*†.............	57 05.1	22	354	25	356	
356	760 3160	......do*	112 00 19.5	22	355	02	357	Red Creek astronomical station.
357	763 7188	......do*	04 56.8	89 59	356	02	358	East of Red Creek, near Whoop-up trail.
358	768 2493	......do*	10 46.3	58	357	02	359	
359	771 4268	......do*	15 01.4	59	358	02	360	
360	774 4353	......do*	18 59.7	59	359	02	361	
361	777 2061	......do*	22 34.6	59	360	02	362	
362	779 2675	......do*	25 19.0	59	361	03	363	
363	781 6772	......do*	28 37.9	58	362	03	364	
364	785 0279	Stone, 12 × 6′*	32 50.3	58	363	269 58	365	Astronomical station south branch Milk River, on west bank.
365	787 6221	Stone, 10′ × 6′*	36 27.5	55	364	58	366	
366	790 7610	......do*	40 38.7	55	365	57	367	
267	793 7613	......do*	44 36.3	54	366	57	368	
368	798 2305	......do*	50 19.6	53	367	57	369	
369	801 3201	......do*	54 26.0	54	368	57	370	
370	804 3361	......do*	58 25.1	54	369	55	371	East bluff north branch of Milk River, astronomical station.
371	807 6209	......do*	113 02 50.8	51	370	55	372	On Milk River Ridge.
372	811 2846	......do*	07 34.3	51	371	55	373	In valley.
373	815 0319	......do*	12 26 0	51	372	55	374	On high ridge.
374	817 7258	......do*	16 13.0	52	373	54	375	East of Saint Mary's River.
375	820 4680	......do*	19 45.0	52	374	55	376	West of Saint Mary's River.
376	824 3946	......do*	24 54.4	51	375	54	377	
377	825 6138	Stone, 12′ × 6′*†	26 35.3	52	376	45	378	Rocky Mountain astronomical station, near lake.
378	828 6483	Stone, 10′ × 6′*†	30 36.2	42	377	45	379	
379	831 2653	......do*	33 59.9	42	378	46	380	
380	836 3385	Stone, 12′ × 6′*	40 39.0	41	379	....	.....	Belly River astronomical station.
381	846 0240	12′ × 6′*................	53 19.6	....	.....	....	.....	Chief Mountain Lake astronomical station.
382	853 2529	7′ × 6′..................	114 02 56.5	....	...	....	.....	Summit of Rocky Mountains.

* Indicates that an iron tablet was buried 2 feet deep and 10 feet east of the monument; and † indicates that an iron tablet was buried also in the center of the monument.

ARCHIBALD CAMPBELL,
United States Commissioner.

D. R. CAMERON,
Major R. A., Her Britannic Majesty's Commissioner, May 29, 1876.

W. J. TWINING,
Captain of Engineers, United States Chief Astronomer.

S. ANDERSON,
Captain Royal Engineers, British Chief Astronomer.

UNITED STATES NORTHERN BOUNDARY COMMISSION.

REPORTS

OF THE

CHIEF ASTRONOMER AND HIS ASSISTANTS.

UNITED STATES NORTHERN BOUNDARY COMMISSION.

WASHINGTON, D. C., *February* 14, 1877.

SIR: I have the honor to submit my final report as chief astronomer and surveyor of the northern boundary.

The maps and records of the commission have already been fowarded to the Department, but the text of my own report has been withheld on account of a delay in completing some computations relating to the declinations of the stars used. As it now appears that the work cannot be finished before the 23d of the present month, and as it is desirable that the records should be completed at once, I send my report to you herewith, and will, as soon as practicable, forward to the Department the unfinished discussion of the standard places of fixed stars, as an appendix. As this work forms no part of the record of the commission, but was undertaken as a matter of scientific interest, I can now inform you that the work of the commission is complete.

The subreports of the officers, and a complete index of the records, were sent to the Department in July last.

In closing my connection with the Northern Boundary Commission, I desire to express my appreciation of the kindly courtesy which you have always extended to me and to the officers under my command, and to say that it is a source of gratification to know that my labors have met with your constant approval.

My thanks are due to Capt. J. F. Gregory and Lieut. F. V. Greene, and to assistants Lewis Boss, C. L. Doolittle, O. S. Wilson, and A. Downing for the intelligent and thorough manner in which they have performed the duties assigned to them. * * * * *

I am, very respectfully, your obedient servant,

W. J. TWINING,
Captain of Engineers, Chief Astronomer.

ARCHIBALD CAMPBELL, Esq.,
Commissioner of the Northern Boundary.

WASHINGTON, *February* 15, 1877.

SIR: In compliance with the request of Major Twining, United States Engineers, I have the honor to transmit herewith to the Department his report as chief astronomer of the late Northern Boundary Commission.

I have the honor to be, very respectfully, your obedient servant,

ARCHIBALD CAMPBELL,
Late Commissioner Northern Boundary Survey.

Hon. HAMILTON FISH,
Secretary of State.

REPORT

OF

CAPT. W. J. TWINING,

CORPS OF ENGINEERS, BREVET MAJOR, U. S. A., CHIEF ASTRONOMER AND SURVEYOR.

REPORT.

CHAPTER I.

GENERAL CHARACTERISTICS OF THE COUNTRY

SIR: The portion of the continent traversed by that part of the northern boundary of the United States surveyed by this commission, has heretofore been little known, by far the larger part being unexplored. Lying off the usual lines of travel, and presenting no inducement to commercial enterprise, there was nothing to bring its actual value fairly to the notice of the general public, while the rigor of the climate, the lack of forest, and the distance from railway communication effectually checked immigration.

To the disadvantages already named may also be added the dangers of Indian warfare and the destructive incursions of grasshoppers. The experience of the British settlements along the Red River of the North, even to Lake Winnipeg, extending through nearly seventy years, has been one of almost unprecedented hardship, degenerating in later times into a mere struggle for existence. Cut off almost entirely from communication with the outer and progressive world, the forms of civilized life finally gave way, and were superseded by the manners of a nomadic semi-barbarous people, though, even in this stage of decay, the natural politeness of a French ancestry and the teachings of a few pious priests of the Catholic Church had left their impress on the succeeding generations.

The peculiar isolation of the distant regions lying about the Lakes Winnipeg and Manitoba, and the territory drained by the rivers emptying into these vast bodies of water, is due, not simply to distance from the centers of civilization, for their distance from the settled portions of Canada, and from the ocean communication by the Saint Lawrence, is no greater, and, in fact, is much less, than that of many of the Northwestern States and Territories of the United States from their respective centers of trade along the eastern coast. The difficulty has been in the singularly impracticable nature of the country, and of the water-routes lying to the northwest of Lake Superior. This region of swamps and sterile pine-lands has opposed an effectual barrier to communication toward the Canadas, and has forced the traffic of these remote settlements to find an outlet through Minnesota, and thence to the seaboard.

Within the last few years, the rapid growth of the great States of the Northwest has given an impulse to the more distant Territories beyond, so that now the lines of settlement are stretching out, up the rich valley of the Red River, and rapidly extending to the west, along the smaller streams flowing into that water-course. Thus a better knowledge of the resources of the great Northwest has been obtained through the slow progress of actual settlement.

The survey of the northern boundary, from the Lake of the Woods to the Rocky Mountains, by giving the results of careful examination along a continuous line, has already contributed largely to the actual knowledge necessary to form a correct judgment in regard to the resources and probable future of a vast tract of country which was, at one time, classed, by unthinking and careless writers, as part of the "Great American Desert," and a few years later exalted by the same class of authorities into something little less than a tropical paradise.

It is of vital importance to the interests of the Northwest that the question of the fertility and general availability for settlement of the region east of the Rocky Mountains, comprising the northern part of Dakota and Montana, should be definitely settled, in order that a just understanding of the climatic conditions and other considerations may induce a gradual and healthful immigration. It is useless to expect to find repeated in these high northern latitudes all the favorable conditions of soil and climate found in the Middle States. On the other hand, it is not well to exaggerate the excellence of the special productions of the northern lands, since the actual facts are sufficient to warrant their settlement and cultivation.

The great agricultural bonanza of America was found in the valley of the Mississippi, occupied by the Middle Western States. No other portion of the continent can unite the various advantages possessed by those broad and fertile plains, since in no other part may we expect to find the richness of soil favored by the climate necessary to a widely-varied production. In the extreme Northwest, we may, however, reasonably expect to find that certain specialties in agriculture will well repay the labor of cultivation. Thus, the test of actual settlement has proved the special adaptation of the soil and climate of the far Northwest to the production of wheat, barley, oats, and the hardier sorts of vegetables. In these specialties, the large production compensates for the lack of more varied agricultural resources.

There is, however, a limit to the extent of the arable lands fixed by the amount of the annual rain-fall. Commencing with the valley of the Red River, where the annual deposition amounts to from seventeen to nineteen inches, the amount of the rain-fall decreases, until in longitude 106° it will scarcely exceed seven inches. Here we find a fact which sets a limit to the western extension of the cultivated area of the United States. The same conditions of humidity found along the northern boundary exist also in the southern latitudes, giving to some places almost the character of a desert, although, on the northern line, there is no great area to which that name can be properly applied.

No one can point to a given meridian of longitude upon the map of those great plains, and say that to this line the settlements may extend. The varying conditions of humidity from year to year, or perhaps through series of years, fix their own limit, by the operation of unknown laws. The western line of the cultivated areas may therefore, from time to time, be advanced or withdrawn, as the variations of the seasons may be favorable, or unfavorable, to production. Over the belt of disputed territory thus established will ultimately be found a straggling line of frontier occupation, clinging to a few advanced points, where favored by the special character of the surroundings. Such a belt of territory will probably be found, of about one hundred miles in width, separating the easily-cultivated from the actually-irreclaimable lands. On the forty-ninth parallel, the varying line of settlement will probably be in the vicinity of longitude 102°. What the ultimate effect of tree-planting on the advance of the frontier will be, cannot be predicted. The data are too uncertain to form the basis of any reasonable hypothesis, and all predictions must of necessity be mere idle speculation.

The principle of irrigation will here find no extensive application. Under the most favorable circumstances, to irrigate a given area implies that the rain-fall of a very much larger area is utilized to increase the production of the lesser portion. Even then, the conditions of climate must be such as to compensate for the great labor and expense by double crops. Thus, if twelve inches of water were required for purposes of irrigation, the annual precipitation being only six inches, the difference must be supplied from the rain-fall of surrounding areas, and as but a small part of this can be saved or applied economically, it is evident that the ratio of the cultivated to the uncultivated lands must be exceedingly small. In any case, a system of irrigation can only be applied to the low-lying lands of the valleys bordering the streams. No such condition of low level lands, surrounded by elevated mountains or plains, obtains in the territories of the Northwest in the vicinity of the boundary. The running streams are few and insignificant, for the most part ceasing to flow in summer, and forming only a series of stagnant pools. The valleys are deep and narrow, with constantly-varying elevations. The climate is cold, and the season too short for more than one crop. Under these circumstances, it seems evident that the natural laws under whose operation this immense territory has become what it now is, will scarcely be materially affected by the future efforts of man.

A brief explanation of the characteristics of the country will make clear what has been said, and will serve to explain the general scope of the work performed by the engineers of the commission.

Considered in a general sense, with regard to level and superficial character, the country extending from the Lake of the Woods to the Rocky Mountains, in the vicinity of the forty-ninth parallel of latitude, may be divided into four distinct areas: 1st. The region of swamps, forming the summit-level drained by the Mississippi, the Red River, and the streams flowing north from the Lake of the Woods; 2d. The valley of the Red River; 3d. The prairie plateau, extending from the eastern escarpment of the Pembina Mountains to the Coteau of the Missouri; 4th. The prairie plateau from the Coteau of the Missouri to the Rocky Mountains. This latter division is quite diverse in character, being intersected by the Coteau of the Missouri and a narrow belt of the "mauvaises terres," or bad lands of the south.

If considered with regard to drainage, the boundary-line will be found to follow very nearly the dividing ridge of that part of the continent. From the base of the mountains eastward as far as the Milk River ridge, the small streams flow to the north into the Bow River, though they take their rise only a few miles south of the line. From the Milk River ridge eastward as far as the Coteau, the drainage is to the south, the line following pretty nearly parallel to the dividing ridges of the Cypress Hills and the Woody Mountain. From the Coteau to the Turtle Mountain, the boundary lies in the valley of the Mouse River, which, after making a deep bend to the south, flows again to the north, and empties into the Assiniboine. East of the Turtle Mountain, the drainage is about equal in both directions, though all the southern waters find their outlet again to the north by the Sheyenne into the Red River.

The streams between the valley of the Red River and the Rocky Mountains, excepting only the mountain-torrents flowing to the north into the Bow River, and thence into the Saskatchewan, are merely prairie streams, to which the name river is only given by sufferance. Many of them are the most insignificant of rivulets, which, during the melting of the snows in the early spring, may carry a reasonable volume of water, but in the summer consist, for the most part, of a series of pools, more or less stagnant, and with no appreciable current. The Mouse River and the Milk River are the most considerable of those along the northern boundary, and may be taken as the type of all the prairie streams of Dakota and Montana. Thus, the Mouse River, though having a length of as much as four hundred miles and draining the eastern slope of the Coteau of the Missouri, from the north of Woody Mountain to the bend of the Missouri below Fort Stevenson, yet carries an insignificant volume of water, being reduced to almost nothing during August and September. In like manner, the Milk River, rising near the Rocky Mountains, ceases to flow during the month of August. As these rivers are not fed by springs, the lack of rain and the rapid evaporation reduces the volume of their flow in proportion to the distance from their sources.

It may be said, then, that the boundary-line intersects no stream of any importance from the Red River to the Saint Mary's; and that this, in itself, is sufficient to prove the very small average rain-fall over the included area.

Partly from the same cause, doubtless, the proportion of the two Territories bordering upon the line which is covered by natural forests, is remarkably small. Along the slopes of the Pembina Mountains, the boundary cuts through a distance of thirteen miles, and on the Turtle Mountain, thirty-four miles of a pretty nearly continuous growth of forest. West of the Turtle Mountain, there is no timber to be found near the line, except along the Mouse River. The line actually cuts no growth of trees, or even bushes of any size, for a distance of six hundred miles. In northeastern Dakota, certain kinds of oak, aspen, and birch grow freely where protected from prairie-fires, and it is probable that with such protection the natural forests would extend over a large part of the Territory. Judging from the growth along the Mouse River, it seems most probable that the western limit of the extension of the wooded areas, either by natural growth or by artificial planting, will be in the vicinity of longitude 102°.

The detailed topography of the country between the Lake of the Woods and the Rocky Mountains is singularly lacking in points of general interest, and I have, therefore, confined the following description to such matters as are necessary to a correct understanding of the astronomical and topographical work of the commission.

A most complete and accurate account of the geology and resources of the country in the vicinity of the boundary-line will be found in the report of Mr. Dawson, the geologist accompanying the English expedition, which is already published.

An admirable description of the water-communications from Lake Superior to Lake Winnipeg, and of the northwest territory between the boundary-line and the Saskatchewan River, including an account of the Red River settlement and the Hudson's Bay Company, will be found in the report of the Canadian Exploring Expeditions, 1857–'58: H. Y. Hind, London, 1846.

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[illegible]BWA[illegible] CAMP [illegible] THE W[illegible]

THE LAKE OF THE WOODS.

The Lake of the Woods is a name usually applied to a group of four lakes lying on the northern boundary of the United States, and nearly in a right line with Lakes Superior and Winnipeg. These four lakes, numbering from the northwest, are the Lac Plat, the Clear Water, the White Fish, and the Lake of the Sand Hills; the latter, by common usage, has adopted the name Lake of the Woods. The official sanction to this title was given by the commissioners under the sixth and seventh articles of the treaty of Ghent, in fixing the northwest point, and it is, therefore, useless, at this late day, to inquire into the extent and significance of the original term. It is, however, a little difficult to understand the process of reasoning by which those commissioners, while including the Clear Water and the Lake of the Sand Hills under the general title, yet rejected the Lac Plat.

The geography of the region has never been well known, and, even at the present time, the northern and eastern shores of this lake-system are but illy defined. The drainage is toward the north, by way of the Winnipeg River, into Lake Winnipeg. The principal affluent is the Rainy River, which enters from the southeast, though a number of small tributaries are received from the south and west, draining the swampy belt which borders the lake in those directions. The Rainy River is a stream of three hundred yards in width, flowing with a deep, swift current. The discharge of the lake is by two outlets, with a short series of rapids, into the Winnipeg River.

The boundary-line enters the lake from the Rainy River, and, leaving the various islands alternately to the right and left, enters the bay known as the Northwest Angle, at the extreme northern end of which the "most northwest point" is located. The southeastern portion of the Lake of the Sand Hills, or, as now known, the Lake of the Woods, therefore, pertains to the domain of the United States. It connects with the Clear Water Lake on the north by channel-ways between numerous rocky islands. The islands cease a short distance south of the entrance to the Northwest Angle. The western and southern shores are bordered by vast swamps, the division between the swamps and the lake being distinctly marked, in some places, by small ridges of sand-hills, but generally only by narrow sandy beaches, or an accumulation of drift-wood and brush. Buffalo Point is quite an open piece of ground, well raised from the lake, and the same is true of the shore where it cuts the forty-ninth parallel. The forests are mostly composed of small pines and tamaracks, though on the higher ground elm, birch, and aspen are found. The waters of the lake are shallow, the greatest depth found in coasting being eighteen feet, though, doubtless, in some parts the depth is much greater. The width of the lake being great (in some directions as much as fifty miles), the winds have an uninterrupted sweep over its surface. It is thus liable to sudden and violent tempests, which make navigation in small boats both difficult and dangerous

The vicinity of the Lake of the Woods is inhabited by a few small bands of Ojibway or Chippewa Indians, who subsist by trapping, hunting, and fishing. Their lands are not ceded, and they receive no annuities. Their *locus* is doubtful, some living within the lines of the United States, and others on British territory. The only present economical value of the Lake of the Woods is in its being on the line of water and land communication between the eastern and western provinces of the Dominion of Canada.

The military route called the Dawson Road has its terminus at the Northwest Angle, and though not such a road as ever to enter into competition with the easier, though less direct, routes toward the south, yet answers the purpose for which it was built, in giving a line of independent communication between Manitoba and the Canadas. Great efforts have been made by the Dominion Government to utilize it for purposes of immigration and general transit; but I have yet to see the person who has dared its discomforts a second time. The government supports, by subsidy, two steamers and several steam-launches. The landing at the Northwest Angle is on British soil, but to reach it the vessels pass through American waters. The road for twelve miles from the angle is continuous corduroy; east of that the route passes through a country of sand-ridges, alternating with swamps, or *muskegs*, for a distance of seventy miles, to Oak Point. It then enters the valley of the Red River, and, after crossing an almost continuous succession of bogs for thirty miles, reaches Fort Garry.

Of the portion of land belonging to the United States cut off by the north and south meridian line, and amounting in all to about one hundred and fifty square miles, much the greater part is covered with a deep bog, on which a few scattering tamaracks struggle for existence. In some localities, where the ground is high, deciduous trees predominate, but, as a general rule, the forests are composed of coniferous trees of small size and little value.

The Lake of the Woods receives two additional tributaries, one from the southwest, called the War Road River, and another from the west, called Reed River. These streams are simply small channels cut in the marshes, or *muskegs*. They drain a width of marsh varying from eight to sixteen miles in width. By the Reed River, the Indians are in the habit of making a portage to the headwaters of the Roseau River, and thus reaching the Roseau Lake. The actual length of the land portage is eight miles, but this is through a swamp, where the traveler sinks from one to three feet into the mud and water, and may consider himself fortunate if he does not once or more disappear entirely beneath the surface. After reaching the northeastern branch of the Roseau, the difficulties of the trip are over.

LAKE ROSEAU.

Lake Roseau is a shallow lake, about three miles in greatest length. The shores are lined with a broad margin of tall grass and reeds, from which the lake takes its name. It is fed by two tributaries, the East Roseau and the Pine River; the former being composed of two branches, one from the north of the boundary and the other draining the broad swamps lying between the Lake of the Woods and the Red Lake in Minnesota. It discharges into the Roseau River, a tributary of the Red River of the North.

THE ROSEAU RIVER.

This stream, after keeping a westerly course south of the boundary, finally crosses at a point thirty-three miles east of Pembina, and, flowing for the rest of its course through Manitoba, enters the Red River thirteen miles north of the line. The stream is used by lumbermen in floating out logs from the pineries near Lake Roseau. It is interrupted, at one point, by rocky rapids, but, with that exception, is a clear flowing stream. Its average fall is not less than two feet to the mile, from which it is quite evident that it can never be made navigable excepting above the rapids. It is quite probable that, by cutting down the rapids a few feet, the river might be made to drain, much more thoroughly than it does now, the vast region of swamps through which it takes its course. The first effect of cutting down the barrier would be to increase the current, which would again establish nearly the present regimen, but at a lower level. Lateral channels would then rapidly form through the soft material of the marshes, and a general system of natural drainage would establish itself, which would ultimately render available for settlement many hundreds of square miles now covered by bogs. The greatest depth found in the Roseau Swamp was about fourteen feet, at which a sounding-pole would strike a hard clay pan. The river flows through the swamp, and at about the same level, for many miles. We may say, then, that a gradual wearing-out of the river-channel to the depth of ten feet would effect the drainage of the greater part of this immense swamp. This is the process which is now actually going on, and which will be completed, like all the operations of nature, slowly but none the less surely.

From the levels given herewith, it will be seen that the difference of level between the Red River and the Lake of the Woods is two hundred and fifty feet. Of this, the greatest rise takes place in the first sixteen miles eastward from the Red River. The total rise here amounts to one hundred and seventy feet. This swamp region is, therefore, a summit-level cut off from the Red River Valley by a ridge, through which the Roseau River, the natural channel of drainage, breaks in a series of abrupt rapids, obstructed with bowlders, but through which, in course of time, it will wear a deep and easy channel. At present, the whole of this country must remain uninhabited and without any special value.

THE RED RIVER.

From the sixteen-mile ridge begins the valley proper of the Red River of the North. Its characteristics at the boundary-line are identically the same as those at any other point of section—a valley apparently perfectly level, but in reality sloping toward the river quite rapidly, intersected by small running streams, which are simply the lines of drainage of the prairies, and which, therefore, are exceedingly variable in the amount of their discharge. Along these water-courses, as well as on the main river, and, in fact, wherever protection from the prairie fires is offered, will be found lines of forest, mostly of whitewood, but in some cases of oak. The valley is immensely fertile, as has been proved by actual settlement; the only drawbacks being the long and cold winter, the occasional incursions of grasshoppers, and a liability to heavy floods.

These floods in the lower valley were at one time supposed by the half-breeds to be caused by an extraordinary rise of the Missouri River, which, breaking through some low point of the Coteau, poured an immense volume of water into the Mouse River near its southern bend, and caused an overflow in the lower Assiniboine and Red Rivers. This supposition was speedily found to be without basis.

A very simple explanation is found in the tortuous course of the river, and in the fact that its course is from south to north. The melting of the snows on the upper waters causes a sudden and violent rise before the outlets are cleared of ice. The natural result is an ice-jam in every sharp bend, which acts as a dam to back the waters over the low-lying lands above.

It is said that the river is quite rapidly widening its own channel. But of this I saw no evidence, beyond the ordinary wash which takes place in all alluvial streams where there is a constant cutting away of the banks in the bends of the river, the material excavated being again deposited below.

Five small steamers ply on the river between Fort Garry and Moorhead, which is the station on the Northern Pacific Railroad. All the lands along the river and many of its branches are already taken up, and little settlements are beginning to make their appearance at various points.

For many years the people of the Northwest have looked upon this valley as the great wheat-field of the world. It seems that this anticipation will, in time, be realized. The valley at the forty-ninth parallel has a width of about fifty miles, which I do not think is materially reduced toward the south. Taking this as the uniform width, the entire area within the domain of the United States can be estimated at about 10,000 square miles, of which the greater part can be cultivated.

The Dominion Government have displayed great activity, and presented many inducements to immigrants to settle in the valley between Pembina and Fort Garry. Their lands have been surveyed nearly on the same plan as the public lands of the United States. They have offered free transportation over the Dawson route, and, if it were not for the intolerable discomforts of the communication, would probably have succeeded in attracting a very large immigration. As it is, their efforts are by no means a failure. A large colony of Mennonites, amounting to several thousand, have taken up land between Point Michel and the Pembina Mountains. These people apparently selected their homes on British soil, because they dislike a republican form of government. They are industrious, sober, and economical, and, although they are destined to great suffering, will doubtless succeed in making for themselves comfortable homes. They have to fear the incursion of grasshoppers, which, if it should befall them in the first years, would be fatal to their enterprise, and discourage all future immigration. The long winters and the scarcity of fuel will try them severely, until they become thoroughly accustomed to provide against the rigors of the climate; but this is a difficulty which has been met and overcome on the prairies of Indiana, Illinois, and Iowa, and which will be met successfully on the plains of Northeastern Dakota and Manitoba.

PEMBINA MOUNTAIN.

The Pembina Mountain, which borders the western edge of the Red River Valley, is not a mountain in the ordinary acceptation of the word, but is dignified by the title only by comparison with the level lands of the region in which it is situated. It is, in reality, the sharp edge of the high prairie plateau which extends westward to the foot of the Coteau of the Missouri. The Pembina River breaks through the escarpment in a deep gorge, causing the apparent width of the rough ground to appear much greater than it really is. The eastern face of the mountain, though quite

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sharp in the vicinity of the boundary, becomes much more gentle both to the north and south, so that at the distance of a few miles it is reduced to a long, rolling slope, at the foot of which the numerous small streams emptying into the Red River take their rise. Being protected from prairie-fires, the slopes are covered with a very fair growth of forest, which on the south of the line is mostly of oak of small size. The distance along the line, from the foot of the eastern slope to the level of the second prairie plateau, including the width of the gorge of the Pembina River, is thirteen miles. From the point thus reached, the level prairie extends westward to the foot of the Turtle Mountain, without presenting to the eye any special points worthy of description.

TURTLE MOUNTAIN.

This elevation, which, like the Pembina Mountain, is only so called by comparison, is an irregular mass of drift, rising at the highest point to not more than 500 feet above the general level. The eastern slope is gentle, while the western escarpment is quite sharp. It is covered by a continuous forest of birch, aspen, and oak, interlaced with briers and wild-pea vines, forming an almost impenetrable thicket. Many fine lakes were found along the line of the boundary, one of which is more than a mile in width. It was named Lake Farquhar, out of courtesy to the first chief astronomer of the commission. The width of the mountain, from east to west, was found to be thirty-four miles. Its extension in the direction of its greatest length, from northwest to southeast, is somewhat greater. As the entire contour of the mountain was not surveyed, the exact proportion lying within the limits of the United States cannot be stated exactly, but may be given approximately at two-thirds of the whole. The Indians report that many small prairies are found in the southern part, and that the general surface is less rugged.

THE MOUSE RIVER.

From the western slope of the Turtle Mountain to the foot of the Coteau the line crosses what may be called the valley of the Mouse River. This stream rises to the north of Woody Mountain, and runs southeast until it strikes the boundary. It then follows, nearly parallel to the line, eastward for about seventy miles, when, making a bold sweep to the southeast for a hundred miles, it doubles back upon its course, and, crossing the line again twenty miles west of Turtle Mountain, empties into the Assiniboine. The distance across the bend on the forty-ninth parallel is only fifty miles. The boundary actually crosses this stream four times. There is a good growth of forest along the valley proper of the river, beginning at the second crossing, and ending about twenty miles south of the first crossing west of Turtle Mountain.

THE RIVIÈRE DES LACS.

Sixteen miles west of the second crossing of the Mouse River, the line cuts the head of the Rivière des Lacs. This singular stream heads far within the bend of the Mouse River, and, at first sight, impresses one strongly as being an ancient bed of that stream. The lake in which it heads is long and narrow, apparently draining only a very small area of flat prairie. It is undoubtedly fed by springs, for the surface-drainage is totally inadequate to furnish the necessary water-supply. The water itself is foul with vegetable decay, although there is but little of rank aquatic growth to be seen.

Three miles north of the line, and just at the northwest point of this singular lake, stands the prominent butte known as the "Hill of the Murdered Scout." So level is the general surface that the hill, although of small elevation, is the prominent landmark for many miles. Looking from its summit, the deep valley of the Mouse River, on the north and east, may be distinctly traced. Toward the south and west, the Coteau of the Missouri bounds the sight, forming apparently a steep and continuous barrier. This illusive appearance is merely the result of distance, for on nearer approach, the mighty ridge becomes a series of swelling slopes, stretching out in endless convolutions to the far horizon

The legend from which this isolated butte takes its name is curiously illustrative of the habits of the nomadic Indian tribes. As told me by an ancient half-breed, it ran as follows: Late in the fall of 1830, a party of Assiniboines, extending their wanderings far to the east of their own country, camped on the point of the lake to the north of the butte. One of their number, ascending the hill to watch the surrounding country for traces of hostile occupation, discovered a camp of Sioux close under the hill on the south. Cautiously approaching the crest, he came suddenly upon a Sioux warrior lying rolled in his buffalo-robe, and apparently overcome with sleep. Seizing a large fragment of granite rock, the Assiniboine approached his foe with stealthy step. With one vigorous blow he struck the Sioux, and fearing to have missed his aim, or that it might not have been fatal, turned and ran from the spot. Looking back and seeing his enemy quivering on the ground, he returned and dispatched him. In memory of this deed, which, in the scale of Indian glory, ranks far above the honor of a well-contested fight, he dug in the gravelly soil the figure of a man lying at full length, with outstretched legs and uplifted arms. He also scooped out each of the footprints marking his path as he fled. These marks, though only a few inches deep, were still distinctly visible when I visited the spot in the summer of 1873, and will probably remain for many years. In the hollow representing the head of the murdered man there was a red granite stone, smooth, oblong in shape, and about eight inches in greatest diameter, which was said to have been the stone used.

From the Hill of the Murdered Scout, the country is a level or gently-rolling prairie to the foot of the Coteau. Along the valley of the Mouse River, in this interval, there are numerous outcrops of lignite, for an account of which see Dawson's report, before referred to.

THE COTEAU OF THE MISSOURI.

The Coteau of the Missouri is one of the singular physical characteristics of the region. It extends in a direction from northwest to southeast for many hundred miles, with a height of from two hundred to three hundred feet. At the line it has a width of forty-five miles, though without a distinct western slope. The eastern slope is distinctly visible for a great distance, and retains its apparent abruptness of outline nearly to the crossing of the Northern Pacific Railway, though at that point the rise is so gradual as to be almost imperceptible. What its northern extension may be is not well known, though it certainly extends beyond the Woody Mountain. It consists of a mass of drift, containing no rock *in place*, and very similar in appearance to Turtle Mountain, which is apparently one of its outlyers.

From Turtle Mountain to the southeast, there is a series of rough hills with intervals of rolling prairie, extending to Devil's Lake, and thence to Lake Jesse, forming, with the Coteau of the Prairie on the eastern border of Minnesota, a line of drift-formation almost exactly parallel, and similar in character to the Coteau of the Missouri.

The Coteau forms, in the latitude of the boundary, pretty nearly the western limit of the area adapted to agricultural purposes, until the fertile belt near the Rocky Mountains is reached, though, as a grazing country, the limit may be placed somewhat farther to the west. The surface of the Coteau consists of an irregular collection of pointed hillocks, growing more and more irregular in design and contour, until they are merged in the bad lands.

These bad lands, or "mauvaises terres," as they are termed by the half-breeds, set at defiance all rules of topography, as well as all adequate description. Lacking even the continuous lines of drainage on which the eye may rest, and which give form and system to an ordinary *terrain*, they stretch in an endless and tiresome succession of arid and treeless hills and ridges, a tumultuous expanse of baked mud. A large part of the country from the western edge of the Coteau to Frenchman's Creek may properly be called "bad lands."

In this interval, the line intersects the headwaters of the Quaking Ash, the Little Rocky, and Frenchman's Creek, the first being a tributary of the Missouri and the latter two of the Milk River. Where crossed by the line, they are all small rivulets. Frenchman's Creek, though the largest, is strongly alkaline.

WOODY MOUNTAIN.

Woody Mountain, to the northeast of the crossing of Frenchman's Creek, lies about twenty miles within the British territory. It is a mass of drift, rising in an irregular plateau to the height of 3,800 feet above sea-level. It is a locality well known in the Northwest as the winter rendezvous of the half-breed hunters. The cart-trail from the Red River settlements leads to Woody Mountain, and thence to Fort N. J. Turnay, a trading-post on Frenchman's Creek, from which point a trail leads southeast to Fort Peck, on the Missouri River.

Going westward from Frenchman's Creek, the boundary lies about midway between the Milk River and the Cypress Hills, cutting successively the Cottonwood, and the east and west forks of the former.

THE THREE BUTTES.

There are no special points of topographical interest until the Three Buttes are reached. These buttes, or "Sweet Grass Hills," as they are called by the half-breeds, lie to the south of the boundary. Each consists of a clump of foot-hills lying around a central cone, which shoots up to a height of 7,000 feet, or more, above sea-level. The slopes of the principal peaks consist of a mass of blocks of broken stone of small size, which are crossed and recrossed as closely as a network of vines, by innumerable paths made by the mountain-sheep. These buttes are the center of the feeding-ground of the great northern herd of buffaloes.

This herd, which ranges from the Missouri River north to the Saskatchewan, made its appearance, going south, about the last of August. The number of animals is beyond all estimation. Looking at the front of the herd from an elevation of 1,800 feet above the plain, I was unable to see the end in either direction. The half-breeds, Sioux, Assiniboines, Gros Ventres of the prairie, and Blackfeet, all follow the outskirts of this herd; but, with all their wasteful slaughter, they make but little impression upon it. It is even said by the traders at Fort Benton that the number of buffaloes is increasing, owing to the destruction of the wolves in late years.

Numerous small rivulets take their rise among the foot-hills surrounding the buttes, which, however, owing to the rapid evaporation during the dry season, will scarcely flow more than two or three miles before they entirely disappear. It is not uncommon to see one of these little brooks flowing in the early morning, but drying up during the later hours of the day, and again renewing its flow during the cool hours of the night. It is singular that no timber of any size is to be found among these mountains; the only trees are a stunted pine, growing along the upper slopes.

The vicinity of the buttes is the finest grazing country in the north part of Montana, and, being a rendezvous for the migratory herds of buffaloes, it is, as a natural consequence, a debatable ground of the Indian tribes in the vicinity.

The tribes disputing this territory are the Blackfeet, North Assiniboines, and the Gros Ventres of the prairie, though an occasional war-party of Sioux may be found, coming from the direction of the Bear's Paw Mountains.

Westward from the Three Buttes the general character of the country improves rapidly. After passing the North Fork of the Milk River, the effect of the Rocky Mountains on the rain-fall can be distinctly seen in the increased growth of the herbage. The soil also improves, gradually but very perceptibly, up to the very base of the Rocky Mountains. The strip of land, of about twenty-five miles in width, lying close to and including the foot-hills of the mountains, has been very appropriately called the "fertile belt"

THE MILK RIVER RIDGE.

The Milk River Ridge, lying between the North Fork of the Milk River and the Saint Mary's, is the dividing-line between the waters flowing to the Missouri and those emptying into the Saskatchewan. The distinction between the two systems is very marked. The streams flowing to the south and east, having their sources in the prairie or low down in the foot-hills, are sluggish in their flow, with a more or less alkaline tendency. The South Fork is particularly noticeable for the milky color of its waters, which gives the name of Milk River to the stream into which it flows. West of the Milk River Ridge, however, the two rivers crossed, namely, the Saint Mary's and the Belly River, are both mountain-streams, which take their rise in large lakes lying far up among the rugged peaks of the main divide. The Saint Mary's, although not more than one hundred and fifty feet in width, and having at its summer stage a depth of about three feet, would be a difficult stream to cross in the early spring, owing to its swift current and the rough masses of bowlders which form its bed. The Belly River is of less size but similar in character.

THE ROCKY MOUNTAINS.

The main ridge of the Rocky Mountains, into which the line at this point enters, has a general direction from northwest to southeast. I had

been led to suppose that the ascent to the summit was a gradual slope, and was greatly surprised to find that the rolling prairie abutted sharply against an impassable escarpment of rocky precipices. It was found to be impossible to carry a continuous line even so far as the crossing of the Belly River, and the three stations at this point, the Chief Mountain Lake, and the old monument on the summit of the main divide, are connected by traverses. The last station observed astronomically was on the west shore of Chief Mountain Lake, seven miles from the summit, and was reached by rafting from the north end of the lake. The connection between the two final stations was made by a traverse of thirty-five miles, through the South Kootanie Pass. Chief Mountain Lake has a length of nine miles, and is bordered so closely by the precipitous slopes of the surrounding mountains that it is impossible to make one's way along the shore, even on foot.

The highest peak of the Rocky Mountains in the vicinity of the boundary is at the southeast end of the lake, and has an elevation above the sea-level of 10,400 feet. The elevation of the lake is about 4,000 feet, which may also be taken as the height of the base of the main range.

CHAPTER II.

GENERAL NARRATIVE.

The field-work of the commission occupied a part of the summer of 1872, and of the two following years, 1873 and 1874.

The act of appropriation authorizing the survey was approved March 19, 1872, but the field-parties of the joint commission did not meet on the line until the 1st of September. At that time the engineer officers attached to the United States commission were Maj. F. U. Farquhar, chief astronomer, Capt. W. J. Twining, Capt. J. F. Gregory, and Lieut. F. V. Greene.

Under the instructions of Major Farquhar, I took charge of the astronomical parties, and Captain Gregory, assisted by Lieutenant Greene, began the survey of the. line.

The initial point of the survey was fixed, by joint observation, at Pembina, and the following scheme was agreed upon by the chief astronomers of the two commissions, and approved by the commissioners.

Astronomical stations were to be observed at approximate intervals of twenty miles. The points so determined in latitude were to be considered as absolute. The connection from one station to the next in succession, was to be made by a tangent-line to the prime vertical circle at the first station. From the line so traced and marked upon the ground, the proper calculated offsets to the circle of latitude were to be measured at certain intervals. From the last calculated offset the relative error of position due to observation and the local deflection of the plumb-line, was to be deduced, and each intermediate point, already fixed, was to be corrected by the proper proportional amount, depending upon its distance from the initial point.

Each commission agreed to make a topographical survey of a belt of territory five miles wide on its own side of the line, and it was agreed to consolidate the topographical work of both parties on a series of maps, on a scale of one inch to two miles. It was also finally agreed to plant iron monuments along the southern border of Manitoba, from longitude 96° to longitude 99°, at intervals of one mile, and, west of Manitoba, to mark the line by stone pyramids or otherwise, at approximate intervals of three miles, to the summit of the Rocky Mountains.

Where forests were encountered, a clear cutting was to be carried through. "The northwest point" of the Lake of the Woods, as determined by a previous joint commission, was to be recovered, and a due-south line was to be surveyed and marked from that point to the forty-ninth parallel, or until it cut the waters of the lake. The several points of agreement above given were taken by the chief astronomers as the basis of their work, and finally received the approval of both commissioners.

During the months of September and October, I observed one latitude station on the Red River and one on the west shore of the Lake of the Woods, where it is intersected by the parallel of 49°.

The country being impassable between the two points, it was necessary, in order to reach the latter, to go by way of Fort Garry, thence by the Dawson Road to the Northwest Angle, and by small boats to the parallel. In this duty I was greatly delayed by accidents and the state of the weather. My orders were to observe also at the Northwest Angle, but not to delay beyond the 7th of November. I remained at the angle, after returning from the lower station, until that date, without being able to fix a station, on account of continuous storms. I then returned to Pembina, which I reached on the 14th of November, and there received orders to return to Saint Paul.

In the mean time Major Farquhar and Captain Anderson had found what were supposed to be the remains of the old monument, and after sufficiently verifying its position, had started the meridian-line to the south. Lieutenant Greene had carried the first tangent eastward from the Red River thirty-three miles. The English parties had also observed one astronomical station east of the Red River, in addition to the joint stations at Pembina and the Lake of the Woods.

Owing to the lack of funds, the parties of this commission could not remain in the field during the winter, but left the uncompleted line, between the Red River and the Lake of the Woods, for another season.

The English commission, being barracked near Pembina, were able to complete their astronomical and topographical work, on that part of the boundary, during the winter.

The winter of 1872–'73 was passed in active preparation for the following season. The astronomical and topographical notes of the preceding summer were worked, and the declinations of the stars to be used for latitude observation were prepared, the computations being made for every fifth day, from June 1 to September 30. The office of the commission, during this winter, was located in Detroit, Mich.

In the spring of 1873, Major Farquhar having been relieved from the commission at his own request, I was appointed chief astronomer and surveyor. The parties were organized in Saint Paul, Minn., and reached Pembina on the 1st of June. Captain Gregory was placed in charge of an astronomical party, I taking one myself, and giving Lieutenant Greene the general care of the line and the topography. The English being ready to take the field, there was no delay. After observing jointly the stations at Point Michel and the eastern base of the Pembina Mountain, it was thought best, the methods being essentially the same, and the results on the four joint determinations agreeing very nearly, to carry forward the astronomical work by alternate stations. By the methods adopted the line was checked every twenty miles, a new departure being made at each astronomical station. The cutting in Pembina Mountain was commenced on the east by the English, and on the west by the parties under Lieutenant Greene, and the station on the summit of the plateau of Pembina Mountain was, meanwhile, observed by Assistant Boss. Captain Gregory, having observed at the station at Long River, moved forward to South Antler Creek, while I took the station on the west side of Turtle Mountain.

During these movements the United States parties were accompanied by an escort of two companies of the Seventh Cavalry, and Capt. A A. Harbach's company of the Twentieth Infantry, all being under the command of Maj. Marcus A. Reno. Major Reno established his depot at the second crossing of Mouse River, at which point the main body of the escort was collected.

In Turtle Mountain the first serious difficulty and delay was encountered. The cutting at this point, which I had supposed would not exceed twenty miles in length, was found to be thirty-four miles. Owing to the dense mass of small undergrowth, the cutting was most difficult, as the parties were not prepared to meet so formidable an obstacle.

Leaving Lieutenant Greene at Turtle Mountain, I moved forward to the Rivière des Lacs, and observed the station near that point, while Captain Gregory moved to a station midway between the third and fourth crossings of the Mouse River.

It had been agreed between the English chief astronomer and myself, at the beginning of the summer, that we would attempt to complete the survey of the line for the distance of four hundred miles, during that summer. It was now evident that it could be done with ease by the astronomical parties, but that, owing to the delay in Turtle Mountain, the surveyors would have great difficulty in completing their allotted task. I therefore sent Captain Gregory forward to fix the remaining three astronomical points, and established my camp at the Wood End, near the third crossing of Mouse River.

The river here is no longer a running stream, the water being found only in pools. The valley also becomes much less distinctly cut, while the wood definitely ceases. The half-breed road which had so conveniently followed near the line for so great a distance, leads up the valley of the river, skirting the edge of the Coteau at a respectful distance, to avoid the rough ground. It was evident that it was to be of no more use to us, as its direction was too much to the north. The advanced party, therefore, reluctantly leaving the smooth, beaten path which had seemed like a connecting link with civilized life, turned abruptly westward, and plunged into the hills of the Coteau. The detail of the work performed by this party, as given by Captain Gregory, will be found in his report, which is transmitted herewith. The difficulties encountered, and the sufferings endured by his party, in the storm which shortly after broke upon them, while among the bad lands west of the Coteau, I commend to the consideration of those theorists who have insisted on drawing an isothermal line of 60° through this region.

For some days after the departure of the working-parties, the weather remained clear and bright; but on the 20th of September a sudden fall of the barometer indicated an approaching storm. During the night it broke upon us in a mingled snow and rain, the wind blowing a furious gale from the northwest. Throughout the day flocks of ducks and other aquatic birds had been winging their way towards the south, while at night the air was filled with wild-geese urging their flight before the tempest, and piercing the sky with harsh cries and the rushing of wings. My camp being comfortably located in a deep valley, and covered from the violence of the wind by a dense grove of trees, I was scarcely aware of the real fury of the storm. At the Wood End we were apparently on the eastern edge, and the snow, although falling continuously for several days, did not lie heavily upon the ground. The working-parties in the Coteau caught its full force, and being on short allowance and without the shelter of timber, suffered severely. The snow fell to the depth of ten inches on a level, while the weather was bitterly cold. It is a source of wonder to me that the entire train of animals did not perish.

On the 8th, Captain Gregory returned with his party, his animals worn out and totally exhausted with fatigue and hunger, they having been for three days without forage. He reported having passed Lieutenant Greene at the three hundred and eighty mile point. That officer, though much delayed, had, with his accustomed energy, pushed his work along regardless of weather, and now reported that he would be at the depot on the 14th.

Our supplies being short, I at once started back to the second crossing of Mouse River, reaching it by easy marches in three days Leaving orders here for Lieutenant Greene to join me at Fort Totten, and to use his own discretion in regard to his route, I at once started directly across the country. There was a sufficient supply of provisions, and by eking out the forage with flour and hard bread, I was able to make a half ration of forage. The prairie had been burning in every direction for several days, and it was evident that not much grass could be found. From previous experience, I felt certain that there was no part of that country in which occasional pools of water could not be found, and I only feared that we might be caught in another heavy storm while on the open plains. I therefore directed the march toward what I supposed to be the head of the Cut Bank Creek, which we reached after a march of twenty-four miles, having suffered much for want of water. We found it to be a succession of pools, and, by following down along the old half-breed trail, crossed the Mouse River two miles south of the mouth of Willow Creek. I hesitated, here, whether to follow south up the Mouse River two days, and then strike for Lake Gereau, or to take the risk of crossing the open plain on a direct course for Devil's Lake. Ascending one of the sand hillocks, and looking east, I could just distinguish the top of a butte resting like a dark spot on the distant horizon. This promised water, and I therefore started for it the next morning. We passed at noon a shallow pond of fresh water, and after marching over a flat plain which would be impassable for wagons in wet weather, camped by a stinking pool in a ridge of hills which appears to be a prolongation of Turtle Mountain, though separated from it by a low plain of some width.

The prairie fires, which for some days had been burning brightly in every direction, had swept every vestige of grass from these plains, except in the immediate vicinity of the ponds, leaving the ground covered with a light film of ashes. Our march from this point was most distressing, owing to this cause. A strong east wind raised the dust and ashes in clouds, filling the eyes, nose, and mouth with an irritating alkali, which bit and smarted with undying zeal

We reached Fort Totten on the 20th October, the only notable camp being that on the Hurricane Lake. This lake, of which I had never heard before, although tolerably familiar with that part of the country, is a beautiful sheet of water, perhaps a mile in width. The north and west banks are covered by a heavy forest. In the lake is a large island, partly timbered and partly prairie, connected with the north shore by a swampy peninsula which is impassable, even on foot. The water is green and clear, and a perfect delight to the traveler wearied and disgusted with the usual alkaline or offensive fresh waters of the plains. I think this lake is the head of the north branch of the big Coulé, which empties into the Sheyenne, and am quite certain that it had never before been visited by white men.

Lieutenant Greene arrived on the 22d with his party. He had followed down the Mouse River from the second crossing until he reached the great bend, and then had made a straight trail to Devil's Lake.

I had made arrangements at Pembina to complete the survey between the Red River and the Lake of the Woods during the winter. A work so difficult could only be justified by the fact that the ground was utterly impassable in summer. The freezing of the swamps would enable the supply-train to move east as far as the Roseau Lake. I had, therefore, caused hay to be cut at several points, and a part of the winter clothing to be prepared. Lieutenant Greene, being in charge of the topographical work, took charge of the party detailed. The men, though they had had a rather rough summer, most of them, readily volunteered for the winter. Having detailed the party to remain, and provided it with the necessary transportation, I consolidated what was left into two parties, and on the morning of the 24th took up the march to Fort Seward. The weather was now unusually cold, with heavy winds from the north and constant snow. The ice on the ponds was five inches thick. The men suffered greatly, as their clothing was hardly suitable for such exposure. We arrived on the 28th at Fort Seward.

The animals being worn down with work, I left most of the wagons in store, retaining only enough to carry forage, and started the herd to Saint Cloud, Minn., under charge of the quartermaster's clerk, with a sufficient number of herders. The remaining men were sent by rail to Saint Paul, where they were discharged.

The office was still retained at Detroit, but, the topographers being in the field, no work could be done on the maps. The computers at once began preparation of the ephemeris for the ensuing year. In this ephemeris the apparent places of the stars to be used were computed for every fifth day. This work being done in the office saved many vexatious delays in the field, and enabled me to count with certainty on a prompt and rapid movement of the several parties.

The detail of the winter work in the field, under the charge of Lieutenant Greene, will be found in his report. It presents many points of interest, on account of its novelty. Its difficulties were met with great good judgment by the officer in charge. Of this the best proof is that no animals were lost, and none of the men seriously frozen, although exposed for months in the ordinary avocations of camp and field during the most severe weather. The capabilities of this region for settlement are already sufficiently proven by practice, but the incidents of the survey show that, with proper forethought and preparation, the rigors of the winter are little to be dreaded.

The field-parties finished their allotted task, and returned to Saint Paul on the 14th of March, where they were discharged.

Pending the passage of the act of appropriation for the survey, work was commenced on the preliminary maps, and all necessary preparation was made for the active field-operations of the ensuing summer.

As the parties could not be organized before the passage of the appropriation for the following year, there would only be four months in which to reach the ground, complete the survey, and to return. Of this time at least one-half would be occupied in travel, leaving only the short space of two months to make the survey. I scarcely expected to accomplish the work in this time, and had made estimates looking toward a retreat by way of Salt Lake, or for a winter's march of six weeks to Fort Abercrombie. Neither of these alternatives presented any great attraction, and it is perhaps due, in part, to this that the survey was pushed along with such remarkable rapidity. All preparations had been made to organize the expedition The train which had wintered at Saint Cloud was sent, under charge of Lieutenant Ladley, by rail to Bismarck, taking up on the way the wagons left at Fort Seward.

I was notified of the passage of the appropriation on the 5th of June, and started for Bismarck with the parties fully organized, on the 6th. Reaching Bismarck on the 8th, I found the steamer Fontenelle waiting, but, contrary to the spirit of the contract made at Saint Paul, the boat had been loaded with two hundred tons of freight. This, with our wagons and animals, crammed the steamer to its utmost capacity, and made a rapid trip to Fort Buford an impossibility. The river was high, running with a strong current, and it was manifest that five days was too little time for the boat, loaded as it was, even supposing it possible under any circumstances, which I very much doubted. There was nothing else to be done but to resign one's self to a week of utter weariness and discomfort. In other and more civilized lands the word "steamer" conveys an idea of speed, as well as a certain assurance of comfort, and at least a semblance of the ways and practices of ordinary life. But no one in search of the amenities need look on the deck of an up-river boat. The hull is a shallow box, over which is thrown a light deck and small cabin supported on upright posts. The machinery is rough, primitive in design, and constantly suggestive of unpleasant accidents. The high-pressure engines, exhausting in the open air, thumping over the centers, with leaky cylinders badly packed, or, as in this case, cracked and rudely banded with iron, can hardly be called reassuring. The light, thin upper works, burned in hundreds of holes by the sparks which are constantly flying in clouds over the deck, suggest an alternative scarcely more inviting. As an actual fact, however, I do not recollect ever to have heard of a single case of accident by explosion of boilers or by fire on the Upper Missouri. I am disposed to class this, also, among the special providences, rather than to attribute it to any skill on the part of the builders or owners. Certainly no thought of anything so worthless as human life entered into their calculation. The power of the machinery is apparently calculated with reference to down-stream work in a swift current, for, by the kindliest estimate of its performance, I have not been able to figure an up-stream speed so great as three miles an hour.

Owing to the slow progress made by the boat, I was obliged to land the live stock at the Tobacco Garden, and herd it from that point to Fort Buford, where it arrived on the 15th of June, a few hours after the boat. Five days were consumed in shoeing the animals and making other necessary preparations. The escort, consisting of two companies of the Seventh Cavalry and five companies of the Sixth Infantry, with their train, was concentrated here, under the command of Major Marcus A. Reno.

On the 21st the expedition started from Fort Buford. Supplies for six weeks were carried in the train, and arrangements had been made to have further supplies sent up from Fort Benton. On reaching the Big Muddy it was found to be impassable, and we were delayed a day and a half building a bridge. The stream was one hundred and twenty feet wide and five feet deep, with a soft mud bottom, which made it very difficult to set up the trestles. On the 25th we reached the Quaking Ash or Poplar River, where the various parties separated. The topographical parties, under Lieutenant Greene, escorted by three companies Sixth Infantry, followed up this stream to the boundary. The details of their march and subsequent operations will be found in the report of Lieutenant Greene.

Captain Gregory continued with the main party as far as the Little Rocky, where he branched off, accompanied by Captain Bryant, with two companies, to the northwest, intending to make his first astronomical station to the east of Frenchman's Creek; but, becoming involved in the bad lands, he was obliged to cross that stream fourteen miles below the line, at Fort Turnay, and follow up the west bank.

I continued with the remainder of the escort, which marched up the valley of the Milk River, passing Fort Belknap, and finally established a camp on the Sandy, a southern branch of the Milk River, about forty-five miles from Fort Benton. At Fort Belknap agency the mails were found, and forwarded to the parties on the line. The supplies from Fort Benton not having arrived, I went to that place on the 12th of July, and remained until the 24th, at which time the long-expected steamer made her appearance, having left, however, the main part of her stores at Cow Island, one hundred and twenty miles down the river. I sent a train, under charge of Lieutenant Ladley, to bring up what forage was required; and having sent another supply-train with the necessary supplies to the Sweet Grass Hills, I returned to my camp on the Sandy.

From this camp, accompanied by Major Reno, I marched to the East Butte of the Sweet Grass Hills, where the escort had established their permanent camp. I there learned that Captain Gregory's camp was only eight miles distant, though with rough country between. I therefore sent my train by the trail, and, riding directly across, found Captain Gregory camped on a small pool of water about two miles south of the line. Lieutenant Greene's advance party was reported to be only a few miles back, and the supply-train from Fort Benton, passing between the first and second buttes, were expected to reach the West Butte the next day.

On the following day I moved my camp to the West Butte, and encamped on a small brook about one mile north of the line, where the permanent depot was established. This depot was established on the 1st of August. Captain Gregory and the advanced parties of Lieutenant Greene were immediately supplied, and pushed forward without delay.

The work advanced rapidly, and at the end of August our line had been joined by traverse with that of the old northwestern boundary survey, on the summit of the Rocky Mountains, and the survey was complete.

I then concentrated the parties at the supply depot at the Sweet Grass Hills, and having detached Lieutenant Greene to carry a meridian from the line to Fort Shaw, in order to get a telegraphic connection for longitude, I left the Sweet Grass Hills with the remainder of the men, the escort meanwhile taking the direct trail to Fort Buford. I arrived at Fort Benton September 8. Lieutenant Greene joined me again, on the 11th, with his party.

I had previously had Mackinaw boats built and in readiness for our arrival, and on the 12th I started down the Missouri with the entire party, in six open boats. After a voyage of eighteen days we arrived at Bismarck, Dak., and thence, by Northern Pacific Railroad, reached Saint Paul, where the parties were discharged.

Thus in four months the expedition completed a journey of nearly four thousand miles, three-fourths of which was by land and in open boats by water, and carried to completion the survey of three hundred and fifty-five miles of the boundary-line.

It will be observed, by reference to the index of the records and maps, that a large amount of work has been done, and much information obtained by the commission, in addition to merely defining the line between the United States and the Dominion of Canada. Besides the official maps, a second series has been made, on a scale of one inch to eight miles, on which the lines of exploration by the different parties have been carefully located.

It will be seen that a large number of reconnaissances have been made, which, in the aggregate, give a quite complete view of the whole region traversed. This series of maps also shows a boat-survey of the Missouri River from Fort Benton, Mont., to Bismarck, Dak., made while returning from the field, in October, 1874. The latitudes were determined each day when the weather permitted, while the longitudes depend on the mean of the determinations of six chronometers. The astronomical points thus fixed are considered as absolute, and the co-ordinates of each day's travel, given by the compass and estimated distances, were multiplied by a constant multiple to reduce them to the astronomical coordinates. This work was done under the direction of Lieut. F. V. Greene.

From the barometric observations of the different parties, extending through 1872–'73–'74, a sufficiently accurate profile has been prepared by Captain Gregory.

All the details relating to the reconnaissance-maps and profile will be found in the accompanying reports of Captain Gregory and Lieutenant Greene.

CHAPTER III.

THE NORTHWEST POINT, LAKE OF THE WOODS.

Every one who is at all familiar with the geography of the Northwest, has noticed the anomalous shape of the northern boundary of the United States, at the Lake of the Woods. After crossing Lake Superior, it follows the apparent channel of the water-ways communicating with the Lake of the Woods, and, reaching the northwestern point of that lake, drops suddenly to the south, nearly half a degree, and follows the forty-ninth parallel of latitude to the Pacific coast. This curious configuration resulted from a lack of geographical knowledge at the time when the various treaties defining the boundary were made. The most northwestern point of the Lake of the Woods having been fixed upon as one point of the boundary, and the forty-ninth parallel of latitude as the line to be followed thence to the Rocky Mountains, and the latitude of the most northwestern point being unknown, the second article of the convention of London (October 20, 1818) specified that the connection should be made by a line north or south, as the case might be. Subsequently, it being found that the direction was south, it was so agreed upon and defined, in the treaty of November 10, 1842. The latter treaty thus simply defines, in more definite language, what had already been promulgated in the treaty of 1818, and the latter, in turn, adjusts certain difficulties arising under previous treaties (September 3, 1783; November 19, 1794; December 24, 1814).

Thus we find that the commissioners, under the sixth and seventh articles of the treaty of Ghent, fixed and marked the geographical position of the northwestern point, and there rested from their labors, leaving to subsequent commissions the duty of marking the line westward.

The recovery of this position gave rise to much discussion, and at one time promised considerable trouble. The point being indicated, and definitely fixed by the joint commission under the sixth and seventh articles of the treaty of Ghent, admitted of no change of location by the present commissioners. Its description, by latitude and longitude, was not sufficiently accurate to determine its position, since the methods employed were inadequate. It became necessary, then, to examine the details of the work done by the astronomers of the former commission, in order to form a fair judgment in regard to the accuracy of their work. During the winter of 1872–'73 the necessary copies of the record were obtained, and I was able to determine, within very narrow limits, the true position of the monument. The water of the lake being much higher in 1872 than when the monument was built, the site was overflowed to the depth of several feet. The superstructure had entirely rotted away, being composed of aspen, and there only remained a few fragments of oak to mark the spot.

The following letter to the commissioner gives, in detail, the technical points of the position taken by the chief astronomers, in regard to the recovery of the monument:

UNITED STATES NORTHERN BOUNDARY COMMISSION,
In the field, Lat. 49° *N., Long.* 102° 57′ *W., October* 1, 1873.

SIR: In your memorandum of September 15, you request my opinion in regard to the initial point of the United States northern boundary, at the northwest point of the Lake of the Woods, and whether I consider the objection of the English commissioner to the point selected by the English and American chief astronomers, as well taken, and, finally, in case of a difference of opinion between yourself and the English commissioner, which cannot be reconciled, what means of settlement remain.

Before answering these interrogatories, I beg leave to state briefly the means used, originally, to fix the "most northwest" point of the Lake of the Woods, and the method followed in recovering the monument erected at that time.

I have before me the reports of Dr. I. L. Tiarks, astronomer (November 18, 1825), and David Thompson, surveyor (October, 1824), who were employed by the British Government to determine the northwest point, and whose reports were adopted at the time by the commissioner on the part of the United States.

From these reports, it appears that a question arose between the angle at the Rat Portage and the northern point of the bay, now known as the Northwest Angle.

This question was settled by Tiarks in favor of the latter, on the principle that the northwest point was that point at which, if a line were drawn in the plane of a great circle, making an angle of 45° with the meridian, such a line would cut no other water of the lake. He therefore determined the relative position of the two points in question by means of their latitude and longitude; the latitudes were fixed by means of the sextant, and the longitude by the mean of several chronometer determinations.

The point fixed as the northwest point being in a swamp, its position was given by certain courses and distances from a reference monument. The question now is to find this monument. It is described by Thompson as a "square monument of logs, twelve feet high by seven feet square, the lower part of oak, the upper part of aspen." Its latitude is given by Tiarks 49° 23′ 06″.48 north; its longitude, approximately, 95° 14′ 38″ west from Greenwich.

So far as these co-ordinates are concerned, for any purpose of again finding the point, the longitude may be entirely rejected. It appears to have been determined by two chronometers, and as the distance traveled, and the elapsed time, were great, it may very easily be wrong by ten miles. It is only given by Tiarks as an approximation.

This is of little consequence, as the location of the northwest point, east and west, is confined to the narrow channel of the bay, which, at this point, runs generally north and south, and (the swamp included) has a width of only two hundred or three hundred feet.

The latitude, then, and the visible channel are the guides to be followed in searching for the ancient monument.

From the report of Tiarks, I find that the latitude of the monument, that being the point at which he observed, was determined by three series of circum-meridian altitudes of the sun. The results, and number of observations in each, were as given below, viz:

Latitudes.	Number of observations.
49° 23′ 02″. 37	9
49° 23′ 03″. 60	15
49° 23′ 09″. 24	29

The true mean latitude from these observations is 49° 23′ 05″ 07, but the latitude, combining according to the number of the observations in each series, is 49° 23′ 06″.48, which is the result Tiarks adopted. This method of weighting the observations should not have been used, as there is always a constant error in such series, due to the correction for index-error, and, in this case, a small additional inaccuracy arising from the fact that no barometric correction was applied to the refraction. These errors are, however, of comparatively little consequence, and their sum would probably not exceed four seconds of arc.

There remains a greater defect, arising from the unknown eccentricity of the sextant used. This Tiarks himself recognized, but, as he was more especially concerned in getting the relative latitude of two points within half a degree of each other, he took no means to eliminate the resulting error, which he regarded as being common to both stations.

This oversight is fatal when it becomes a question of recovering the exact point of observation, as there may have been an error of eccentricity on the limb of the sextant, which would give an error of a half mile in the latitude, though, as the instrument was one of very large radius (9″), and made by a maker of great reputation (Troughton), it is not probable that the eccentricity was so great.

Leaving this point for the present, I will state the means used to recover the monument.

In the fall of 1872, Major Farquhar and Captain Anderson, the chief astronomers of the joint commission for determining the boundary, observed for latitude near the northwest point of the Lake of the Woods, and, guided by their results and by information obtained from Indians, discovered what they agreed in supposing to be the remains of the monument, but in a latitude about five hundred feet south of that given by Tiarks.

Its position with reference to the northwest point of the bay, as given by the several courses and distances, is sufficiently exact.

The evidence appears to me to be strong enough to warrant them in the conclusion at which they arrived.

Owing, however, to the large possible error in the determination of the latitude by Tiarks, and considering that the northwest point, so determined, lies within what must be acknowledged to be English territory, I am of the opinion that the English commissioner may, without being considered as acting in an obstructive manner, take the ground that the evidence is not conclusive; but in making such objection, it is incumbent on him to suggest some other point, as the "most northwestern," which the shape of the bay would render possible.

There is another means of reducing the uncertainty of Tiarks's determination of the latitude, which I respectfully suggest for your consideration, in case of a final disagreement between yourself and the English commissioner. It is to take accurate observations for latitude at the angle near the Rat Portage. That station was marked by Thompson by a monument in stone, six feet high and four feet base, which can doubtless still be found. Tiarks observed there in the same manner as at the northwest point. Hence, by finding the amount of the error of his work at the Rat Portage, and applying the same correction to his work at the Northwest Angle, the error due to the eccentricity of his sextant will be eliminated, and the uncertainty of his latitude will be reduced within a very small limit.

If the latitude, so found, should still indicate that the monument was near the point agreed upon by Major Farquhar and Captain Anderson, I do not see that any further objection could be made by Her Majesty's commissioner to an immediate settlement of the vexed question.

If, however, such objection should still be made, the matter will then have passed beyond my province as the chief astronomer of the commission.

I am, very respectfully, your obedient servant,

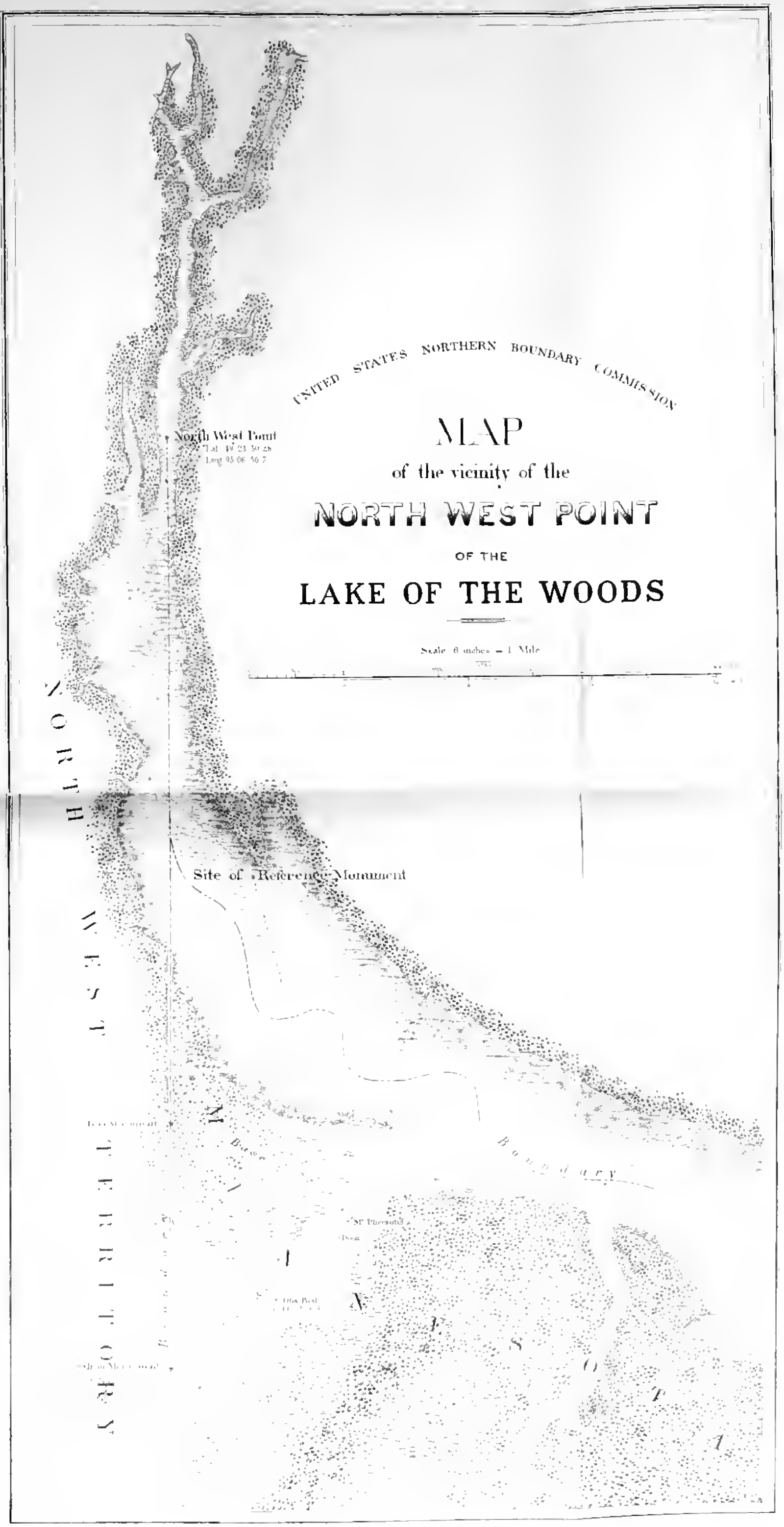
W. J. TWINING,

Captain of Engineers, Chief Astronomer United States Northern Boundary Commission.

ARCHIBALD CAMPBELL, Esq.,

United States Commissioner, Northern Boundary.

While the shape and general character of the surroundings of the Northwest Angle of the Lake of the Woods, were such as to confine the search to a very small portion of the bay, the scale of the maps was too small to serve as a definite basis of agreement. A new survey was there-


UNITED STATES NORTHERN BOUNDARY COMMISSION
MAP
of the vicinity of the
NORTH WEST POINT
OF THE
LAKE OF THE WOODS
Scale 6 inches = 1 Mile
North West Point
Site of Reference Monument
NORTH WEST TERRITORY
MINNESOTA
Boundary

fore made by an English party already on the ground. This survey was subsequently carried down to the forty-ninth parallel, where it was taken up by the parties under Lieut. F. V. Greene, and continued to the mouth of the Rainy River. The work of the English in the vicinity of the Northwest Point was checked by Capt. James F. Gregory, United States Engineers. The details will be found in his report, which is transmitted herewith.

The position of the Northwest Point, as fixed by Capt. S. Anderson, R. E., and Maj. F. U. Farquhar, United States Engineers, during the fall of 1872, was not finally agreed to by the commissioners until September, 1874.

CHAPTER IV.

ASTRONOMICAL DETERMINATIONS OF LATITUDE, AND METHODS OF SURVEY.

On account of the peculiar nature of the disputes liable to arise in regard to an international boundary-line, and the acrimony with which such controversies are usually prosecuted, it has been thought best to give, in a condensed form, the observations made by the United States parties, and the methods employed in fixing the positions of the monuments which mark the line.

An abstract of the British tangent-lines and mounds is added, in order to complete the record of the connections between astronomical stations.

Official copies of the English astronomical observations are on file in the Department of State.

In obedience to the instructions of the commissioner, an official copy of the United States astronomical and geodetic record was transmitted to the chief astronomer of Her Majesty's commission, October 14, 1875. It was accompanied by a descriptive memoir, from which the following explanations are taken :

Astronomy.—The astronomical record consists of—

1st, The observations made with the zenith telescope to determine latitude;

2d, Instrumental constants;

3d, Abstract of chronometer records;

4th, Star catalogues 1872, '73, and '74.

Instruments.—The instruments used in determining the latitude were zenith telescopes Nos. 7, 11, and 20, Würdemann. Nos. 7 and 11 were of 25 inches focal length. Both were of small power, and more or less damaged by use. No. 7 was used only on three stations in 1873; it being found that the level was badly ground, and that the instrument was loose on its horizontal axis. No. 20 was of 32 inches focal length, with a magnifying power of sixty diameters. It was found to be, in every respect, a perfect instrument.

The chronometers used were by Negus, of New York, and Bond, of Boston.

In computing the latitude of any station, the arithmetical mean of all the determinations was taken as the true latitude, no weights being applied. It is thought that the accuracy of the computation, and the number of authorities combined in each declination, warrant the assumption that the star places are nearly absolute, leaving in the determinations only the error of the observation. This view has been found to be correct, or nearly correct, by subsequently examining the residuals given by each pair of stars, when referred to the mean latitudes of a large number of stations.

In order to prevent the suppression of observations, a mathematical criterion was applied. This, while of doubtful utility in computations made under the supervision of one skillful computer, I thought to be desirable as a number of observers were engaged simultaneously, and the computations were to be completed, promptly, in the field.

The standard number of observations, though varying with different stations, was finally fixed at about sixty, it being found that, with the 32-inch instrument, sixty observations would give a mean result of which the probable error would be about four feet. This probable error was considered to be very much within the differences which might arise from the methods employed in computing the declinations of the stars used, and the general errors incident to such work.

Instrumental constants.—The observations by which the instrumental constants were determined, are given in full. It will be observed that no effort was made to determine the run of the micrometers, nor the differences due to changes of temperature. I am of the opinion that all such corrections are, even under the most favorable circumstances, somewhat hypothetical, and therefore liable to introduce unknown errors into the work, and that they are rather matters of curiosity than of practical importance in field-work.

The method of determining the mean places of the stars used is the only part of these computations which calls for any special remark.

In the fall of 1872, the astronomical party was ordered into the field, under my charge, without time for careful preparation.

The only authorities available at the time for computing the star places, were the Greenwich Observations from 1836 to 1867. The computations for the two stations observed in 1872, depended entirely on these observations. During the winter of 1872–'73, a careful and systematic examination of the existing authorities was commenced, and the list of stars, as given for 1873, was prepared. This work was continued during the subsequent winter, and the results are given in the star catalogue of 1874, which, however, differs very slightly from that of 1873.

The principles which were adopted in the discussion of these star places, were mainly derived from the work of Argelander, Bonner Beobachtungen, Band VII.

Some few stars were taken from the second part of that work without modification. These are British Association Catalogue numbers 198, 979, 4918, 5313, 5502, 6114, 7515, 7377, 8083, 8206, and 8273. The positions of Greenwich 12 year 73, and B. A. C. 896, were taken from Part I. For the remainder, the following catalogues and observations were consulted: Bradley, 1755, B; Lalande, Fedorenko, 1790, Fed; D'Agelet (Gould), 1800, D'A; Lalande, 1800, L.L; Piazzi, 1800, Pi; Groombridge, 1810, Gr; Struve, 1830, P. M; Argelander's Abo, 1830, Abo; Taylor's Madras, 1835, T; Jacob's Madras, 1848–1852, J_{48}, &c.; Bessel's zones (Weisse) (+15° to 45°), 1825, W_2 B; Pond's Greenwich, 1830, Pd; Airy's First Cambridge Catalogue, 1830, CC; Rümker, 1836, R; Edinburgh (Henderson , 1835, 1844, Edinburgh (Smyth), E_{37}, &c.; Cambridge (Challis), 1839–1860, Ch_{39}, &c.; Armagh (Robinson), 1840, Arm; Bonn North Zones, 1842, Ö A; Radcliffe Catalogue of 6317 stars, 1845, R C; Radcliffe, 1860, R C_2; Radcliffe, later observations, 1861–1870, R C_6, &c.; Bonn, (Vol. VI). 1866, Arg; Brussels (Quetelet), 1859–1866, Q_{59}, &c.; Königsberg; Washington (transit circle), 1867–'71, Wn; Washington Catalogue (mural circle), 1860, Y; the entire series of Greenwich catalogues and observations since the directorship of Airy, 1836–1871, Ay_{40}, Ay_{45}, Ay_{50}, Ay_{60}, Ay_{64}, Ay_{68}, &c.;

Paris observations, 1856–1867, P_{56}, &c.; Durhâm, D; the volumes of the Astronomische Nachrichten; Leiden, 1870, L; Pulkowa, 1845, Pul.

The dates after the name of each catalogue refer to the epochs to which each was reduced, and the initials following the date, the designation by which these catalogues and observations will be subsequently referred to.

Systematic corrections, as deduced by Argelander, in Vol. VII, Bonn Obs., were applied to most observations of a date earlier than 1860. In one case, that of Yarnall's Washington Catalogue, a special comparison was made with Wolfer's Fundamental List, in the Tabulæ Reductionum, which is the basis of Argelander's work. But this correction was omitted in a few of the later reductions.

Owing to the great discrepancy in the number of observations on the different stars, the weights were adopted to suit each particular case—*i. e.*, no uniform weight was given to the positions taken from any one catalogue, though a general standard was adopted for each, which was nearly as follows:

B	½	C C	1	Wn	1
D'A	¼	R	½	Y	1
Fed	¼	E	1	Ay_{40}	1
L. L	$\frac{1}{10}$	Ch	1	Ay_{45}	1½
Pi	⅓	A	1	Ay_{50}	1
Gr	½	Ö A	⅓	Ay_{60}	1½ to 2
P. M	1	$R C_1$	1	Ay_{64}	1½ to 2
Abo	1	$R C_2$	1	Ay_{68}, &c	1½
T	⅔	$R C_6$, &c	1	P	2
J	⅔	Arg	1½	Pul	2
W_2 B	⅓	Q	1	L (16 symmetrical observations)	4
Pond	1	K	½		

These weights represent the degree of confidence in the several authorities when represented by from three to five observations. In a few of the later reductions, the weights were made decimal fractions in all cases, and increased for some of the modern authorities.

The ordinary method of combining the observations to obtain the result for 1872, 1873, or 1874, as required, was, briefly, as follows: The right ascension found in the Greenwich Catalogues, or, these failing, in that of the British Association, was used to obtain the annual precession in declination, the secular variation in declination being taken directly from these authorities. All observations in a given case were then reduced to the required mean epoch, proper motion being always neglected. The resulting corrections (k) to the value of the assumed declination, the systematic corrections referred to above having been applied, were regarded as made up of three parts: x, a correction to the assumed declination at the required epoch; ty, a correction varying with the time, or, in other words, the proper motion; and v a residual error of observation. Equations of condition were accordingly made of the form $(x+ty-k=0)\sqrt{p}$, in which p denotes the weight. The value of t was usually taken to the nearest tenth of a year, reckoning from the date of observation, where that could be ascertained, to the required epoch. These equations were treated in the ordinary manner. But the value of x was usually derived from observations made in 1830, or later.

The following example will serve to illustrate the above explanation:

B. A. C. 67.

With the annual precession, $+20''.018$, computed for 1864 from the A. R. found in Ay_{64} (using Struve's constants), and the secular variation, $-0''.035$, adopted from that catalogue, each set of observations is reduced to the required epoch, 1873.0; a systematic correction having first been applied to the declinations as given by D'A, L. L, Pi, W_2 B, Arm, and Y.

R C_{67}, R C_{68}, and R C_{69} were combined so as to form one equation. Ay_{68}, Ay_{69}, and Ay_{70} were treated in the same manner, the weights in combining being strictly according to the number of observations in each year. Rejecting Lalande, we have the following conditional equations and weights, assumed δ for 1873 being $37° 15' 53''.0$:

		Weight.
B.	$x-117.0y-7''.79=0$	$\frac{1}{2}$
D'A.	$x-\ \ 88.8\ \ -2.77=0$	$\frac{1}{4}$
Pi.	$x-\ \ 73.\ \ \ -4.41=0$	$\frac{1}{3}$
W_2 B.	$x-\ \ 48.\ \ \ -3.68=0$	$\frac{1}{4}$
T.	$x-\ \ 38.\ \ \ -2.20=0$	$\frac{2}{3}$

Arm.	$x-\ 33.9\ -2.25=0$	1
Yar.	$x-\ 25.7\ -1.94=0$	1
K.	$x-\ 11.2\ -2.60=0$	$\frac{1}{3}$
Ay_{64}	$x-\ 8.5\ -0.85=0$	3
Q_{64}	$x-\ 8.1\ -1.25=0$	$\frac{1}{2}$
L.	$x-\ 4.1\ -0.55=0$	4
R. C_{69}	$x-\ 3.7\ -0.56=0$	$1\frac{1}{2}$
Ay_{69}	$x-\ 3.6\ -1.64=0$	$1\frac{1}{2}$

From the above, result the following normal equations:

$$+\ 14.8x-\ \ 262.6y=+\ 22''.18$$
$$-262.6x+14339.1y=-907''.92$$

from which,

$$x=+''.55 \text{ and } y=-''.053$$

Using T and the succeeding authorities for the value of x, we obtain 37° 15′ 53″.55, as the δ for 1873.0; a result identical with that derived from the direct solution of the normal equations. The following table exhibits the reduction, in tabular form. Column one contains the designation of the various authorities; column two, the epoch to which each catalogue is found reduced; column three, the mean epoch of observation (in the cases of B, L. L, Pi, W_2 B, and T arbitrarily assumed); column four contains the declination as given by the catalogue itself. In cases such as Ay_{64} and L, where the observations have been reduced to the date of the catalogue, in some instances with proper motion, the seconds of δ are adopted so as to correspond with the mean date of observation—*i. e.*, as they would have been had no proper motion been applied; column five contains the systematic correction as derived from Vol. VII, Part I, Bonn Observations (Argelander); column six, the declination as it results from each authority, the precession being applied to reduce it to 1873.0; column seven, the number of observations on which each authority is based; column eight, the final value of the declination for 1873 as it is given by each authority; column nine, the residuals or the corrections which the declination and proper motion adopted for 1873.0 give to each catalogue.

Catalogue.	Epoch, reduction.	Epoch, observation.	Cat. δ.	Sys. corr.	δ 1873.0.	No. obs.	Resulting δ 1873.0.	Residuals.
			° ′ ″		° ′ ″		″	″
B	1755	1756	36 36 36.6	....	37 15 60.8	4	54.6	−1.0
D'A	1800	1784.2	51 33.8	−0.4	55.8	4	51.1	+2.5
L. L	1800	1795	51 32.1	−1.8	[52.3]	3	....	......
Pi	1800	1800	51 37.2	−1.8	57.4	9	53.5	0.0
W_2 B	1825	1825	59 54.7	+0.9	56.7	1	54.1	−0.6
T	1835	1835	37 03 15.0	+0.4	55.2	4	53.2	+0.4
Arm	1840	1839.1	04 54.9	−0.3	55.3	6	53.5	+0.1
Y	1860	1847.3	11 34.2	+0.5	54.9	4	53.6	0.0
K	1861	1861.8	11 55.4	....	55.6	1	55.0	−1.5
Ay_{64}	1864	1864.5	12 53.7	....	53.8	22	53.4	+0.1
Q_{64}	1864	1864.9	12 54.1	....	54.3	1	53.8	−0.3
R C_{67}	1867	1867.8	13 54.4	....	54.5	1	54.3	−0.7
R C_{63}	1868	1868.8	14 12.4	....	52.5	2	52.3	+1.3
Ay_{68}	1868	1868.8	14 14.7	....	54.8	4	54.6	−1.0
L	1870	1868.9	14 53.5	....	53.6	15	53.3	+0.2
R C_{69}	1869	1869.8	14 33.7	....	53.8	5	53.6	−0.1
Ay_{69}	1869	1869.8	14 34.5	....	54.6	2	54.4	−0.8
Ay_{70}	1870	1870.8	14 53.5	....	53.6	1	53.5	0.0

δ, 1873.0, 37° 15′ 53″.55. An. prec., +20″.014 μ′, −″.053. Sec. var., −″.035.

The computation was generally carried to hundredths of a second in the details, but is not rigidly correct to that place.

The stars comprised in the catalogue of 1873 and 1874 were reduced as above, with the exception of a few declinations for 1874, which were treated in a manner varying so slightly as not to require special explanation.

Connection of astronomical stations.—The geodetic record gives the determination of the azimuths for each tangent, the station-errors, and the final offsets to the parallel of latitude in which the station-errors are distributed.

These tangents were run with an 8-inch transit-theodolite, Würdemann, graduated to 10′, reading by two verniers to 10″, with illuminated axes, circular and striding level, the tangent-screws working against springs, which was found to be a serious defect.

Azimuths.—The instrument was mounted in the meridian of the astronomical station, and an approximate 90° turned off, from any data available. On this approximate line, at a distance of one to three miles, a bull's-eye lantern was placed; its light, two inches in diameter, at a distance of two miles, gave an image equal to a second-magnitude star. The azimuth of this mark was determined by observations on circumpolar stars near elongation. The stars most frequently used in the early part of the evening in summer were β and γ Cephei and Polaris (eastern elongation), and β and γ^2 Ursæ Minoris (western elongation). Ten readings were taken on each star, and ten on the mark, five with lamp east and five lamp west. The star-readings were reduced to elongation from the recorded time (simultaneous time-observations with sextant), and the mean of the ten constituted the result for that star. The other stars were taken in different parts of the arc, to eliminate errors of graduation, and the final mean was the mean of results by stars. Five stars, with fifty readings, was considered a good determination, although three stars were used when it was not practicable to get more in one night. Treating all the readings (thirty to fifty in number) by least squares, the probable error of this work ranges from 0″.8 to 4″.0 at a station, with a mean of 1″.8. The transit was carefully leveled before each pointing and the level examined afterward; if deranged, the observation was rejected.

Having thus determined the true azimuth of the mark, its distance from the transit was chained, and the difference between the azimuth and 270° or 90°, with this distance in feet, gave the solution of a triangle, of which the required side was the distance, in feet, of the mark from the prime vertical sought. Having thus found the direction of the tangent, it was traced to the meridian of the next astronomical station by means of the transit, above described, and two targets, the distance being chained at the same time.

Tracing the tangent.—Calling the point where the transit stood during the azimuth observations (marked with stake and pencil-point), Station 1, the transit was carried to Station 2, set up, leveled, and pointed at the target, which was over Station 1. The other target, in front, was then by signals, ranged into the line of 1 and 2, and this gave Station 3. The transit was then taken to 3 and the rear target to 2, the front target was ranged into line, and gave Station 4; and so on to the next astronomical station.

The collimation was so adjusted that its error was as small as possible, and, to cut out the remaining error from this source, two sights were taken at each station. With clamp north, the telescope was pointed to the back target, and then revolved in the Y^s to align one point in front; the instrument was then turned 180° in azimuth, which brought the clamp south, resighted on the back target, and another point in front similarly determined. The mean of the two was taken as a point of the tangent.

The telescope was not reversed in the Y^s, on account of the dust. The targets used are shown in the accompanying report of Lieut. Greene.

The communication between the front and rear targets and the transit-instrument, was kept up by means of large flags, and the United States Army signal code of three elements. The men were instructed in this, and quickly learned it, but to insure accuracy each man was provided with a printed card containing the alphabet. A few special signals were added. By this means, and by transporting the targets and men in light wagons, as much as eighteen miles of line has been traced in one day. The greatest length of chaining in one day was fifteen miles. In rough ground two chainings were made. At the end of the tangent a series of azimuth observations was taken, similar to those at the beginning, the transit being placed over the terminal stake, and the mark over the stake next before it. The average azimuth-error in eighteen miles was 20″; when less than this, the tangent was considered correct; if over, it was adjusted in computing the offsets for the mounds. The difference between the computed offset from the tangent to the parallel of 49°, and the measured distance to the astronomical mound, was taken to be the "station-error," *i. e.*, the difference between the astronomical and relative geodetic determinations of the two stations. This was distributed between the stations in direct proportion to the distance. This made the forty-ninth parallel, as marked, a line of irregular curvature.

Computations.—The astronomical station being considered absolute, the offsets to the mounds were computed by the ordinary formula. For convenience, a table was computed for latitude 49°, giving the offsets and true azimuth for distances of 1,000 feet up to 200,000. Between the even thousands, the offset was readily interpolated. The final offset was, then, the sum of this computed offset, ± the proportional part of the station-error, ± the error of the initial point north or south of 49°, ± the correction due to azimuth error. A list of these offsets and the stakes from which they were to be measured was furnished to the "mound party," who followed.

Topography.—All topographical work, except some sketching along the tangents, was done with the stadia-rod and a 6-inch theodolite. The theodolites were made by Würdeman, and were similar, in nearly all particulars, to the larger transit used on the tangent-line. The cross-hairs were fixed, and the distance was read by noting the number of spaces covered on the rod; the smallest space marked was five feet, and the rod read by estimation to one foot. Each rod was graduated for its own instrument by measuring with great care 1,000 feet, and marking the points covered by the extreme wires; this distance was then subdivided and marked.

The rods read to 1,500 feet, and in rough, broken country were found more accurate than the chain, and at all times more expeditious.

The angles were kept by the method of traversing, or "keeping the azimuth"; each recorded angle being the angle of the line of sight with the true meridian, and were counted from 0° to 360°. The line always started from some stake on the tangent from which the azimuth was taken. When practicable the line was again closed on the tangent. Of one thousand four hundred miles of stadia-work, sixty-nine lines, comprising seven hundred and fifty miles, were closed, with an average error of 2.7 feet per 1,000 feet of line. As much as twelve miles of this sort of work, exclusive of side-pointings, has been done in one day by a single party with one theodolite and five rods. The vertical angle was always read, and gave an approximation to the vertical heights.

In the office, the stadia-readings have all been reduced to horizontal and vertical distances by means of tables. From the horizontal distances, the rectangular co-ordinates were computed, and these gave the error of the line, which was distributed at each station, proportionately to the length of line. The adjusted stations were then plotted by co-ordinates.

In projecting the maps the polyconic method has been adopted. Each sheet is projected with reference to its own central meridian, and to the forty-ninth parallel, as determined at the Lake of the Woods, for central parallel. The parallel actually marked in ink is the approximate parallel traced on the ground.

The length of 1° of longitude, in latitude 49°, is taken to be 240,076 feet.

APPENDIX D.

SUMMARY OF ASTRONOMICAL STATIONS, OBSERVED BY THE UNITED STATES ASTRONOMICAL PARTIES.

Number.	Position.	Observer.	Number of observations.	Latitude.	Probable error of single result.	Probable error of final result.	United States numbers.
				° ′ ″	″	″	
1872.							
1	Lake of the Woods..........	Capt. W. J. Twining..	84	48 59 45.67	±0.63	±0.07	2 east.
4	Red River, Initial Point.....	....do	104	48 59 55.92	±0.82	±0.08	1 do.
1873.							
5	Pointe Michel, 20 miles west of Red River.	....do	60	48 59 57.20	±0.42	±0.05	2 west.
6	Pembina Mountains, east side.	Capt. J. F. Gregory...	74	49 00 02.50	....	±0.24	3 do.
7	Pembina Mountains, west side	Assistant Lewis Boss	79	48 59 51.55	±0.35	±0.04	4 do.
8	Long River..................	Capt. J. F. Gregory...	82	48 59 58.54	....	±0.037	5 do.
11	Turtle Mountain, west side ..	Capt. W. J. Twining..	79	48 59 53.76	±0.35	±0.04	6 do.
13	South Antler Creek	Capt. J. F. Gregory...	81	49 01 48.76	±0.828	±0.092	7 do.
15	West of Rivière des Lacs, 237 miles west of Red River.	Capt. W. J. Twining..	72	49 01 01.63	±0.324	±0.038	8 do.
17	Mouse River	Capt. J. F. Gregory...	80	48 58 10.29	±0.588	±0.066	9 do.
19	Mid Coteau..................	....do	66	49 00 44.73	±0.457	±0.056	10 do.
21	Bully Spring.................	....do	64	49 01 09.11	±0.408	±0.051	11 do.
23	Four hundred and eight and a half Mile Point.	....do	59	48 59 28.90	±0.359	±0.047	12 do.
1874.							
25	Frenchman's Creek	....do	68	48 58 09.10	±0.359	±0.043	13 do.
27	Pool on Prairie	....do	66	49 00 02.95	±0.303	±0.037	14 do.
29	East Fork, Milk River.......	....do	62	49 00 01.86	±0.288	±0.036	15 do.
31	Milk River Lakes	....do	75	48 59 55.39	±0.387	±0.045	16 do.
33	East Butte	....do	60	48 59 06.30	±0.326	±0.042	17 do.
35	Red River	....do	60	49 01 01.42	±0.275	±0.035	18 do.
37	North Fork, Milk River......	....do	62	48 59 59.31	±0.270	±0.034	19 do.
40	Chief Mountain Lake	....do	47	49 00 04.00	±0.335	±0.049	20 do.

NOTE.—The instrument used at stations Nos. 6, 13, and 17 was Würdemann, No. 11, 25-inch, having a defective level, and being, at station No. 6, also loose upon its horizontal axis. No. 6 being a joint station, was not reobserved. At stations Nos. 1 and 4, Würdemann, No. 7, 25-inch was used. At all other stations, the instrument used was Würdemann, No. 20, 32-inch.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 1.—Initial point, 2¼ miles north of Pembina, Dakota.—Observer, W. J. Twining, Captain United States Engineers.—Zenith Telescope, Würdemann No. 7.—Chronometer, Negus Sidereal No. 1514.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6553	21.041	40.8	41.4	....	32 18 19.35						
6586	24.556	45.8	37.6	......	65 46 09.20	−2 18.27	+1.71	−0.04	... ...	48 59 57.67	September 16.
6728	19.873	44.5	42.4	......	43 25 30.61						
6748	24.727	39.6	47.9	....	54 40 45.00	−3 10 94	−1.39	−0.05	....	55.43	
6780	22.505	44.3	43.2	......	57 43 01.32						
6817	22.647	40.4	47.4	....	40 16 47.94	+0 05.59	−1.39	0.00	....	58.83	
6937	18.384	45.2	44.4	......	36 28 07.01						
6970	26.024	45.7	43.9	....	61 41 46.54	−5 00.44	−0.58	−0.09	....	55.67	
7024	19.853	45.0	44.4	......	61 51 22.63						
7073	25.025	29.7	60.3	......	36 01 58.89	+3 23.45	−6.75	+0.06	....	57.52	
7215	19.844	51.7	33.2	......	57 07 32.77						
7277	28.688	34.6	57.4	....	40 40 47.91	+5 47.90	−0.97	+0.10	....	57.37	
7345	16.390	45.4	46.5	......	47 08 22.11						
7448	28.042	53.4	39.9	....	51 06 43.70	−7 38.36	+2.79	−0.13	....	57.20	
7480	20.696	47.1	46.0	......	45 58 52.84						
7489	22.758	50.2	42.6	... ..	52 03 37.20	−1 21.11	+1.96	−0.02	....	55.85	
7505	19.952	47.8	44.9	......	37 57 55.90						
7605	23.200	45.7	47.7	......	60 06 12.88	−2 07.77	+0.20	−0.03	....	56.79	
7636	19.223	47.3	46.4	......	55 36 50.39						
7679	27.602	38.7	55.0	......	42 12 05.88	+5 29.61	−3.46	+0.10	....	54.39	
7755	20.596	47.5	47.0	....	58 47 15.31						
7765	26.312	45.1	48.5	0 32	39 05 04.37	+3 44.85	−0.65	+0.07	+.14	54.25	
7820	15.457	48.5	44.9	.. ...	48 49 55.53						
7882	26.827	45.6	48.4	......	49 24 45.42	−7 27.27	+0.18	−0.13	....	53.25	
7962	28.703	38.2	37.2	......	41 16 49.17						
8024	15.215	41.8	38.9	......	56 25 18.59	+8 50.58	+0.88	+0.16	....	55.50	
8206	29.075	36.5	39.8	... ...	20 37 22.84						
8273	16.400	38.7	38.0	......	67 05 54.89	+8 18.60	−0.58	+0.16	....	57.05	
6553	21.633	40.9	39.3	... .	32 18 19.50						
6586	25.045	32.1	48.8	......	65 46 09.44	−2 14.22	−3.40	−0.04	....	56.84	September 18.
6621	24.694	41.5	39.9	......	40 07 48.03						
6681	29.400	36.8	45.8	......	57 46 29.44	+2 48.92	−1.66	+0.05	....	56.04	
6728	19.742	44.0	38.7	......	43 25 30.85						
6748	24.573	34.2	48.8	.... ..	51 40 45.28	−3 10.04	−1.66	−0.05	......	56.31	
6780	23.112	41.3	42.0	......	57 43 01.64						
6817	23.219	40.2	43.3	......	40 16 48.20	+0 04 22	−1.98	0.00	......	57.16	
6987	18.027	43.7	40.7	......	36 28 07.30						
6970	25.627	37.6	47.3	......	61 41 46.94	−4 58.87	−1.51	−0.09	......	56.45	
7100	14.974	46.0	40.2	......	42 45 39.20						
7166	29.594	30.7	57.6	......	55 33 33.94	−9 35.11	−4.30	−0.17	......	56.99	
7215	18.735	43.6	42.9	......	57 07 33.17						
7277	27.579	40.5	46.6	......	40 40 48.37	+5 47.90	−1.21	+0.10	......	48 59 57.56	

Observations for Latitude.—Station No. 1—Continued.

B. A. C. No.	Readings. Microm.	Readings. Level. N.	Readings. Level. S.	Readings. Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7345	16.074	45.9	41.1	....	47 08 22.55						
7448	27.674	39.6	49.0	....	51 06 44.20	−7 36.31	−1.03	−0.13	......	48 59 55.90	September 18.
7480	20.658	43.4	44.8	....	45 58 53.30						
7489	22.683	40.6	47.9	....	52 03 37.70	−1 19.66	−1.96	−0.02	......	53.86	
7505	21.264	44.5	41.0	....	37 57 56.32						
7605	24.525	42.1	46.5	....	60 06 13.46	−2 08.28	−0.88	−0.03	....	55.70	
7636	18.759	44.0	44.3	....	55 36 50.98						
7679	27.111	42.7	45.9	....	42 12 06.39	+5 28.55	−0.79	+0.10	....	56.55	
7820	16.249	43.8	44.6	1 31	48 49 56.09						
7882	27.654	46.6	42.1	....	49 24 45.99	−7 28.64	+0.83	−0.13	+1.12	54.22	
7962	29.236	43.4	44.8	....	41 16 49.69						
8024	15.652	42.3	46.4	....	56 25 19.24	+8 54.36	−1.24	+0.16	....	57.75	
8083	18.876	43.0	46.4	......	56 27 56.59						
8128	25.780	44.4	45.0	... ..	41 22 53.77	+4 31.59	−0.90	+0.08	.....	55.95	
6728	19.967	40.0	37.2	....	43 25 31.20						
6748	24.902	38.7	38.7	....	51 40 45.71	−3 14.13	+0.63	−0.05	.....	54.90	September 21.
7100	14.993	38.4	39.8	....	42 45 39.71						
7166	29.810	53.5	34.8	....	55 33 31.69	−9 42.84	+3.89	−0.17	......	58.08	
7215	18.790	39.4	39.4	....	57 07 33.77						
7277	27.620	36.6	42.6	......	40 40 49.06	+5 47.35	−1.35	+0.10	......	57.51	
7345	14.465	40.8	38.7	....	47 08 23.20						
7448	26.120	40.7	39.7	......	51 06 44.93	−7 38.48	+0.70	−0.13	......	56.15	
7480	20.687	41.0	39.6	....	45 58 54.00						
7489	22.733	40.7	39.9	....	52 03 38.47	−1 20.48	+0.49	−0.02	......	56.22	
7505	20.834	39.5	41.3	....	37 57 56.94						
7605	24.236	45.0	36.7	....	60 06 14.33	−2 13.83	+1.46	−0.03	......	53.23	
7636	17.837	39.7	41.9	......	55 36 51.81						
7679	26.073	43.5	38.6	......	42 12 07.10	+5 23.98	+0.61	+0.10	....	54.14	
7755	18.725	38.2	43.7	....	58 47 16.83						
7765	24.344	47.9	34.0	....	39 05 05.55	+3 41.04	+1.89	+0.07	....	54.19	
7787	19.274	40.6	41.5	....	52 01 12.35						
7800	22.918	44.2	38.0	....	45 53 49.52	+2 23.35	+1.19	+0.03	....	55.50	
7820	15.372	41.3	41.1	....	48 49 56.93						
7882	26.807	49.0	34.4	....	49 21 46.85	−7 29.82	+3.33	−0.13	......	55.27	
7962	31.073	42.0	42.4	....	41 16 50.48						
8024	17.673	47.7	37.4	....	56 25 20.27	+8 47.12	+2.23	+0.16	....	54.85	
8036	20.195	44.0	41.4	....	49 21 39.23						
8059	21.686	44.8	40.8	....	48 36 10.78	+0 58.65	+1.48	+0.02	....	55.15	
8083	18.223	41.2	44.7	......	56 27 57.56						
8128	24.998	53.9	32.4	... ..	41 22 54.51	+4 26.51	+4.05	+0.08	......	56.67	
8206	28.406	45.0	42.0	....	30 37 23.94						
8273	15.865	45.9	42.2	....	67 05 56.70	+8 13.33	+1.51	+0.16	....	55.32	
8344	16.899	42.2	46.1	....	60 30 47.75	+6 33.96	+3.53	+.11	....	55.64	
8366	21.035	40.7	48.0	....	60 36 15.82	+3 51.27	+2.77	+.07	....	56.17	
46	31.106	40.2	48.8	....	60 40 20.73	−2 41.90	+2.47	−.05	....	56.54	
67	26.914	54.4	34.8	....	37 15 48.31						
120	14.558	44.2	45.0	......	32 52 43.71						
175	29.651	48.0	40.7	....	65 26 52.01	-9 53.72	+1.46	−0.18	....	55.41	
198	25.650	45.0	43.5	0 14	47 35 12.33						
219	19.276	39.7	48.9	......	50 16 21.27	+4 10.74	−1.73	+ 0.07	+0.03	48 59 55.91	

Observations for Latitude.—Station No. 1—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
12-Yr. 73	18.211	42.5	45.9	....	67 05 52.88						
345	25.198	46.2	42.0	....	30 41 19.74	+4 34.85	+0.18	+0.09	....	48 59 56.43	September 21.
6937	18.004	36.6	35.4	....	36 28 08.24						
6970	25.759	42.2	39.7	....	61 41 48.37	−5 05.06	+0.83	−0.09	....	53.99	September 26.
7024	19.328	37.3	34.9	....	61 51 24.55						
7073	24.182	40.9	31.6	....	36 02 00.30	+3 10.94	+2.63	+0.06	....	56.05	
7100	15.356	34.7	37.5	....	42 45 40.48						
7166	30.221	44.4	28.0	....	55 33 35.52	−9 44.75	+3.06	−0.17	....	56.14	
7215	19.841	32.7	39.6	....	57 07 31.84						
7277	28.531	45.2	27.4	....	40 40 49.74	+5 41.84	+2.45	+0.10	....	56.68	
7345	16.194	37.5	34.5	....	47 08 24.17						
7448	27.923	40.3	32.5	....	51 06 46.04	−7 41.39	+1.80	−0.13	....	55.38	
7480	20.705	36.2	37.0	....	45 58 55.06						
7489	22.863	43.6	29.7	....	52 03 39.62	−1 24.89	+2.95	−0.02	....	55.32	
7505	20.525	35.0	38.2	....	37 57 57.83						
7505	23.907	45.8	28.0	....	60 06 15.59	−2 13.04	+3.28	−0.03	....	56.92	
7636	21.756	38.6	35.3	....	55 36 53.13						
7679	29.935	42.2	31.7	....	42 12 08.22	+5 21.74	+3.10	+0.10	....	55.61	
7755	20.324	36.3	37.4	....	58 47 18.26						
7765	25.878	44.5	29.6	0 35	39 05 06.64	+3 38.48	+3.10	+0.07	+0.16	54.27	
7820	16.585	35.6	38.3	....	48 49 58.23						
7882	28.019	44.7	29.6	....	49 24 48.10	−7 29.78	+2.79	−0.13	....	56.09	
7962	28.371	36.9	37.4	....	41 16 51.71						
8024	14.992	42.0	32.8	....	56 25 21.75	+8 46.30	+1.96	+0.16	....	55.15	
8036	21.610	33.0	41.6	....	49 21 40.64						
8059	23.034	18.8	26.4	....	48 36 12.20	+0 56.02	+3.10	+0.02	....	55.56	
8083	18.331	37.0	39.3	....	56 25 59.14						
8128	25.041	47.1	28.5	....	41 22 55.87	+4 23.95	+3.67	+0.08	....	55.20	
8206	28.103	31.0	55.9	0 30	30 37 24.98						
8273	15.672	58.0	19.2	....	67 05 58.27	+8 09.00	+5.38	+0.16	+0.11	56.28	
8344	16.448	38.2	39.2	....	60 30 49.45	+6 32.55	+4.72	+0.11	....	56.88	
46	30.695	36.7	41.0	....	60 49 31.44	−2 47.89	+3.98	−0.05	....	56.54	
67	26.427	49.9	27.9	....	37 15 49.55						
120	14.365	40.3	37.2	....	32 52 44.83						
175	29.410	36.6	41.0	....	65 26 53.81	−9 51.83	−0.29	−0.18	....	57.02	
198	25.959	36.4	41.2	....	47 25 13.79						
219	19.681	41.2	35.9	....	50 16 22.78	+4 06.96	+0.11	+0.07	....	55.42	
239	27.838	39.4	37.9	....	60 25 29.10						
259	17.059	35.4	41.9	....	37 48 30.29	−7 03.23	−1.12	−0.12	....	55.22	
487	18.899	36.4	40.6	....	47 58 51.40						
522	20.231	39.5	37.5	....	50 02 44.30	−0 52.40	−0.49	−0.02	....	56.44	
6937	18.656	34.6	29.7	....	36 28 08.36						
6970	26.253	22.9	42.0	....	61 41 48.55	−5 58.85	−3.19	−0.09	....	56.32	September 27.
7024	20.452	35.8	39.9	....	61 51 24.72						
7073	25.399	34.0	42.2	....	36 02 00.42	+3 14.60	−2.77	+0.06	....	54.46	
7215	19.966	36.7	39.4	....	57 07 35.06						
7277	28.728	35.5	40.5	....	40 40 49.87	+5 41.67	−1.73	+0.10	....	55.50	
7480	20.021	42.9	33.7	....	45 58 55.27						
7489	22.070	26.6	50.0	....	52 03 39.85	−1 20.60	−3.19	−0.02	....	53.75	
7820	15.091	30.2	37.4	....	48 49 58.49						
7882	26.411	32.7	44.2	....	49 24 48.15	−7 25.42	−2.18	−0.13	....	48 59 55.74	

Observations for Latitude.—Station No. 1—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7962	28.171	39.4	37.5	....	41 16 51.95						
8024	14.671	33.2	44.5	....	56 25 22.06	+8 50.94	−2.12	+0.16	....	48 50 55.99	September 27.
8083	17.735	39.5	38.2	....	56 27 59.54						
8128	24.633	29.0	48.7	....	41 22 56.20	+4 31.35	−4.14	+0.08	....	55.16	
8206	29.036	40.5	37.5	....	30 37 25.18						
8273	16.451	26.5	52.0	....	67 05 58.85	+8 15.06	−5.06	+0.16	....	52.17	
8344	16.230	36.2	42.2	....	60 20 49.79	+6 37.82	−1.12	+0.11	....	56.60	
46	30.438	33.4	46.0	....	60 49 31.79						
67	26.343	40.2	39.2	....	37 15 49.80	−2 41.09	−2.61	−0.05	....	57.05	
120	14.012	40.0	39.9	....	32 52 45.06						
175	29.012	36.9	44.2	....	65 26 54.17	−9 50.06	−1.62	−0.18	....	57.75	
198	24.446	40.6	40.7	....	47 35 14.09						
219	18.092	36.3	45.5	....	50 16 23.69	+4 09.95	−2.09	+0.07	....	56.52	
239	27.182	39.1	43.0	....	60 25 29.41						
259	16.488	37.5	44.6	....	37 48 30.53	−7 00.67	−2.47	−0.12	....	56.73	
6624	24.673	39.2	44.9	0 21	40 07 48.74						
6681	20.426	45.0	39.5	....	57 46 30.49	+2 47.07	−0.04	+0.05	+.06	56.76	September 28.
7024	22.308	45.8	42.1	....	61 51 24.80						
7073	27.246	40.0	48.0	....	36 02 00.53	+2 14.25	−0.97	+0.06	....	56.05	
7160	15.769	45.6	42.4	....	42 45 40.75						
7166	30.550	44.7	43.6	....	55 33 35.87	−9 41.45	+0.97	−0.17	....	57.66	
7215	19.232	44.0	44.5	....	57 07 35.27						
7277	27.961	45.6	44.0	....	40 40 59.01	+5 43.38	+0.25	+0.10	....	56.37	
7345	15.669	46.5	43.4	....	47 08 24.56						
7448	27.341	45.0	46.2	....	51 06 46.48	−7 39.15	+0.43	−0.13	....	56.67	
7480	20.699	45.9	45.8	....	45 58 55.48						
7489	22.793	46.5	45.3	....	52 03 40.08	−1 22.37	+0.29	−0.02	......	55.68	
7505	21.051	46.0	45.8	......	37 57 58.05						
7605	24.394	48.6	43.6	....	60 06 16.09	−2 11.51	+1.17	−0.03	......	56.67	
7636	13.253	41.4	47.8	....	55 36 53.64						
7679	21.654	32.6	59.3	....	42 12 08.66	+5 30.47	−6.77	+0.10	.....	54.95	
7755	18.184	44.8	46.5	....	58 47 18.83						
7765	23.757	48.1	42.0	....	39 05 07.07	+3 39.23	+0.99	+0.07	.....	53.24	
7787	18.743	41.8	46.1	....	52 01 11.22						
7800	22.320	48.8	41.3	....	45 53 51.25	+2 20.71	+1.39	+0.03	....	54.86	
7820	15.208	44.5	45.8	....	48 49 58.75						
7882	26.540	46.9	44.0	....	49 21 48.72	−7 25.77	+0.36	−0.13	....	58.19	
7962	29.498	46.1	45.7	....	41 16 52.20						
8024	16.106	48.9	43.7	....	56 25 22.37	+8 46.81	+1.26	+0.16	....	55.51	
8036	21.569	43.6	49.0	....	49 21 41.21						
8059	23.035	50.8	42.1	....	48 36 12.77	+0 57.67	+0.71	+0.02	....	55.42	
8083	19.321	45.9	47.0	....	56 27 59.76						
8128	26.080	48.0	45.2	....	41 22 56.38	+4 25.83	+0.38	+0.08	....	54.41	
8206	28.536	36.9	35.7	....	30 37 25.30						
8273	15.992	39.9	33.9	....	67 05 59.21	+8 13.45	+1.62	+0.16	....	57.53	
8344	17.682	34.2	40.0	....	60 50 50.13						
8366	21.821	33.9	40.5	....	60 36 18.22	+6 33.10	+0.27	+0.11	......	54.57	
46	31.876	34.6	40.4	....	60 49 32.13	+3 50.28	+0.09	+0.07	....	54.58	
67	27.675	41.0	34.0	....	37 15 50.05	−2 45.26	+0.27	−0.05	....	56.05	
120	14.401	38.4	36.6	......	32 52 45.28						
175	29.490	40.6	35.9	....	65 26 54.52	−9 53.56	+1.46	−0.18	....	48 59 57.62	

Observations for Latitude.—Station No. 1—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″		″	° ′ ″	
198	24. 750	34. 0	41. 3	....	47 35 14. 38						
219	18. 533	47. 4	28. 5	....	50 16 23. 39	+4 04. 56	+2. 61	+0. 07	....	48 59 56. 13	September 28.
239	28. 459	37. 6	37. 8	....	60 25 29. 78						
259	17. 677	40. 5	35. 1	....	37 48 30. 77	−7 04. 14	+1. 17	−0. 12	....	57. 18	
12-Yr. 73	19. 533	38. 3	37. 8	....	67 05 55. 35						
345	26. 425	40. 5	35. 7	0 20	30 44 51. 20	+4 31. 11	+1. 19	+0. 09	+0. 04	55. 71	
401	29. 667	36. 5	40. 0	....	28 01 20. 96						
438	15. 108	43. 5	33. 0	....	69 36 24. 70	+9 32. 71	+1. 57	+0. 18	....	48 59 57. 29	

104 determinations.
Mean latitude, 48° 59′ 57″.92
Value of micrometer turn used, 78″.675
Value of one division of level, 0″.8995

ϵ 1″.23
τ 0″.82
ϵ_0 0″.12
τ_0 0″.08

1872.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 2, east.—Lake of the Woods, 89 miles east of Pembina.—Observer W. J. Twining, Captain United States Engineers.—Zenith Telescope, Würdemann No. 7.—Chronometer, Negus Sidereal No. 1514.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
198	25.106	38.3	37.0	0 35	47 35 19.31						
219	19.194	34.8	40.4	....	50 16 28.53	+ 3 52.56	−0.88	+0.07	+0.16	48 59 45.83	October 16.
239	28.289	35.7	39.4	....	60 25 35.65						
259	17.045	48.4	27.2	....	37 48 34.84	− 7 22.31	+3.94	−0.13	....	46.74	
12-Yr. 73	19.395	38.1	38.0	....	67 06 01.60						
345	25.832	49.5	37.1	....	30 41 54.57	+ 4 13.21	+2.81	+0.08	....	41.18	
401	28.470	39.9	37.9	....	28 04 24.01						
438	14.418	45.9	32.3	....	69 36 31.01	+ 9 12.77	+3.51	+0.17	....	43.96	
487	18.487	40.9	37.7	....	47 58 59.82 }						
522	20.341	46.0	32.8	....	50 02 49.87 }	− 1 12.93	+3.69	−0.02	....	45.58	
560	25.658	45.9	32.7	....	50 09 46.06						
611	25.693	38.5	40.3	....	63 46 26.60						
656	18.084	39.4	39.6	....	34 23 06.34	− 4 59.22	−0.40	−0.09	....	46.76	
744	23.081	39.0	40.8	....	66 49 40.08						
752	20.018	49.7	30.1	....	31 13 45.93	− 2 00.49	+4.00	−0.01	....	46.47	
825	14.154	40.0	39.5	0 26	19 28 08.04						
896	31.945	47.2	32.0	....	78 54 37.61	−11 39.84	+3.53	−0.26	+0.11	46.36	
6728	19.579	41.7	38.8	....	43 25 32.34						
6748	24.787	40.6	39.5	....	54 40 47.33	− 3 24.87	+0.90	−0.06	......	45.80	October 17.
6937	17.894	41.8	40.9	....	36 28 09.47						
6970	25.872	41.3	41.7	....	61 41 50.61	− 5 13.83	+0.11	−0.10	......	46.22	
7024	19.397	40.8	42.7	....	61 51 27.01						
7073	23.970	45.5	38.7	....	36 02 01.92	+ 2 59.89	+1.10	+0.05	....	45.52	
7100	13.914	42.0	42.2	....	42 45 42.49						
7166	29.027	43.6	41.0	....	55 33 38.28	− 9 51.51	+0.51	−0.18	....	46.21	
7215	17.861	40.3	41.0	....	57 07 37.89						
7277	26.255	47.8	37.8	....	40 40 52.14	+ 5 30.20	+1.42	+0.10	......	46.73	
7345	16.309	45.2	40.9	....	47 08 27.19						
7448	28.343	44.7	42.0	....	51 06 49.68	− 7 53.39	+1.57	−0.13	....	46.49	
7480	20.173	45.8	41.4	....	45 58 58.50						
7489	20.639	44.5	42.9	....	52 03 43.54	− 1 37.01	+1.35	−0.02	......	45.34	
7505	20.024	46.8	40.6	....	37 58 00.86						
7605	23.721	43.3	41.8	....	60 06 20.22	− 2 25.43	+1.06	−0.01	....	46.13	
7636	21.801	44.0	41.2	....	55 36 57.66						
7679	29.715	46.6	42.5	....	42 12 12.00	+ 5 11.32	+0.88	+0.09	....	47.12	
7755	18.810	43.7	45.1	....	58 47 23.36						
7765	24.070	47.0	42.2	....	39 05 10.34	+ 3 26.91	+0.76	+0.06	....	41.58	
7787	19.346	44.0	45.0	....	52 01 18.47						
7800	22.584	46.9	42.4	....	45 53 55.12	+ 2 07.37	+0.79	+0.03	......	44.99	
7820	15.670	45.5	43.4	....	48 50 02.90						
7882	27.457	46.6	42.5	....	49 21 53.07	− 7 43.67	+1.39	−0.13	....	48 59 45.57	

Observations for Latitude.—Station No. 2—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7962	28.130	44.4	45.3	....	41 16 56.10						
8024	15.111	48.3	41.7	....	56 25 27.53	+ 8 32.13	+1.28	+0.15	....	48 59 45.38	October 17.
8036	20.917	43.6	46.0	......	49 21 45.89						
8059	21.982	49.6	40.0	....	48 36 17.44	+ 0 41.89	+1.62	+0.02	....	45.19	
8083	18.537	45.4	44.4	......	56 28 05.07						
8128	24.918	47.6	42.2	....	41 23 10.58	+ 4 11.01	+1.44	+0.07	......	45.34	
8206	29.244	45.3	45.3	....	30 37 28.70						
8273	17.149	49.6	41.9	......	67 06 05.50	+ 7 55.79	+1.73	+0.15	....	44.77	
8314	25.221	45.2	46.1	......	73 42 13.54						
8324	18.443	49.6	41.6	......	24 26 08.19	− 4 26.63	+1.60	−0.09	....	45.75	
8344	16.384	40.7	38.7	0 20	60 30 56.14	+ 6 17.92	+1.91	+0.11	+0.04	45.21	
8366	20.529	40.0	38.9	......	60 36 24.25	+ 3 34.86	+1.70	+0.06	....	45.91	
46	30.612	40.4	38.9	....	40 49 38.23						
67	25.991	43.2	36.7	....	37 15 54.33	− 3 01.75	+1.80	−0.05	......	46.25	
120	13.758	40.4	39.6	......	32 52 49.04						
175	29.307	43.5	36.5	0 13	65 27 01.01	−10 11.66	+1.75	−0.19	+0.02	44.95	
198	24.055	40.5	39.7	......	47 35 19.57						
219	18.834	43.1	36.9	....	50 16 28.80	+ 3 48.98	+1.57	+0.07	......	44.80	
239	27.615	39.4	40.5	......	60 25 35.97						
259	16.401	43.7	36.1	......	37 48 35.04	− 7 21.13	+1.46	−0.13	......	45.70	
12-Yr. 73	19.388	39.4	40.7	....	67 05 01.94						
345	25.884	46.4	34.1	....	30 44 54.74	+ 4 15.54	+2.38	+0.08	......	46.34	
401	20.044	39.9	40.6	......	28 01 24.17						
438	14.926	44.4	36.3	....	69 36 31.37	+ 9 15.37	+1.66	+0.17	....	44.97	
474	13.697	42.0	38.9	....	48 04 20.79						
487	17.783	42.1	38.9	......	17 59 00.08						
522	19.576	42.5	38.4	......	50 02 50.14	− 7 19.91	+1.46	−0.12	......	44.98	
560	24.880	42.1	38.7	......	70 09 46.32	− 1 10.53	+1.64	−0.02	......	46.20	
611	25.765	40.1	40.6	......	63 46 26.92						
656	18.138	41.6	39.6	......	34 23 06.53	− 4 59.93	+0.34	−0.69	......	47.05	
741	22.466	40.7	40.6	....	66 49 40.41						
752	19.499	40.9	40.8	......	31 13 46.09	− 1 56.71	+0.01	−0.01	......	46.54	
825	14.658	40.9	41.0	.....	19 28 08.13						
896	32.378	42.3	40.3	......	78 54 37.95	−11 37.06	+0.43	−0.26	......	46.15	
979	18.177	39.9	43.4	......	77 15 42.38						
999	25.375	45.1	38.0	......	20 34 20.81	+ 4 43.15	+0.81	+0.10	....	45.66	
1101	19.503	41.8	41.1	......	31 15 13.35						
1127	22.225	43.0	40.2	......	66 47 52.82	− 1 47.08	+0.72	−0.03	......	46.69	
1203	25.538	41.4	41.9	......	62 41 40.92						
1228	19.751	42.8	40.6	......	35 25 24.25	− 3 17.65	+0.38	−0.07	......	45.25	
1254	24.716	40.6	42.7	......	50 00 09.19						
1287	20.431	43.9	39.7	......	48 04 58.55	− 2 48.46	+0.47	−0.05	......	45.83	
6728	19.424	45.2	35.1	......	43 25 32.34						
6748	26.586	37.7	43.1	......	54 49 47.34	− 3 24.06	+1.05	−0.06	......	47.78	October 18.
6780	22.101	40.7	40.5	......	57 43 03.99						
6817	21.887	35.2	46.4	......	40 16 50.02	− 0 08.42	−2.48	0.00	....	46.10	
6937	18.141	42.0	41.0	......	36 28 09.48						
6970	26.176	44.0	35.1	......	61 41 50.65	− 5 15.99	+1.33	−0.10	......	45.31	
7024	20.019	42.1	40.8	......	61 51 27.04						
7053	24.561	44.2	39.6	....	36 02 01.92	+ 2 58.67	+1.39	+0.05	......	48 59 41.59	

Observations for Latitude.—Station No. 2— Continued.

B. A. C. No.	Readings				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″		″	° ′ ″	
7100	14.524	41.5	42.4	......	42 45 42.51						
7166	29.645	45.8	37.9	......	55 33 38.35	− 0 54.82	+1.51	−0.18	......	48 59 46.91	October 18.
7215	17.822	40.6	43.4	......	51 07 37.97						
7277	26.184	45.6	38.7	......	40 40 52.20	+ 5 28.94	+0.92	+0.10	......	45.04	
7345	16.145	41.9	42.4	......	47 08 27.28						
7448	28.138	40.6	44.2	......	51 06 49.80	− 7 51.77	−0.92	−0.13	......	45.73	
7480	20.737	42.8	42.3	......	45 58 58.61						
7489	23.160	40.6	44.4	......	52 05 43.62	− 1 35.31	−0.74	−0.02	......	45.04	
7505	20.555	43.9	41.0	......	37 58 00.95						
7605	24.209	39.0	46.3	......	60 06 20.41	− 2 23.74	−0.99	−0.04	......	45.91	
7636	18.796	42.0	43.5	......	55 36 57.83						
7679	26.663	40.7	44.8	......	42 12 12.13	+ 5 09.46	−1.26	+0.09	......	43.27	
7755	19.490	40.6	44.7	......	58 47 23.54						
7765	24.757	46.7	38.6	0 17	39 05 10.46	+ 3 27.19	+0.90	+0.06	+0.04	45.19	
7787	19.432	42.2	43.0	......	52 01 18.65						
7800	22.678	44.0	41.5	......	45 53 55.28	+ 2 06.90	+0.38	+0.03	......	44.28	
7820	15.920	42.9	42.3	......	48 50 03.05						
7882	27.693	43.7	41.8	......	49 24 53.25	− 7 43.12	+0.76	−0.13	......	45.46	
7962	28.609	43.4	42.4	......	41 16 56.27						
8024	15.640	44.5	41.7	......	56 25 27.76	+ 8 30.17	+0.85	+0.15	......	43.19	
8036	25.463	44.3	42.2	0 22	49 21 46.10						
8059	26.591	43.9	42.3	......	48 36 17.64	+ 0 44.37	+0.83	+0.02	+0.06	47.15	
8083	18.472	42.3	44.0	......	56 28 05.30						
8128	24.850	45.2	41.0	......	41 23 00.76	+ 4 10.89	+0.56	+0.07	......	44.55	
8206	28.341	33.7	33.6	......	30 37 28.83						
8273	16.275	35.2	32.3	......	67 06 05.80	+ 7 54.65	+0.67	+0.15	......	42.78	
8314	25.366	33.6	33.9	......	73 42 13.86						
8324	18.614	36.5	31.0	......	24 26 08.30	− 4 27.61	+1.17	−0.09	......	46.55	
8344	16.412	33.7	33.7	......	60 30 56.51	+ 6 18.78	+0.81	+0.11	......	45.21	
8366	20.572	33.9	33.9	......	60 36 21.54	+ 3 35.11	+0.81	+0.06	......	45.53	
46	30.638	33.7	33.8	......	60 49 38.51	− 3 00.83	+0.79	−0.05	......	46.42	
67	26.041	35.6	32.0	......	37 15 54.50						
120	14.809	34.6	33.2	......	32 52 49.21						
175	30.284	34.8	33.0	......	65 27 01.34	−10 08.75	+0.72	−0.19	......	47.05	
198	26.187	36.1	31.7	......	47 35 19.82						
219	20.357	32.6	35.3	......	50 16 29.07	+ 3 49.34	+0.38	+0.07	......	44.24	
12-Yr. 73	19.051	44.9	22.6	......	67 06 02.27						
345	25.592	24.0	43.6	......	30 41 54.90	+ 4 17.31	+0.61	+0.08	......	46.57	
474	14.892	34.5	33.3	......	48 04 21.05						
487	18.958	34.4	33.4	0 28	47 59 00.34	− 7 17.90	+1.17	−0.12	......	46.96	
522	20.745	35.1	32.6	......	50 02 50.41						
560	26.025	35.9	31.9	......	50 09 46.58	− 1 10.30	+0.79	−0.02	+0.11	45.95	
611	26.115	32.0	35.7	......	63 46 27.24						
656	18.456	38.2	27.7	......	34 23 06.71	− 5 01.19	+1.53	−0.09	......	47.23	
744	23.046	36.5	31.8	......	66 49 40.73						
752	20.081	32.0	36.3	......	31 13 46.25	− 1 56.68	+0.09	−0.04	......	46.86	
825	13.180	33.7	34.6	......	19 28 08.21						
836	30.905	36.6	31.7	......	78 54 38.29	−11 37.22	−0.90	−0.26	......	46.67	
979	17.559	23.3	45.6	......	77 15 42.71						
999	24.766	42.8	20.7	......	20 34 20.90	+ 4 43.50	+0.0[illegible]	+0.10	......	45.19	
1203	27.217	32.6	35.5	......	62 41 41.17						
1228	19.428	38.0	29.8	......	35 25 24.39	− 3 47.52	+1.19	−0.07	......	48 59 46.18	

Observations for Latitude.—Station No. 2—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
1274	24.434	33.8	33.8	......	50 00 09.41						
1587	20.121	36.6	31.1	......	48 04 58.73	− 2 49.66	+1.24	−0.05	......	48 59 45.60	October 18.
1274	26.051	39.0	41.9	......	50 00 10.28						
1587	21.766	41.3	39.4	......	48 04 59.46	− 2 48.46	−0.22	−0.05	......	46.14	October 22.
7755	19.007	38.4	39.7	......	58 47 21.47						
7765	24.208	40.3	37.9	0 20	39 05 11.08	+ 3 26.56	+0.25	+0.06	+0.05	44.70	October 23.
7820	16.299	37.3	40.7	......	48 50 01.88						
7882	28.098	41.0	37.2	......	49 21 54.15	− 7 44.14	+0.09	−0.13	......	44.83	
8036	21.801	38.4	40.4	......	49 21 47.13						
8059	22.862	41.4	37.5	......	48 36 18.66	+ 0 46.74	+0.43	+0.02	......	45.08	
8083	18.528	40.7	38.1	......	56 28 06.49						
8128	24.960	39.4	39.7	......	41 23 01.67	+ 4 10.66	+0.52	+0.07	......	45.33	
8206	28.519	39.7	39.6	......	37 37 29.53						
8253	16.399	40.6	39.2	......	67 06 07.29	+ 7 56.77	+0.34	+0.15	......	45.67	
8311	21.853	40.5	39.2	......	73 42 15.46						
8524	18.678	38.0	40.6	......	24 26 08.87	− 4 26.51	−0.29	−0.09	......	45.28	
8341	15.724	39.1	40.2	......	60 30 57.54						
8306	19.964	38.9	40.6	......	60 36 25.97	+ 6 18.82	+0.18	+0.11	......	45.71	
40	20.973	39.1	40.5	......	60 40 30.89	+ 3 34.39	−0.02	+0.06	......	45.09	
67	25.354	40.6	39.0	......	37 15 55.36	− 3 01.70	+0.04	−0.05	......	48 59 45.91	

Mean latitude, 48° 59′ 45″.67.
Number of determinations, 84.
Value of micrometric turn, 78″.675.
One division of level, 0″.8995.

ε 0″.95
r 0″.063
$ε_0$ 0″.010
r_0 0″.007

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 2 west.—Pointe Michel, 20 miles west of Pembina.—Observer, W. J. Twining, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
4804 4827	11. 402 25. 232	27. 5 29. 5	30. 4 28. 4	....	50 24 54. 84 47 20 41. 54	+ 7 09. 11	−0. 40	+0. 12	....	48 59 57. 02	June 13.
4897 4918	14. 303 23. 003	29. 6 29. 0	28. 6 29. 4	....	38 20 09. 78 59 48 45. 01	− 4 29. 93	+0. 13	−0. 09	....	57. 50	
4937 4974	27. 299 9. 746	28. 9 31. 4	29. 2 28. 2	....	50 08 58. 41 48 08 62. 24	− 9 04. 63	+0. 65	−0. 15	....	56. 20	
5026 5097	15. 142 24. 201	31. 0 32. 0	30. 1 29. 5	....	38 44 30. 36 59 24 45. 33	− 4 41. 08	+0. 76	−0. 08	....	57. 45	
5271 5313	20. 705 16. 039	30. 2 35. 0	32. 4 27. 0	....	42 48 28. 59 55 06 33. 74	+ 2 24. 77	+1. 30	+0. 04	....	57. 28	
5502 5523	8. 387 28. 225	31. 5 31. 5	29. 9 30. 2	....	55 29 38. 43 42 03 43. 00	+10 15. 52	+0. 65	+0. 18	....	57. 07	
5545 5624	8. 402 29. 623	30. 1 32. 0	31. 8 29. 4	....	69 02 32. 81 28 35 34. 21	+10 58. 43	+0. 20	+0. 20	....	57. 35	
5644 5658	17. 608 23. 534	36. 2 27. 0	25. 0 34. 1	.... 0 32. 5	42 27 54. 98 55 37 64. 69	− 3 03. 87	+0. 92	−0. 05	+0. 14	56. 98	
5693 5823	25. 032 12. 491	31. 0 30. 0	30. 0 29. 0	....	31 54 42. 29 65 52 12. 21	+ 6 29. 12	+0. 45	+0. 11	....	56. 93	
5853 5911	24. 645 13. 329	31. 5 28. 7	27. 4 31. 0	....	49 49 37. 51 48 21 57. 24	− 5 51. 11	+0. 40	−0. 09	....	56. 58	
6047 6073	26. 897 10. 595	30. 0 33. 2	30. 0 27. 4	1 00	72 12 30. 79 26 04 11. 47	− 8 25. 81	+1. 30	−0. 15	+0. 29	56. 76	
6114 6157	12. 660 25. 866	30. 0 32. 0	31. 0 28. 9	....	76 58 33. 44 20 47 39. 80	+ 6 49. 75	+0. 47	+0. 14	....	56. 98	
6268 6289	15. 174 24. 726	32. 6 31. 5	28. 7 29. 7	....	39 26 18. 57 58 43 31. 22	− 4 56. 37	+1. 27	−0. 09	....	57. 21	
6318 6365	12. 697 20. 380	30. 0 33. 0	31. 2 28. 0	....	59 27 41. 99 38 14 52. 87	+ 8 37. 63	+0. 85	+0. 15	....	57. 56	
6937 6970	12. 855 21. 995	29. 1 35. 5	32. 7 27. 0	....	36 27 50. 92 61 41 25. 79	− 4 43. 59	+1. 10	−0. 08	....	55. 79	
7024 7073	15. 810 22. 671	30. 8 35. 3	32. 2 27. 0	....	61 50 61. 86 36 01 43. 91	+ 3. 32. 88	+1. 54	+0. 06	....	57. 36	
7100 7166	9. 606 27. 777	33. 3 34. 4	29. 5 28. 4	....	42 45 24. 32 55 33 13. 59	− 9 23. 80	+2. 19	−0. 16	....	57. 18	
7215 7277	12. 451 24. 116	31. 0 36. 4	32. 0 27. 3	....	57 07 13. 88 40 40 33. 00	+ 6 01. 94	+1. 81	+0. 10	....	57. 29	
7320 7-Yr. 2395	21. 900 16. 238	31. 5 38. 0	32. 4 26. 3	....	38 09 11. 30 59 44 48. 01	+ 2 55. 69	+2. 41	+0. 05	....	57. 81	
5271 5313	21. 583 16. 896	35. 9 29. 0	29. 0 35. 6	....	42 48 28 77 55 06 33. 95	+ 2 25. 43	+0. 07	+0. 04	....	56. 92	June 14.
5415 5460	28. 825 14. 345	33. 0 32. 8	32. 7 32. 9	....	58 16 10 21 40 00 46. 18	− 8 31. 33	+0. 04	−0. 15	....	18 59 56. 76	

Observations for Latitude—Station No. 2—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5502 5523	9. 444 29. 280	31. 3 35. 0	31. 1 30. 6	....	55 29 38. 68 42 09 43. 23	+10 15. 46	+0. 36	+0. 18	......	48 59 56. 96	June 14.
5545 5624	10. 203 31. 397	34. 0 31. 2	32. 0 33. 2	....	69 02 33 10 28 35 24. 41	+10 57. 60	+0. 67	+0. 20	....	57. 23	
5644 5658	15. 165 21. 104	32. 2 37. 7	35. 2 30. 1	.... 0 20	42 27 55. 23 55 37 64. 96	− 3 04 27	+1. 03	−0. 05	+0. 05	56. 86	
5693 5823	25. 007 12. 481	33. 2 37. 1	34. 9 31. 2	....	31 54 42. 50 65 52 12. 49	+ 6 28. 65	+0. 94	+0. 11	....	57. 20	
5853 5911	25. 777 14. 464	34. 9 34. 8	33. 4 33. 2	....	49 49 37. 78 48 21 57 61	− 5 51. 01	+0. 69	−0. 09	....	57. 28	
6114 6157	12. 256 25. 444	31. 2 29. 6	26 0 28. 0	....	76 58 33. 74 20 47 39. 90	+ 6 49. 19	+1. 52	+0. 14	....	57. 67	
6268 6289	13. 579 23. 115	23. 0 28. 0	25 3 20. 1	....	39 26 13. 83 58 43 31. 51	− 4 56. 53	+1. 25	−0 09	......	57. 30	
6318 6365	11. 435 28. 072	25. 0 27. 2	23. 2 21. 6	....	59 27 45. 28 38 14 53. 13	+ 8 36. 20	+1. 66	+0. 15	.... ..	57. 22	
5271 5313	22. 433 17. 702	32. 0 31. 8	32. 1 32. 8	....	42 48 29. 02 55 06 34. 22	+ 2 26. 79	−0. 25	+0 05	....	58. 21	June 15
5415 5460	28. 609 12. 166	34 0 30. 1	31. 0 31. 9	....	58 16 10 46 40 00 46. 40	− 8 30. 18	−0. 40	−0 14	....	57. 71	
5502 5523	14. 460 34. 324	32. 1 32. 0	32. 6 33 0	....	55 29 38. 93 42 09 43. 46	+10 16. 33	−0. 33	+0. 18	.... ..	57 38	
5693 5823	24 835 12. 311	33. 0 33. 3	32. 1 32. 8	....	31 54 42. 72 65 52 12. 77	+ 6 28. 59	+0. 31	+0. 12	....	56. 76	
5853 5911	26. 555 15. 187	33 7 33. 0	32. 1 33. 1	....	49 49 38 05 48 21 57. 87	− 5 52. 72	+0. 33	−0. 09	......	55. 48	
6047 6073	26. 791 10. 541	33. 0 34. 9	31. 0 32. 1	....	72 12 31 36 26 04 11. 90	− 8 24 20	+0. 40	−0. 15	....	57. 68	
6114 6157	12. 559 25. 792	32. 9 35. 3	34 2 32. 1	....	76 58 34 02 20 47 40. 11	+ 6 50 59	+0. 42	+0. 14	....	58. 22	
6268 6289	14. 375 23. 898	34 0 38. 0	35. 5 30. 4	....	39 26 14. 09 58 43 31. 81	− 4 56. 66	+1 36	−0. 09	....	58. 56	
6318 6365	11. 526 28 229	32 2 37. 0	36. 2 32. 5	....	59 27 45. 58 38 14 53. 40	+ 8 38. 25	+0. 11	+0. 15	....	58. 00	
6421 6476	20 351 20. 931	34. 9 35. 1	31. 8 34. 1	....	49 17 21. 10 48 41 55. 73	+ 0 18. 00	+0. 25	+0 01	... ..	56. 67	
6553 6586	17 740 21. 529	37. 1 33. 1	32. 1 36. 5	....	32 17 62 22 65 45 46. 79	− 1 57 47	+0. 36	−0 03	.... ..	57. 37	
6624 6681	21. 915 15. 833	36 1 36. 5	33 5 31 4	....	40 07 29. 38 57 45 67. 56	+ 3 08. 71	+0 83	+0. 05	.... .	58. 06	
6728 6718	15 244 22 762	33 5 37 9	36. 6 32. 7	....	43 25 11 77 54 40 24. 38	− 2 51. 21	+0. 17	−0. 05	.... ..	57 29	
6780 6817	17. 918 18. 680	35. 8 32. 8	31 8 38. 0	....	57 42 30. 57 40 16 28. 91	+ 0 23. 95	−0. 94	+0 01	.... .	57 26	
7024 7073	16. 662 23. 614	34. 1 35. 1	37 0 36. 0	....	61 50 62 41 36 01 41. 43	+ 3 35. 70	−0 85	+0. 06	....	58. 33	
7100 7166	10. 717 28 840	38. 1 35. 4	33. 9 35. 6	....	42 45 21. 85 55 33 11. 13	− 0 22. 31	1. 10	−0 16	.. ..	58 12	
7215 7277	13. 687 25 100	36. 0 34 0	35 0 37 4	....	57 07 14. 11 40 40 33. 50	6 03 12	−0. 51	+0. 10	.. ..	48 59 56. 94	

Observations for Latitude.—Station No. 2—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7320	20. 895	37. 5	34. 2	....	38 09 11. 79						
7-Yr. 2395	15. 227	36. 5	35. 6	....	59 44 48. 52	+ 2 55. 86	+0. 94	+0. 05	....	48 59 57. 01	June 15.
5415	29. 523	29. 0	27. 9	....	58 16 10. 98						
5460	13. 032	28. 3	28. 4	....	40 00 46. 90	− 8 31. 67	−0. 22	−0. 15	.....	57. 31	June 17.
5502	8. 563	28. 1	28. 0	....	55 29 39. 49						
5523	28. 372	24. 1	32. 2	....	42 09 43. 98	+10 14. 62	−1. 78	+0. 18	......	54. 76	Rejected.
5545	9. 923	25. 0	31. 3	....	69 02 33. 94						
5624	31. 265	28. 9	23. 4	....	28 35 25. 05	+11 02. 19	−1. 29	+0. 20	......	60. 60	Rejected as doubtful on record.
5644	16. 244	30. 0	27. 1	....	42 27 56. 00						
5658	21. 177	26. 5	31. 0	0 16	55 37 65. 80	− 3 04. 09	−0. 36	−0. 05	+0. 01	56. 44	
5693	27. 710	29. 2	28. 2	....	31 54 43. 19						
5823	15. 152	27. 9	31. 2	....	65 52 13. 38	+ 6 29. 61	−0. 51	+0. 11	....	57. 53	
5853	22. 537	28. 7	30. 1	....	49 49 38. 64						
5911	11. 181	29. 7	29. 8	....	48 21 58. 47	− 5 52. 26	−0. 33	−0. 09	....	55. 88	
6047	27. 671	30. 1	30. 1	....	72 12 32. 00						
6073	11. 372	30. 4	30. 2	....	26 04 12. 39	− 8 25. 72	+0. 04	−0. 15	......	56. 36	
6114	13. 928	29. 7	31. 4	....	76 58 31. 63						
6157	27. 145	31. 0	30. 0	....	20 47 40. 58	+ 6 50. 69	−0. 16	+0. 14	......	57. 68	
6268	16. 449	40. 0	21. 5	....	39 26 11. 66						
6289	25. 993	21. 6	40. 0	....	58 43 32. 44	− 4 56. 13	+0. 02	−0. 09	.....	57. 35	
6318	12. 179	27. 3	33. 9	....	59 27 46. 21						
6365	28. 838	34. 8	27. 2	....	38 14 53. 95	+ 8 36. 89	+0. 22	+0. 15	......	57. 34	
6421	20. 280	31. 3	31. 0	....	49 17 21. 71						
6476	20. 825	31. 4	31. 0	....	48 41 56. 34	+ 0 16. 91	+0. 16	+0. 01	....	56. 10	
6553	17. 232	30. 5	32. 4	......	32 17 62. 75						
6586	21. 043	33. 2	29. 6	....	65 45 47. 42	− 1 58. 25	+0. 38	−0. 03	......	57. 19	
6621	21. 779	31. 0	31. 5	....	40 07 29. 96						
6681	15. 700	32. 3	30. 0	......	57 46 08. 44	+ 3 08. 62	+0. 40	+0. 05	......	58. 27	
6728	17. 753	31. 5	31. 0	....	43 25 12. 35						
6748	23. 332	33. 0	29. 5	0 33	54 40 25. 00	− 2 53. 10	+0. 89	−0. 05	+0. 14	56. 56	
6780	18. 598	29. 0	33. 2	....	57 42 40. 18						
6817	19. 311	33. 2	29. 0	....	40 16 29. 47	+ 0 22. 12	0. 00	+0. 01	....	48 59 56. 96	

Mean latitude (60 determinations), 48° 59′ 57″.20.

$\epsilon = \pm\ 0''.63$
$\tau = \pm\ 0''.42$
$\epsilon_0 = \pm\ 0''.08$
$\tau_0 = \pm\ 0''.05$

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 3.—East side of Pembina Mountain, 35 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 11.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5026	21.762	42.3	30.0	....	38 41 30.73						
5097	11.477	28.2	45.0	....	59 24 45.76	− 4 30.67	− 1.40	−0.08	....	48 59 66.10	June 15.
5271	16.931	40.7	33.6	....	42 48 29.02						
5313	21.019	41.0	33.7	....	55 06 31.22	+ 2 31.89	+ 1.36	+0.04	....	64.91	
5415	11.609	38.8	35.9	....	58 16 10.44						
5460	25.689	30.5	41.2	....	40 00 46.41	− 8 20.48	− 3.35	−0.13	....	61.87	
5502	26.870	37.0	37.7	....	55 29 38.93						
5523	10.255	42.6	32.2	....	42 09 43.46	+10 16.62	+ 3.01	+0.17	....	61.09	
5545	25.712	50.0	21.8	....	69 02 33.38						
5624	7.871	12.0	59.0	....	28 35 21.61	+11 02.88	− 6.76	+0.21	....	55.32	
5693	13.459	41.2	31.6	....	31 54 42.72						
5823	24.139	42.6	35.2	....	65 52 12.78	+ 6 56.82	+ 4.31	+0.12	....	69.03	
5853	14.596	37.0	41.1	....	49 49 38.04						
5911	23.820	31.7	46.6	....	48 21 57.87	− 5 42.72	− 5.89	−0.09	....	59.25	
6268	24.101	43.0	37.6	....	39 26 14 09						
6289	16.591	24.2	56.0	....	58 43 51.81	− 4 39.03	− 8.18	−0.08	....	65.66	
6318	26.052	48.0	32.3	....	59 27 45.58						
6365	11.899	21.8	59.2	....	38 11 53.39	+ 8 45.86	− 6.73	+0.14	....	58.75	
6421	19.658	35.6	45.8	....	49 17 21.09						
6476	18.882	31.0	56.7	....	48 41 55.72	+ 0 28.83	− 9.27	+0.01	....	57.97	
6553	20.536	37.5	41.6	....	32 18 02 22						
6586	17.696	35.4	47.3	....	65 45 46.78	− 1 45.52	− 5.89	−0.03	....	63.06	
6728	22.819	47.5	35.7	....	43 25 11.78						
6748	18.648	28.0	55.2	....	54 40 24.39	− 2 34.97	− 4.77	−0.04	....	68.30	
6780	19.124	53.5	30.0	....	57 42 39.57						
6817	18.732	31.5	52.0	....	40 16 28.91	+ 0 25.71	+ 0.93	+0.01	....	60.89	
7024	21.570	42.3	12.2	....	61 51 02.41						
7073	15.438	27.0	58.0	....	36 01 41.43	+ 3 47.50	− 9.58	+0.06	....	61.40	
4804	21.590	41.0	32.2	....	50 24 55.35						
4827	12.925	27.0	45.8	....	47 20 12.06	+ 7 13.41	− 3.10	+0.12	....	59.13	June 16
4897	22.211	30.6	41.0	....	38 20 10.30						
4918	15.111	40.6	30.6	....	59 48 45.59	− 4 23.80	− 0.12	−0.08	....	68.95	
4937	12.787	26.0	41.4	....	50 08 58.99						
4974	27.406	48.3	22.0	....	48 09 04.43	− 9 05.40	+ 2.45	−0.15	....	58.61	
5026	22.782	33.8	56.1	....	38 41 30.73						
5097	15.515	27.0	43.5	....	59 24 45.99	− 4 28.89	− 5.83	−0.08	....	63.56	
5271	17.615	47.5	24.0	....	42 48 29.28						
5313	21.939	14.6	57.2	....	55 06 31.47	+ 2 41.77	− 7.16	+0.05	....	66.53	
5415	12.181	26.0	44.0	....	58 16 10.72						
5460	25.911	28.0	42.3	....	40 00 46.64	− 8 18.88	−10.01	−0.11	....	59.65	
5502	28.041	15.2	51.7	....	55 29 39.20						
5523	11.182	47.6	22.7	....	42 09 41.93	+10 26.40	− 4.53	+0.18	....	48 59 64.11	

Observations for Latitude.—Station No. 3—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5545	27.443	22.0	48.3	....	69 02 33.64						
5624	9.471	30.0	41.0	....	28 35 24.82	+11 07.75	−11.56	+0.21	....	48 59 55.63	June 16.
5693	15.272	33.1	38.3	....	31 54 42.95						
5823	26.409	10.7	61.0	....	65 52 13.07	+ 6 53.80	−17.21	+0.13	....	64.73	
5853	15.733	21.6	51.0	....	49 49 36.57						
5911	24.678	25.6	47.0	....	48 21 58.16	− 5 32.35	−15.75	−0.09	....	59.17	
6114	26.088	28.3	44.4	....	76 58 34.32						
6157	14.931	47.0	26.0	....	20 47 40.34	+ 6 54.54	+ 1.52	+0.15	....	63.54	
6268	23.836	41.0	32.8	....	39 26 14.36						
6289	15.977	41.0	32.3	....	58 43 32.12	− 4 52.00	+ 5.24	−0.09	....	66.39	
6318	26.568	41.0	32.2	....	59 27 45.89						
6365	12.526	33.3	39.8	....	38 14 53.66	+ 8 41.73	+ 0.71	+0.15	....	62.37	
6553	21.942	28.2	41.5	....	32 18 02.48						
6586	18.891	44.5	21.6	....	65 45 47.10	− 1 53.36	+ 2.05	−0.04	....	63.44	
6624	18.186	44.2	24.6	....	40 07 29.67						
6681	23.278	44.0	25.0	....	57 46 07.87	+ 3 09.19	+11.97	+0.05	....	69.98	
6728	22.917	45.5	22.2	....	43 25 12.06						
6748	18.451	23.2	41.5	....	54 40 24.68	− 2 45.93	+ 0.78	−0.05	....	63.17	
6780	20.609	34.0	32.5	....	57 42 39.87						
6817	19.800	31.2	36.1	....	40 16 29.18	+ 0 30.06	− 1.05	+0.01	....	63.55	
6937	23.927	27.6	40.4	....	36 27 51.73						
6970	16.496	42.0	26.0	....	61 41 26.65	− 4 36.10	+ 0.99	−0.09	....	63.99	
7024	22.789	35.5	32.0	....	61 51 02.50						
7073	16.919	31.7	36.7	....	36 01 44.71	+ 3 38.10	− 0.47	+0.06	....	61.39	
7100	27.171	48.6	19.0	....	42 45 25.12						
7166	12.316	18.5	49.0	....	55 33 14.42	− 9 11.91	− 0.28	−0.16	....	67.39	
7215	24.742	26.1	41.6	....	57 07 14.68						
7277	14.849	43.2	25.0	....	40 40 33.76	+ 6 07.57	+ 0.84	+0.10	....	62.73	
5271	23.190	25.0	46.8	....	42 48 29.57						
5313	19.033	34.0	38.5	....	55 06 34.73	+ 2 34.45	− 8.15	+0.04	....	58.49	June 17.
5415	27.648	34.0	38.7	....	58 16 11.00						
5460	13.971	38.7	34.2	....	40 00 46.90	− 8 28.17	− 0.15	−0.15	....	60.48	
5545	10.277	45.0	27.0	....	69 02 33.93						
5624	28.253	20.8	52.0	....	28 35 25.06	+11 07.90	− 4.09	+0.21	....	63.51	
5693	25.271	15.5	57.9	....	31 54 43.19						
5823	14.522	50.5	24.7	....	65 52 13.38	+ 6 39.38	− 5.15	+0.12	....	62.63	
5853	24.591	34.0	41.3	....	49 49 38.64						
5911	15.376	26.8	49.0	....	48 21 58.47	− 5 39.04	− 9.15	−0.09	....	60.27	
6114	13.512	41.0	34.1	....	76 58 31.63						
6157	21.619	40.9	31.7	....	20 47 40.58	+ 6 52.68	+ 4.06	+0.15	....	61.49	
6268	15.659	39.8	36.0	....	39 26 14.66						
6289	23.606	51.1	21.5	....	58 43 32.44	− 4 55.61	+ 9.42	−0.09	....	67.27	
6421	19.939	34.6	42.0	....	49 17 21.72						
6476	20.434	48.0	28.9	....	48 41 56.33	+ 0 18.39	+ 3.63	0.00	....	61.04	
5026	16.110	27.5	33.5	....	38 44 31.18						
5097	23.478	30.0	31.5	....	59 24 46.50	− 4 33.76	− 2.33	−0.08	....	62.67	June 18.
5271	21.561	32.8	28.8	....	42 48 29.87						
5313	17.411	22.0	38.8	....	55 06 35.02	+ 2 31.19	− 3.97	+0.04	....	62.71	
5415	26.820	44.4	11.8	....	58 16 11.29						
5460	13.307	09.5	51.8	....	40 00 47.17	− 8 22.08	− 3.04	−0.15	....	48 59 63.96	

Observations for Latitude.—Station No. 3—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N	S.								
				m s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5502 5523	11.642 28.471	28.0 24.8	32.9 36.0	....	55 29 39.79 42 09 45.48	+10 25.28	− 4.99	+0.19	....	48 59 63.11	June 18.
5545 5624	10.381 28.305	31.7 21.6	29.9 38.8	....	69 02 34.25 28 35 25.31	+11 05.97	− 4.77	+0.21	....	61.20	
5644 5658	17.174 21.800	29.8 20.0	30.1 40.7	....	42 27 56.99 55 38 05.81	− 2 51.88	− 6.23	−0.05	....	62.89	
5693 5823	25.067 14.537	24.3 28.5	35.7 32.6	....	31 54 43.46 65 52 13.72	+ 6 38.67	− 4.81	+0.12	....	62.57	
5853 5911	24.095 14.828	22.3 20.0	38.3 32.2	....	49 49 37.19 48 21 58.79	− 5 42.09	− 5.95	−0.09	....	59.86	
6114 6157	13.223 21.578	30.9 19.5	31.7 43.4	....	76 58 34.97 20 47 40.85	+ 7 01.90	− 7.66	+0.15	....	62.30	
6268 6289	15.653 23.287	28.0 20.8	35.2 40.7	....	39 26 14.97 58 43 32.79	− 4 43.64	− 8.40	−0.08	....	61.76	
6318 6365	13.031 27.387	40.5 11.1	22.7 52.8	....	59 27 46.56 38 14 54.26	+ 8 53.40	− 7.41	+0.16	....	66.56	
6421 6476	19.815 20.705	42.6 26.4	21.3 37.7	....	49 17 22.05 48 41 56.66	+ 0 33.07	+ 3.10	+0.01	....	62.13	
6553 6586	18.022 21.036	30.4 32.2	33.8 32.1	....	32 18 03.04 65 45 47.76	− 1 51.99	− 1.02	−0.04	....	62.35	
6624 6651	22.428 16.991	38.2 14.5	26.1 50.7	....	40 07 20.27 57 46 08.51	+ 3 22.01	− 7.47	+0.06	....	63.99	
6728 6748	17.096 21.397	38.6 17.3	26.9 48.3	....	43 25 12.66 51 40 25.32	− 2 39.80	− 5.98	−0.04	....	63.17	
6780 6817	19.587 20.546	33.0 18.4	32.6 48.7	....	57 42 40.50 40 16 29.77	+ 0 35.03	− 9.27	+0.01	....	61.50	
6937 6970	16.043 23.580	24.5 46.8	42.6 20.5	....	36 27 52.32 61 41 27.26	− 4 40.04	+ 2.54	−0.08	....	62.21	
7024 7073	17.311 24.087	33.8 30.0	33.6 28.7	....	61 51 03.30 36 01 45.29	+ 3 34.61	+ 3.26	+0.06	....	62.22	
7100 7166	11.517 26.487	33.7 40.6	33.9 26.8	....	42 45 25.60 55 33 15.05	− 9 16.21	+ 4.25	−0.17	....	68.21	
4897 4918	14.846 21.890	36.6 28.6	32.4 40.8	....	38 20 10.93 59 48 46.28	− 4 21.72	− 2.48	−0.08	....	64.32	June 19.
5026 5097	14.211 21.570	25.0 31.8	44.3 37.7	....	38 44 31.41 59 24 46.77	− 4 32.31	− 7.81	−0.08	....	58.89	
5271 5313	20.579 16.413	33.0 28.7	36.0 40.5	....	42 48 30.19 55 06 35.32	+ 2 34.03	− 4.59	+0.04	....	62.24	
5502 5523	9.573 26.477	35.3 19.2	33.0 49.2	....	55 29 40.10 42 09 45.77	+10 23.07	− 8.59	+0.19	....	62.61	
5545 5624	8.678 26.669	43.5 16.0	25.5 52.5	....	69 02 34.57 28 35 25.57	+11 08.46	− 5.74	+0.21	....	63.00	
5644 5658	15.959 20.472	30.8 19.8	29.0 49.1	....	42 27 56.59 55 38 06.14	− 2 47.68	− 5.74	−0.05	....	67.89	
5693 5823	23.419 12.806	25.7 31.5	43.2 39.3	....	31 54 43.71 65 52 14.06	+ 6 34.33	− 7.81	+0.12	....	55.51	
5853 5911	23.078 13.968	32.1 21.8	38.2 45.0	....	49 49 37.52 48 21 59.12	− 5 39.60	− 8.46	−0.09	....	60.17	
6114 6157	12.434 23.801	50.0 14.0	21.1 57.6	....	76 58 35.31 20 47 41.13	+ 7 02.34	− 4.56	+0.15	....	48 59 66.15	

Observations for Latitude.—Station No. 3—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6268	14. 663	25. 0	46. 5	....	39 26 15. 29						
6289	22. 313	31. 4	40. 6	....	58 43 33. 15	− 4 44. 24	− 9. 52	−0. 08	....	48 59 60. 38	June 19.
6318	9. 954	36. 0	35. 6	....	59 27 46. 92						
6365	24. 206	21. 5	50. 0	....	38 14 54. 58	+ 8 49. 53	− 8 71	+0. 16	....	61. 73	
6421	19. 276	33. 7	38. 0	....	49 17 22. 40						
6476	20. 063	24. 0	47. 8	... .	48 41 57. 01	+ 0 29. 24	− 8. 71	+0. 01	....	60. 25	
6553	17. 208	26. 0	45. 9	....	32 18 03. 35						
6586	20. 052	27. 0	45. 3	....	65 45 48. 12	− 1 45. 67	−11. 84	−0. 03	....	48 59 58. 19	

Mean latitude (74 determinations), 49° 00′ 02″.50.

$\varepsilon = \pm 3''.164$
$r_0 = \pm 0''.243$

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 4, west side of Pembina Mountain, 47 miles west of Pembina.—Observer, Lewis Boss.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″			″	° ′ ″	
5271	20.683	27.0	28.2	......	42 48 31.47						
5313	16.170	22.8	31.9	......	55 06 36.84	+ 2 20.63	−2.30	+0.04	......	48 59 51.92	June 25.
5415	26.781	27.2	26.4	......	58 16 13.20						
5460	10.031	26.7	27.3	......	40 00 49.60	− 8 39.71	+0.04	−0.15	......	51.28	
5502	8.951	26.5	27.7	......	55 29 41.77						
5523	28.558	28.2	26.2	......	42 09 46.12	+10 08.36	+0.18	+0.18	......	52.67	
5545	8.756	27.9	26.8	......	69 02 36.28						
5624	27.719	23.6	31.2	......	28 35 26.99	+10 50.43	−1.45	+0.21	......	50.82	
5693	25.658	26.8	28.2	......	31 54 45.26						
5823	13.330	25.6	27.8	......	65 52 15.99	+ 6 22.23	−0.80	+0.12	......	52.17	
5853	24.591	30.0	23.5	......	49 49 41.17						
5911	13.059	19.9	35.0	......	48 22 01.01	− 5 57.81	−1.92	−0.10	......	51.26	
6047	27.418	28.0	27.3	......	72 12 34.74						
6073	10.961	21.2	34.3	......	26 04 11.56	− 8 30.42	−2.72	−0.16	......	51.10	
6114	11.504	26.2	29.0	......	76 58 37.41						
6157	24.548	21.7	33.5	......	20 47 42.52	+ 6 44.72	−3.26	+0.14	......	51.56	
6268	12.267	26.6	28.2	......	39 26 17.23						
6289	22.118	29.1	25.6	......	58 43 35.25	− 5 05.65	+0.42	−0.09	......	50.94	
6421	18.816	28.2	26.7	......	49 17 24.50						
6476	19.160	25.4	29.3	......	48 41 59.12	+ 0 10.67	−0.53	0.00	......	51.95	
6553	16.190	27.1	28.0	......	32 17 65.22						
6586	20.212	25.8	30.0	......	65 45 50.33	− 2 04.79	−1.14	−0.04	......	51.80	
6624	21.120	24.0	31.4	......	40 07 32.61						
6681	15.286	28.2	27.1	......	57 46 11.10	+ 3 01.01	−1.47	+0.05	......	51.45	
6728	16.333	22.4	33.3	......	43 25 15.07						
6748	22.091	29.3	26.7	......	54 40 27.85	− 2 58.66	−1.85	−0.05	......	50.90	
6780	19.047	29.0	27.0	......	57 42 43.05						
6817	19.585	22.2	33.3	......	40 16 32.13	+ 0 16.69	−2.03	0.00	......	52.25	
4937	27.704	28.0	27.8	......	50 00 00.84						
4974	9.978	24.8	32.1	......	48 09 04.85	− 9 00.99	−1.61	−0.16	......	51.09	June 26.
5026	15.018	27.0	30.5	......	38 41 32.91						
5097	24.325	31.0	27.2	......	59 24 48.20	− 4 48.77	+0.07	−0.08	......	51.82	
5271	21.572	30.0	29.3	......	42 48 31.70						
5313	17.118	28.0	31.1	......	55 06 37.03	+ 2 17.58	−0.53	+0.04	......	51.46	
5415	27.081	30.4	29.2	......	58 16 13.41						
5460	10.347	28.1	32.2	......	40 00 49.29	− 8 39.21	−0.65	−0.15	......	51.31	
5502	9.213	31.2	29.3	......	55 29 42.00						
5523	28.821	27.3	33.2	......	42 09 46.33	+10 08.48	−0.89	+0.18	......	51.94	
5545	8.800	32.6	28.2	......	69 02 36.52						
5624	29.767	26.6	35.8	......	28 35 27.17	+10 50.57	−1.07	+0.21	......	48 59 51.54	

Observations for Latitude.—Station No. 4—Continued.

B. A. C. No.	Readings.				Declination	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5644	15.426	29.7	32.6	....	42 27 58.47						
5658	21.646	33.7	28.8	....	55 38 08.47	− 3 12.99	+0.44	−0.05	......	48 59 50.87	June 26.
5693	25.300	27.8	35.0	....	31 54 45.46						
5823	13.026	36.2	27.3	....	65 52 16.25	+ 6 20.83	+0.38	+0.12	....	52.19	
5853	25.458	32.1	31.3	....	49 49 41.42						
5911	13.906	28.1	35.6	....	48 22 01.27	− 5 58.43	−1.49	−0.10	......	51.33	
6047	27.674	26.0	26.4	....	72 12 35.03						
6073	11.160	24.1	28.2	......	26 04 14.78	− 8 32.39	−1.00	−0.16	......	51.36	
6114	12.065	25.0	27.0	....	76 58 37.69						
6157	25.071	25.0	27.6	....	20 47 42.72	+ 6 43.54	−1.03	+0.14	....	52.85	
6268	14.321	22.9	30.2	....	39 26 17.50						
6289	24.150	20.4	23.8	....	58 43 35.58	− 5 04.94	−0.38	−0.69	....	51.13	
6318	12.273	25.4	27.4	....	59 27 49.38						
6365	28.711	23.6	29.1	....	38 14 56.80	+ 8 50.03	−1.67	+0.15	....	51.60	
6421	18.152	27.0	26.5	....	49 17 24.79						
6476	18.491	22.5	30.9	....	48 41 59.40	+ 0 10.52	−1.76	0.00	....	50.85	
6583	16.714	24.0	29.0	......	32 18 05.49						
6586	20.743	25.3	28.0	....	65 45 50.66	− 2 05.01	−1.72	−0.04	....	51.31	
6624	22.665	27.7	25.4	....	40 07 32.90						
6681	16.820	21.1	32.2	....	57 46 11.42	+ 3 01.36	−1.96	+0.03	....	51.59	
6728	16.172	21.0	32.8	....	43 25 15.37						
6748	21.940	20.0	24.7	....	54 40 28.17	− 2 58.97	−1.67	−0.04	....	51.09	
6780	18.355	27.1	26.7	....	57 42 43.37						
6817	18.853	22.5	31.3	....	40 16 32.43	+ 0 15.45	−1.87	0.00	......	51.48	
6937	13.997	27.0	27.8	....	36 27 54.83						
6970	23.302	24.0	31.1	....	61 41 30.09	− 4 48.71	−1.76	−0.08	......	51.91	
7024	14.853	31.4	23.3	......	61 51 06.10						
7073	21.520	19.6	35.4	....	36.01 47.76	+ 3 26.86	−1.72	+0.06	....	52.13	
7100	10.094	25.4	29.3	....	42 45 26.41						
7166	28.424	25.8	29.9	....	55 33 17.80	− 9 28.73	−1.78	−0.16	....	51.44	
7215	14.057	30.1	25.4	....	57 07 18.02						
7277	25.596	20.8	35.5	......	40 40 36.62	+ 5 58.03	−2.23	+0.10	......	53.22	Rejected
7320	21.313	29.9	26.2	....	38 09 15.01						
7-Yr. 2395	15.773	21.3	35.0	....	59 44 51.93	+ 2 51.89	−2.23	+0.03	....	53.16	Rejected.
7377	19.120	24.5	31.9	....	59 27 41.79						
7398	10.220	27.2	29.4	....	38 51 38.99	− 9 46.42	−2.14	−0.17	......	51.66	
7416	24.079	24.5	32.4	....	62 02 40.55						
7453	14.472	27.8	29.2	....	36 07 02.96	− 4 58.08	−2.07	−0.09	... ...	51.52	
7480	17.090	31.8	25.0	....	45 58 43.39						
7489	19.353	20.3	36.4	....	52 03 26.27	− 1 10.21	−2.07	−0.02	......	52.53	
7505	17.399	26.7	29.8	....	37 57 47.80						
7605	21.284	24.9	32.0	....	60 06 00.90	− 2 00.54	−2.27	−0.03	......	51.51	
7627	21.610	26.4	30.2	....	25 19 37.34						
7686	15.899	25.3	31.2	....	72 34 17.95	+ 2 57.20	−2.16	+0.06	....	52.75	
7755	16.174	32.0	25.3	....	58 47 05.76						
7765	23.647	20.2	36.9	....	39.04 58.99	+ 3 51.87	−2.23	+0.07	......	52.08	
4937	28.191	30.9	25.7	....	50 08 60.92						
4974	10.209	39.2	19.0	....	48 09 04.96	− 9 17.94	+5.69	−0.16	....	50.53	June 27.
5026	18.927	31.0	27.2	....	38 41 33.04						
5097	28.265	29.2	32.0	....	59 24 48.43	− 4 49.73	+0.22	−0.08	......	48 59 51.14	

Observations for Latitude.—Station No. 4—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5271 5313	21.628 17.220	27.0 28.3	28.7 27.1	....	42 48 31.92 55 06 37.24	+ 2 16.77	−0.11	+0.04	....	48 59 51.28	June 27.
5415 5460	27.762 11.010	29.5 27.0	25.6 28.3	....	58 16 13.63 40 60 49.47	− 8 59.77	+0.58	−0.15	....	52.21	
5502 5523	9.401 29.009	32.4 21.5	22.3 34.0	....	55 29 42.22 42 09 46.54	+10 08.39	−0.53	+0.18	......	52.42	
5853 5911	25.158 13.555	31.0 24.3	26.2 33.2	....	49 49 41.66 48 22 01.52	− 6 00.01	−0.91	−0.10	....	50.58	
6047 6073	26.368 9.814	34.0 22.0	23.4 35.4	....	72 12 35.29 26 04 14.98	− 8 33.63	−0.62	−0.16	....	50.73	
6114 6157	12.071 25.001	28.5 27.1	28.3 30.4	0 59	76 58 37.86 20 47 42.91	+ 6 41.19	−0.69	+0.14	+0.21	51.29	
6268 6289	14.417 24.251	26.9 30.5	31.3 27.4	 16	39 26 17.76 58 45 35.88	− 5 05.12	−0.29	−0.09	+0.03	51.35	
5271 5313	20.694 16.506	25.5 32.1	30.9 24.8	....	42 48 32.42 55 06 37.66	+ 2 16.15	+0.42	+0.03	....	51.64	June 29.
5415 5460	27.413 10.648	30.5 27.8	26.3 29.6	....	58 16 14.05 40 60 49.96	− 8 40.18	+0.53	−0.15	....	52.19	
5502 5523	9.152 28.712	29.6 27.8	28.0 30.2	....	55 29 42.68 42 09 46.97	+10 06.90	−0.18	+0.18	....	51.73	
5545 5624	9.186 30.070	27.0 32.3	31.3 26.2	....	69 02 37.22 28 35 27.72	+10 47.98	+0.40	+0.21	....	51.06	
5641 5658	15.886 22.112	25.7 34.6	32.6 21.1	....	42 27 59.11 55 37 60.20	− 3 13.18	+0.80	−0.06	....	51.73	
5693 5823	25.875 13.655	28.8 30.2	29.9 29.2	....	31 51 46.05 65 52 17.04	+ 6 19.16	−0.02	+0.11	....	50.80	
5853 5911	25.371 13.740	30.0 29.0	29.2 30.8	....	49 49 42.18 48 22 02.04	− 6 00.88	−0.22	−0.10	....	50.91	
6114 6157	9.427 22.325	32.5 28.1	26.4 30.5	....	76 58 38.51 20 47 43.29	+ 6 40.19	+0.83	+0.14	....	52.06	
6268 6289	14.218 24.099	29.0 31.1	29.5 27.9	....	39 26 18.27 58 43 36.47	− 5 06.58	+0.60	−0.09	....	51.30	
6421 6476	19.707 19.956	31.2 27.3	27.2 30.7	....	49 17 25.66 48 41 60.26	+ 0 07.73	+0.14	0.00	....	50.83	
6047 6073	27.477 10.840	25.1 30.4	26.3 21.7	....	72 12 36.16 26 04 15.63	− 8 36.90	+1.74	−0.16	....	51.27	June 30
6114 6157	12.223 25.082	27.9 29.7	24.3 22.3	....	76 58 38.84 20 47 43.49	+ 6 38.98	+2.45	+0.14	......	52.72	
6268 6289	13.363 23.267	28.2 25.4	21.3 23.3	....	39 26 18.55 58 43 36.78	− 5 07.30	+2.01	−0.09	....	52.29	
6318 6365	11.690 27.982	26.3 29.5	26.3 23.2	....	59 27 50.58 58 14 57.86	+ 8 25.50	+1.40	+0.15	....	51.27	
6421 6476	18.189 18.723	25.2 28.3	27.6 24.6	....	49 17 25.96 48 41 60.56	+ 0 07.26	+0.29	0.00	....	50.81	
6553 6585	16.422 20.551	25.5 28.7	27.3 21.7	....	32 18 06.49 65 45 51.90	− 2 08.11	+0.49	−0.04	....	51.54	
6624 6681	22.180 16.133	27.8 26.4	25.6 27.0	....	40 07 31.00 57 46 12.61	+ 2 58.31	+0.36	+0.03	.....	52.02	
6780 6817	18.639 19.040	30.5 24.3	21.0 29.8	....	57 42 41.60 40 16 33.51	+ 0 12.41	+0.22	0.00	.....	48 59 51.73	

Observations for Latitude.—Station No. 4—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6937	14.652	24.2	30.7	......	36 27 55.90						
6970	24.076	31.2	23.7	......	61 41 31.31	− 4 52.40	+0.22	−0.08	......	48 59 51.35	June 30.
7024	15.984	30.4	24.6	......	61 51 07.33						
7073	22.514	25.1	30.1	......	36 01 48.83	+ 3 22.61	+0.18	+0.06	......	50.93	
7100	11.775	27.0	28.2	......	42 45 27.53						
7166	30.202	29.0	26.2	......	55 33 18.97	− 9 31.74	+0.36	−0.16	......	51.71	
7215	13.344	27.7	27.3	......	57 07 19.22						
7277	24.700	28.3	27.2	......	40 40 37.69	+ 5 52.35	+0.33	+0.10	......	51.23	
7320	21.468	28.2	27.4	......	38 09 16.07						
7-Yr. 2395	16.106	28.0	27.3	......	59 44 53.08	+ 2 46.37	+0.33	+0.03	......	51.31	
7377	28.544	27.4	28.0	......	59 27 42.94						
7398	9.536	28.4	27.3	......	38 51 40.04	− 9 49.77	+0.11	−0.17	......	51.66	
7416	24.860	29.2	26.4	......	62 02 41.73						
7453	15.138	27.0	28.9	......	36 07 04.01	− 5 01.65	+0.20	−0.09	......	51.33	
7480	18.406	26.8	29.0	......	45 58 44.45						
7489	20.781	29.6	26.2	......	52 03 27.37	− 1 13.69	+0.27	−0.02	......	52.47	
7505	16.600	29.1	26.8	......	37 57 48.84						
7605	20.604	28.1	27.9	......	60 06 01.97	− 2 04.23	+0.56	−0.03	......	51.70	
7627	21.201	27.8	28.0	......	25 19 38.26						
7686	15.644	28.1	27.3	......	72 34 18.96	+ 2 52.42	+0.14	+0.06	......	51.23	
7755	15.145	27.6	27.8	......	58 47 06 83						
7765	22.486	29.3	26.2	......	39 04 59.98	+ 3 47.77	+0.65	+0.07	......	48 59 51.90	

Mean latitude (79 determinations), 48° 59′ 51″.55.

$\varepsilon = 0''.53$
$\tau = 0''.35$
$\varepsilon_0 = 0''.06$
$\tau_0 = 0''.04$

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 5.—Long River, 77 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5415 5460	28.092 11.438	28.0 31.3	27.2 21.8	....	58 16 16.35 40 00 51.97	− 8 36.73	+1.63	−0.15	....	48 59 58.91	July 9.
5502 5523	9.210 28.890	28.5 29.4	27.8 26.9	....	55 29 45.11 42 09 49.29	+10 10.62	+0.71	+0.18	....	58.71	
5853 5911	25.176 13.716	30.3 27.0	28.7 32.7	....	49 49 45.02 48 22 01.93	− 5 55.58	−0.91	−0.10	....	58.39	
6047 6073	26.603 10.205	30.8 27.7	30.0 32.8	....	72 12 39.02 26 04 17.75	− 8 28.79	−0.96	−0.16	....	58.48	
6114 6157	12.145 25.254	30.4 27.5	30.5 33.3	....	76 58 41.72 50 47 45.59	+ 6 46.65	−1.38	+0.14	....	59.06	
6268 6289	13.756 23.480	30.5 31.0	31.0 30.5	....	39 26 21.30 58 43 39.86	− 5 01.71	0.00	−0.09	....	58.78	
6318 6365	11.290 27.784	31.0 29.2	30.3 32.6	....	59 27 53.67 38 15 00.64	+ 8 31.77	−0.60	+0.15	....	58.48	
6421 6476	19.463 19.855	31.0 29.0	31.2 33.2	....	49 17 28.95 48 41 63.64	+ 0 12.16	−0.98	+0.00	....	57.48	
6553 6586	16.791 20.768	30.0 31.6	32.3 31.4	....	32 17 69.19 65 45 55.16	− 2 03.40	−0.40	−0.04	....	58.33	
6624 6681	22.026 16.156	31.2 33.0	32.0 21.1	....	40 07 36.95 57 45 75.87	+ 3 02.13	+0.25	+0.05	....	58.84	
6728 6748	16.264 21.990	31.6 32.0	33.0 32.5	....	43 25 19.56 51 40 32.64	− 2 57.66	−0.42	−0.05	....	57.97	
6780 6817	19.013 19.608	31.0 31.2	33.7 33.3	....	57 42 47.88 40 16 36.53	+ 0 17.53	−1.07	+0.00	....	58.66	
7024 7073	15.670 22.387	33.5 29.2	32.0 36.4	....	61 51 10.62 36 01 51.74	+ 3 28.41	−1.27	+0.06	....	58.38	
7100 7166	08.754 27.040	33.9 30.6	31.9 35.3	....	42 45 32.52 55 33 23.21	− 9 27.37	−0.60	−0.17	....	59.22	
7215 7277	13.501 35.010	32.1 33.5	33.6 32.6	....	57 07 29.37 40 40 40.94	+ 5 57.10	−0.14	+0.10	....	58.71	
7350 7-Yr. 2395	21.919 16.407	34.0 31.9	31.9 34.1	....	38 09 19.00 59 44 56.26	+ 2 51.02	−0.02	+0.05	....	58.68	
7377 7398	28.500 9.502	30.6 35.5	35.3 30.6	....	59 27 45.84 38 54 42.96	− 9 45.36	+0.04	−0.18	....	57.90	
7416 7453	23.617 14.015	29.8 37.1	36.2 29.2	....	62 02 44.87 36 07 06.83	− 4 57.00	+0.33	−0.09	....	59.09	
7480 7489	17.981 20.250	34.3 32.2	32.1 34.3	....	45 58 47.44 52 03 30.41	− 1 10.40	+0.02	−0.02	....	58.52	
7505 7605	16.876 20.777	34.0 34.0	32.7 33.5	....	37 57 51.70 60 06 05.42	− 2 01.01	+0.40	−0.03	....	48 59 57.89	

Observations for Latitude.—Station No. 5—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7627	22.143	34.5	32.8	....	25 19 40.80						
7686	16.391	30.7	37.1	....	72 34 21.82	+ 2 58.47	−1.05	+0.06	....	48 59 58.79	July 9.
7755	15.533	34.1	33.7	....	58 47 09.69						
7765	23.058	29.5	38.5	....	39 05 02.71	+ 3 53.48	−1.92	+0.07	....	57.83	
7787	16.456	33.5	34.2	....	52 01 05.78						
7800	21.428	31.1	37.0	....	45 53 44.21	+ 2 34.27	−1.47	+0.04	....	57.83	
7820	12.522	34.5	33.2	....	48 49 51.22						
7882	26.590	30.7	37.7	....	49 24 41.57	− 7 16.49	−1.17	−0.13	....	58.60	
5271	20.965	27.9	22.7	....	42 48 34.48						
5313	16.360	20.8	30.6	....	55 06 39.52	+ 2 22.88	−1.03	+0.04	....	58.89	July 10.
5415	27.657	26.0	26.0	....	58 16 16.49						
5460	11.060	24.3	28.0	....	40 00 52.11	− 8 34.96	−0.83	−0.15	....	58.36	
5502	9.644	26.9	25.7	....	55 29 45.27						
5523	29.384	26.6	29.0	....	42 09 49.45	+10 12.48	−0.27	+0.18	......	59.75	
5545	8.431	25.6	27.1	....	69 02 39.90						
5624	29.490	25.5	28.0	....	28 35 30.01	+10 53.41	−0.89	+0.21	....	57.69	
5644	16.030	26.3	26.8	....	42 28 01.79						
5658	22.084	24.6	28.5	....	55 38 11.93	− 3 07.84	−0.98	−0.05	......	57.99	
5853	25.141	27.0	26.2	....	49 49 45.23						
5911	13.708	23.6	29.4	....	48 22 05.15	− 5 54.74	−1.11	−0.10	......	59.24	
5502	9.359	26.8	28.0	....	55 29 44.41						
5523	29.092	25.9	28.9	....	42 09 49.60	+10 12.27	−0.94	+0.18	....	58.51	July 11.
5545	8.358	30.8	24.2	....	69 02 40.06						
5624	29.434	22.2	33.2	....	28 35 30.14	+10 53.93	−0.98	+0.21	....	58.26	
5644	16.517	27.5	27.8	....	42 28 01.96						
5658	22.597	26.7	28.6	....	55 38 12.23	− 3 08.65	−0.49	−0.05	....	57.91	
5693	24.571	28.0	27.3	....	31 54 48.63						
5823	12.196	28.9	27.7	....	65 52 20.37	+ 6 23.97	+0.42	+0.11	....	59.60	
5853	25.508	28.1	28.4	....	49 49 45.44						
5911	14.023	27.6	29.1	....	48 22 05.36	− 5 56.35	−0.40	−0.10	....	58.55	
6017	26.490	28.4	28.0	....	72 12 39.51						
6073	10.035	28.0	28.0	....	26 04 18.11	− 8 30.56	+0.09	−0.16	....	58.18	
6114	12.568	29.0	26.9	....	76 58 42.25						
6157	25.598	27.3	28.2	....	20 47 45.83	+ 6 41.29	+0.27	+0.15	......	58.75	
6268	13.657	29.2	26.1	....	39 26 21.79						
6289	23.449	29.2	26.1	....	58 43 40.41	− 5 03.82	+1.38	−0.08	....	58.58	
6318	11.014	27.0	28.5	....	59 27 54.23						
6365	27.441	31.8	24.0	....	38 15 01.14	+ 8 29.69	+1.40	+0.15	......	58.92	
6421	19.750	27.5	28.6	....	49 17 29.48						
6476	20.121	29.0	27.4	....	48 42 01.21	+ 0 11.52	+0.11	0.00	....	58.48	
6553	16.390	29.0	27.2	....	32 18 09.68						
6586	20.403	27.7	29.2	....	65 45 55.78	− 2 04.51	+0.07	−0.01	.. ....	58.25	
5415	27.663	26.0	25.1	....	58 16 16.81						
5460	10.958	31.2	21.0	....	40 00 52.40	− 8 38.31	+2.47	−0.15	....	58.61	July 12.
5502	9.560	25.0	27.2	....	55 29 45.60						
5523	29.243	28.5	24.0	....	42 09 49.70	+10 10.71	+0.51	+0.18	....	59.05	
5693	25.271	27.7	26.2	....	31 54 48.79						
5823	12.837	22.1	33.0	....	65 52 20.59	+ 6 25.80	−2.10	+0.11	....	58.50	
6017	27.299	27.0	29.2	....	72 12 40.01						
6073	10.847	29.0	27.7	....	26 04 18.48	− 8 30.46	−0.20	−0.16	....	48 59 58.42	July 13.

Observations for Latitude.—Station No. 5—**Continued.**

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ′	″	″	″	° ′ ″	
6114	12.438	27.1	29.3	....	76 58 42.79						
6157	25.461	29.9	27.0	....	20 47 46.27	+ 6 41.07	+0.16	+0.14	....	48 59 58.90	July 13.
6268	14.171	31.1	25.6	......	39 26 22.27						
6289	23.959	27.5	29.3	......	58 43 40.97	− 5 03.70	+0.83	−0.09	....	58.66	
6318	11.405	27.1	29.6	......	59 27 54.79						
6365	27.819	32.0	25.5	......	38 15 01.64	+ 8 29.29	+0.89	+0.15	....	58.54	
6421	19.551	28.7	29.3	......	49 17 30.06						
6476	19.853	29.0	29.6	......	48 42 04.76	+ 0 10.30	−0.27	0.00	....	57.44	
6553	16.285	29.3	30.0	......	32 18 10.16						
6586	20.308	30.0	29.8	......	65 45 56.40	− 2 04.82	−0.11	−0.04	......	58.31	
6624	22.581	30.8	29.1	......	40 07 38.05						
6681	16.749	30.2	30.1	....	57 46 17.21	+ 3 00.95	+0.40	+0.05	....	59.03	
6728	15.530	31.2	29.2	....	43 25 20.71						
6748	21.308	30.0	30.7	....	54 40 33.88	− 2 59.28	+0.29	+0.05	....	58.25	
6780	18.545	27.0	34.0	......	57 42 49.15						
6817	19.037	31.4	27.0	......	40 16 37.67	+ 0 15.27	+0.09	0.00	....	58.77	
6937	14.747	31.8	31.0	....	36 27 59.95						
6970	24.098	33.0	30.0	......	61 41 35.92	− 4 50.14	+0.85	−0.09	....	58.55	
7024	15.478	26.0	37.0	....	61 51 11.94						
7073	22.120	36.7	26.7	......	36 01 52.87	+ 3 26.08	−0.22	+0.06	......	58.32	
7109	10.387	32.2	31.0	....	42 45 33.72						
7166	28.708	30.5	33.0	......	55 33 23.51	− 9 28.15	−0.20	−0.17	....	59.70	
7215	13.847	31.5	32.1	....	57 07 23.72						
7277	25.320	32.1	32.0	....	40 40 42.14	+ 5 55.98	−0.11	+0.10	......	58.90	
7320	21.691	32.5	31.8	....	38 09 20.17						
7-Yr. 2395	16.229	33.1	31.3	....	59 44 57.57	+ 2 49.38	+0.56	+0.05	......	58.86	
7377	28.719	31.4	33.0	....	59 27 47.14						
7398	9.813	33.0	32.0	......	38 51 44.13	− 9 46.61	−0.14	−0.18	......	58.70	
7416	23.346	29.5	35.2	......	62 02 46.17						
7453	13.700	37.4	27.7	......	36 07 07.98	− 4 59.29	+0.89	−0.09	......	58.58	
7480	17.876	32.8	32.5	......	45 58 48.67						
7489	20.173	34.0	31.3	.....	52 03 31.68	− 1 11.27	+0.67	−0.02	......	59.55	
7505	17.833	31.0	31.1	......	37 57 52.96						
7605	21.763	33.0	33.4	......	60 06 06.25	− 2 01.94	+0.56	−0.03	......	58.19	
7627	21.953	31.0	32.1	...	25 19 41.83						
7686	16.311	31.0	35.6	....	72 34 23.08	+ 2 55.68	−0.60	+0.06	....	57.60	
7755	15.928	33.0	33.7	....	78 47 10.06						
7765	23.137	30.0	36.7	......	39 05 03.87	+ 3 54.99	−1.05	+0.07	.....	58.37	
7787	16.812	31.3	35.2	......	52 01 07.00						
7804	21.730	31.7	32.0	......	45 53 45.40	+ 2 32.59	−0.27	+0.04	......	58.56	
7829	12.578	34.6	32.0	......	18 19 52.43						
7882	26.717	32.0	35.0	......	49 24 42.81	− 7 18.70	−0.09	−0.13	......	58.70	
7962	27.692	36.2	31.0	....	41 16 48.68						
8024	10.432	30.3	37.1	......	56 25 16.26	+ 8 55.51	−0.36	+0.16	......	57.81	
8036	17.611	31.0	33.6	......	49 21 36.59						
8059	19.708	34.0	33.5	......	18 36 08.42	+ 1 05.06	+0.20	+0.02	......	57.39	
8083	11.900	32.4	35.0	....	56 27 51.36						
8128	23.707	36.0	31.1	....	41 22 54.06	+ 4 32.26	+0.41	+0.08	......	57.99	
5693	21.311	25.6	21.4	....	31 51 19.46						
5823	11.980	27.0	21.8	....	65 52 21.07	+ 6 22.60	+0.76	+0.11	....	48 59 58.58	July 14

Observations for Latitude.—Station No. 5—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6047	26. 558	27. 0	27. 0	....	72 12 40. 28						
6073	10. 077	27. 0	27. 0	......	26 04 18. 68	− 8 31. 36	0. 00	−0. 16	....	48 59 57. 96	July 14.
6114	12. 012	26. 2	27. 7	....	76 58 43. 08						
6157	25. 033	29. 0	24. 7	10	20 47 46. 47	+ 6 44. 01	+0. 62	+0. 14	+0. 01	59. 56	
6268	13. 779	27. 1	26. 0	....	39 26 22. 53						
6289	23. 557	27. 3	25. 7	....	58 43 41. 27	− 5 03. 39	+0. 60	−0. 69	....	59. 02	
6624	22. 568	22. 1	22. 1	....	40 07 38. 62						
6681	16. 730	21. 0	23. 7	....	57 46 17. 86	+ 3 01. 14	−0. 60	+0. 05	....	58. 83	July 15.
6728	16. 084	22. 9	22. 0	....	43 25 21. 32						
6748	21. 916	23. 6	21. 2	....	54 40 34. 53	− 3 00. 95	+0. 74	−0. 05	....	57. 67	
6780	19. 323	22. 5	22. 1	....	57 42 49. 80						
6817	19. 813	20. 5	24. 1	... .	40 16 38. 26	+ 0 15. 20	−0. 71	0. 00	....	58. 52	
6937	14. 260	23. 6	21. 1	....	36 23 00. 51						
6970	23. 573	17. 5	27. 0	....	61 41 36. 59	− 4 48. 96	−1. 56	−0. 09	....	57. 91	
7100	11. 119	21. 9	21. 0	....	42 45 34. 34						
7166	29. 521	23. 4	19. 3	....	55 33 24. 17	− 9 30. 97	+1. 11	−0. 17	....	59. 22	
7215	13. 823	23. 3	25. 3	....	57 07 24. 34						
7277	25. 227	28. 6	20. 5	....	40 40 42. 74	+ 5 53. 84	+1. 36	+0. 10	....	58. 84	
7377	28. 922	24. 2	26 1	....	59 27 47. 80						
7398	10. 002	25. 0	25. 2	......	38 51 44. 71	− 9 47. 04	−0. 47	−0. 18	....	58. 56	
7480	18. 065	28. 5	22. 5	....	45 58 49. 29						
7489	20. 371	22. 0	20. 0	....	52 03 32. 30	− 1 11. 55	−0. 22	−0. 02	....	59. 00	
7505	17. 392	27. 0	24. 2	....	37 57 53. 43						
7605	21. 286	23. 5	28. 8	....	60 06 07. 33	− 2 00. 82	−0. 56	−0. 03	....	48 59 58. 97	

Mean latitude (82 determinations), 48° 59″ 58.54″.

$\varepsilon = \pm$ 0″. 49775

$r_0 = \pm$ 0″. 037

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 6.—West side of Turtle Mountain, 150 miles west of Pembina.—Observer, W. J. Twining, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6047 6073	26.002 9.279	26.6 25.0	25.2 27.3	....	72 12 43.86 26 04 21.51	−8 38.87	−0.20	−0.17	....	48 59 53.45	July 28.
6114 6157	12.012 24.797	25.8 25.3	26.5 27.2	....	76 58 46.73 20 47 49.07	+6 36.69	−0.58	+0.14	....	54.15	
6268 6289	15.285 25.318	28.6 23.6	25.0 30.0	....	39 26 26.09 58 43 45.32	−5 11.30	−0.62	−0.09	....	53.69	
6421 6476	22.483 22.546	26.5 25.1	27.5 28.9	....	49 17 34.52 48 42 09.19	+0 01.95	−1.07	0.00	....	52.74	
6553 6586	16.021 20.334	27.2 25.7	27.0 28.8	....	32 18 14.03 65 46 01.29	−2 13.82	−0.65	−0.04	....	53.15	
6624 6681	24.035 18.479	26.8 25.5	27.7 29.0	....	40 07 42 37 57 46 22.03	+2 52.39	−0.98	+0.05	....	53.66	
6728 6748	18.551 24.602	24.5 27.5	30.1 27.3	....	43 25 25.30 54 40 38.84	−3 07.75	−1.20	−0.05	....	53.07	
6780 6847	20.693 20.915	26.1 26.5	28.7 28.3	....	57 42 54.19 40 16 42 20	+0 06.89	−0.98	0.00	....	54.10	
7024 7073	15.965 22.349	25.0 27.2	30.4 28.0	....	61 51 17.23 36 01 57.39	+3 18.08	−1.38	+0.06	....	54.07	
7100 7166	11.376 29.954	29.5 20.5	25.5 34.8	....	42 45 38.55 55 33 28.73	−9 36.43	−2.30	−0.17	....	54.74	
7215 7277	15.694 26.828	27.2 26.1	28.0 29.1	....	57 07 28.95 40 40 46.65	+5 45.55	+0.85	+0.10	....	54.30	
7320 7-Yr. 2395	23.725 18.552	27.0 27.1	28.5 28.5	....	38 09 24.84 59 45 02.87	+2 40.51	+0.67	+0.01	....	55.08	
7377 7398	30.488 11.284	27.5 26.0	28.4 30.0	....	59 27 52.70 38 51 48.85	−9 55.85	−1.09	−0.18	....	53.66	
7416 7453	26.044 16.117	28.0 26.0	28.0 30.0	....	62 02 51.50 36 07 12.58	−5 08.01	−0.89	−0.09	....	53.05	
7480 7489	21.514 24.142	27.6 28.8	28.4 27.2	....	45 58 53.65 52 03 36.81	−1 20.61	+0.18	−0.02	....	51.78	
7505 7605	16.934 21.125	28.7 25.6	27.4 31.0	....	37 57 57.52 60 06 11.49	−2 10.10	−0.91	−0.03	....	53.47	
7627 7686	22.[illegible] 17.161	28.1 27.1	28.2 29.7	....	25 19 45.86 72 34 28.23	+2 47.05	−0.60	+0.06	....	53.55	
7755 7765	17.954 23.135	29.8 24.0	27.4 33.1	....	58 47 16.03 39 05 08.48	+3 42.81	−1.40	+0.06	....	53.73	
7787 7800	17.811 22.504	27.6 25.5	29.4 31.3	....	52 01 11.97 45 53 51.00	+2 24.68	−1.69	+0.01	....	54.51	
7820 7882	13.719 28.153	28.7 26.1	28.2 31.4	....	48 49 57.74 49 24 48.38	−7 27.85	−1.07	−0.13	....	48 59 54.01	

Observations for Latitude.—Station No. 6—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7902	29.905	28.0	29.7	....	41 16 53.34						
8024	12.921	28.0	30.0	....	56 25 20.45	+8 46.97	0.83	+0.16	......	48 59 53.20	July 28.
8036	19.824	29.8	27.9	....	49 21 41.76						
8059	21.657	25.1	32.4	....	48 36 14.00	+0 56.87	−1.20	+0.02	......	53.57	
8083	16.803	28.1	29.4	....	56 27 58.97						
8128	25.376	25.7	32.0	....	41 22 59.15	+4 26.00	−1.69	+0.08	......	53.45	
8206	28.065	27.1	30.2	....	20 37 30.63						
8273	12.278	28.0	30.1	....	67 05 58.26	+8 09.83	−1.09	+0.15	....	53.33	
8314	22.333	29.4	28.0	....	73 42 05.78						
8324	14.149	26.4	32.0	....	24 26 12.04	−4 13.93	−1.14	−0.08	....	53.76	
8344	11.419	29.2	29.1	....	60 30 50.28						
67	24.065	27.1	31.0	....	37 15 54.10	+6 32.37	−0.85	+0.11	....	53.82	
5853	25.300	22.3	38.3	....	49 49 47.96						
5911	13.643	32.0	30.2	....	48 22 09.44	−6 01.69	−3.17	−0.10	....	53.74	July 29.
6047	28.459	31.6	30.8	....	72 12 44.10						
6073	11.723	31.0	31.2	....	26 04 21.71	−8 39.28	+0.14	−0.17	....	53.60	
6114	13.154	30.6	31.4	....	76 58 46.98						
6157	25.902	33.4	28.8	....	20 47 49.26	+6 35.54	+0.85	+0.14	....	54.65	
6268	14.298	31.0	31.0	....	39 26 26.34						
6289	24.329	32.5	29.8	....	58 43 45.60	−5 11.24	+0.60	−0.09	....	55.24	
6318	13.114	30.9	31.4	....	59 27 59.48						
6365	29.261	33.1	29.2	....	38 15 05.82	+8 21.00	+0.76	+0.15	....	54.56	
6421	22.160	31.0	31.4	....	49 17 34.81						
6476	22.176	32.4	30.2	....	48 42 09.47	+0 00.50	+0.40	0.00	....	53.04	
6553	17.508	31.4	31.3	....	32 18 14.28						
6586	21.842	32.1	31.1	....	65 46 01.61	−2 14.47	+0.25	−0.04	....	53.69	
6624	23.411	32.1	30.9	....	40 07 42.65						
6681	17.895	31.1	52.2	....	57 46 22.35	+2 51.15	+0.02	+0.05	......	53.72	
6728	18.285	32.2	31.0	... .	43 25 25.59						
6748	24.387	32.9	31.4	....	54 40 39.16	−3 09.33	+0.60	−0.05	....	53.60	
6780	20.369	32.1	31.0	....	57 42 54.51						
6817	20.528	33.2	29.9	....	40 16 42.49	+0 04.93	+0.98	0.00	....	54.41	
6937	14.938	31.2	32.0	....	36 28 04.67						
6970	24.599	33.2	30.0	....	61 41 41.51	−4 59.76	+0.53	−0.09	....	53.77	
7024	16.711	32.0	31.4	....	61 51 17.57						
7073	23.009	32.2	31.1	....	36 01 57.68	+3 15.41	+0.38	+0.06	....	53.48	
7100	10.207	31.4	32.0	....	42 45 38.86						
7166	28.901	33.0	30.6	....	55 33 29.06	−9 40.03	+0.40	−0.17	....	54.16	
7215	15.128	32.0	31.5	....	57 07 29.26						
7277	26.251	31.4	32.3	....	40 40 46.95	+5 45.12	−0.09	+0.10	....	53.24	
7320	22.163	31.4	32.2	....	38 09 25.13						
7-Yr. 2395	17.032	33.0	31.0	....	59 45 03.20	+2 39.20	+0.27	+0.04	......	53.68	
7377	30.151	33.2	30.5	....	59 27 53.01						
7398	10.924	30.3	33.6	....	38 51 49.14	−9 56.66	−0.14	−0.18	....	54.11	
7416	27.001	32.0	32.0	....	62 02 51.84						
7453	17.049	32.4	31.5	....	36 07 12.84	−5 08.79	+0.20	−0.09	....	53.66	
7480	18.656	31.5	32.5	....	45 58 53.96						
7489	21.988	32.5	31.5	....	52 03 37.13	−1 21.66	0.00	−0.02	....	53.87	
7755	15.759	31.5	31.5	....	58 47 16.35						
7765	22.885	32.8	30.1	....	39 05 08.77	+3 41.10	+0.60	+0.06	....	48 59 54.32	

Observations for Latitude.—Station No. 6—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7787	19.434	32.0	30.6	....	52 01 12.28						
7800	23.998	30.5	32.1	......	45 53 51.30	+2 21.61	−0.01	+0.04	....	48 59 53.40	July 20.
7962	29.424	31.4	31.5	......	41 16 53.62						
8024	12.491	31.6	31.4	......	56 25 20.74	+8 45.39	+0.02	+0.16	....	52.75	
8036	20.541	32.7	30.2	....	49 21 42.04						
8059	22.322	31.0	31.8	......	48 36 14.28	+0 55.26	+0.38	+0.02	....	53.82	
8083	17.208	36.2	31.4	......	56 27 59.26						
8128	25.715	32.4	30.3	....	41 22 59.41	+4 23.95	+0.42	+0.08	....	53.79	
8205	19.022	30.8	32.1	......	30 37 20.86						
8273	13.295	32.1	31.0	....	67 05 58.52	+8 07.97	−0.04	+0.15	....	52.77	
8314	23.057	30.8	32.2	....	73 42 06.03						
8324	14.830	33.0	30.0	....	24 26 12.25	−4 15.26	+0.36	−0.08	....	54.16	
8344	9.858	30.7	32.2	....	60 30 50.53						
67	22.436	33.2	30.0	......	37 15 54.32	+6 30.26	+0.38	+0.11	....	53.18	
6047	28.332	32.4	31.5	....	72 12 44.86						
6073	11.573	32.1	32.0	......	26 01 22.31	−8 39.99	+0.22	−0.17	....	53.65	August 1.
6114	12.479	33.0	31.0	....	76 58 47.80						
6157	25.229	29.9	34.8	....	20 47 49.84	+6 35.60	−0.65	+0.14	....	53.91	
6268	13.037	32.0	32.0	....	39 26 27.15						
6289	23.134	34.0	31.0	......	58 43 46.48	−5 13.28	+0.04	−0.09	....	53.49	
6318	11.720	32.0	33.0	......	59 28 00.37						
6365	27.854	33.1	32.2	......	38 15 06.63	+8 20.60	−0.02	+0.15	......	54.23	
6421	21.511	33.1	32.2	......	49 17 35.71						
6456	21.504	33.5	32.1	......	48 42 10.39	+0 00.22	+0.51	0.00	......	53.78	
6553	15.966	32.1	33.4	......	32 18 15.09						
6586	20.349	34.3	31.4	......	65 46 02.62	−2 15.99	+0.36	−0.04	......	53.19	
6624	22.467	33.2	32.4	......	40 07 43.54						
6681	16.904	33.0	33.1	....	57 46 23.37	+2 50.74	+0.16	+0.05	....	54.40	
6728	18.264	33.7	32.4	......	43 25 26.53						
6748	21.404	33.1	33.0	....	51 40 40.18	−3 10.51	+0.31	−0.05	......	53.10	
6780	20.265	33.5	32.8	....	57 42 55.55	+0 04.31	+0.25	0.00	......	54.08	
6817	20.405	33.5	33.1	......	40 16 43.43						
6937	15.314	33.4	34.2	......	36 28 05.59						
6970	21.992	31.1	33.7	......	61 41 42.60	−5 00.28	−0.09	−0.09	......	53.63	
7024	15.567	34.1	33.6	......	61 51 18.66						
7073	22.859	33.1	31.9	....	36 01 58.60	+3 15.22	−0.29	+0.06	......	53.62	
7100	9.062	33.7	34.3	......	42 45 39.84						
7166	27.790	34.1	33.9	......	55 33 30.15	−9 41.08	−0.09	−0.17	......	53.66	
7215	14.662	31.2	33.7	......	57 07 30.36						
7277	25.785	31.3	37.0	......	40 40 48.23	+5 45.12	−1.16	+0.10	......	53.36	
7320	23.251	34.7	33.4	......	38 09 26.10						
7 Yr. 2395	18.125	32.0	36.3	......	59 45 04.33	+2 39.11	−0.67	+0.04	......	53.72	
7377	29.837	32.1	36.4	......	59 27 51.16						
7398	10.554	36.7	32.0	......	38 51 50.11	−9 58.30	+0.09	−0.18	......	53.74	
7416	21.968	31.3	37.2	......	62 02 52.96						
7453	11.961	38.5	30.3	......	36 07 13.79	−5 10.49	+0.51	−0.09	......	53.31	
7480	20.600	31.5	31.4	......	45 58 55.00						
7489	23.571	35.7	33.2	......	52 03 38.21	−1 22.97	+0.58	−0.02	......	48 59 51.19	

Observations for Latitude.—Station No. 6—Continued.

B. A. C. No.	Readings.				Declination,	Corrections.				Latitude.	Remarks.
	Microm	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7505 7605	17. 399 21. 681	34. 5 35. 7	34. 2 34. 0	....	37 57 58. 78 60 06 12. 91	−2 12. 86	+0. 44	−0. 03	....	48 59 53. 40	August 1.
7627 7686	23. 549 18. 232	35. 2 34. 2	34. 2 36. 3	....	25 19 46. 92 72 34 29. 67	+2 44. 97	−0. 25	+0. 06	....	53. 07	
7755 7765	16 123 23. 211	34. 2 35. 2	36. 2 35. 2	.... 0 20	58 47 17. 43 39 05 09. 73	+3 39. 92	−0. 41	+0. 06	+0. 06	53. 18	
7787 7800	20. 087 24. 646	34. 2 33. 1	35. 9 37. 0	....	52 01 13. 33 45 53 52. 30	+2 21. 45	−1. 25	+0. 04	....	53. 06	
7820 7882	14. 105 28. 595	35. 7 33. 3	34. 2 36. 9	....	48 49 59. 04 49 24 49. 69	−7 29. 59	−0. 47	−0. 13	......	54. 17	
7962 8024	28. 845 11. 906	34. 0 35. 0	26. 1 34. 8	....	41 16 54. 69 56 25 21. 75	+8 45. 57	−0. 42	+0. 16	....	53. 53	
8036 8059	18. 308 20. 090	36. 0 32. 5	33. 9 37. 4	....	49 21 43. 01 48 36 15. 25	+0 55. 29	−0. 62	+0. 02	....	53. 82	
8083 8128	17. 314 25. 833	35. 3 34. 7	34. 1 34. 9	....	56 28 00. 24 41 23 00. 30	+4 24. 32	+0. 22	+0. 08	....	54. 89	
8206 8273	26. 931 11. 175	35. 8 33. 4	34. 0 36. 9	....	30 37 31. 66 67 05 59. 44	+8 08. 87	−0. 38	+0. 15	......	54. 19	
8314 8324	23. 642 15. 411	35. 0 33. 8	35. 2 36. 3	....	73 42 06. 93 24 26 12. 96	−4 15. 39	−0. 60	−0. 08	......	48 59 53. 88	

Mean latitude (79 determinations), 48° 59′ 53″.76.

ε = 0″.53
r = 0″.35
ε_0 = 0″.06
r_0 = 0″.04

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 7.—South Antler Creek, 193 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 11.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5693	25.327	36.2	35.8	......	31 54 52.20						August 1.
5823	12.170	45.0	28.8	......	65 52 25.00	+ 8 08.84	+5.43	+0.14	......	48 61 53.01	Rejected.
5853	22.051	35.2	38.7	......	49 49 50.05						
5911	12.252	42.3	31.8	......	48 22 10.12	− 4 12.72	+2.29	−0.07	......	49 01 49.58	
6047	21.332	35.7	39.0	......	72 12 44.87						
6073	13.388	43.0	32.0	......	26 04 22.33	− 6 46.61	+2.52	−0.13	......	49.38	
6114	9.190	35.8	39.7	......	76 58 47.81						
6157	23.282	33.5	42.6	......	20 47 49.84	+ 8 32.43	−4.25	+0.18	......	47.18	
6268	19.470	40.1	36.0	......	39 26 27.13						
6289	21.737	33.7	42.5	......	58 43 46.48	− 3 15.60	−1.54	−0.05	......	49.53	
6318	13.376	39.6	26.9	......	59 28 00.37						
6365	29.967	34.8	42.2	......	38 15 06.63	+10 13.42	−1.54	+0.18	......	48.56	
6421	19.809	28.0	31.5	......	49 17 35.69						
6476	22.891	31.9	28.3	......	48 42 10.40	+ 1 54.51	+0.03	+0.03	......	47.61	
6553	21.179	32.3	28.5	......	32 18 15.09						
6586	21.718	28.3	32.7	......	65 46 02.62	− 0 20.03	−0.20	0.00	......	48.63	
6624	26.022	30.2	31.0	......	40 07 43.54						
6681	18.329	29.6	32.0	......	57 46 23.37	+ 4 45.83	−1.05	+0.11	......	48.34	
6728	21.110	31.7	30.4	......	43 25 26.53						
6748	23.130	30.8	31.9	......	54 40 40.18	− 1 15.05	+0.07	−0.02	......	48.36	
6780	19.693	30.7	32.1	......	57 42 55.55						
6817	22.910	32.8	30.0	......	40 16 43.43	+ 1 59.52	+0.46	+0.03	......	49.50	
6937	19.118	32.8	31.3	......	36 28 05.60						
6970	24.100	32.2	32.1	......	61 41 42.60	− 3 05.10	+0.52	−0.05	......	49.47	
7024	16.731	31.5	33.2	......	61 51 18.66						
7073	25.053	33.9	31.5	......	36 01 58.59	+ 5 09.20	+0.23	+0.09	......	48.14	
7100	15.193	33.5	31.7	......	42 45 39.83						
7166	27.716	32.4	33.3	......	55 33 30.15	− 7 45.28	+0.29	−0.13	......	49.87	
7215	15.619	32.3	33.7	......	57 07 30.36						
7277	27.161	35.4	31.1	......	40 40 48.23	+ 7 38.55	+0.95	+0.13	......	48.93	
7320	21.713	33.5	32.9	......	38 09 26.11						
7-Yr. 2395	17.392	31.3	31.8	......	59 45 01.33	+ 4 32.00	+1.01	+0.08	......	48.31	
7377	27.660	32.1	31.3	......	59 27 51.16						
7398	14.636	36.0	30.6	......	38 51 50.11	− 8 03.89	+1.05	−0.14	......	49.15	
7416	23.827	33.1	33.4	......	62 02 52.96						
7453	18.555	36.1	30.4	......	26 07 13.79	− 3 15.88	+1.77	−0.06	......	49.20	
7480	22.333	34.6	31.8	......	45 58 55.00						
7489	21.480	34.0	38.7	......	52 03 38.22	+ 0 31.69	+1.31	+0.01	......	49.65	
7505	22.042	32.5	33.8	......	37 57 58.78						
7605	22.542	42.0	25.5	......	60 06 12.92	− 0 18.58	−4.97	−0.01	......	49 01 52.23	

Observations for Latitude.—Station No. 7—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7627 7686	25.236 17.726	33.6 35.8	33.7 31.9	....	25 19 46.93 72 34 29.68	+ 4 39.03	+1.24	+0.09	....	49 01 48.66	August 1.
7755 7765	17.122 26.088	33.9 36.1	34.3 32.0	....	58 47 17.43 39 05 09.73	+ 5 33.12	+1.21	+0.10	....	48.01	
7787 7800	18.518 25.376	33.9 37.0	34.5 31.3	....	52 01 13.34 45 53 52.30	+ 4 14.80	+1.67	+0.08	....	49.37	
7820 7882	18.203 27.237	34.5 24.5	33.6 44.0	....	48 49 59.07 49 24 49.70	− 5 35.65	−6.09	−0.09	....	42.56	Rejected.
7962 8024	30.796 13.612	34.6 41.5	34.0 27.0	....	41 16 54.69 56 25 21.75	+10 38.45	+4.94	+0.19	....	51.80	
8036 8059	19.641 24.187	35.1 32.3	33.6 36.1	....	49 21 43.01 48 36 15.25	+ 2 48.90	−0.72	+0.05	....	47.36	
8083 8128	16.791 26.917	33.4 37.0	34.7 31.1	....	56 28 00.25 41 22 60.30	+ 6 16.22	+1.51	+0.10	....	48.10	
8206 8273	30.317 14.170	35.9 41.5	32.5 27.5	....	30 37 31.66 67 05 59.43	+ 9 59.93	+5.69	+0.19	....	51.36	
8314 8324	23.015 19.182	33.8 37.3	35.1 31.3	....	73 42 06.93 24 26 12.96	− 2 22.41	+1.54	−0.05	....	49.03	
46 67	22.173 20.650	33.3 38.0	35.7 31.0	....	60 49 29 70 37 15 55.16	− 0 56.59	+1.51	−0.02	....	47.33	
5853 5911	24.407 17.622	23.7 23.6	23.6 24.7	....	49 49 50.26 48 22 10.33	− 4 12.09	−0.33	−0.07	....	47.81	August 2.
6047 6073	26.125 15.187	25.7 25.0	24.7 25.6	....	72 12 45.12 26 04 22.44	− 6 46.39	+0.13	−0.13	....	47.39	
6114 6157	14.054 27.731	24.0 29.5	26.9 21.2	....	76 58 48.08 20 47 50.03	+ 8 28.16	+1.77	+0.18	....	49.16	
6268 6289	19.080 24.478	26.7 27.0	24.4 24.6	....	39 26 27.39 58 43 46.77	− 3 20.56	+1.54	−0.05	....	48.01	
6318 6365	13.141 29.605	24.5 32.7	26.9 19.3	....	59 28 00.67 38 15 06.90	+10 11.70	+3.60	+0.18	....	49.26	
6421 6476	19.797 22.966	25.4 21.7	26.9 28.0	....	49 17 36.03 48 42 10.70	+ 1 57.74	−1.57	+0.03	....	49.57	
6553 6586	20.822 21.315	29.1 20.5	24.0 33.7	....	32 18 15.36 65 46 02.96	− 0 18.32	−2.65	0.00	....	48.19	
6624 6681	26.143 18.427	27.6 34.5	26.7 20.7	....	40 07 43.84 57 46 23.72	+ 4.46.68	+4.81	+0.11	....	55.38	Rejected.
6728 6748	20.852 22.880	28.5 26.6	26.7 29.0	....	43 25 26.56 54 40 40.54	− 1 15.35	−0.20	−0.02	....	48.13	
6780 6817	24.060 27.259	23.0 29.8	32.8 26.2	....	57 42 55.91 40 16 43.74	+ 1 58.86	−2.03	+0.03	....	46.68	
6937 6970	18.786 23.773	29.8 24.7	27.4 32.7	....	36 28 05.90 61 41 42.98	− 3 05.29	−1.83	−0.05	....	47.27	
7024 7073	17.467 25.804	24.6 33.5	32.8 24.5	....	61 51 19.04 36 01 58.92	+ 5 09.75	+0.26	+0.09	....	49.08	
7100 7166	16.036 28.558	29.5 26.3	23.4 31.9	....	42 45 40.19 55 33 30.54	− 7 45.21	−1.47	−0.13	....	48.52	
7215 7277	16.011 28.345	24.8 36.1	33.6 23.0	....	57 07 30.75 40 40 48.30	+ 7 38.26	+1.41	+0.13	....	49.33	
7320 7-Yr. 2395	22.645 15.302	31.0 29.1	28.1 30.0	....	38 09 26.45 59 45 04.73	+ 4.32.82	+0.65	+0.08	....	49 01 49.14	

Observations for Latitude.—Station No. 7—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7377	25.457	26.8	32.7	....	59 27 54.74						
7398	12.421	33.4	26.2	....	38 51 50.47	− 8 04.34	+0.43	−0.14	....	49 01 48.55	
7416	23.881	27.8	32.5	....	62 02 53 37						
7453	18.613	34.8	25.1	....	36 07 14.13	− 3 15.73	+1.47	−0.06	....	49.43	
7480	22.033	31.6	28.0	....	45 58 55.38						
7489	21.210	30.8	29.2	....	52 03 38.60	+ 0 30.58	+1.70	+0.01	....	49.28	
7505	22.113	29.5	30.7	....	37 57 59.13						
7605	22.620	31.5	29.6	....	60 06 13.30	− 0 18.84	+0.23	−0.01	....	47.60	
7627	25.206	31.5	30.0	....	25 19 47.22						
7686	17.705	32.1	29.8	....	72 34 30.07	+ 4 38.69	+1.24	+0.09	....	48.66	
7755	16.848	29.2	32.8	....	58 47 17.82						
7765	25.820	33.3	25.8	....	39 05 10.08	+ 5 33.35	+0.29	+0.10	....	47.69	
7787	18.789	30.5	31.7	....	52 01 13.72						
7800	25.656	32.7	29.0	....	45 53 52.67	+ 4 15.14	+0.82	+0.08	....	49.24	
7820	18.633	32.1	30.0	....	48 49 59.45						
7882	27.681	31.0	31.5	....	49 24 50.07	− 5 36.17	+0.52	−0.09	....	49.02	
7962	31.252	34.3	28.3	....	41 16 55.02						
8024	14.093	31.7	32.2	....	56 25 22.12	+10 37.53	+1.80	+0.19	....	48.09	
8036	19.183	29.2	34.5	....	49 21 43.37						
8059	23.707	38.5	25.2	....	48 36 15.60	+ 2 48.08	+2.62	+0.05	....	50.23	
8083	17.340	31.0	32.8	....	56 28 00.61						
8128	27.438	36.6	27.2	....	41 23 00.64	+ 6 15.18	+2.49	+0.10	....	48.40	
8206	30.377	33.2	30.7	....	30 37 31.96						
8273	14.132	25.5	39.0	....	67 05 59.78	+10 03.57	−3.60	+0.19	....	46.03	
8314	23.137	28.0	36.0	....	73 42 07.27						
8321	19.399	32.3	31.9	....	24 26 13.23	− 2 18.88	−2.49	−0.05	....	48.83	
46	22.043	31.6	32.8	....	60 49 29.93						
67	20.642	23.5	40.6	....	37 15 55.35	− 0 52.05	−5.99	−0.02	....	44.58	Rejected.
5693	27.540	23.6	25.3	....	31 54 52.50						
5823	14.360	28.0	24.6	....	65 58 25.39	+ 8 09.69	+0.56	+0.14	....	49.33	August 3.
5853	21.669	26.4	26.6	....	49 49 50.45						
5911	17.803	27.0	27.0	0 15	48 22 10.54	− 4 14.76	−0.07	−0.07	+0.03	45.63	
6047	26.621	26.7	28.8	....	72 12 45.36						
6073	15.715	32.9	22.5	....	26 04 22.62	− 6 45.20	+2.72	−0.13	....	51.38	
6114	14.607	27.4	28.0	....	76 58 48.31						
6157	28.323	33.0	22.7	....	20 47 50.21	+ 8 29.60	+3.17	+0.18	....	52.22	
6268	18.838	29.8	26.1	....	39 26 27.64						
6289	24.140	21.8	34.5	....	58 43 47.05	− 3 16.99	−2.95	−0.05	....	47.36	
6318	13.290	28.3	28.1	....	59 27 60.96						
6365	29.883	28.5	28.1	....	38 15 07.17	+10 16.50	+0.20	+0.18	....	50.95	
6421	20.150	27.5	29.7	....	49 17 36.29						
6476	24.253	29.1	28.2	....	48 42 11.01	+ 1 55.29	−0.43	+0.03	....	48.54	
6553	21.835	29.7	28.1	....	32 18 15.63						
6586	22.391	24.7	33.6	....	65 46 03.30	− 0 20.66	−2.39	0.00	....	46.41	
6624	23.321	30.3	28.0	....	40 07 44.14						
6681	18.653	25.1	33.6	....	57 46 24.06	+ 4 44.90	−2.03	+0.11	....	47.08	
6728	21.190	32.0	27.1	....	43 25 27.18						
6748	23.219	27.3	32.0	....	54 40 40.88	− 1 15.39	−0.03	−0.02	....	48.59	
6780	20.723	27.4	32.0	....	57 42 56.26						
6817	23.918	32.7	27.0	....	40 16 44.07	+ 1 58.71	+0.36	+0.03	....	49 01 49.27	

Observations for Latitude.—Station No. 7—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7021	18.028	29.0	32.0	....	61 51 19.42						
7073	26.328	33.2	28.0	....	36 01 59.24	+ 5 08.38	+0.72	+0.09	......	49 01 48.72	
7109	16.066	29.7	31.8	....	42 45 40.53						
7166	28.629	33.0	28.8	....	55 33 30.91	− 7 46.77	+0.69	−0.13	......	49.51	
7215	16.437	29.8	32.0	....	57 07 31.13						
7277	28.765	34.3	28.3	....	40 40 48.65	+ 7 38.03	+1.24	+0.13	......	49.29	
7320	25.189	31.0	31.5	....	38 09 26.79						
7-Yr. 2395	17.887	35.9	26.9	....	59 45 05.12	+ 4 31.30	+2.78	+0.08	......	50.11	
7377	27.970	30.7	32.1	....	59 27 54.95						
7398	14.953	33.0	30.0	....	38 51 50.81	− 8 03.63	+0.52	−0.14	......	49.63	
7416	24.778	31.0	32.1	....	62 02 53.76						
7453	19.523	33.0	30.0	....	36 07 14.47	− 3 15.24	+0.62	−0.06	......	49.43	
7480	21.750	32.0	31.3	0 26	45 58 55.75						
7489	20.933	33.0	30.4	09	52 03 38.99	+ 0 30.35	+1.08	+0.01	+0.11	48.92	
7505	22.542	32.7	30.8	....	37 57 59.48						
7605	23.035	31.1	32.8	....	60 06 13.70	− 0 18.32	+0.07	−0.01	......	48.33	
7627	25.744	32.8	31.3	....	25 19 47.53						
7686	18.239	31.4	32.7	....	72 34 30.47	+ 4 38.84	+0.07	+0.09	......	48.00	
7755	17.250	30.8	33.9	....	58 47 18.21						
7765	26.227	34.8	30.1	....	39 05 10.43	+ 5 33.16	+0.52	+0.10	......	48.10	
7787	18.883	31.8	33.0	....	52 01 14.10						
7800	25.744	33.3	31.3	....	45 53 53.04	+ 4 14.91	+0.26	+0.08	......	48.82	
7820	18.499	33.3	31.3	....	48 49 59.82						
7882	27.569	32.0	33.3	....	49 24 50.44	− 5 36.99	+0.23	−0.09	......	48.28	
7962	31.608	35.3	30.8	....	41 16 55.38						
8024	14.440	32.0	34.5	....	56 25 22.49	+10 37.86	+0.65	+0.19	......	47.64	
8036	19.200	30.8	35.6	....	49 21 43.73						
8059	23.715	37.1	29.2	....	48 36 15.96	+ 2 47.75	+1.01	+0.05	......	48.65	
8083	16.848	32.0	34.4	....	56 28 00.97						
8128	26.977	36.0	30.5	....	41 23 00.98	+ 6 16.33	+1.01	+0.10	......	49 01 48.42	

Mean latitude (81 determinations), 49° 01′ 48″.76.

$\epsilon = 1''.223$
$r = 0''.828$
$\epsilon_0 = 0''.136$
$r_0 = 0''.092$

1873.

UNITED STATES NORTHERN BOUNDARY

Observations for Latitude.

[Astronomical Station No. 8—about 7 miles west of Rivière des Lacs, 237 miles west of Pembina.—Observer, W. J. Twining, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No 1513.]

B. A. C. No.	Readings.					Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.	Declination.	Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6421	20.615	26.1	26.5	......	49 17 39.38						
6476	22.717	24.3	28.7	......	48 42 14.17	−1 05.22	−1.07	+0.02	......	49 01 00.94	August 16.
6553	18.185	26.3	26.5	......	32 18 18.39						
6586	20.479	26.4	27.1	......	65 46 06.96	−1 11.18	−0.20	−0.02	......	01.28	
6624	23.451	26.6	26.9	......	40 07 47.32						
6681	15.917	28.1	25.8	......	57 46 27.77	+3 53.76	+0.44	+0.02	......	01.76	
6728	17.792	26.7	27.1	......	43 25 30.61						
6748	21.871	26.9	27.0	......	54 40 41.69	−2 06.56	−0.11	−0.03	......	00.97	
6780	17.089	17.1	36.6	......	57 43 00.17						
6817	19.300	34.3	19.6	......	40 16 47.56	+1 08.60	−1.07	−0.02	......	01.41	
6937	24.983	26.1	28.8	......	36 28 09.68						
6970	22.610	27.8	27.3	......	61 41 47.63	−3 50.65	−0.49	−0.07	......	01.45	
7024	15.942	26.2	28.3	......	61 51 23.75						
7073	24.294	27.0	27.8	......	36 02 02.80	+4 19.14	−0.65	+0.07	......	01.83	
7100	10.574	26.9	28.0	......	42 45 44.43						
7166	27.246	26.9	28.0	......	55 34 35.26	−8 27.29	−0.49	−0.15	......	01.91	
7215	12.679	26.6	28.2	......	57 07 35.54						
7277	25.851	27.4	27.3	......	40 40 52.58	+6 48.69	−0.33	+0.11	......	02.53	
7320	22.919	25.5	28.9	......	38 09 30.64						
7 Yr. 2395	15.750	27.3	27.3	......	59 45 09.60	+3 42.44	−0.76	+0.06	......	01.86	
7377	27.326	28.1	26.6	......	59 27 59.55						
7398	10.107	24.0	30.8	......	38 51 54.75	−8 54.25	−1.18	−0.16	......	01.55	
7416	21.811	27.3	27.3	......	62 02 58.44						
7453	13.890	25.0	29.6	......	36 07 18.32	−4 05.77	−1.13	−0.07	......	01.41	
7480	19.861	26.6	28.1	......	45 59 00.03						
7489	20.563	26.0	28.8	......	52 03 43.47	−0 21.78	−0.96	0.00	......	59.01	Rejected.
7505	18.754	25.8	28.0	......	37 58 03.44						
7605	20.972	27.0	29.6	......	60 46 18.43	−1 09.82	−0.85	−0.02	......	01.24	
7627	22.112	28.1	28.3	......	25 19 50.87						
7686	14.713	25.7	30.8	......	72 34 35.36	+3 49.57	−0.95	−0.08	......	01.81	
7755	14.390	29.1	28.9	......	58 47 22.92						
7765	23.436	31.1	26.9	......	39 05 14.49	−4 40.49	+1.05	−0.15	......	00.23	
7787	17.399	29.2	24.6	......	52 01 18.63						
7800	23.886	32.7	2[illegible].4	......	45 53 57.50	+3 21.28	+1.32	+0.05	......	00.73	
7820	13.459	28.1	31.5	......	48 50 04.26						
7882	26.521	36.0	24.7	......	49 24 54.89	−6 29.18	−1.76	−0.11	......	01.25	
7962	28.794	33.9	31.2	......	41 16 59.51						
8024	9.865	32.0	29.6	......	56 25 27.04	+9 47.32	+0.25	+0.18	......	01.02	
8026	17.800	30.3	31.0	......	49 21 48.19						
8059	21.000	30.3	31.0	......	48 36 20.30	+1 57.90	−0.31	−0.03	......	49 01 01.82	

Observations for Latitude.—Station No. 8—Continued.

B. A. C. No.	Readings. Microm.	Readings. Level. N.	Readings. Level. S.	Readings. Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
8083 8128	14.916 25.441	30.0 30.3	31.0 30.8	....	56 28 05.50 41 23 04.93	+5 26.56	−0.33	+0.10	......	49 01 01.54	
8206 8273	27.750 9.975	31.4 29.5	30.0 32.0	....	30 37 35.83 67 06 04.56	+9 11.51	−0.25	+0.17	......	01.63	
8314 8324	21.055 14.851	30.0 30.5	31.5 31.0	....	73 42 14.97 24 26 16.72	−3 12.49	−0.44	−0.06	......	01.36	
8344 67	9.305 23.946	30.0 29.7	31.4 32.0	....	60 30 56.34 37 15 59.26	+7 34.27	−0.83	+0.15	......	01.39	
6047 6073	26.816 12.117	25.3 28.0	24.5 22.1	....	72 12 47.84 26 04 24.69	−7 36.67	+1.49	−0.14	......	01.55	August 17.
6114 6157	10.435 25.265	24.4 27.6	25.9 22.8	....	76 58 50.98 20 47 52.12	+7 40.14	+0.74	+0.16	......	02.59	
6268 6289	14.821 22.825	25.1 25.8	25.6 25.0	....	39 26 30.39 58 43 50.21	−4 08.34	+0.07	−0.07	......	01.96	
6553 6586	17.690 19.959	24.5 25.9	28.0 26.9	....	32 18 18.61 65 46 07.25	−1 10.49	−1.00	−0.62	....	01.51	
6624 6681	23.010 15.434	26.8 23.6	25.8 29.0	....	40 07 47.57 57 46 28.08	+3 55.06	−0.98	+0.07	....	01.98	
6728 6748	17.189 21.225	25.3 23.6	27.0 28.9	....	43 25 30.92 54 40 44.94	−2 05.23	−1.56	−0.03	......	0 .11	
6780 6817	17.954 20.191	26.1 22.4	26.0 29.8	....	57 43 00.49 40 16 47.84	+1 09.41	−1.63	+0.02	..	01.97	
6937 6970	15.735 23.350	23.7 24.0	26.4 25.9	....	36 28 09.97 61 41 47.98	−3 56.27	−1.03	−0.07	......	01.61	
7024 7073	14.964 23.334	24.7 21.5	24.6 27.0	....	61 51 21.10 36 02 03.10	+4 19.70	−1.20	+0.08	......	02.18	
7627 7686	24.150 16.825	25.5 27.2	24.9 24.0	....	25 19 51.15 72 34 35.76	+3 47.28	+0.85	+0.08	......	01.67	
7755 7765	14.472 23.545	24.7 28.0	27.1 24.0	....	58 47 23.32 39 05 14.84	+4 41.51	+0.36	+0.08	...	01.03	
7787 7800	16.950 23.499	25.7 24.8	26.7 27.7	....	52 01 19.02 45 53 57.91	+3 23.50	−0.87	+0.06	......	00.85	
7820 7852	13.807 26.358	27.5 27.0	25.0 26.8	....	48 50 04.63 49 24 55.27	−6 29.43	+0.60	−0.11	......	01.01	
7962 8024	29.319 10.305	26.0 29.0	28.0 26.0	....	41 16 59.86 56 25 27.41	+9 47.16	+0.22	+0.19	......	01.22	
8036 8059	18.015 21.799	29.1 26.7	25.0 29.0	....	49 21 48.48 48 36 20.68	+1 57.41	+0.18	+0.03	......	02.20	
8206 8273	28.404 10.656	28.8 28.5	28.0 28.9	....	30 37 36.14 67 06 04.94	+9 10.68	+0.69	+0.17	......	01.48	
8314 8324	22.465 16.232	28.5 27.4	28.9 30.0	....	73 42 12.36 24 26 17.00	−3 13.39	−0.67	−0.06	......	00.56	
8344 67	8.485 23.112	29.2 27.0	28.0 31.5	....	60 30 56.72 37 15 59.57	+7 33.84	−0.74	+0.13	......	01.38	
6114 6157	10.247 25.045	29.0 28.8	25.9 22.0	....	76 58 51.14 20 47 52.24	+7 39.14	+2.21	+0.16	......	03.20	August 18 Rejected.
6268 6289	12.694 20.705	27.0 30.0	29.7 27.0	....	39 26 30.56 58 43 50.42	−4 08.57	+0.07	−0.07	......	01.92	
6318 6365	10.580 38.785	28.9 27.0	28.1 29.9	....	59 28 04.41 38 15 10.27	−9 21.86	−0.47	+0.17	......	49 01 01.92	

Observations for Latitude.—Station No. 8—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6421	19.056	31.5	25.1	......	49 17 39.84						
6476	21.135	24.0	32.7	......	48 42 14.64	+1 04.51	−0.51	+0.02	......	49 01 01.26	
6553	18.083	27.5	29.1	......	32 18 18.81						
6586	20.379	29.3	27.8	......	65 46 07.52	−1 11.24	−0.02	−0.02	......	01.89	
6624	23.465	28.8	28.7	......	40 07 47.80						
6681	15.914	28.3	29.6	......	57 46 28.36	+3 54.29	−0.27	+0.07	......	02.17	
6728	17.856	27.7	30.0	......	43 25 31.18						
6748	21.944	29.4	28.6	......	54 40 45.28	−2 06.84	−0.33	−0.03	......	01.03	
6780	17.895	28.6	29.2	......	57 43 00.79						
6817	20.077	27.9	30.0	......	40 16 48.10	+1 07.70	−0.60	+0.02	......	01.57	
6937	15.250	29.1	29.0	......	36 28 10.24						
6970	22.891	29.0	29.6	......	61 41 48.31	−3 57.17	−0.11	−0.07	......	01.92	
7024	14.884	28.6	30.0	......	61 51 24.41						
7073	23.191	29.6	29.0	......	36 02 03.38	+4 17.84	−0.18	+0.08	......	01.65	
7416	23.926	27.1	31.9	......	62 02 59.21						
7453	15.965	30.8	28.1	......	36 07 18.95	−4 07.01	−0.47	−0.07	......	01.53	
7480	19.211	30.1	28.9	......	45 59 00.75						
7489	19.844	29.0	30.1	......	52 03 44.22	−0 19.64	+0.02	−0.01	......	02.85	
7505	17.933	29.0	30.1	......	37 58 04.09						
7605	20.194	30.8	30.0	......	61 06 19.22	−1 10.15	−0.07	−0.02	......	01.11	
7627	22.654	30.9	30.0	......	25 19 51.42						
7686	15.297	30.7	31.0	......	72 31 36.16	+3 48.27	+0.14	+0.08	......	02.28	
7755	13.998	31.0	31.0	......	58 47 23.72						
7765	23.113	28.5	32.4	......	39 05 15.18	+4 42.81	−0.87	+0.08	......	01.47	
7820	14.635	30.0	31.5	......	48 50 05.01						
7882	27.126	30.8	30.8	......	49 24 55.64	−6 27.57	−0.33	−0.11	......	02.32	
6114	10.877	26.1	29.6	......	76 58 51.27						
6157	25.746	26.5	30.6	......	20 47 52.32	+7 41.35	−1.69	+0.16	......	01.61	August 19
6268	13.119	29.3	30.0	......	39 26 30.70						
6289	21.444	30.1	29.2	......	58 43 50.59	−4 09.00	+0.04	−0.07	......	01.62	
6318	11.592	28.7	30.6	......	59 28 04.60						
6365	29.700	28.8	30.3	......	38 15 10.13	+9 24.64	−0.76	+0.17	......	01.56	
6421	18.625	29.5	30.2	......	49 17 40.03						
6476	20.726	28.9	31.6	......	48 42 14.83	+1 05.19	−0.76	+0.02	......	01.88	
6553	17.394	29.7	32.2	......	32 18 18.97						
6586	19.585	30.6	32.1	......	65 46 07.75	−1 10.77	−0.89	−0.02	......	01.68	
6624	22.891	31.4	31.5	......	40 07 48.00						
6681	15.225	29.9	31.3	......	57 46 28.61	+3 55.06	−1.00	+0.07	......	02.44	
6728	17.116	31.1	33.3	......	43 25 31.40						
6748	21.225	32.1	32.2	......	54 40 45.53	−2 06.56	−0.44	−0.03	......	01.44	
6937	15.086	31.6	34.8	......	36 28 10.45						
6970	22.719	33.0	33.4	......	61 41 48.61	−3 56.83	−0.84	−0.07	......	01.84	
7024	15.105	32.3	33.6	......	61 51 24.75						
7073	23.724	31.1	35.0	......	36 02 03.62	+4 18.12	−1.16	+0.08	......	01.23	
7100	10.957	33.5	34.0	......	42 15 45.33						
7166	27.635	31.1	35.1	......	55 33 36.26	−[illegible] 35.18	−0.71	−0.15	......	02.45	
7215	12.063	31.0	32.5	......	57 07 36.57						
7277	25.237	30.5	35.0	......	40 10 53.50	+6 47.82	1.11	+0.11	......	01.86	
7329	22.638	33.0	34.1	......	38 09 31.55						
7-Yr. 2395	15.522	31.0	33.7	......	50 45 10.79	+3 40.79	−0.18	+0.06	......	49 01 01.84	

Observations for Latitude.—Station No. 8—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7377	28. 915	31. 7	33. 8	......	59 28 00. 65						
7398	11. 646	32. 2	36. 1	......	38 51 55. 60	−8 55. 81	−0. 67	−0. 16	......	49 01 01. 53	
7416	33. 461	35. 1	33. 1	......	62 02 59. 56						
7453	25. 510	32. 0	36. 3	......	36 07 19. 23	−4 06. 70	−0. 51	−0. 07	......	02. 11	
7489	19. 867	34. 5	34. 1	......	45 59 01. 05						
7489	20. 505	33. 0	35. 8	......	52 03 41. 56	−0 19. 89	−0. 53	−0. 01	......	02. 47	
7627	22. 995	33. 9	35. 8	......	25 19 51. 66						
7686	15. 635	34. 1	36. 1	......	72 34 36 51	+3 48. 35	−0. 87	+0. 08	......	49 01 01. 66	

Mean latitude (72 determinations), 49° 01′ 01″. 63.

$\epsilon = 0''.457$

$r = 0''.324$

$\epsilon_0 = 0''.0574$

$r_0 = 0''.0383$

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 9—Mouse River, 271 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′	″	″	″	° ′ ″	
6047 6073	26.020 9.158	28.5 27.2	26.2 28.5	....	72 12 48.12 26 01 24.80	−10 26.49	+0.33	−0.21	.....	48 58 10.09	August 19.
6114 6157	14.480 21.845	28.0 28.7	28.1 28.2	....	76 58 51.28 20 47 52.32	+ 4 48.50	+0.13	+0.10	......	10.53	
6268 6289	15.109 26.400	33.5 25.2	25.0 33.6	....	39 26 39.70 58 43 50.59	− 6 59.51	+0.03	−0.12	....	11.01	
6318 6365	15.637 26.212	30.4 29.7	28.7 31.0	....	59 28 04.61 38 15 10.43	+ 6 32.90	+0.13	+0.11	......	10.66	
6421 6476	21.831 18.942	28.3 33.4	33.0 29.3	....	49 17 40.03 48 42 11.83	− 1 47.34	−0.20	−0.03	......	09.86	
6553 6586	17.203 23.727	32.8 30.1	30.8 33.7	....	32 18 18.98 65 46 07.76	− 4 02.39	−0.52	−0.08	.....	10.38	
6624 6684	21.512 19.811	32.5 29.1	31.3 34.7	....	40 07 18.60 57 46 28.61	+ 1 03.20	−1.44	+0.02	......	10.08	
6728 6748	16.192 24.231	33.0 30.6	31.0 33.6	....	43 25 31.40 54 40 45.53	− 1 58.68	−0.33	−0.08	......	09.37	
6780 6817	22.230 19.415	30.6 34.8	33.7 30.0	....	57 43 01.05 40 16 48.32	− 1 43.17	+0.56	−0.03	......	11.74	
6937 6970	15.159 26.148	37.9 26.9	28.1 39.3	....	26 28 10.45 61 41 48.60	− 6 48.29	−0.85	−0.12		10.23	
7024 7073	20.851 23.150	30.8 38.7	35.5 28.3	....	61 51 24.75 36 02 03.62	+ 1 25.42	+1.87	+0.03	.....	11.51	
7100 7166	11.334 29.883	34.3 31.4	32.6 36.3	....	42 45 45.33 55 33 36.26	−11 28.80	−1.05	−0.20	....	10.74	
7215 7277	17.408 23.718	31.7 40.8	36.5 29.3	....	57 07 36.57 40 40 53.51	+ 3 54.44	+2.19	+0.07	......	11.74	
7627 7686	21.282 19.736	28.2 20.6	24.0 32.1	....	25 19 51.16 72 34 36.54	+ 0 57.44	−2.39	+0.02	....	09.17	
7755 7765	19.396 22.336	24.3 25.2	28.3 25.8	....	58 47 24.14 39 05 15.50	+ 1 51.46	−0.85	+0.03	....	10.46	
7787 7800	21.130 22.042	24.7 26.1	28.2 28.7	....	52 01 19.76 45 53 58.45	+ 0 33.88	−1.34	+0.01	....	11.65	
7962 8024	23.531 12.332	32.3 21.0	22.0 33.9	....	41 17 00.55 56 25 28.20	+ 6 56.09	−0.85	+0.12	......	09.74	
8026 8059	21.821 29.317	27.3 27.2	27.2 27.6	....	49 21 49.21 48 36 21.40	− 0 54.76	−0.10	−0.02	....	10.42	
8083 8128	18.961 23.117	24.8 28.5	29.8 26.5	....	56 28 06.64 11 23 06.07	+ 2 31.30	−0.98	+0.04	......	09.72	
8206 8273	26.701 16.485	27.0 25.5	28.1 30.0	....	30 37 36.74 67 06 05.71	+ 6 19.57	−1.83	−0.12	......	48 58 09.09	

Observations for Latitude.—Station No. 9—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
46	22.020	26.3	29.7	....	60 49 34.26						
67	14.500	33.0	23.1	....	37 16 00.20	− 4 39.40	+2.13	−0.06	....	48 58 09.90	
6047	29.448	25.7	33.0	....	72 12 48.22						
6073	12.595	33.0	26.7	....	26 04 24.87	−10 26.16	−0.33	−0.21	....	09.85	August 20.
6114	17.288	15.7	16.3	....	76 58 51.53						
6157	25.036	17.1	15.9	....	20 47 52.38	+ 4 47.87	+0.20	+0.10	....	10.12	
6268	16.539	16.5	17.8	....	39 26 30.83						
6289	27.863	19.1	15.5	....	58 43 50.74	− 7 00.73	+0.75	−0.12	....	10.69	
6318	16.024	16.0	18.9	....	59 28 04.76						
6365	26.575	19.8	16.0	....	38 15 10.56	+ 6 32.01	+0.29	+0.11	....	10.07	
6421	22.945	17.0	19.0	....	49 17 40.15						
6476	20.018	19.7	17.3	....	48 42 15.01	− 1 48.75	+0.13	−0.03	....	08.93	
6553	17.474	19.3	18.7	....	32 18 19.13						
6586	24.031	19.5	19.0	....	65 46 07.97	− 4 03.62	+0.36	−0.08	....	10.21	
6624	21.705	19.3	19.7	....	40 07 48.19						
6681	20.069	20.5	19.3	....	57 46 29.05	+ 1 00.78	+0.26	+0.02	....	09.68	
6728	16.435	21.9	18.8	....	43 25 31.61						
6748	24.494	19.8	21.1	....	54 49 45.77	− 4 59.42	+0.59	−0.08	....	09.78	
6780	22.852	19.2	21.9	....	57 43 01.30						
6817	20.029	23.0	18.5	....	40 16 48.54	− 1 44.89	+0.59	−0.03	....	10.59	
6937	15.735	21.9	20.8	....	36 28 10.69						
6970	26.748	20.8	21.9	....	61 41 48.89	− 6 49.18	0.00	−0.12	....	10.49	
7024	19.862	20.3	22.5	....	61 51 25.04						
7073	22.157	23.5	19.8	....	36 02 03.85	+ 1 25.27	+0.49	+0.03	....	10.23	
7100	11.907	22.3	21.0	....	42 45 45.58						
7166	30.473	21.6	22.0	....	55 33 36.56	−11 29.80	+0.29	−0.20	....	11.36	
7215	18.513	21.7	22.0	....	57 07 36.87						
7277	24.803	23.5	21.0	....	40 40 53.77	+ 3 53.70	+0.72	+0.07	....	09.81	
7320	21.451	22.8	22.0	....	38 09 31.81						
7-Yr. 2395	20.157	22.9	22.0	....	59 45 11.11	+ 0 48.08	+0.56	+0.02	....	10.12	
7377	31.136	22.3	22.6	....	59 28 00.98						
7398	12.056	23.5	21.7	....	38 51 55.96	−11 48.90	+0.49	−0.21	....	09.85	
7416	26.976	22.8	22.5	....	62 02 59.90						
7453	15.653	23.7	21.8	....	36 07 19.50	− 7 00.69	+0.72	−0.15	....	09.58	
7480	18.653	23.7	22.0	....	45 59 01.35						
7489	23.840	22.0	23.5	....	52 03 41.88	− 3 12.72	+0.07	−0.05	....	10.12	
7505	18.351	24.7	21.0	....	37 58 04.67						
7605	24.903	21.9	24.8	....	60 06 19.93	− 4 03.43	+0.26	−0.07	....	09.66	
7627	21.563	24.5	22.3	....	25 19 51.89						
7686	20.111	23.2	23.9	....	72 34 36.91	+ 0 53.95	+0.49	+0.02	....	08.85	
7755	19.864	22.7	21.5	....	55 47 24.44						
7765	22.792	25.2	22.0	....	39 05 15.79	+ 1 48.79	+0.46	+0.03	....	09.39	
7787	21.937	22.6	24.3	....	52 01 20.09						
7800	22.738	25.0	22.3	....	45 53 58.78	+ 0 29.76	+0.33	+0.01	....	09.54	
7962	26.859	25.2	23.0	....	41 17 00.86						
8024	15.666	24.0	24.6	....	56 25 28.55	+ 6 55.86	+0.52	+0.12	....	11.20	
8036	22.316	21.6	27.1	....	49 21 19.55						
8059	20.796	28.3	20.5	....	48 36 21.75	− 0 56.47	+0.75	−0.02	....	09.91	
8083	19.533	23.8	25.2	....	56 28 07.01						
8124	23.605	27.6	21.8	....	41 23 05.38	+ 2 31.29	+1.11	+0.01	....	48 58 09.4[illegible]	

Observations for Latitude.—Station No. 9—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
8206 8273	26. 272 16. 144	26. 8 25. 3	23. 0 24. 8	....	70 37 37. 02 67 06 06. 08	+ 6 15. 55	+1. 41	+0. 12	......	48 58 08. 63	
8314 8324	25. 893 16. 010	24. 8 28. 2	25. 3 21. 9	....	53 42 13. 50 21 26 17. 80	− 6 06. 08	+1. 90	−0. 12	......	11. 35	
46 67	27. 842 20. 280	26. 3 25. 4	21. 5 25. 8	....	60 49 31. 46 37 16 00. 49	− 4 40. 96	+0. 46	−0. 06	......	06. 92	Rejected.
120 175	11. 650 30. 780	25. 0 27. 0	26. 3 24. 6	....	32 52 57. 34 65 27 01. 65	−11 50. 76	+0. 36	−0. 22	......	08. 88	
198 219	23. 541 20. 028	27. 0 26. 5	21. 5 24. 7	....	47 35 24. 17 50 16 32. 29	+ 2 10. 15	+1. 41	+0. 03	......	09. 82	
239 259	28. 256 13. 723	21. 5 33. 0	29. 9 18. 5	....	60 25 38. 04 37 48 42. 14	− 9 01. 07	+2. 00	−0. 16	......	10. 86	
12-Yr. 73 345	19. 482 23. 636	27. 0 25. 0	24. 5 26. 6	....	67 06 03. 50 30 45 02. 97	+ 2 34. 34	+0. 29	+0. 05	......	07. 92	
401 458	27. 542 15. 355	27. 2 27. 2	24. 9 25. 1	....	28 01 34. 61 69 36 39. 90	+ 7 33. 54	+1. 44	+0. 14	......	09. 38	
6114 6157	16. 727 24. 528	21. 0 22. 7	22. 2 22. 0	....	76 58 51. 52 20 47 52. 46	+ 4 49. 84	−0. 16	+0. 10	......	11. 77	August 21.
6268 6289	15. 413 26. 693	23. 4 22. 3	23. 3 23. 6	....	39 26 20. 84 58 43 50. 88	− 6 59. 10	−0. 05	−0. 12	......	11. 57	
6318 6365	15. 648 26. 240	23. 0 23. 6	24. 0 24. 1	....	59 28 04. 89 38 15 10. 70	+ 6 33. 54	−0. 49	+0. 11	......	10. 96	
6421 6456	21. 740 18. 829	22. 7 25. 2	25. 0 23. 0	....	49 17 43. 26 48 42 15. 17	− 1 48. 16	−0. 03	−0. 03	......	09. 54	
6553 6586	17. 492 24. 027	24. 6 24. 8	23. 9 21. 5	....	32 18 19. 27 65 46 08. 19	− 4 02. 80	+0. 33	−0. 08	......	11. 18	
6624 6681	22. 040 20. 378	24. 8 25. 9	25. 0 24. 8	....	40 07 48. 36 57 46 29. 04	− 1 01. 75	+0. 29	+0. 02	......	10. 76	
6728 6748	15. 935 23. 965	25. 2 26. 5	26. 1 25. 2	....	43 25 31. 81 54 40 45. 99	− 4 58. 35	+0. 13	−0. 08	......	10. 60	
6780 6817	22. 542 19. 711	24. 7 23. 2	27. 2 22. 8	....	57 13 01. 43 40 16 49. 73	− 1 45. 18	+1. 28	−0. 03	......	11. 65	
6937 6970	15. 310 26. 529	27. 8 27. 3	25. 6 26. 3	....	36 28 10. 90 61 11 49. 16	− 6 49. 40	+1. 05	−0. 12	......	11. 56	
7320 7-Yr. 2495	21. 537 20. 191	21. 0 18. 3	19. 0 21. 7	....	38 09 32. 05 59 45 11. 43	0 50. 01	−0. 46	+0. 02	......	11. 31	
7377 7398	20. 293 11. 248	19. 8 20. 3	20. 5 20. 0	....	59 28 01. 20 38 51 56. 21	11 47. 60	−0. 13	−0. 21	......	10. 82	
7416 7453	26. 514 15. 245	20. 8 19. 5	19. 5 20. 9	....	62 02 40. 22 36 07 19. 75	− 6 58. 69	−0. 03	−0. 15	......	11. 11	
7480 7489	18. 115 23. 267	21. 0 18. 3	19. 4 21. 9	....	15 59 04. 72 52 04 45. 18	− 3 11. 42	−0. 65	−0. 05	......	11. 33	
7505 7605	18. 938 25. 435	19. 5 20. 0	20. 9 21. 3	....	37 58 01. 93 60 06 20. 26	− 4 01. 39	−0. 88	−0. 07	......	10. 56	
7627 7686	21. 379 19. 876	20. 9 19. 3	20. 5 22. 3	....	25 19 52. 10 72 34 37. 26	+ 0 55. 84	−0. 85	+0. 02	......	09. 69	
7755 7765	19. 430 22. 369	20. 7 21. 0	21. 0 20. 8	....	58 47 21. 78 39 05 16. 08	+ 1 49. 20	−0. 03	+0. 03	......	09. 63	
7787 7800	21. 387 22. 253	20. 7 21. 0	21. 0 20. 8	....	52 01 20. 42 45 53 59. 08	+ 0 32. 18	−0. 03	+0. 01	......	48 58 11. 91	

Observations for Latitude.—Station No. 9—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	R frac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
*7820	13. 503	21. 0	20. 8	....	48 50 06. 00						
7882	28. 590	20. 2	22. 0	....	49 24 56. 65	− 9 20. 54	−0. 52	−0. 16	...	48 58 10. 10	
7962	26. 777	21. 8	20. 8	....	41 17 01. 16						
8024	15. 594	20. 0	22. 6	....	56 25 28. 90	+ 6 55. 49	−0. 52	+0. 12	....	10. 12	
8036	21. 783	20. 7	22. 0	....	49 21 49. 88						
8059	20. 282	22. 0	20. 8	....	48 36 22. 06	− 0 55. 77	−0. 03	−0. 02	....	10. 15	
8083	18. 519	20. 8	22. 0	....	56 28 07. 35						
8128	22. 657	21. 5	20. 8	....	41 23 06. 68	+ 2 33. 74	−0. 16	+0. 04	....	10. 64	
8206	26. 341	21. 0	21. 0	......	30 37 37. 28						
8273	16. 145	20. 7	21. 1	....	67 06 06. 86	+ 6 18. 82	−0. 16	+0. 12	....	10. 85	
8314	25. 885	20. 7	21. 1	....	73 42 13. 85						
8324	16. 053	21. 0	20. 8	....	24 26 18. 04	− 6 05. 30	−0. 07	−0. 12	....	10. 45	
46	24. 850	20. 3	22. 5	....	60 49 34. 83						
67	17. 315	22. 6	20. 6	....	37 16 00. 76	− 4 39. 96	−0. 07	−0. 06	....	07. 71	Rejected.
120	11. 619	22. 0	21. 2	....	32 52 57. 60						
175	30. 670	21. 6	22. 0	....	65 27 01. 97	−11 47. 77	+0. 13	−0. 22	....	11. 92	
198	23. 283	22. 0	21. 7	....	47 35 24. 51						
219	19. 759	21. 6	22. 0	....	50 16 32. 59	+ 2 10. 93	−0. 03	+0. 03	......	09. 48	
239	28. 692	21. 8	22. 0	....	60 25 38. 46						
259	14. 173	22. 5	21. 2	....	37 48 42. 41	− 8 50. 44	+0. 36	−0. 16	......	11. 19	
12-Yr. 73	19. 053	21. 7	22. 3	....	67 06 03. 81						
345	23. 243	21. 1	23. 0	....	30 45 03. 22	+ 2 35. 68	−0. 82	+0. 05	....	08. 43	
401	27. 372	21. 9	23. 0	....	28 04 34. 84						
438	15. 119	23. 0	22. 0	....	69 36 31. 18	+ 7 35. 25	−0. 03	+0. 14	....	48 58 09. 87	

Mean latitude (80 determinations), 48° 58′ 10″.29.

$\epsilon = \pm\ 0''.8721$
$\tau = \pm\ 0''.5882.$
$\epsilon_0 = \pm\ 0''.0974.$
$\tau_0 = \pm\ 0''.0658.$

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 10—Mid Coteau, 312 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7787 7800	15.864 21.667	25.5 28.0	28.6 26.5	....	52 01 25.06 45 54 03.33	+ 3 00.05	−0.36	+0.05	......	49 00 43.94	September 4.
7820 7882	12.888 26.110	26.5 27.7	28.0 27.3	....	48 50 10.55 49 25 01.24	− 6 50.25	−0.25	−0.12	......	45.27	
7962 8024	28.358 10.161	29.0 26.0	26.0 29.8	....	41 17 05.38 56 25 33.81	+ 9 24.61	−0.18	+0.17	......	44.20	
8036 8059	17.321 20.360	25.5 31.6	30.0 24.0	....	49 21 54.47 48 36 26.64	+ 1 34.29	+0.69	+0.02	......	45.55	
8083 8128	14.876 24.642	27.0 28.5	28.6 27.2	....	56 28 12.21 41 23 10.91	+ 5 03.01	−0.07	+0.09	......	44.61	
8206 8273	27.006 10.581	31.0 26.0	25.3 31.1	....	30 37 40.87 67 06 11.50	+ 8 48.24	+0.14	+0.17	......	44.73	
8314 8324	22.175 15.284	29.0 27.0	28.6 30.1	....	76 42 18.98 21 26 21.16	− 3 33.81	−0.47	−0.07	......	45.72	
46 67	21.380 17.205	30.2 27.0	28.0 31.0	....	60 49 38.98 37 16 04.51	− 2 09.54	−0.40	−0.03	......	41.78	Rejected.
120 175	9.720 27.754	32.3 25.6	25.4 32.9	....	32 53 01.16 65 27 06.64	− 9 18.62	−0.09	−0.17	......	45.02	
239 259	25.061 12.477	28.1 31.1	30.1 27.2	....	60 25 42.91 37 48 45.98	− 6 30.45	+0.42	−0.11	......	44.32	
Gr. 12-Yr. 73 345	13.528 23.406	29.4 29.0	29.7 30.0	....	67 06 08.24 30 45 06.47	+ 5 06.49	−0.29	+0.10	......	43.65	
401 438	28.762 9.230	32.2 26.9	26.7 32.1	....	28 01 37.87 69 36 38.41	+10 06.03	+0.07	+0.19	......	44.43	
6421 6456	18.631 20.011	21.0 22.1	21.6 21.3	....	49 17 42.78 48 42 17.70	+ 0 43.75	+0.04	+0.01	......	44.04	September 5.
6553 6586	18.458 21.457	24.0 23.1	20.6 21.7	....	32 18 21.47 65 46 11.32	− 1 33.05	+1.07	−0.03	......	44.39	
6624 6681	21.325 17.515	23.9 24.0	21.4 21.1	....	40 07 51.01 57 46 32.32	+ 3 31.30	+1.27	+0.06	......	44.29	
6728 6748	17.813 22.570	23.2 22.1	22.0 23.1	....	46 25 34.82 51 40 49.42	− 2 27.60	+0.04	−0.04	......	44.52	
6780 6817	19.506 20.989	22.7 21.9	22.9 24.0	....	57 43 05.09 40 16 51.80	+ 0 46.01	−0.51	+0.02	......	43.97	
6937 6970	16.153 24.516	23.6 21.0	22.8 22.5	....	36 28 14.03 61 41 53.25	− 4 19.48	+0.51	−0.08	......	44.59	
7024 7073	17.001 24.581	22.7 25.4	24.3 22.0	....	61 51 29.53 36 02 07.38	+ 3 55.19	+0.40	+0.07	......	44.11	
7100 7166	11.510 28.946	23.3 25.9	24.0 22.0	....	42 45 49.51 55 33 41.10	− 9 01.00	+0.71	−0.16	......	44.86	
7215 7257	14.222 26.610	23.3 26.0	24.4 22.0	....	57 07 41.56 40 40 57.86	+ 6 24.37	+0.65	+0.11	......	49 00 44.84	

Observations for Latitude.—Station No. 10—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7320	23.287	24.6	23.4	....	38 09 35.80						
7-Yr. 2395	16.910	25.0	23.0	....	59 45 16.12	+ 3 17.86	+0.71	+0.05	......	49 00 44.58	
7377	29.190	23.4	24.7	....	59 28 06.05						
7398	11.171	26.3	21.8	....	38 52 00.13	− 9 19.08	+0.71	−0.16	......	44.56	
7416	24.146	26.3	21.8	....	62 03 05.12						
7453	15.432	23.3	25.0	....	36 07 23.56	− 4 30.37	+0.62	−0.08	......	44.51	
7480	19.959	25.5	23.0	....	45 59 06.02						
7489	21.367	25.0	23.8	....	52 03 49.86	− 0 43.68	+0.83	−0.02	......	45.07	
7505	18.861	23.2	25.9	....	37 58 09 33						
7605	21.868	28.0	22.1	....	60 06 25.35	− 1 33.30	+0.71	−0.03	......	44.72	
7627	23.489	29.3	20.7	....	25 19 55.36						
7686	16.887	22.0	28.5	....	72 34 42.70	+ 3 24.84	+0.47	+0.07	......	44.41	
7755	15.425	23.5	13.2	....	58 47 29.95						
7765	23.866	07.2	29.6	....	39 05 20.31	+ 4 21.90	−2.70	+0.08	......	41.41	
7962	29.470	19.3	17.0	....	41 17 06.15						
8024	11.310	16.3	20.2	....	56 25 34.11	+ 9 23.46	−0.36	+0.17	......	43.40	
8036	18.412	18.0	18.8	....	49 21 54.78						
8059	21.472	17.5	19.1	....	48 36 26.95	+ 1 34.01	−0.53	+0.02	......	44.36	
8083	15.931	17.5	19.0	....	56 28 12.78						
8128	25.589	17.8	19.0	....	41 23 11.19	+ 4 59.66	−0.60	+0.09	......	41.04	Rejected.
8206	28.365	18.5	19.0	....	30 37 41.59						
8273	11.375	20.7	18.3	....	67 06 11.86	+ 8 47.16	+0.42	+0.17	......	44.47	
8314	23.135	18.9	19.1	....	73 42 19.36						
8324	16.189	19.7	18.1	....	24 26 21.40	− 3 35.52	+0.31	−0.07	......	45.10	
8366	16.335	19.1	19.0	....	60 36 32.21						
67	24.896	20.0	19.5	....	37 16 04.89	+ 4 25.63	+0.14	+0.08	......	44.40	
120	20.145	20.0	19.6	....	32 53 01.41						
175	28.178	20.6	19.0	....	65 27 06.99	− 9 19.52	+0.44	−0.17	......	44.95	
198	25.551	21.5	18.0	....	47 35 28.94						
219	16.510	18.2	21.0	....	50 16 37.11	+ 4 40.52	+0.16	+0.08	......	43.79	
239	26.819	20.5	19.0	....	60 25 43.29						
259	14.249	19.0	20.2	....	37 48 46.36	− 6 30.02	+0.07	−0.11	....	44.76	
Gr. 12-Yr. 73	15.181	19.8	19.3	....	67 06 08.59						
345	25.045	19.7	19.5	....	30 45 06.70	+ 5 06.06	+0.16	+0.10	.....	43.97	
401	29.978	19.6	19.5	....	28 04 38 10						
438	10.461	18.4	20.3	....	69 36 38.75	+10 05.56	−0.40	+0.19	......	43.77	
474	13.137	24.6	13.6	....	48 04 30 45	− 6 28.31	+0.42	−0.11	......	44.69	
{ 487	18.327	24.6	13.6	....	47 59 08.75						
{ 522	18.942	14.7	23.6	....	50 02 53.58	− 0 19.08	+0.47	−0.01	......	42.55	
560	25.652	14.7	23.8	....	50 09 54.93						
611	24.981	20.0	18.5	....	63 46 33.26						
656	16.943	18.3	20.3	....	34 23 17.15	− 4 09.40	−0.11	−0.07	....	45.63	
744	21.073	19.3	20.0	....	66 49 47.47						
752	18.929	20.2	19.0	....	31 13 57.30	− 1 06.52	+0.11	−0.02	....	45.95	
825	9.635	19.2	20.4	....	19 28 21.25						
896	30.480	21.7	18.9	....	78 54 43.01	−10 46.77	+0.36	−0.25	......	45.47	
979	14.099	20.0	21.0	....	77 15 47.29						
999	24.882	20.9	19.6	....	20 34 32.00	+ 5 34.57	+0.07	+0.12	......	44.15	
1029	16.112	21.0	19.3	....	25 12 22.92						
1067	21.539	19.7	21.0	....	72 54 43.10	− 2 48.39	+0.00	−0.05	......	49 00 44.65	

Observations for Latitude.—Station No. 10—Continued.

B. A. C. No.	Readings. Microm.	Level. N.	Level. S.	Merid. dist.	Declination.	Corrections. Microm.	Level.	Refrac.	Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″		″	° ′ ″	
1203	21.964	22.1	18.4	......	62 41 46.81						
1228	16.251	20.0	20.9	......	55 25 32.13	− 2 24.06	−0.62	−0.05	......	49 00 45.98	
1274	26.777	19.0	21.7	......	50 09 15.71						
1287	23.691	22.0	18.6	......	48 05 03.98	− 1 54.37	−0.16	−0.03	......	45.61	
6421	19.272	17.6	18.0	......	49 17 42.83						
6476	20.722	17.0	19.1	......	48 42 17.82	+ 0 44.99	−0.56	+0.01	......	44.81	September 6
6573	18.247	19.5	17.0	......	52 18 21.56						
6586	21.212	17.5	19.5	......	65 46 11.45	− 1 32.03	+0.11	−0.03	......	44.55	
6624	23.843	19.7	17.2	......	40 07 51.14						
6681	16.974	1[illegible].4	20.2	......	57 46 52.48	+ 3 33.16	−0.07	+0.06	......	44.96	
6728	17.105	19.0	19.2	......	43 25 34.97						
6748	22.343	19.0	19.2	......	54 40 43.59	− 2 27.07	−0.09	−0.04	......	45.08	
6780	19.274	18.0	20.5	......	57 43 05.28						
6817	20.780	20.0	19.0	......	40 16 51.96	− 0 47.04	−0.33	+0.02	......	45.35	
6937	15.828	20.0	19.5	......	36 28 14.18						
6970	24.162	20.5	19.4	......	61 41 53.47	− 4 18.58	−0.36	−0.08	......	45.53	
7024	16.922	20.0	20.0	......	61 51 29.76						
7073	24.542	19.2	21.0	......	36 02 07.56	− 3 57.05	−0.40	+0.07	......	45.38	
7100	11.327	20.5	19.7	......	42 45 49.71						
7166	28.717	20.0	20.6	......	55 33 41.54	− 6 56.47	+0.04	−0.16	......	48.94	Rejected.
7215	14.010	20.2	20.2	......	57 07 41.80						
7277	26.305	20.0	21.0	......	40 40 52.66	+ 6 24.51	−0.22	+0.11	......	44.13	
7320	23.041	20.5	20.4	......	38 09 36.00						
7-Yr. 2395	16.674	22.0	19.0	......	59 45 16.38	− 3 17.65	+0.69	+0.05	......	44.58	
7377	29.171	19.8	22.0	......	59 28 06.32						
7398	11.210	22.4	19.6	......	38 52 00.34	− 9 17.25	+0.14	−0.16	......	46.06	
7416	24.397	22.1	20.0	......	62 03 05.40						
7453	15.713	20.7	21.7	......	36 07 23.77	− 4 29.44	+0.25	−0.08	......	45.31	
7480	20.069	22.1	20.3	......	45 50 06.26						
7489	21.490	21.2	21.2	......	52 03 50.14	− 0 44.1[illegible]	−0.40	−0.02	......	44.45	
7505	18.671	25.1	17.3	......	37 58 00.12						
7605	21.680	18.5	25.1	......	60 06 25.86	− 1 33.33	−0.27	−0.03	....	44.40	
7627	23.486	21.2	22.4	......	25 19 55.53						
7686	16.800	23.2	21.2	......	72 34 43.02	3 24.65	+0.18	+0.07	......	44.19	
7755	16.016	23.2	21.6	......	58 47 30.25						
7765	24.388	21.4	23.5	......	39 05 20.55	+ 4 19.76	−0.11	+0.08	......	45.13	
7787	17.226	22.1	22.8	......	52 01 25.66						
7800	23.068	23.0	22.2	......	45 54 03.97	[illegible] 01.26	−0.02	+0.05	......	46.15	
7820	13.972	24.0	21.0	......	48 50 11.13						
7882	27.212	21.8	21.2	......	49 25 01.84	− 6 50.74	+0.14	−0.12	....	45.76	
7962	29.427	22.7	23.7	0.5	41 17 05.91						
8024	11.233	23.6	23.3	......	56 25 34.42	9 25.51	−0.16	+0.17	+0.01	44.70	
8036	18.541	23.1	23.9	......	49 21 57.17						
8050	21.597	27.1	23.6		48 30 27.25	1 35.82	−0.29	[illegible]	....	4[illegible].71	
8083	15.877	23.3	23.4		56 28 12.90						
8128	25.625	23.0	24.0		41 2[illegible] 11.45	− 5 12.46	−0.25	+0.03	....	49 00 44.48	

Mean of station (65 determinations) 49 00 44.73

[illegible]

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 11—Bully Spring, 363 miles west of Pembina.—Observer, J. F. Gregory, United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6937	16.380	15.2	17.0	....	36 27 75.73						
6970	24.002	17.0	15.3	......	61 41 55.47	− 3 56.49	−0.02	−0.07	......	49 01 09.02	September 11.
7024	16.264	18.4	14.0	......	61 51 31.82						
7073	24.570	14.5	18.0	......	36 02 09.17	+ 4 17.71	−0.20	+0.08	......	08.49	
7100	11.697	17.1	15.4	......	42 45 51.51						
7166	28.350	15.5	17.6	......	55 33 43.46	− 8 36.70	−0.09	−0.15	......	10.54	
7215	13.186	17.1	16.1	......	57 07 43.99						
7277	26.399	16.8	18.0	......	40 40 59.96	− 6 47.79	−0.04	−0.12	......	09.85	
7320	23.491	20.0	15.1	......	38 09 37.86						
7-Yr. 2395	16.338	14.3	21.1	......	59 45 18.76	+ 3 41.94	−0.42	−0.06	......	09.89	
7377	28.683	19.3	17.0	......	59 28 08.74						
7398	11.438	15.3	21.0	......	38 52 02.28	− 8 57.07	−0.76	−0.16	......	09.52	
7416	23.802	21.0	15.3	......	62 03 07.92						
7453	15.846	14.3	22.3	......	36 07 25.68	− 4 06.85	−0.51	−0.07	......	09.37	
7480	19.622	19.1	17.7	......	45 58 08.48						
7489	20.260	17.0	20.5	......	52 03 52.49	− 0 19.80	−0.47	−0.01	......	10.20	
7627	23.864	23.0	14.4	......	25 19 56.99						
7686	16.524	14.1	23.7	......	72 34 45.95	− 3 47.74	−0.22	+0.08	......	09.67	
7755	15.451	18.0	20.1	......	58 47 32.95						
7765	24.530	18.7	19.4	......	39 05 22.73	+ 4 41.70	−0.62	−0.08	......	09.00	
7787	17.430	18.3	19.7	......	52 01 28.22						
7800	23.981	18.3	19.5	......	45 54 06.41	− 3 23.26	−0.58	−0.06	......	10.05	
7820	14.309	17.0	20.7	......	48 50 13.61						
7882	26.822	20.0	18.9	......	49 25 04.35	− 6 28.25	−0.58	−0.11	......	10.04	
7962	29.415	20.5	17.7	......	41 17 08.23						
8024	10.560	19.0	18.0	......	56 25 37.20	+ 9 45.02	−0.85	+0.17	......	08.76	
8036	18.093	17.7	19.1	......	49 21 57.67						
8059	21.778	20.2	16.0	......	48 36 20.82	+ 1 54.34	−0.62	+0.03	......	08.74	
8083	15.571	18.2	17.5	......	56 28 17.67						
8128	26.022	17.0	18.6	......	41 23 13.81	+ 5 24.27	−0.20	−0.10	......	08.91	
8206	29.640	17.0	18.6	......	30 37 43.28						
8273	10.918	16.5	19.0	......	67 06 15.17	+ 9 09.87	−0.91	+0.17	......	08.36	
6624	24.776	13.0	16.7	......	40 07 52.45						
6681	17.237	20.3	10.0	......	57 45 31.15	+ 3 53.92	−1.47	+0.07	......	08.76	September 15.
6728	18.058	16.0	14.2	......	43 25 36.52						
6748	22.063	14.0	16.6	......	54 40 51.36	− 2 04.36	−0.18	−0.03	......	09.37	
6780	18.370	15.3	15.2	......	57 43 07.14						
6837	20.627	15.3	16.0	......	40 16 53.56	+ 1 09.76	−0.14	0.00	......	09.97	
6937	16.195	17.3	16.1	......	36 28 17.84						
6970	23.839	17.7	16.7	......	61 41 57.60	− 3 [illegible]	+0.40	−0.07	......	49 01 [illegible]	

Observations for Latitude.—Station No. 11—Continued.

B. A. C. No.	Readings.					Corrections.				Latitude.	Remarks.
	Microm	Level. N.	Level. S.	Merid. dist.	Declination.	Microm.	Level.	Refrac	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7024	15.743	17.0	17.4	....	61 51 32.06						
7073	24.063	18.8	15.7	....	36 02 09.34	+ 4 18.15	−0.40	+0.08	.....	49 01 09.53	
7100	12.196	19.6	15.0	....	42 45 51.72						
7106	28.882	16.4	18.0	....	55 33 43.70	− 8 37.73	+0.67	−0.15	......	10.50	
7215	13.348	17.2	17.0	....	57 07 44.24						
7257	26.401	18.1	16.5	....	40 41 00.18	+ 6 45.00	+0.40	+0.12	.....	07.73	
7320	23.183	19.0	16.3	....	38 09 38.08						
7-Yr. 2395	16.112	19.0	17.0	....	59 44 39.63	+ 3 39.40	+1.05	+0.06	......	09.67	
7377	29.0[illegible]5	17.7	18.5	....	59 27 09.03						
7398	11.713	20.3	15.7	....	38 51 02.52	− 8 56.53	−0.85	−0.16	......	09.93	
7416	23.913	20.4	16.0	....	62 02 08.21						
7453	15.892	18.0	18.3	....	56 07 25.91	− 4 08.87	+0.91	−0.07	......	09.03	
7480	20.021	19.1	17.5	....	45 59 08.74						
7489	20.741	19.8	17.0	....	52 03 52.78	− 0 22.31	−0.18	−0.61	......	09.39	
7627	23.841	19.1	18.2	....	25 19 57.24						
7686	16.529	18.9	19.1	....	72 34 46.28	+ 2 46.87	+0.16	+0.08	......	08.87	
7755	16.257	19.5	19.0	....	58 47 33.29						
7765	25.294	19.0	19.5	....	29 05 23.00	+ 4 40.40	0.00	+0.03	.....	08.63	
7787	17.020	19.7	18.8	....	52 00 58.55						
7800	23.532	19.0	19.4	....	45 51 06.72	+ 3 22.65	+0.11	+0.06	.....	09.85	
7820	14.849	17.2	21.0	....	48 50 13.92						
7882	27.430	23.2	16.0	....	49 24 04.68	− 6 30.26	+0.76	−0.11	.....	09.79	
7962	29.770	20.0	20.0	....	41 17 08.53						
8024	10.938	21.9	18.7	....	56 25 37.56	+ 9 41.31	+0.71	+0.17	....	08.24	
8036	18.752	37.0	03.3	....	49 21 58.00						
8059	22.457	03.6	37.0	....	48 36 30.15	+ 1 54.96	+0.67	+0.03	......	09.13	
8083	14.851	22.0	18.4	....	56 28 16.03						
8128	25.264	19.8	21.0	....	41 23 14.11	+ 5 23.09	+0.53	+0.10	......	08.79	
8206	28.800	21.0	20.0	....	30 37 43.51						
8273	11.141	22.0	19.5	....	67 06 15.57	+ 9 07.01	−0.78	+0.17	......	08.42	
8314	22.977	21.7	20.0	....	73 42 23.16						
8324	16.706	21.0	20.3	....	24 26 23.51	− 3 14.57	+0.53	−0.07	......	09.22	
46	28.112	21.0	20.7	....	60 40 49.07						
67	24.564	22.0	19.5	....	37 16 07.55	− 1 50.03	+0.62	−0.03	.....	08.81	
120	11.045	20.3	21.0	....	72 53 03.88						
175	28.407	23.0	19.0	....	65 27 10.52	− 8 58.70	+0.74	−0.17	......	09.07	
198	25.207	20.2	20.1	....	47 35 31.97						
219	15.525	23.0	18.1	....	50 16 40.21	+ 5 00.41	−1.11	+0.08	..	07.69	
239	26.021	21.5	20.0	....	60 25 46.05						
259	14.110	21.8	19.0	....	37 48 48.96	− 6 09.57	−0.96	−0.10	.....	09.10	
Gr. 12-Yr. 73	14.879	21.1	19.0	....	67 06 11.98						
345	25.409	19.7	21.0	....	30 41 08.96	+ 5 27.34	+0.25	+0.10	......	08.16	
474	14.048	25.5	17.1	....	48 04 33.19						
487	10.229	25.5	15.1	....	47 59 11.48						
522	19.181	17.0	23.8	....	50 03 01.57	− 0 01.49	−0.80	0.00	..	08.82	
560	25.861	16.8	23.8	....	50 09 57.14	− 6 06.78	−0.76	−0.10	..	09.29	
611	23.613	19.0	21.7	....	63 46 36.27						
656	16.243	23.0	17.7	....	31 23 19.21	− 3 48.67	−0.78	−0.17		09.58	
744	20.461	21.0	20.0	....	66 49 49.72						
752	19.000	20.2	20.6	....	31 13 53.11	− 0 45.33	−0.11	−0.02	.....	49 01 09.12	

Observations for Latitude.—Station No. 11—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
825	9.996	21.7	19.4	....	19 28 22.60						
896	30.150	20.5	20.5	....	78 54 45.42	−10 25.33	+0.51	−0.24	......	49 01 08.95	
979	13.740	20.7	20.4	....	77 15 19.48						
999	25.245	21.0	19.7	....	20 34 33.10	+ 5 56.97	+0.36	+0.13	......	08.85	
1101	16.758	19.5	21.1	....	25 12 24.28						
1127	21.498	23.4	17.1	....	72 54 45.07	− 2 27.07	+1.05	−0.05	......	08.61	
1203	22.920	21.0	19.3	....	62 41 48.36						
1228	18.021	20.6	19.6	....	35 25 33.33	− 2 32.00	+0.60	−0.04	......	09.40	
1254	21.869	22.2	17.7	....	50 00 16.85						
1287	18.890	19.0	20.7	....	48 05 05.18	− 1 32.43	+0.62	−0.02	......	09.18	
6624	23.926	12.8	11.7	....	40 07 52.54						
6681	16.419	17.1	07.9	....	57 46 34.28	+ 3 52.92	+2.30	+0.07	......	08.70	September 16.
6728	17.802	9.3	15.7	....	44 25 36.64						
6748	21.818	13.0	12.0	....	54 40 51.50	− 2 04.61	−1.20	−0.03	......	08.23	
6780	18.883	14.1	10.7	....	57 43 07.29						
6817	21.108	9.5	15.6	....	40 16 53.69	+ 1 09.04	−0.60	+0.00	......	08.93	
6937	16.638	15.4	10.6	....	36 28 15.98						
6970	24.285	11.2	15.0	....	61 41 55.91	− 3 57.27	+0.22	−0.07	......	08.85	
7024	16.208	11.1	12.0	....	61 51 32.27						
7073	24.506	12.1	14.2	....	36 02 09.50	+ 4 17.47	0.00	+0.08	......	08.84	
7100	11.797	14.0	12.5	....	42 45 51.90						
7166	28.481	12.7	14.0	....	55 33 43.93	− 8 37.66	+0.04	−0.15	......	10.14	
7215	13.310	14.0	13.4	....	57 07 44.48						
7277	26.408	13.8	14.1	....	40 40 00.38	+ 6 46.40	+0.07	+0.12	......	09.02	
7787	17.290	7.4	22.2	....	52 01 28.84						
7800	23.748	23.6	6.1	....	45 54 07.00	+ 3 20.38	+0.60	+0.06	......	08.96	
7820	11.768	15.2	14.7	....	48 50 14.22						
7882	27.378	18.0	12.0	....	49 25 04.99	− 6 31.26	+1.45	−0.11	......	09.68	
7962	29.672	19.0	12.0	....	41 17 08.81						
8024	10.882	16.5	14.7	....	56 25 37.90	+ 9 43.01	+1.9[illegible]	+0.17	......	08.50	
8036	18.190	15.0	16.0	....	49 21 58.33						
8059	21.854	18.0	13.0	....	48 36 30.48	+ 1 53.68	+0.89	+0.03	......	09.01	
8083	15.180	17.6	13.4	....	56 28 16.39						
8128	25.581	17.0	11.0	....	41 22 71.41	+ 5 22.72	+1.61	+0.10	......	09.83	
8206	28.886	16.0	15.8	....	30 37 43.79						
8273	11.211	16.8	15.8	....	67 06 15.95	+ 9 08.11	+0.27	+0.17	......	08.72	
8314	22.958	18.0	14.2	....	73 42 23.56						
8324	16.670	14.7	17.4	....	21 26 23.73	− 3 15.10	+0.25	−0.07	......	49 01 08.73	

Mean latitude (64 determinations), 49° 01′ 08″.11.

$\varepsilon = 0''.613$
$\tau = 0''.408$
$\varepsilon_0 = 0''.077$
$\tau_0 = 0''.051$

1873.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 12—408 miles west of Pembina.—Observer, J. F. Gregory, Lieutenant United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1481.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7100	10.336	14.0	17.0	......	42 45 52.47						
7106	30.243	18.0	13.8	......	55 33 44.65	−10 17.66	+0.27	−0.18	......	48 59 30.99	September 20. Rejected.
7215	11.907	14.3	17.0	......	57 07 15.21						
7277	24.783	16.0	15.8	......	40 41 01.00	− 5 06.43	−0.56	+0.09	......	29.08	
7320	22.027	15.0	16.5	......	38 09 38.88						
7-Yr. 2395	18.179	14.7	17.0	......	59 45 20.17	+ 1 59.39	−0.85	−0.03	......	28.09	
7377	30.500	14.7	17.0	......	59 28 10.50						
7398	9.973	16.8	14.6	......	38 52 03.59	−10 36.90	−0.62	−0.19	......	29.69	
7416	25.685	15.0	17.0	......	62 03 09.49						
7453	14.415	19.0	13.0	......	36 07 26.76	− 5 48.75	−0.89	−0.10	......	30.16	
7480	18.233	14.2	17.5	......	45 59 09.80						
7489	22.181	18.5	13.8	......	52 03 53.54	− 2 02.70	−0.31	−0.03	......	29.65	
7505	17.639	17.0	15.0	......	37 58 12.31						
7605	23.206	15.3	17.1	......	60 06 23.93	− 2 52.73	+0.04	−0.05	......	28.[illegible]	
7627	22.029	15.7	16.9	......	25 19 58.18						
7686	17.973	18.0	11.7	......	72 34 47.78	− 2 05.85	−0.47	−0.04	......	29.24	
7755	17.073	13.0	19.8	......	58 47 34.72						
7765	22.840	20.0	12.8	......	39 05 24.0[illegible]	+ 2 58.94	+0.09	+0.65	......	28.48	
7787	18.981	17.3	15.0	......	52 01 29.89						
7800	22.224	14.2	17.9	......	45 54 07.96	+ 1 40.62	−0.31	+0.02	......	29.23	
6553	16.757	13.8	12.8	......	32 18 22.90						
6586	22.259	14.8	12.0	......	65 46 13.58	− 2 50.71	+0.85	−0.06	......	28.32	September 21.
6624	22.466	14.8	11.7	......	40 07 52.85						
6681	1[illegible].158	12.6	14.0	......	57 46 31.77	+ 2 14.60	−0.38	+0.13	......	28.82	
6728	16.338	13.8	12.8	......	43 25 37.67						
6748	23.622	11.6	12.0	......	54 49 52.65	− 3 16.60	+0.80	−0.07	......	29.29	
6780	20.450	12.4	11.3	......	57 43 07.90						
6817	19.410	15.6	11.3	......	49 16 54.16	− 0 32.27	−0.53	−0.01	......	29.28	
6937	14.585	11.0	16.0	......	36 28 16.50						
6970	25.190	18.9	08.0	......	61 11 56.70	− 5 38.35	+1.32	−0.10	......	29.47	
7021	17.419	12.8	13.5	......	64 51 33.12						
7073	22.512	12.8	13.1	......	35 02 10.19	− 2 37.[illegible]	−0.22	−0.04	......	28.52	
7215	14.960	14.6	12.4	......	57 07 45.43						
7277	24.789	12.0	15.0	......	40 41 01.17	+ 5 01.95	−0.18	+0.00	......	28.19	
7320	22.117	11.1	15.8	......	38 09 39.64						
7-Yr. 2395	18.330	17.0	10.0	......	59 45 20.38	− 1 5[illegible].43	0.51	0.03	......	28.[illegible]	
7377	30.575	11.1	13.0	......	59 28 10.42						
7398	10.025	13.0	11.1	......	38 52 03.55	−10 37.62	0.0[illegible]	−0.19	......	29.18	
7416	25.513	11.6	12.7	......	62 03 09.74						
7453	14.290	13.0	11.5	......	36 07 27.93	− 5 40.4[illegible]	−0.09	−0.10	......	48 59 28.[illegible]	

Observations for Latitude.—Station No. 12—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7480	18. 333	13. 0	14. 6	....	45 59 10. 09						
7489	22. 303	16. 1	11. 1	....	52 03 54. 17	− 2 03. 18	+0. 76	−0. 03	......	48 59 29. 63	
7595	17. 379	15. 6	11. 6	......	37 78 12. 48						
7605	22. 953	13. 0	15. 7	....	60 06 30. 19	− 2 52. 95	+0. 29	−0. 05	......	28. 63	
7627	21. 723	16. 0	12. 8	....	25 19 58. 35						
7686	17. 680	13. 8	15. 5	......	72 34 48. 07	+ 2 65. 44	+0. 33	+0. 04	......	29. 02	
7755	17. 485	14. 7	14. 5	....	58 47 34. 98						
7765	23. 220	15. 7	13. 1	....	39 05 21. 28	+ 2 57. 94	+0. 62	+0. 05	....	28. 24	
7787	19. 492	14. 4	14. 5	....	52 01 30 14						
7800	22. 635	16. 0	13. 0	......	45 54 08. 20	+ 1 39. 07	+0. 65	+0. 02	....	28. 91	
7820	12 907	13. 0	15. 6	....	48 50 15. 47						
7882	28. 767	17. 1	12. 0	....	49 25 06. 28	− 8 12. 10	+0. 56	−0. 14	......	29. 20	
7962	28. 250	12. 2	17. 2	....	41 17 09. 97						
8024	12. 699	20 0	09. 0	......	56 25 39. 37	+ 8 02. 51	− 1. 34	+0. 11	......	28. 66	
8036	19. 676	14. 7	14. 4	....	49 21 59. 68						
8059	20. 094	16. 0	12. 4	....	48 36 31. 82	+ 0 12. 97	+0. 87	0. 00	......	29. 59	
8083	16. 862	14. 6	13. 2	....	56 28 17. 89						
8128	24. 000	14. 0	13. 2	....	41 23 15. 63	+ 3 41. 47	+0. 49	+0. 07	......	28. 79	
8206	26. 911	14. 0	13. 5	......	30 37 44. 77						
8273	12. 535	15. 7	12. 2	....	67 06 17. 65	+ 7 26. 05	+0. 89	+0. 14	......	28. 29	
8314	24. 722	13. 0	14. 8	....	73 42 25. 32						
8324	15. 180	15. 8	11. 7	....	24 26 24. 57	− 4 56. 06	+0. 51	−0. 10	.....	29. 29	
46	23. 577	15 7	12. 0	......	60 49 51. 04						
67	16. 755	13. 7	14. 0	......	37 16 09. 03	− 3 31. 67	+0. 76	−0. 06	......	29. 07	
120	10. 146	13. 0	14 2	......	32 53 05. 82						
175	30. 755	13. 8	13. 6	......	65 27 12. 58	−10 59. 15	−0. 22	−0. 20	......	29. 03	
198	23. 518	16. 8	10. 3	......	47 35 33. 69						
219	17. 091	11. 4	15. 4	......	50 16 42. 00	+ 3 19. 41	+0. 56	+0. 06	....	27. 88	
239	27. 198	13. 0	14 0	....	60 25 48. 63						
259	12. 021	15. 6	11. 0	......	37 48 50. 41	− 7 50. 90	+0. 80	−0. 11	......	20. 29	
G. 12-Yr. 73	16. 694	14. 6	12. 1	....	67 06 14. 02						
345	24. 016	09. 9	17. 0	......	30 45 10. 21	+ 3 47. 18	−1. 03	+0. 08	....	28. 35	
401	28. 269	15. 7	11. 8	......	28 04 41. 33						
438	11, 289	11. 3	16. 1	....	69 36 42 99	+ 8 46. 85	−0. 50	+0. 17	......	28 98	
7215	14. 778	19. 5	13. 3	......	57 07 49. 55						
7277	24. 583	14. 3	19. 4	......	40 41 02. 12	+ 5 04. 22	+0. 25	+0. 09	.....	28. 89	September 26.
7320	21. 549	18 7	15. 1	......	38 09 39. 97						
7-Yr. 2395	17. 751	17. 1	16. 8	......	59 45 21. 64	+ 1 57. 84	+0. 87	+0. 03	......	29. 57	
7377	30. 538	14. 6	19. 5	......	59 28 11. 70						
7398	9. 942	20. 9	13. 0	....	38 52 01. 56	−10 39. 04	+0. 67	−0. 19	......	29. 57	
7416	25. 133	21. 1	12 8	......	62 03 09. 12						
7453	13. 800	15. 7	18. 7	......	36 07 27. 90	− 5 4[illegible]	+1. 18	−0. 10	......	30. 75	Rejected.
6553	17. 210	19. 0	19. 5	......	32 18 23. 38						
6586	22. 690	20. 5	18. 8	......	65 46 11. 38	− 2 50. 03	+0. 27	−0. 06	....	29. 66	September 28
6624	22. 271	20. 0	19. 7	......	40 07 53. 51						
6681	19. 970	20. 7	19. 9	......	57 46 55. 66	+ 2 13. 45	+0. 25	+0. 03	.....	28. 31	
6728	16. 271	18. 3	22. 3	......	43 25 37. 89						
6748	23. 569	22. 4	18. 5	......	54 40 53. 02	− 3 45. 41	−0 02	−0. 07	......	28. 92	
6589	20. 902	19. 0	22. 0	......	57 43 08. 91						
6617	19. 844	22. 0	19. 0	......	40 16 55 06	− 0 32. 83	0. 01	−0. 01	......	48 59 29. 16	

Observations for Latitude.—Station No. 12—Continued.

B. A. C. No.	Readings. Microm.	Level. N.	Level. S.	Merid. dist.	Declination.	Corrections. Microm.	Level.	Refrac.	Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6937	14.762	22.0	19.6	....	36 28 17.45						
6970	25.696	20.5	20.7	....	61 41 58.06	− 5 39.25	+0.49	−0.10	....	48 59 28.90	
7024	17.778	21.2	19.9	....	61 51 34.55						
7073	22.762	21.7	19.5	....	36 02 11.16	+ 2 31.64	+0.78	+0.04	....	28.31	
7215	14.958	21.6	19.2	....	57 07 46.99						
7277	24.729	19.6	21.0	....	40 41 02.50	+ 5 08.17	+0.22	+0.09	....	28.23	
7416	25.273	20.8	18.6	....	62 03 11.57						
7453	13.927	18.0	20.7	....	36 07 28.30	− 5 52.04	+0.02	−0.10	....	27.82	
7962	28.283	22.0	17.7	....	41 17 11.79						
8024	12.813	18.5	21.7	....	56 25 41.62	+ 8 00.00	+0.25	+0.14	....	27.10	Rejected.
8036	20.514	19.0	21.0	....	49 22 01.77						
8059	20.896	20.0	20.0	....	48 36 33.90	+ 0 11.85	−0.44	+0.00	....	29.24	
8083	16.989	21.0	19.0	....	56 28 20.18						
8128	20.066	18.4	21.5	....	41 23 17.51	+ 3 39.58	−0.25	+0.07	....	28.25	
8206	26.883	19.0	21.0	....	30 37 46.30						
8273	12.546	20.7	19.1	....	67 06 20.20	+ 7 21.84	−0.09	+0.14	....	28.14	
8314	24.981	20.3	19.9	....	73 42 27.97						
8324	15.396	19.2	20.7	....	24 26 25.87	− 4 57.40	−0.25	−0.10	....	29.17	
46	23.210	20.9	19.1	....	60 49 53.48						
67	16.467	17.0	22.8	....	37 16 10.79	− 3 29.22	−0.59	−0.06	....	31.96	Rejected.
120	9.912	22.2	17.4	....	22 53 06.81						
175	30.563	16.5	23.4	....	65 27 15.07	−10 40.75	−0.47	−0.20	....	29.52	
198	23.709	20.5	19.0	....	47 35 35.75						
219	17.306	18.2	21.6	....	50 16 44.12	+ 3 18.67	−0.42	+0.06	....	28.25	
239	27.661	20.2	19.6	....	60 25 51.00						
259	12.474	18.6	21.2	....	37 48 52.15	− 7 51.21	−0.44	−0.14	....	29.78	
12-Yr. 73	16.145	20.4	19.9	....	67 06 16.47						
345	23.383	19.0	21.0	....	30 45 11.65	+ 3 44.58	−0.33	+0.07	....	28.38	
391	28.150	21.3	19.3	....	28 04 42.64						
438	11.258	19.0	22.0	....	69 36 46.47	+ 8 44.12	−0.22	+0.16	....	28.62	
474	12.685	21.0	20.0	....	48 04 38.79	− 7 40.32	−0.25	−0.13	....	29.30	
487	17.858	20.5	20.3	....	47 59 15.05						
522	21.111	19.5	21.3	....	50 03 05.20	− 1 40.93	−0.36	−0.03	....	28.80	
560	27.811	19.1	21.2	....	50 10 01.21						
611	25.072	21.0	20.0	....	63 46 40.29						
656	14.400	19.4	21.5	....	34 23 21.93	− 5 31.13	−0.25	−0.10	....	48 59 29.63	

Mean latitude (79 determinations), 48° 59′ 28″.90.

$\varepsilon = \pm 0''.539$
$r = \pm 0''.359$
$\varepsilon_0 = \pm 0''.071$
$r_0 = \pm 0''.047$

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 13—Frenchman's Creek, 462 miles west of Pembina, Dakota.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdmann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings. Microm.	Readings. Level. N.	Readings. Level. S.	Readings. Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5271 5313	20.756 19.345	18.1 17.5	12.9 13.0	....	42 48 19.24 55 06 26.21	+ 0 43.83	+2.16	+0.01	......	48 58 08.72	July 6.
5415 5460	30.581 10.810	19.0 14.4	10.3 14.5	....	58 16 03.58 40 00 40.09	−10 14.15	+1.92	−0.18	......	09.42	
5502 5523	12.232 28.800	14.5 12.6	11.0 16.0	....	55 29 33.43 42 09 37.93	+ 8 34.65	−0.65	+0.15	......	09.83	
5545 5624	11.166 29.013	14.1 11.7	14.2 15.7	....	69 02 28.67 28 35 19.85	+ 9 15.31	−0.91	+0.17	......	08.83	
5644 5658	15.952 25.238	14.0 13.0	13.0 14.0	....	42 27 51.65 55 38 02.05	− 4 48.45	0.60	−0.08	......	08.32	
5693 5823	25.073 15.953	16.0 12.5	10.2 11.0	....	31 54 39.58 65 52 11.88	+ 4 43.29	+1.03	+0.09	....	10.14	
5853 5911	27.697 12.907	16.0 13.8	10.9 13.5	....	49 49 37.69 48 21 59.09	− 7 39.42	+1.20	−0.13	......	10.04	
6047 6073	29.821 10.010	14.5 13.0	13.5 15.4	....	72 12 34.35 26 04 14.32	−10 15.08	−0.31	−0.20	......	08.74	
6114 6157	15.499 25.091	14.5 15.2	11.0 12.5	....	76 58 38.39 20 47 42.38	+ 4 57.95	+0.71	+0.11	......	09.15	
6206 6245	14.896 26.097	14.5 16.8	11.4 12.5	....	79 58 50.54 17 45 47.95	+ 5 47.94	+0.98	+0.13	......	08.30	
6268 6289	13.473 26.733	16.0 16.5	13.4 13.0	....	39 26 19.96 58 43 38.68	− 6 51.90	+1.36	−0.12	....	08.66	
6318 6365	14.078 26.006	14.5 17.3	11.8 12.3	....	59 27 52.94 38 15 00.73	+ 6 41.58	+1.05	+0.11	......	09.57	
6421 6476	22.001 28.817	17.3 13.0	12.9 17.5	....	49 17 31.18 48 42 01.12	− 1 38.90	−0.02	−0.02	......	08.86	
6553 6586	16.736 24.364	13.9 17.6	17.0 13.3	....	32 18 12.26 65 45 58.63	− 3 56.95	+0.27	−0.08	......	08.68	
6624 6681	21.897 19.693	16.7 14.5	14.2 16.6	....	40 07 40.91 57 46 19.93	+ 1 08.46	+0.09	+0.02	....	08.99	
6728 6748	15.330 24.780	14.7 17.5	16.8 14.0	....	43 25 25.40 54 40 38.82	− 4 53.55	+0.31	0.08		08.79	
6780 6817	22.391 19.192	14.2 17.1	17.0 14.2	....	57 42 53.99 40 16 43.26	− 1 39.37	+0.02	0.03	......	09.21	
6830 6865	13.927 27.230	16.0 16.0	15.8 15.5	....	47 36 20.92 50 33 46.91	− 6 55.10	+0.16	−0.12	....	08.86	
6937 6970	13.902 26.982	16.7 16.0	15.0 16.0	....	36 28 07.32 61 41 43.09	− 6 46.30	+0.38	−0.12	....	09.16	
7024 7073	27.668 30.494	17.3 14.7	14.8 17.5	....	61 51 19.98 36 02 01.79	+ 1 27.78	−0.07	+0.03	....	48 58 08.62	

Observations for Latitude.—Station No. 13—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7100	9.184	17.0	15.0	....	42 45 42.93						
7166	31.344	15.3	17.1	....	55 33 33.01	−11 28.36	+0.04	−0.20	....	48 58 09.45	
7215	16.433	15.7	17.0	....	57 07 33.50						
7277	24.046	16.7	16.5	....	40 40 52.92	+3 56.48	−0.25	+0.07	....	09.51	
7320	20.740	16.0	17.1	....	38 09 31.86						
7-Yr. 2395	19.168	17.1	16.0	....	59 45 09.05	+0 48.83	0.00	+0.02	....	09.30	
7377	31.523	15.1	18.5	....	59 27 59.45						
7398	8.688	18.7	15.1	....	38 51 56.65	−11 49.32	−0.04	−0.20	....	08.57	
7416	27.065	16.1	17.8	....	62 02 58.73						
7453	13.505	17.6	16.5	....	36 07 20.77	−7 01.21	−0.13	−0.12	....	08.29	
7505	1.589	17.1	17.0	....	37 58 05.67						
7566	15.830	17.0	17.4	....	37 42 22.33						
7595	33.480	17.5	17.0	....	60 32 13.99	−9 08.26	+0.02	−0.16	....	09.76	
7605	8.478	17.0	17.5	....	60 06 20.67	−4 05.06	−0.09	−0.07	....	08.45	
7627	20.640	16.4	18.1	....	25 19 56.90						
7686	18.971	19.5	15.7	....	72 34 38.21	+0 51.81	+0.47	+0.02	....	09.88	
7755	19.060	17.7	17.8	....	58 47 26.78						
7765	22.459	17.1	18.2	....	39 05 19.89	+1 45.58	−0.27	+0.03	....	08.67	
7787	20.287	16.1	19.1	....	52 01 23.24						
7800	21.146	18.5	17.0	....	45 54 02.56	+0 26.68	−0.33	+0.01	....	09.26	
7820	11.531	19.0	16.8	....	48 50 09.41						
7882	29.747	16.9	19.2	....	49 25 00.68	−9 25.84	−0.02	−0.16	....	09.02	
7907	10.498	17.3	18.8	....	74 42 48.12						
7945	29.181	18.0	18.5	....	22 54 10.38	+9 40.35	−0.22	+0.20	....	09.58	
7962	26.858	19.0	17.5	....	41 17 06.45						
8024	13.719	17.7	19.5	....	56 25 34.53	+6 48.14	−0.07	+0.12	....	08.68	
5115	27.399	40.2	38.4	....	61 16 24.50						
5178	14.869	42.7	37.7	....	37 02 47.09	−6 29.22	+1.52	−0.11	....	07.99	July 7.
5271	21.291	18.2	06.1	....	42 48 19.45						
5313	19.917	12.0	13.2	....	55 06 26.43	+0 42.68	+2.43	+0.01	....	08.06	
5415	30.439	12.8	12.6	....	58 16 03.82						
5460	10.643	17.0	09.0	....	10 00 40.32	−10 14.92	+1.83	−0.18	....	08.80	
5502	12.280	14.5	12.0	....	55 29 33.68						
5523	28.825	12.0	14.5	....	42 09 38.17	+8 33.94	0.00	+0.15	....	10.01	
5545	11.433	13.0	14.0	....	69 02 28.95						
5624	29.301	14.2	13.5	....	28 35 20.09	+9 15.03	−0.07	+0.17	....	09.65	
5614	16.033	15.0	13.0	....	43 27 51.91						
5658	25.332	13.4	14.7	....	55 38 02.33	−4 45.86	+0.16	−0.08	....	08.34	
5693	25.806	13.7	14.5	....	31 54 39.83						
5823	16.677	15.0	14.1	....	65 52 12.20	+4 43.58	−0.04	+0.09	....	09.64	
5853	27.900	16.0	13.5	....	19 49 38.00						
5911	13.135	12.4	17.7	....	18 21 59.10	−7 38.65	−0.62	−0.13	....	09.30	
6047	29.960	17.1	13.9	....	72 12 34.70						
6073	10.141	14.8	16.7	....	26 04 11.79	−10 15.64	0.29	−0.20	....	09.10	
6114	15.600	18.3	13.3	....	56 58 38.73						
6157	25.927	13.9	18.2	....	20 47 42.61	+4 59.01	+0.16	−0.11	....	09.99	
6206	15.193	16.1	16.0	....	70 58 50.90						
6245	26.419	17.0	15.4	....	17 45 18.21	+5 48.71	+0.38	+0.13	....	08.77	
6268	13.771	18.0	14.7	....	39 26 20.28						
6289	26.985	15.8	17.1	....	58 43 39.04	−6 50.47	+0.47	−0.12	....	48 58 09.52	

Observations for Latitude.—Station No. 13—Continued.

B. A. C. No.	Readings. Microm.	Level. N.	Level. S.	Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6318	13.885	15.7	17.6	....	59 27 53.31						
6365	26.846	18.0	17.4	....	38 15 01.07	+ 0 42.61	−0.29	+0.11	....	48 58 09.60	
6421	22.291	19.6	16.8	....	49 17 31.54						
6476	19.091	17.0	20.0	....	48 42 04.79	− 1 39.40	−0.04	−0.02	....	08.71	
6553	16.903	18.3	19.8	....	32 18 12.58						
6586	24.528	20.5	17.9	....	65 45 59.01	− 3 56.86	+0.25	−0.08	....	09.10	
6624	21.695	19.0	19.0	....	40 07 41.26						
6681	19.478	19.0	20.0	....	57 46 20.31	+ 1 08.87	−0.22	+0.02	....	09.46	
6728	15.706	19.0	20.0	....	43 25 25.76						
6748	25.139	19.5	19.2	....	54 40 39.20	− 4 53.62	−0.16	−0.08	....	09.22	
6780	22.580	19.3	19.2	....	57 42 54.37						
6817	19.381	17.8	20.5	....	40 16 43.60	− 1 39.37	−0.58	−0.03	....	09.60	
6830	13.598	19.4	18.8	....	47 36 21.29						
6865	26.961	16.0	21.8	....	50 33 47.29	− 6 55.10	−1.16	−0.12	....	07.91	
6937	13.875	18.6	20.0	....	36 28 07.67						
6970	26.925	18.3	20.4	....	61 41 43.48	− 6 45.37	−0.78	−0.12	....	09.30	
7024	19.025	19.8	19.7	....	61 51 20.36						
7073	21.859	19.5	20.9	....	36 02 02.13	+ 1 28.03	−0.29	+0.03	....	09.01	
7100	9.601	20.0	20.7	....	42 45 43.27						
7166	31.771	22.2	19.1	....	55 33 33.37	−11 28.67	+0.54	−0.20	....	09.99	
7215	16.620	19.6	22.2	....	57 07 33.98						
7277	24.231	22.3	20.8	....	40 40 53.22	+ 3 56.42	−0.25	+0.07	....	09.89	
7320	20.697	23.0	20.5	....	38 09 32.19						
7-Yr. 2395	19.140	21.4	22.2	....	59 45 09.41	+ 0 48.37	+0.38	+0.02	....	09.57	
7377	33.087	20.5	23.6	....	59 27 59.80						
7398	9.246	24.0	20.5	....	38 51 56.97	−11 49.51	+0.09	−0.20	....	08.76	
7416	27.180	22.6	22.0	....	62 02 59.09						
7453	13.603	23.0	21.9	....	36 07 21.09	− 7 01.74	+0.38	−0.12	....	08.61	
7480	17.751	21.8	23.6	....	45 59 02.24						
7489	24.027	21.9	20.7	....	52 03 45.04	− 3 14.95	+0.54	−0.05	....	09.18	
7505	1.273	23.9	22.0	....	37 58 06.99						
7566	16.508	24.3	22.4	....	37 42 22.64						
7595	34.187	24.0	23.0	....	60 32 14.32	− 9 09.16	+0.65	−0.16	....	09.81	
7605	9.197	23.7	23.5	....	60 06 20.99	− 4 06.14	+0.47	−0.07	....	08.25	
7627	20.803	25.0	22.0	....	25 19 57.17						
7686	19.190	24.0	23.6	....	72 34 38.52	+ 0 50.11	+0.76	+0.02	....	08.73	
7755	19.286	23.0	24.2	....	58 47 27.06						
7765	22.094	23.0	24.1	....	39 05 20.18	+ 1 45.86	−0.51	+0.03	....	09.60	
7787	20.256	21.0	26.0	....	52 01 23.54						
7800	21.116	24.4	22.3	....	45 54 02.87	+ 0 26.78	−0.65	+0.01	....	09.34	
7820	11.255	22.8	24.0	....	48 50 09.71						
7882	29.457	03.5	23.9	....	49 25 00.97	− 9 25.53	−0.36	−0.16	....	09.59	
7907	11.190	23.0	24.6	....	74 42 48.40						
7945	29.876	23.6	24.0	....	22 54 10.64	+ 9 40.26	−0.45	+0.20	....	09.53	
7962	27.538	25.2	22.2	....	41 17 06.73						
8024	14.378	21.6	26.7	....	56 25 34.82	+ 6 48.79	−0.47	+0.12	....	48 58 09.21	

Mean latitude (68 determinations), 48° 58′ 09″.10.

$\varepsilon = 0''.538$

$r = 0''.359$

$\varepsilon_0 = 0''.065$

$r_0 = 0''.043$

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 14—500 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings. Microm.	Readings. Level. N.	Readings. Level. S.	Readings. Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5415	28.883	22.0	19.3	......	58 16 01.51						
5460	12.782	20.6	21.5	......	40 00 41.00	− 8 20.11	+0.40	−0.15	......	49 00 02.89	July 10.
5502	10.139	22.6	20.2	......	55 29 34.42						
5523	30.321	20.6	22.4	......	42 09 38.88	+10 26.91	+0.13	+0.18	......	03.87	
5545	9.770	22.7	20.7	......	69 02 29.70						
5624	31.265	21.9	22.0	......	28 35 20.73	+11 07.70	+0.42	+0.21	......	03.54	
5644	18.319	21.7	22.0	......	42 27 52.67						
5658	24.010	24.4	19.3	......	55 38 03.13	− 2 56.78	+1.07	−0.05	......	02.14	
5693	26.969	22.2	21.6	......	31 54 40.53						
5823	14.239	24.0	20.6	......	65 52 13.08	+ 6 35.43	+0.89	+0.12	......	03.24	
5853	25.972	23.5	21.7	......	49 40 38.86						
5911	14.784	23.6	22.1	......	18 22 10.29	− 5 47.53	+0.71	−0.10	......	02.68	
6047	28.321	21.8	21.3	......	72 12 35.67						
6073	12.127	22.3	24.7	......	26 04 15.36	− 8 23.03	−0.25	−0.16	......	02.57	
6114	13.621	23.4	23.7	......	76 58 30.72						
6157	26.864	21.2	23.6	......	20 47 43.37	+ 6 51.37	+0.07	+0.15	......	03.14	
6206	12.917	25.4	23.0	......	79 58 51.91						
6245	27.782	23.3	25.3	......	17 45 48.92	+ 7 41.75	+0.09	+0.19	......	02.44	
6268	15.441	25.7	23.2	......	39 26 21.24						
6289	25.043	21.3	24.7	......	58 13 40.11	− 4 58.27	+0.47	−0.09	......	02.78	
6553	18.304	24.7	23.5	......	32 18 13.53						
6586	22.331	25.4	22.6	......	65 46 00.15	− 2 05.18	+0.89	−0.04	......	02.51	
6624	23.426	25.9	21.8	......	40 07 42.29						
6681	17.620	21.0	23.8	......	57 46 21.45	+ 3 10.35	+0.96	+0.05	......	03.23	
6728	17.118	27.2	20.9	......	43 25 26.83						
6748	22.953	24.5	24.0	......	54 10 40.54	− 3 01.87	+1.52	−0.05	......	03.18	
6780	20.498	25.5	23.2	......	57 42 55.52						
6817	20.867	26.3	25.5	......	40 16 41.66	+ 0 11.46	+1.36	0.00	......	02.91	
6830	15.653	25.0	24.0	......	47 36 22.40						
6865	25.450	27.5	21.5	......	50 33 48.11	− 5 01.32	+1.76	−0.08	......	02.56	
6937	15.449	24.0	25.5	......	36 28 08.70						
6970	24.895	25.8	21.3	......	61 41 44.65	− 4 53.42	0.00	−0.09	......	03.16	
7024	17.201	25.8	24.8	......	61 51 21.54						
7073	23.769	24.0	27.0	......	36 02 03.17	+ 3 21.23	−0.15	+0.06	......	03.19	
7100	11.120	26.0	24.8	......	42 15 11.36						
7166	29.658	25.1	26.6	......	55 33 51.52	− 9 35.85	−0.07	−0.17	......	03.35	
7215	14.590	25.5	26.0	......	57 07 35.01						
7277	25.815	26.0	25.8	......	40 40 51.29	+ 5 48.70	−0.07	+0.10	......	03.37	
7320	22.693	24.9	26.5	......	38 09 33.24						
7-Yr. 2395	17.519	27.9	24.8	......	59 45 10.55	+ 2 40.72	+0.76	+0.05	......	49 00 03.22	

Observations for Latitude.—Station No. 14—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7377	30.056	24.1	28.0	....	59 28 00.94						
7398	10.833	30.0	22.6	....	38 51 58.02	− 9 57.12	+0.78	−0.18	....	49 00 02.96	
7416	25.246	26.7	26.8	....	62 03 00.21						
7453	15.298	27.5	26.5	....	36 07 22.11	− 5 09.01	+0.20	−0.09	....	02.26	
7480	18.861	30.3	24.1	....	45 59 03.33						
7489	21.527	26.8	28.1	....	52 03 46.13	− 1 22.81	+1.09	−0.02	....	02.99	
7505	2.732	32.3	22.7	....	37 58 08.01						
7516	17.969	32.8	23.0	....	37 42 23.66						
7595	32.036	26.0	30.0	....	60 32 15.42	− 7 16.96	+1.29	−0.13	....	03.74	
7605	7.042	26.0	30.6	....	60 06 22.09	− 2 13.88	+1.12	−0.04	....	02.25	
7755	17.157	30.0	26.8	....	58 47 28.11						
7765	24.192	26.0	31.0	....	39 05 21.18	+ 3 38.53	−0.40	+0.06	....	02.83	
7789	18.449	26.8	30.0	....	52 01 24.57						
7800	22.950	28.9	28.0	....	45 54 03.87	+ 2 19.81	−0.51	+0.03	....	03.55	
7820	12.917	27.7	29.7	....	48 50 10.71						
7882	27.503	28.6	28.0	....	49 25 01.96	− 7 33.08	−0.31	−0.13	....	02.81	
7907	8.573	28.5	28.0	....	74 42 49.35						
7945	30.891	26.4	30.2	....	22 54 11.46	+11 33.26	−0.74	+0.25	....	03.17	
7962	28.526	27.2	29.0	....	41 17 07.66						
8024	11.764	29.7	27.1	....	56 25 35.75	+ 8 40.68	+0.18	+0.15	....	02.72	
8036	19.462	33.0	24.0	....	49 21 56.75						
8059	21.047	25.7	31.0	....	48 36 29.17	+ 0 49.23	+0.83	+0.02	....	03.04	
5271	23.347	17.9	17.5	....	42 48 20.21						
5313	18.313	22.7	13.0	....	55 06 27.26	+ 2 36.37	+2.25	+0.04	....	02.39	July 11
5415	28.627	18.0	18.3	....	58 16 04.69						
5460	12.533	17.3	19.8	....	40 00 41.17	− 8 19.93	−0.62	−0.15	....	02.23	
5502	10.273	18.9	18.6	....	55 29 31.62						
5523	30.443	18.0	19.8	....	42 09 39.07	+10 26.54	−0.33	+0.18	....	03.24	
5545	9.713	19.0	19.0	....	69 02 29.90						
5624	31.204	19.2	19.7	....	28 35 20.92	+11 07.58	−0.11	+0.21	....	03.09	
5644	17.506	20.3	18.5	....	42 27 52.89						
5658	23.193	19.5	19.3	....	55 38 03.37	− 2 56.53	+0.45	−0.05	....	02.00	
5693	27.378	20.8	18.2	....	31 54 40.74						
5823	14.663	20.8	19.5	....	65 52 13.35	+ 6 34.97	+0.57	+0.12	....	03.00	
5853	25.841	19.7	20.6	....	49 49 39.13						
5911	14.662	23.0	18.0	....	48 22 00.56	− 5 47.25	+0.91	−0.10	....	03.40	
6048	29.013	23.5	19.3	....	72 13 05.97						
6073	12.320	20.5	22.5	....	26 04 15.60	− 8 38.54	+0.49	−0.16	....	02.57	
6114	13.870	23.7	19.5	....	56 58 40.04						
6157	27.036	19.9	23.7	....	20 47 43.60	+ 6 50.84	+0.09	+0.15	....	02.90	
6206	12.803	23.6	20.1	....	79 58 52.23						
6215	27.625	22.0	22.0	....	17 45 49.14	+ 7 40.12	+0.78	+0.19	....	03.07	
6268	15.487	22.2	22.0	....	39 26 21.73						
6289	25.119	24.0	20.4	....	58 43 40.44	− 4 59.29	+0.85	−0.09	....	02.54	
6318	11.945	21.4	23.0	....	59 27 54.71						
6365	28.488	25.2	19.8	....	38 15 02.33	+ 8 33.88	+0.85	+0.15	....	03.40	
6421	29.117	23.5	21.8	....	49 17 32.93						
6476	20.512	23.6	22.0	....	48 42 06.19	+ 0 12.27	−0.74	0.09	....	02.57	
6553	18.533	22.1	21.0	....	32 18 13.83						
6586	22.550	25.8	20.9	....	65 46 00.52	2 04.78	+0.67	−0.14	....	49 00 03.02	

Observations for Latitude.—Station No. 14—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6624	23.459	21.0	22.3	....	40 07 42.62						
6651	17.665	24.8	22.4	....	57 46 21.82	+ 2 59.98	+0.91	+0.05	....	49 00 03.16	
6728	17.264	23.5	24.0	....	43 25 27.18						
6748	23.121	25.9	22.0	....	54 40 40.71	− 3 01.94	+0.76	−0.05	....	02.71	
6780	20.338	24.7	23.8	....	57 42 55.89						
6817	20.731	24.8	21.0	....	40 16 45.01	+ 0 12.21	+0.38	0.00	....	03.04	
6830	15.822	24.0	25.0	....	47 36 22.76						
6865	25.584	27.0	22.6	....	50 33 48.80	− 5 03.24	+0.76	−0.08	....	03.22	
6937	15.453	21.2	24.7	....	36 28 09.01						
6970	21.917	24.7	24.0	....	61 41 45.04	− 4 53.98	+0.04	−0.09	....	02.99	
7024	17.740	22.7	25.9	....	61 51 21.93						
7073	24.186	26.0	22.2	....	36 02 03.51	+ 3 20.23	+0.13	+0.06	....	03.14	
7100	10.863	24.0	21.1	....	42 45 41.72						
7166	20.410	24.8	23.8	....	55 33 34.91	− 9 36.12	+0.20	−0.17	....	03.71	
7215	11.567	24.6	23.8	....	57 07 35.39						
7277	25.777	23.9	24.9	....	40 40 54.65	+ 5 48.22	−0.04	+0.10	....	03.30	
7320	23.428	27.0	21.4	....	38 09 33.59						
7-Yr. 2395	18.255	22.5	26.2	....	59 45 10.91	+ 2 40.69	+0.42	+0.05	....	03.42	
7377	20.855	22.4	26.5	....	50 28 01.32						
7398	10.620	27.1	21.8	....	38 51 58.37	− 9 57.70	+0.27	−0.18	....	02.13	
7416	25.528	25.4	23.8	....	62 03 01.00						
7453	15.570	24.8	24.5	....	36 07 22.45	− 5 09.33	+0.42	−0.09	....	02.53	
7480	19.053	21.2	24.7	....	45 59 03.69						
7489	21.707	26.0	23.3	....	52 03 46.50	− 1 22.44	+0.49	−0.02	....	03.12	
7505	2.950	25.9	23.6	....	37 58 08.36						
7566	18.268	26.0	23.7	....	37 42 24.00						
7595	32.252	25.4	24.3	....	60 32 15.79	− 7 16.25	+0.76	−0.13	....	04.27	
7605	7.249	25.0	25.0	....	60 06 22.46	− 2 13.54	+0.51	−0.04	....	02.34	
7627	22.519	24.7	25.0	....	25 19 58.39						
7686	17.282	26.5	23.7	....	72 31 30.93	+ 2 43.61	+0.56	+0.05	....	03.38	
7755	17.283	26.7	23.9	....	58 47 28.47						
7765	21.279	25.0	25.1	....	39 05 21.51	+ 3 37.32	+0.54	+0.06	....	02.91	
7787	18.606	27.1	23.2	....	52 01 21.92						
7800	23.053	23.8	26.7	....	45 54 04.32	+ 2 18.14	+0.22	+0.03	....	03.01	
7820	13.289	26.0	24.7	....	48 50 11.07						
7882	27.934	27.0	24.0	....	49 25 02.31	− 7 34.92	+0.96	−0.13	....	02.60	
7907	8.500	26.0	25.0	....	51 42 49.69						
7945	30.755	27.0	24.4	....	22 51 11.78	+11 31.31	+0.80	+0.25	....	03.09	
7962	29.185	20.1	31.6	....	41 17 07.99						
8024	12.451	33.7	19.0	....	56 25 36.07	+ 8 39.71	+0.71	+0.15	....	02.60	
8036	19.293	27.0	25.6	....	49 21 57.09						
8059	20.871	28.0	24.7	....	48 36 29.50	+ 0 49.02	+1.05	+0.02	....	49 00 03.38	

Mean latitude (66 determinations), 49° 00′ 02″.95.

$\epsilon = 0''.454$
$\tau = 0''.303$
$\epsilon_0 = 0''.056$
$\tau_0 = 0''.037$

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 15—East Fork of Milk River, 553 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5644	17.561	17.3	20.0	....	42 27 53.61						
5658	23.299	21.7	15.8	....	55 38 01.14	−2 58.21	+0.71	−0.05	....	49 00 01.30	July 15.
5693	27.306	19.0	18.0	....	31 54 41.40						
5823	14.650	20.0	18.7	....	65 52 14.24	+6 33.13	+0.51	+0.12	....	01.58	
6047	28.060	20.5	19.1	....	72 12 36.99						
6073	11.808	19.9	19.8	....	26 04 16.38	−8 24.84	+0.33	−0.16	....	02.01	
6114	13.317	20.9	19.0	....	76 58 41.10						
6157	26.496	19.0	20.9	....	20 47 44.32	+6 49.38	0.00	+0.14	....	02.23	
6206	12.792	21.1	18.7	....	79 58 53.33						
6245	27.581	18.4	21.5	....	17 45 49.84	+7 39.39	−0.16	+0.18	....	00.99	
6268	15.600	22.0	18.0	....	39 26 22.56						
6289	25.259	18.0	22.0	....	58 43 41.60	−5 00.04	0.00	−0.09	....	01.99	
6318	12.820	20.0	20.0	....	59 27 55.89						
6365	29.323	19.5	21.0	....	38 15 03.39	+8 32.63	−0.33	+0.15	....	02.09	
6421	20.606	20.0	20.6	....	49 17 34.10						
6476	20.961	20.5	20.5	....	48 42 07.38	+0 11.03	−0.13	0.00	....	01.64	
6553	18.426	20.7	20.7	....	32 18 14.86						
6586	22.490	20.9	20.8	....	65 46 01.82	−2 06.21	+0.02	−0.04	....	02.08	
6624	23.680	20.7	21.0	....	40 07 43.77						
6681	17.921	21.6	20.7	....	57 46 23.12	+2 58.89	+0.13	+0.05	....	02.52	
6728	17.460	20.7	21.9	....	43 25 28.40						
6748	23.367	22.0	20.7	....	54 40 42.03	−3 03.49	+0.02	−0.05	....	01.69	
6780	20.418	22.1	20.4	....	57 42 57.22						
6817	20.761	19.5	23.4	....	40 16 46.21	+0 10.65	−0.49	0.00	....	01.88	
6830	15.350	20.1	22.7	....	47 36 24.04						
6865	25.179	22.5	20.4	....	50 33 50.10	−5 05.32	−0.11	−0.08	....	01.56	
6937	15.580	20.7	23.0	....	36 28 10.22						
6970	25.120	22.4	21.3	....	61 41 46.41	−4 56.34	−0.27	−0.09	....	01.61	
7024	17.475	21.0	23.0	....	61 51 23.30						
7073	23.850	22.0	22.1	....	36 02 04.69	+3 18.03	−0.47	+0.06	....	01.61	
7100	11.072	23.1	21.0	....	42 45 46.00						
7166	29.691	21.0	23.5	....	55 33 36.28	−9 38.36	−0.09	−0.17	....	02.52	
7215	15.195	21.9	22.4	....	57 07 36.77						
7277	26.342	21.4	23.4	....	40 40 55.92	+5 46.26	−0.56	+0.10	....	02.11	
7320	22.870	21.9	23.6	....	38 09 31.84						
7-Yr. 2395	17.750	22.3	23.1	....	59 45 12.34	+2 39.01	−0.56	+0.01	....	02 11	
7377	30.489	22.4	23.5	....	59 28 02.72						
7398	11.221	21.9	24.5	....	38 51 59.62	−9 58.52	−0.83	−0.18	....	01.64	
7416	25.446	18.5	28.0	....	62 03 02.00						
7453	15.460	25.2	21.6	....	36 07 23.69	−5 10.20	−1.32	−0.09	....	49 00 01.23	

Observations for Latitude.—Station No. 15—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7480 7489	19.286 21.976	24.2 19.9	22.5 27.1	....	45 59 05.03 52 03 47.86	−1 23.56	−1.23	−0.02	......	49 00 01.63	
5644 5678	18.380 24.085	17.1 17.8	19.1 18.9	....	42 27 53.79 55 38 01.33	−2 57.21	−0.09	−0.05	......	01.11	July 16.
5693 5823	27.253 14.583	18.8 18.7	17.7 19.6	....	31 54 41.56 65 52 14.45	+6 33.57	+0.04	+0.12	......	01.73	
5853 5911	26.069 14.862	19.0 17.0	19.5 21.2	....	49 49 40.21 48 22 01.67	−5 48.12	−1.05	−0.10	......	01.67	
6047 6073	28.178 11.953	19.8 18.0	20.1 21.0	....	72 12 37.24 26 04 16.55	−8 21.00	−0.80	−0.16	......	01.93	
6414 6157	14.112 27.276	17.6 21.5	21.4 17.7	....	76 58 41.31 20 47 44.48	+6 48.91	0.00	+0.14	......	01.96	
6206 6245	13.029 27.818	19.2 19.9	20.0 19.9	....	79 58 53.58 17 45 49.99	+7 39.59	−0.18	+0.18	......	01.18	
6268 6289	15.041 25.313	20.2 19.2	19.2 20.4	....	39 26 22.78 58 43 41.86	−5 00.44	−0.04	−0.09	......	01.75	
6318 6365	12.561 29.046	19.7 19.1	20.0 21.0	....	59 27 56.15 38 15 03.61	+8 32.07	−0.49	+0.15	......	01.61	
6421 6476	20.501 20.876	19.3 20.0	20.6 19.8	....	49 17 34.36 48 42 07.63	+0 11.03	−0.25	0.00	......	01.79	
6553 6586	18.910 22.981	19.2 20.6	21.1 20.1	....	32 18 15.09 65 46 02.00	−2 05.46	−0.31	−0.04	......	01.73	
6621 6681	23.630 17.882	19.5 19.7	21.0 20.4	....	40 07 41.03 57 46 23.42	+2 58.55	−0.49	+0.05	......	01.83	
6728 6748	17.573 23.465	18.2 19.3	21.4 20.3	....	43 25 28.68 51 40 42.33	−3 03.02	−0.94	−0.05	......	01.49	
6789 6817	20.931 21.284	20.0 17.3	19.6 22.3	....	57 42 57.53 40 16 46.48	+0 10.96	−1.03	0.00	......	01.94	
6820 6865	15.960 25.772	19.5 18.7	20.0 21.0	....	47 36 24.33 50 33 59.40	−5 04.79	−0.62	−0.08	......	01.87	
6937 6970	16.108 25.051	19.0 21.3	21.0 19.0	....	36 28 10.48 61 41 46.73	−4 56.43	+0.07	−0.09	......	02.15	
7024 7073	17.790 24.167	19.9 20.4	21.0 20.6	....	61 51 23.62 36 02 01.96	+3 18.09	−0.29	+0.06	......	02.15	
7100 7166	11.847 30.437	21.6 19.5	19.4 22.0	....	42 15 46.27 55 33 36.50	−9 58.39	−0.67	−0.17	......	02.80	
7215 7277	15.088 26.225	20.6 19.7	21.0 22.4	....	57 07 37.08 40 40 56.21	+5 46.01	−0.69	−0.10	......	02.06	
7324 7-Yr. 2.95	23.521 18.106	21.7 19.9	20.6 22.6	....	38 09 35.12 59 15 12.65	+2 38.89	−0.76	+0.04	......	02.15	
7377 73[illegible]	20.705 11.431	21.0 20.1	22.0 22.6	....	59 28 03.04 38 51 53.10	−9 58.61	−0.71	−0.18	......	01.97	
5853 5911	26.539 15.334	13.8 13.0	15.6 16.6	....	49 49 40.13 48 22 01.88	−5 48.06	−1.20	−0.10	......	01.80	July 17.
6047 6073	28.021 12.404	15.4 9.4	15.0 20.4	..	72 12 37.18 26 04 16.73	−8 23.77	2.36	−0.16		00.83	
6114 6157	13.887 27.061	17.0 15.7	16.5 13.1	......	76 58 41.60 20 47 44.61	+6 49.22	−0.20	+0.14	......	02.28	
6206 6245	13.131 27.911	14.8 13.0	14.0 16.0	....	79 58 53.41 17 45 50.16	+7 39.41	−0.19	+0.18	......	49 00 00.80	

Observations for Latitude.—Station No. 15—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6268	15.500	14.5	14.5	......	39 26 23.03						
6289	25.178	14.4	14.7	......	58 43 42.11	−5 00.63	−0.07	−0.09	......	49 00 01.79	
6318	12.322	13.0	16.0	......	59 27 56.43						
6365	28.813	14.8	15.0	......	38 15 03.87	+8 32.26	−0.71	+0.15	......	01.85	
6421	21.019	16.0	14.7	......	49 17 34.65						
6476	21,366	14.0	17.7	......	48 12 04.92	+0 10.78	−0.51	0.00	......	01.52	
6553	19.007	14.7	17.6	......	32 18 15.32						
6586	23.058	15.8	16.8	......	65 46 02.42	−2 05.84	−0.87	−0.04	......	02.12	
6624	24.141	15.4	17.1	......	40 07 44.31						
6681	18.434	19.0	14.6	......	57 46 23.73	+2 57.37	+0.60	+0.05	......	02.04	
6728	17.580	18.0	15.8	......	43 25 28.96						
6748	23.523	17.0	16.8	......	54 40 42.61	−3 04.61	+0.54	−0.05	......	01.68	
6780	21.134	16.0	18.0	......	57 42 57.84						
6817	21.448	18.0	16.0	......	40 16 46.77	+0 09.75	0.00	0.00	......	02.05	
6830	16.014	16.7	17.6	......	47 36 24.61						
6865	25.863	17.6	17.0	......	50 33 50.70	−5 05.94	−0.07	−0.08	......	01.58	
6937	16.100	15.7	19.5	......	36 28 10.76						
6970	25.620	18.8	16.9	......	61 41 47.05	−4 55.72	−0.12	−0.09	......	02.67	
7024	17.741	17.7	18.1	......	61 51 23.95						
7073	24.113	16.9	19.3	......	36 02 05.24	+3 17.84	−0.62	+0.66	......	01.87	
7100	10.242	16.5	19.9	......	42 45 46.60						
7166	28.883	18.7	18.0	......	55 33 36.93	−9 39.05	−0.60	−0.17	......	01.91	
7215	15.482	18.7	17.6	......	57 07 37.41						
7277	26.618	16.9	21.1	......	40 40 56.51	+5 45.92	−0.69	+0.10	......	02.29	
7320	23.331	19.5	18.7	......	38 09 35.42						
Gr. 7-Yr. 2395	18.221	17.8	20.6	......	59 45 12.97	+2 38.73	−0.45	+0.04	......	02.51	
7377	30.722	19.6	19.0	......	59 28 03.36						
7398	11.433	17.8	21.0	......	38 52 00.20	−9 59.17	−0.58	−0.18	......	01.85	
7416	25.953	18.4	20.4	......	62 03 02.66						
7453	15.969	19.6	19.8	......	36 07 24.24	−5 10.13	−0.49	−0.09	......	02.74	Rejected.
7480	19.475	18.5	20.9	......	45 59 05.63						
7489	22.197	20.0	19.7	......	52 03 48.49	−1 24.55	−0.47	−0.02	......	02.02	
7505	3.359	19.0	20.7	......	37 58 10.18						
7566	18.589	19.0	21.4	......	37 42 25.81	−7 18.30	−0.17	−0.13	......	02.90	
7595	32.699	20.5	20.2	......	60 32 17.79						
7605	7.707	20.6	20.4	......	60 06 24.36	−2 15.06	−0.33	−0.04	......	49 00 01.89	

Mean latitude (62 determinations), 49° 00′ 01″.86.

$\varepsilon = 0''.427$
$r = 0''.288$
$\varepsilon_0 = 0''.054$
$r_0 = 0''.036$

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 16—Milk River Lakes, 588 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level.		Merid. Dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5641	17.641	16.0	18.4	......	42 27 55.03						
5658	23.601	17.5	17.0	......	55 38 05.62	− 3 05.14	−0.42	−0.05	......	48 59 54.71	July 22.
5693	26.813	17.1	17.0	......	31 54 42.71						
5823	14.362	18.1	18.6	......	65 52 15.92	+ 6 26.45	−0.09	+0.12	......	55.79	
5853	26.146	18.0	19.0	......	49 49 41.67						
5911	14.728	16.2	21.0	......	48 22 03.17	− 5 51.68	−1.29	−0.10	......	56.35	
6047	28.287	19.0	21.1	......	72 12 38.90						
6073	11.825	17.1	22.0	......	26 01 17.86	− 8 31.36	−1.56	−0.16	......	55.30	
6114	13.611	17.5	22.0	......	76 58 43.06						
6157	26.547	21.0	18.1	......	20 47 45.70	+ 6 41.83	−0.36	+0.14	......	55.99	
6206	12.914	18.0	21.0	......	49 58 55.35						
6245	27.457	20.4	19.1	......	17 45 51.19	+ 7 31.75	−0.51	+0.18	......	54.69	
6268	15.380	19.7	19.7	......	39 26 24.42						
6289	25.303	19.2	20.7	......	58 43 43.71	− 5 08.24	−0.33	−0.09	......	55.40	
6318	12.386	19.5	20.6	......	59 27 58.62						
6365	28.650	17.7	22.6	......	38 15 05.30	+ 8 25.49	−1.34	+0.15	......	55.96	
6421	20.535	19.8	20.8	......	49 17 36.22						
6476	20.625	19.7	20.4	......	48 42 09.50	+ 0 02.89	−0.38	0.00	......	55.28	
6553	18.463	18.5	21.0	......	32 18 16.71						
6586	22.787	19.7	20.1	......	65 46 04.16	− 2 14.32	−0.65	−0.04	......	55.42	
6624	23.670	17.8	21.8	......	40 07 45.85						
6651	18.150	20.4	20.0	......	57 46 25.57	+ 2 51.19	−0.80	+0.05	......	56.15	
6728	17.173	18.5	21.3	......	43 25 30.57						
6748	23.350	20.7	19.5	......	54 40 44.37	− 3 11.88	−0.36	−0.05	......	55.18	
6780	20.922	20.7	19.5	......	57 42 50.61						
6817	20.933	17.7	22.8	......	40 16 48.36	+ 0 02.21	−0.87	0.00	......	55.32	
6820	15.323	20.5	20.0	......	47 36 26.31						
6865	25.409	19.0	21.6	......	50 33 54.10	− 5 13.30	−0.47	−0.08	......	56.35	
6937	15.918	18.0	22.8	......	36 28 12.31						
6970	25.716	23.5	18.0	......	61 41 48.87	− 5 04.36	+0.16	−0.04	......	56.30	
7024	17.957	21.6	20.0	......	61 51 25.77						
7073	21.063	18.7	23.0	......	36 02 06.81	+ 3 09.67	−0.60	+0.06	......	55.42	
7100	11.334	20.6	21.0	......	42 45 48.24						
7166	30.231	20.8	21.0	......	55 33 38.69	− 9 47.00	−0.13	−0.17	......	56.16	
7215	15.520	21.0	20.5	......	57 07 39.20						
7277	26.403	18.0	23.7	......	40 40 58.12	+ 5 38.06	−1.16	+0.10	......	55.56	
7320	22.769	20.0	21.0	......	38 09 30.91						
G. 7-Yr. 2595	17.917	[illegible]	22.3	......	59 45 11.77	+ 2 30.72	−0.85	+0.04	......	55.79	
7377	30.203	21.7	20.0	......	59 28 05.15						
7398	10.747	18.8	22.7	......	38 52 01.79	−10 07.47	−0.19	−0.18	......	48 59 55.73	

Observations for Latitude.—Station No. 16—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7416	25. 581	20. 0	22. 0	....	62 03 04. 42						
7453	15. 292	20. 8	21. 0	....	36 07 25. 79	− 5 19. 61	−0. 49	−0. 09	....	48 59 54. 91	
7480	19. 248	19. 5	21. 9	....	45 59 07. 29						
7489	22. 216	21. 0	20. 6	....	52 03 49. 21	− 1 32. 19	−0. 45	−0. 02	....	55. 59	
7505	2. 807	19. 7	21. 1	....	37 58 11. 74						
7566	18. 055	19. 1	21. 9	....	37 42 27. 36						
7595	32. 420	21. 0	20. 5	....	60 32 19 53	− 7 26. 22	−0 51	−0. 13	......	56. 58	
7605	7. 429	20. 7	20. 8	....	60 06 26. 20	− 2 23. 57	−0. 33	−0. 04	....	55. 03	
5545	10. 214	14. 8	11. 5	....	69 02 32. 17						
5624	31. 374	10. 6	16. 8	.. ...	28 35 22. 94	+10 57. 29	−0. 65	+0. 21	....	54. 40	July 23
5644	17. 939	13. 4	14. 3	....	42 27 55. 24						
5658	23. 919	12. 7	15. 6	....	55 38 05. 88	− 3 05. 76	−0. 85	−0. 05	....	53. 90	
5693	26. 715	10. 0	17. 7	....	31 54 42. 91						
5820	14. 317	19. 0	10. 8	....	65 52 16. 18	+ 6 25. 12	+0. 11	+0 12	......	51. 90	
5853	26. 145	14. 0	15. 7	....	49 49 41. 93						
5911	14. 649	16. 0	14. 0	....	48 22 03. 44	− 5 57. 10	+0. 07	−0. 10	....	55. 55	
6047	28. 396	20. 6	13. 2	....	72 12 30. 20						
6073	11. 821	16. 0	18. 0	....	26 04 18. 09	− 8 31. 87	+1. 20	−0. 16	....	54. 82	
6114	13. 790	19. 8	14. 8	....	76 58 43. 36						
6157	26. 678	16. 6	17. 5	....	20 47 45. 93	+ 6 40. 34	+0. 91	+0. 14	....	56. 03	
6206	12. 805	20. 0	14. 8	....	79 58 55. 68						
6245	27. 306	17. 7	19. 0	....	17 45 51. 42	+ 7 30. 44	+0. 42	+0. 18	......	54 59	
6268	15. 567	18. 0	17. 0	....	39 26 24. 72						
6289	25. 553	19. 5	16. 0	....	58 43 41. 04	− 5 10. 20	+1. 00	+0. 09	....	55 09	
6318	12. 231	19. 0	16. 5	......	59 27 58. 36						
6365	28. 400	18. 0	17. 3	....	38 15 05. 60	+ 8 22. 26	+0. 71	+0. 15	......	55. 10	
6421	20. 349	20. 3	15. 0	....	49 17 36. 56						
6476	20. 411	13. 0	22. 0	....	48 42 09. 84	+ 0 01. 93	−0. 83	0. 00	......	54 30	
6553	18. 486	15. 5	18. 7	....	32 18 17. 02						
6586	22. 833	17. 0	17. 1	....	65 46 04. 53	− 2 15. 03	−0. 74	−0. 04	......	54. 96	
6624	23. 370	15. 4	17. 7	....	40 07 46. 18						
6681	17. 922	15. 0	18. 0	....	57 46 25. 83	+ 2 49 23	−1. 18	+0. 05	......	54. 10	
7024	17. 673	14. 8	17. 2	....	61 51 26. 17						
7073	23. 743	16. 0	15. 8	....	36 02 07. 15	+ 3 08. 55	−0. 49	+0. 06	......	54. 78	
7100	11. 037	15. 0	17. 0	....	42 45 48. 61						
7166	29. 951	16. 5	16. 0	....	55 33 39. 09	− 9 47. 53	−0. 33	−0. 17	......	55. 82	
7215	14. 941	15. 4	17. 3	....	57 07 39. 60						
7277	25. 792	14. 0	18. 7	......	40 40 58. 50	+ 5 37. 06	−1. 47	+0. 10	....	54. 71	
7320	22. 820	17. 0	15. 7	....	38 09 37. 34						
G. 7-Yr. 2395	17. 990	14. 8	18. 3	....	59 45 15. 17	+ 2 30. 04	−0. 49	+0. 04	....	55. 83	
7377	30. 177	17. 0	16. 4	....	59 28 05. 55						
7398	10. 612	14. 8	19. 5	....	38 52 02. 15	−10 07. 75	−0. 91	−0. 18	......	55. 01	
7416	25. 236	17. 7	17. 1	....	62 03 04. 80						
7453	14. 963	16. 3	19. 0	....	36 07 26. 11	− 5 19. 11	−0. 47	−0. 09	......	55 80	
7480	19. 214	15. 3	19. 1	....	45 59 07. 66						
7489	22. 207	19. 0	17. 1	....	52 03 50. 59	− 1 32. 97	−0. 42	−0. 02	....	55 72	
7566	18. 241	17. 0	19. 0	....	37 42 27. 71						
7595	32. 630	18. 0	18. 6	....	60 32 19. 93	− 7 26. 97	−0. 58	−0 13	....	56. 11	
7627	22. 615	17. 0	19. 2	....	25 20 01. 61						
7686	17. 705	19 0	17. 3	....	72 34 43. 99	+ 2 32. 52	−0. 11	+0. 05	......	48 59 55. 27	

Observations for Latitude.—Station No. 16—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7755	17.306	19.8	16.7	......	58 47 32.47						
7765	23.959	11.0	21.7	......	39 05 25.19	+ 3 26.66	−1.03	+0.06	......	48 59 54.52	
7787	18.470	17.0	19.0	......	52 01 28.83						
7800	22.579	16.2	18.3	......	45 54 08.62	+ 2 07.64	−0.91	+0.03	......	55.18	
7820	13.023	13.9	20.8	......	48 50 11.89						
7882	27.966	16.3	17.8	......	49 25 06.07	− 7 44.17	−1.87	−0.13	......	54.31	
7907	9.149	17.5	16.0	......	74 12 53.47						
7945	31.100	12.8	19.2	......	22 54 14.87	+11 21.86	−0.87	+0.24	......	55.40	
5693	27.131	15.5	13.8	......	31 51 43.29						
5820	14.728	14.9	16.9	......	65 52 16.61	+ 6 25.27	−0.07	+0.12	......	55.24	July 25.
5853	26.443	15.7	16.0	......	49 49 42.36						
5911	14.967	11.0	18.0	......	48 22 03.89	− 5 56.48	−0.96	−0.10	......	55.59	
6047	28.395	17.1	16.0	......	72 12 39.73						
6073	11.828	19.0	14.0	......	26 01 18.51	− 8 31.62	+1.36	−0.16	......	55.70	
6114	13.663	17.4	16.0	......	76 58 43.91						
6157	26.561	15.5	17.7	......	20 47 46.33	+ 6 40.65	−0.18	+0.11	......	55.73	
6206	12.900	19.3	14.0	......	79 58 56.24						
6245	27.457	12.2	21.1	......	17 45 51.82	+ 7 31.56	−0.80	+0.18	......	54.97	
6268	14.980	16.1	17.4	......	39 26 25.26						
6289	24.917	16.8	17.0	......	58 43 44.65	− 5 08.67	−0.33	−0.09	......	55.86	
6318	12.336	19.7	14.3	......	59 27 58.98						
6365	28.563	12.0	22.0	......	38 15 06.16	+ 8 24.06	−1.03	+0.15	......	55.76	
6421	20.532	15.0	19.7	......	49 17 37.19						
6476	20.594	18.3	16.4	......	48 42 10.48	+ 0 01.93	−0.62	0.00	......	55.14	
6553	18.359	17.5	17.7	......	32 18 17.59						
6586	22.723	17.3	18.3	......	65 46 05.23	− 2 15.56	−0.27	−0.04	......	55.54	
6624	23.470	16.3	19.0	......	40 07 46.70						
6681	18.000	17.2	18.5	......	57 46 26.55	+ 2 49.91	−0.89	+0.05	......	55.70	
6728	17.026	19.0	17.7	......	43 25 31.58						
6748	23.283	19.2	17.8	......	54 49 45.16	− 3 11.36	+0.60	−0.05	......	54.71	
6780	20.760	19.5	16.8	......	57 43 00.71						
6817	20.758	19.0	17.5	......	40 16 49.37	− 0 00.06	+0.91	0.00	......	55.92	
6830	15.468	18.0	18.1	......	47 36 27.38						
6865	25.627	19.2	17.1	......	50 33 54.52	− 5 15.57	+0.45	−0.08	......	55.25	
6937	15.526	19.0	17.4	......	36 28 13.32						
6970	25.408	19.7	17.2	......	64 41 50.03	− 5 06.96	+0.91	−0.09	......	55.53	
7024	17.823	18.7	18.6	......	61 51 26.94						
7073	23.877	17.7	19.0	......	36 02 07.82	+ 3 08.06	−0.27	+0.05	......	55.22	
7100	10.971	17.5	19.0	......	42 45 49.33						
7166	29.309	19.5	17.2	......	55 34 39.77	− 9 48.27	+0.18	−0.17	......	56.29	
7215	15.317	19.0	17.6	......	57 07 40.38						
7277	26.131	17.0	19.0	......	40 10 59.29	+ 5 36.01	−0.13	+0.10	......	55.77	
7329	22.687	17.5	18.7	......	38 09 38.01						
7-Yr. 2395	17.894	19.0	17.2	......	59 45 15.96	+ 2 28.88	+0.13	+0.01	......	56.05	
7377	30.152	16.0	20.6	......	59 28 06.34						
7398	10.538	20.2	16.0	......	38 52 02.86	−10 09.27	−0.09	−0.18	......	55.06	
7416	25.600	19.6	17.0	......	62 03 05.59						
7453	15.251	17.6	18.7	......	36 07 26.83	− 5 21.47	+0.33	−0.10	......	54.97	
7480	18.680	18.0	18.0	......	45 59 08.41						
7489	21.704	18.9	18.7	......	52 03 51.30	1 33.93	−0.16	−0.02	......	48 59 55.77	

Observations for Latitude.—Station No. 16—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7505	2.510	17.0	19.3	....	37 58 12.80						
7566	17.752	17.0	19.5	....	37 42 28.41						
7595	32.178	19.8	17.1	....	60 32 20.71	− 7 28.11	+0.04	−0.13	....	48 59 56.36	
7605	7.183	19.7	17.2	....	60 06 27.38	− 2 25.16	+0.04	−0.04	....	54.93	
7627	25.351	13.8	22.6	....	25 20 02.26						
7686	17.458	23.0	14.1	....	72 34 44.77	+ 2 32.08	+0.02	+0.05	....	55.66	
7755	17.265	18.4	19.0	....	58 47 33.24						
7765	23.893	18.5	18.8	....	39 05 25.89	+ 3 25.89	−0.20	+0.06	....	55.31	
7787	18.506	17.5	20.0	....	52 01 29.58						
7800	22.576	20.0	17.3	....	45 54 08.75	+ 2 06.43	+0.04	+0.03	....	48 59 55.67	

Mean latitude (75 determinations), 48° 59′ 55″.39.

$\varepsilon = 0''.580$
$\tau = 0''.387$
$\varepsilon_0 = 0''.067$
$\tau_0 = 0''.045$

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

Astronomical Station No. 17—East Butte, 634 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5644	16.716	21.5	19.5	......	42 27 56.12						
5658	24.241	14.7	26.1	......	55 38 06.82	− 3 53.75	−2.10	−0.07	......	48 59 05.55	July 29.
5693	25.893	19.8	21.2	......	31 51 43.74						
5823	15.032	18.1	21.8	......	65 52 17.29	+ 5 37.37	−1.81	+0.10	......	06.17	
5853	26.703	21.0	22.0	......	49 49 43.05						
5911	13.693	17.0	26.0	......	48 22 01.62	− 6 44.13	−2.23	−0.11	......	07.37	
6047	28.813	20.5	23.0	......	72 12 40.58						
6073	10.687	22.0	21.5	......	26 01 19.11	− 9 23.05	−0.45	−0.20	......	06.16	
6114	14.476	20.7	23.5	......	76 58 41.80						
6157	25.782	22.5	21.9	......	20 47 46.93	+ 5 51.20	−0.49	+0.13	......	06.70	
6206	13.452	20.7	24.0	......	79 58 57.18						
6245	26.393	23.1	21.8	......	17 45 52.39	+ 6 41.06	−0.45	+0.15	......	05.54	
6268	14.373	23.0	22.0	......	39 26 23.13						
6289	25.910	21.9	23.1	......	58 43 45.65	− 5 59.31	−0.04	−0.10	......	06.44	
6318	12.897	22.0	23.1	......	59 27 59.99						
6365	27.500	22.2	23.6	......	38 15 07.07	+ 7 33.61	−0.56	+0.13	......	06.71	
6421	20.989	21.5	25.1	......	49 17 38.27						
6476	19.411	23.5	21.0	......	43 42 11.53	− 0 48.09	−0.91	−0.02	......	05.88	
6553	16.182	23.1	21.4	......	32 18 13.51						
6586	22.153	23.6	21.1	......	65 43 06.42	− 3 05.48	−0.40	−0.05	......	06.53	
6624	21.503	23.0	21.6	......	40 07 47.84						
6681	17.678	24.1	23.3	......	57 46 27.70	+ 1 53.82	−0.18	+0.03	......	06.47	
6728	16.661	23.9	23.6	......	43 25 32.71						
6748	21.476	22.3	25.0	......	54 40 46.69	− 4 02.76	−0.54	−0.07	......	06.33	
6780	21.353	23.5	23.4	......	57 43 41.98						
6817	19.771	22.5	21.3	......	40 16 40.50	− 0 40.11	−0.38	−0.02	......	06.70	
6830	14.017	24.3	22.5	......	47 36 23.60						
6865	25.790	22.0	25.0	......	50 33 54.76	− 6 44.77	−0.27	−0.10	......	06.54	
6935	14.525	22.3	24.7	......	36 29 14.13						
6970	25.980	23.6	23.7	......	61 41 51.37	− 5 55.83	−0.56	−0.10	......	06.41	
7100	9.771	26.0	21.9	......	42 45 50.56						
7166	30.341	22.6	25.5	......	55 33 41.22	−10 38.97	+0.27	−0.19	......	07.00	
7215	15.673	23.0	25.0	......	57 07 41.75						
7257	21.840	25.5	22.1	......	19 41 40.16	+ 4 45.67	+0.74	+0.08	......	06.79	
7320	21.409	24.5	24.5	......	38 09 39.26						
G. 7 Yr. 2395	18.273	25.7	23.5	......	59 45 17.38	+ 1 37.41	+0.49	+0.03	......	06.25	
7357	30.771	24.0	25.2	......	59 28 07.75						
7398	9.510	25.5	23.0	......	38 52 01.10	−11 40.43	+0.51	−0.19	......	05.84	
7116	26.608	26.9	23.0	......	62 03 07.06						
7153	14.043	23.5	26.6	......	36 07 28.05	− 6 11.67	+0.18	−0.11	......	48 59 05.95	

Observations for Latitude.—Station No. 17—Continued.

B. A. C. No.	Readings. Microm.	Level. N.	Level. S.	Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7480	17.948	26.0	24.0	....	45 59 09.75						
7489	22.617	21.5	26.0	....	52 03 52.74	− 2 25.03	+0.11	−0.04	......	48 59 06.28	
7505	2.010	26.9	23.7	....	37 58 14.05						
7566	17.237	27.0	24.0	....	37 42 29.06						
7595	33.280	24.8	26.6	....	60 32 22.16	− 8 18.31	+0.27	−0.15	......	07.69	
7605	8.314	24.2	27.0	....	60 06 28.81	− 3 15.82	+0.09	−0.06	......	05.64	
7627	21.554	24.9	26.5	....	25 20 05.35						
7686	18.286	26.7	25.1	....	72 34 46.21	+ 1 41.51	0 00	+0.03	......	06.31	
7755	17.820	25.9	26.0	0 13	58 47 34.66						
7765	22.830	23.7	28.0	0 16	39 05 27.16	+ 2 35.63	−0.98	+0.04	+0.05	05.65	
7787	19.096	24.8	27.0	....	52 01 30.96						
7800	21.553	26.0	25.6	....	45 54 10.08	+ 1 16.32	−0.40	+0.02	......	06.46	
7820	12.048	26.9	24.9	....	48 50 17.00						
7862	28.662	25.7	27.0	....	49 25 08.17	− 8 36.08	+0.16	−0.14	......	06.52	
7907	9.738	27.7	25.3	....	24 42 55.62						
7945	30.023	24.0	29.6	....	22 54 16.53	+10 30.11	−0.71	+0.22	......	05.69	
5644	16.503	13.7	14.8	....	42 27 56.24						
5658	24.143	17.3	11.0	0 05	55 38 06.94	− 3 57.32	+1.16	−0.07	+0.01	05.37	July 30.
5693	26.244	11.0	14.4	....	31 54 43.85						
5823	15.442	11.8	16.0	....	65 52 17.41	+ 5 35.54	−0.36	+0.10	......	05.92	
5853	26.757	16.1	14.9	....	49 49 43.20						
5911	13.672	13.0	19.0	....	48 22 04.79	− 6 46.46	−1.07	−0 11	......	06.36	
6114	14.525	13.3	11.0	....	76 58 41.99						
6157	25.827	16.6	16.0	....	20 47 47.05	+ 5 51.07	−0.02	+0.13	......	07.20	
6206	13.451	15.1	17.1	....	79 58 57.39						
6245	26.398	13.0	19.8	....	17 45 52.51	+ 6 42.17	−1.96	+0.15	......	05.31	
5693	26.272	13.0	17.5	....	31 54 44.24						
5823	15.463	17.5	15.0	....	65 52 17.97	+ 5 35.60	−0.45	+0.10	......	06.35	August 2.
5853	26.650	16.9	15.7	....	49 49 43.74						
5911	13.561	12.2	20.4	....	48 22 05.34	− 6 46.58	−1.56	−0.11	......	06.29	
6047	28.697	14.8	19.0	....	72 12 41.39						
6073	10.576	15.6	18.0	....	26 01 19.76	− 9 22.89	−1.47	−0.20	......	06.02	
6114	14.377	15.2	18.2	....	76 58 45.66						
6157	25.650	17.3	16.1	....	20 47 47.52	+ 5 50.17	−0.40	+0.13	......	06.49	
6206	13.476	16.1	17.1	....	79 58 58.09						
6245	26.363	16.4	17.4	....	17 45 52.96	+ 6 40.31	−0.51	+0.15	......	05.47	
6268	14.065	19.0	14.8	....	39 23 26.98						
6289	25.653	14.3	19.3	....	58 43 46.64	− 5 59.96	−0.18	−0.10	......	06 57	
6318	13.224	16.4	17.3	....	59 28 00.99						
6365	27.794	16.5	17.0	....	38 15 07.95	+ 7 32.50	−0.31	+0.13	......	06.88	
6421	20.780	16.3	17.3	....	49 17 39.23						
6476	19.185	16.5	17.0	....	48 42 12.55	− 0 49.55	−0.33	−0.02	......	05.99	
6553	17.238	19.2	11.8	....	32 18 19.38						
6586	23.260	14.8	19.4	....	65 46 07.58	− 3 07.06	−0.04	−0.05	......	06.33	
6624	22.360	18.3	15.3	....	40 07 48.85						
6681	18.578	16.0	17.8	....	57 46 28.93	+ 1 57.48	−0.27	+0.03	......	06.13	
6728	16.378	16.4	17.4	....	43 25 33.79						
6748	24.258	18.0	15.8	....	51 40 47.87	− 4 04.78	−0.27	−0.07	......	05 71	
6780	21.009	16.0	18.0	....	57 43 03.18						
6817	19.376	12.8	15 2	....	40 16 51.56	− 0 50.73	−0.36	−0.02	......	48 59 06.26	

Observations for Latitude.—Station No. 17—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Retrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6830 6865	14.184 25.983	18.3 16.1	15.6 17.9	....	47 36 29.74 50 33 55.94	− 6 06.51	+0.20	−0.10	......	48 59 06.43	
6937 6970	14.630 26.150	18.0 17.0	16.0 17.2	....	36 28 15.47 61 41 52.65	− 5 57.85	+0.40	−0.10	......	06.51	
7024 7073	18.110 22.504	15.6 19.0	18.5 15.0	....	61 51 29.59 36 02 10.03	+ 2 16.49	+0.25	+0.03	......	06.58	
7100 7166	10.218 30.937	18.1 17.7	15.8 15.6	.... 0 16	42 45 51.71 55 33 42.50	−10 43.59	+0.98	−0.19	+0.03	04.33	Rejected.
7820 7882	11.801 28.482	18.4 16.0	12.9 14.6	....	48 50 18.22 49 25 00.38	− 8 38.16	+1.51	−0.14	......	07.01	
7907 7945	9.892 30.117	13.0 19.0	17.1 11.6	....	74 42 56.92 22 54 17.13	+10 28.25	+0.74	+0.22	......	06.38	
7962 8024	27.649 12.961	14.8 18.5	15.8 11.6	....	41 17 14.66 56 25 43.04	+ 7 36.25	+1.32	+0.13	......	06.55	
8036 8059	19.943 19.458	14.6 18.6	15.6 11.5	....	49 22 03.91 48 36 36.26	− 0 15.07	+1.36	0.00	......	06.38	
8083 8128	16.752 23.067	13.0 13.0	17.2 17.3	....	56 28 21.57 41 23 21.45	+ 3 16.16	−1.90	+0.06	.	05.83	
8206 8273	26.845 13.361	16.0 15.4	14.8 15.7	....	30 37 52.95 67 08 21.28	+ 6 58.85	+0.20	+0.13	..	06.29	
8314 8324	25.410 14.923	15.9 17.0	15.7 14.6	....	73 42 28.90 24 26 34.17	− 5 25.76	+0.58	−0.11		06.40	
46 67	23.643 15.900	17.6 15.0	15.0 17.3	....	60 49 55.98 37 16 17.15	− 4 00.52	+0.07	−0.07	......	06.04	
120 175	9.647 31.210	17.3 15.4	15.2 17.2	....	32 53 14.45 65 27 17.84	−11 09.81	+0.07	−0.20	....	06.21	
198 219	23.062 17.553	18.0 14.8	14.8 18.1	....	47 35 40.72 50 16 48.76	+ 2 51.13	−0.02	+0.05	....	05.90	
239 259	22.538 12.419	15.9 18.0	17.1 15.3	....	60 25 54.65 37 48 59.05	− 8 20.70	+0.33	−0.15	....	06.33	
G. 12-Yr. 73 345	17.294 23.613	18.7 14.3	15.5 19.8	....	67 06 21.80 30 45 20.07	+ 3 16.21	−0.51	+0.07	....	48 59 06.79	

Mean latitude (60 determinations), 48° 59′ 06″.30.

ϵ 0″.489
r 0″.326
ϵ_0 0″.063
r_0 0″.042

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 18—Red River, 672 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
5853	21.911	18.7	16.7	....	49 49 41.89						
5911	15.438	17.2	19.5	....	48 22 06.55	− 4 54.26	−0.07	−0.08	....	49 01 01.31	August 8.
6047	27.318	17.8	20.0	....	72 12 42.80						
6073	12.808	20.0	18.5	....	26 04 20.90	− 7 30.72	−0.16	−0.15	....	00.82	
6114	12.438	20.6	18.0	....	76 58 47.14						
6157	27.360	18.7	20.5	....	20 47 48.62	+ 7 43.52	+0.18	+0.17	....	01.75	
6206	11.533	19.8	19.7	....	79 58 59.66						
6245	28.063	20.0	19.7	....	17 45 51.05	+ 8 33.47	+0.09	+0.19	....	00.60	
6268	15.950	22.0	17.7	....	39 26 28.47						
6289	23.913	18.5	21.2	....	58 43 48.31	− 4 07.35	+0.36	−0.07	....	01.33	
6318	10.969	19.7	20.0	....	59 28 02.69						
6365	29.170	20.0	20.6	....	38 15 09.50	+ 9 25.38	−0.20	+0.17	....	01.44	
6421	19.145	21.8	19.1	....	49 17 49.95						
6476	21.189	19.6	22.0	....	48 42 14.31	+ 1 03.49	+0.07	+0.02	....	01.21	
6553	19.165	21.1	20.8	....	32 18 20.94						
6586	21.556	21.3	21.1	....	65 46 09.55	− 1 14.27	+0.11	−0.02	....	01.06	
6624	24.153	21.9	20.6	....	40 07 50.62						
6681	16.743	20.8	21.4	....	57 46 30.93	+ 3 50.18	+0.16	+0.07	....	01.18	
6728	17.872	22.1	19.9	....	43 25 35.64						
6748	22.118	20.1	21.9	....	54 40 49.89	− 2 11.89	+0.09	−0.03	....	00.93	
6780	19.530	21.0	21.1	....	57 43 05.26						
6817	21.522	21.7	20.7	....	40 16 53.42	+ 1 01.88	+0.20	+0.02	....	01.44	
6830	15.862	21.7	20.7	....	47 36 31.73						
6865	24.043	22.0	20.6	....	50 33 57.99	− 4 11.13	+0.54	−0.07	....	01.20	
6937	16.060	22.0	20.6	....	36 28 17.32						
6970	23.947	22.0	20.7	....	61 41 54.86	− 4 01.90	+0.60	−0.07	....	01.63	
7024	16.673	20.6	21.8	....	61 51 31.83						
7073	24.689	22.4	19.9	....	36 02 11.92	+ 4 09.09	+0.29	+0.07	....	01.23	
7100	11.638	21.6	20.3	....	42 45 53.75						
7166	28.630	21.9	20.0	....	55 33 41.73	− 8 47.82	+0.71	−0.15	....	01.98	
7215	13.305	19.0	22.9	....	57 07 45.29						
7277	26.074	23.9	18.9	....	40 41 03.63	+ 6 36.61	+0.25	+0.11	....	01.46	
7320	23.193	21.8	21.1	....	38 09 42.37						
7-Yr. 2395	16.455	22.5	20.6	....	59 45 21.01	+ 3 20.30	+0.58	+0.05	....	01.63	
7377	29.011	20.8	22.4	....	59 28 11.40						
7398	11.368	22.1	21.0	....	38 52 07.27	− 9 03.04	−0.11	−0.16	....	01.02	
7416	24.770	21.1	22.0	....	62 03 10.71						
7453	16.410	22.0	21.8	....	36 07 31.14	− 4 19.69	−0.16	−0.08	....	01.01	
7480	19.638	21.7	21.8	....	45 59 13.15						
7489	20.694	21.4	22.0	....	52 03 56.28	− 0 32.80	−0.16	−0.01	....	49 01 01.71	

Observations for Latitude.—Station No. 18—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″		° ′ ″	
7566	13.923	20.9	22.5	......	37 42 32.81						
7595	26.407	22.0	21.2	....	60 32 25.82	− 6 27.79	−0.18	−0.11	......	49 01 01.24	
7627	23.641	21.7	21.1	....	25 20 06.03						
7686	16.762	21.0	21.9	....	72 31 49.93	+ 3 33.78	−0.07	+0 07	......	01.76	
7755	16.218	17.7	25.0	....	58 47 38.28						
7765	24.808	21.5	18.4	....	39 05 39.35	+ 4 26.83	−0.27	+0.08	......	00.95	
7787	17.692	20.9	21.9	....	52 01 31.46						
7800	23.735	21.0	21.2	....	45 54 13.45	+ 3 07.71	−0.27	+0.05	......	01.41	
7820	13.955	22.0	20.6	....	48 50 20.41						
7882	26.970	20.0	23.1	....	49 25 11.56	− 6 44.29	−0.38	−0.11	......	01.21	
7907	8.016	21.1	21.9	....	71 42 59.22						
7945	31.914	20.8	22.3	....	22 54 19.08	+12 22.34	−0.51	+0.26	......	01.21	
7962	29.197	22.0	21.0	....	41 17 16.68						
8024	10.835	21.0	22.0	....	56 25 45.23	+ 9 30.38	0.00	+0.17	.....	01.50	
8036	18.235	21.9	21.5	....	49 22 06.02						
8059	21.460	20.7	22.6	....	48 36 38.35	+ 1 40.18	−0.33	+0.02	......	02.05	
8083	15.110	21.0	22.0	....	56 28 23.73						
8128	25.016	22.0	21.0	....	41 23 23.42	+ 5 07.71	0.00	+0.09	....	01.37	
8206	28.870	21.2	22.0	....	30 37 54.70						
8273	11.737	22.5	20.8	....	67 06 23.35	+ 8 52.20	+0.20	+0.15	.....	01.59	
8314	23.527	21.0	22.0	......	73 42 30.90						
8324	16.680	22.4	20.9	....	24 26 36.44	3 34.69	+0.11	−0.07	......	01.02	
46	22.204	22.0	22.0	......	60 49 57.89						
67	18.119	22.4	21.9	....	37 16 18.87	− 2 06.89	+0.11	−0.04	......	01.57	
120	11.361	23.3	21.0	....	32 53 16.05						
175	29.265	21.6	23.0	......	65 27 19.60	− 9 16.15	+0.20	−0.17	......	01.70	
198	25.023	22.4	22.1	......	17 35 42.41						
219	15.853	21.5	23.0	......	50 16 50.45	+ 4 44.85	−0.27	+0.03	......	01.09	
239	26.204	21.0	23.6	....	69 25 56.33						
259	13.747	23.7	21.0	....	37 49 00.61	− 6 26.95	+0.02	−0.11	....	01.43	
12-Yr. 73	15.189	20.9	24.0	....	67 05 23.58						
345	25.159	23.7	21.0	....	30 45 21.19	+ 5 09.70	−0.09	+0.10	....	02.24	
401	30.017	22.0	22.5	....	28 01 53.03						
438	10.386	22.0	22.6	......	69 36 51.67	+10 09.80	−0.25	+0.19	......	02.09	
5853	25.358	14.8	15.0	......	49 49 15.01						
5911	15.910	11.0	16.0	....	48 22 06.68	− 4 53.18	−0.49	−0.08	......	01.79	August 9.
6047	27.094	17.0	13.9	......	72 42 42.96						
6073	12.602	13.9	17.5	....	26 04 21.02	− 7 30.16	−0.11	−0.15	......	01.57	
6114	12.530	14.9	16.9	....	76 58 47.31						
6157	27.472	15.8	16.1	....	20 47 48.71	+ 7 41.14	−0.51	+0.17	......	01.82	
6206	11.617	14.0	17.9	....	79 58 59.85						
6245	28.150	16.2	16.3	....	17 45 54.17	+ 8 31.19	−0.84	+0.19	......	00.50	
6268	16.510	18.5	14.8	....	39 26 28.65						
6289	24.442	13.3	20.0	....	58 43 18.52	− 4 06.39	−0.67	−0 07	......	01.45	
6318	11.540	17.4	16.3	......	59 28 02.90						
6365	29.784	13.0	22.7	....	38 15 09.70	+ 9 26.71	−1.91	+0 17	.	01.27	
6421	19.158	14.0	22.0	......	49 17 41.18						
6476	21.255	19.0	17.3	....	48 42 11.54	+ 1 05.14	−1.40	+0.02	.....	01.62	
6753	19.202	18.8	18.0	......	32 18 21.11						
6586	21.589	19.0	18.2	....	65 46 09.82	− 1 17.15	+0.36	−0.02	.	49 01 01.67	

Observations for Latitude.—Station No. 18—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6624	24.242	18.7	19.0	......	40 07 50.85						
6681	16.824	19.0	19.1	......	57 46 31.21	+ 3 50.43	−0.09	+0.07	......	49 01 01.44	
7024	16.741	17.8	19.9	0 08	61 51 32.17						
7073	24.745	19.3	18.0	......	36 02 12.21	+ 4 08.63	−0.18	+0.07	+0.01	00.72	
7100	11.575	20.7	16.6	......	42 45 54.06						
7166	28.541	16.1	21.4	......	55 33 45.07	− 8 47.01	−0.27	−0.15	......	02.13	
7215	14.015	17.1	20.1	......	57 07 45.64						
7277	26.798	20.0	17.8	......	40 41 03.94	+ 6 37.08	−0.18	+0.11	......	01.80	
7962	20.251	20.6	18.5	......	41 17 17.05						
8024	10.904	17.9	21.9	......	56 25 45.61	+ 9 29.91	−0.42	+0.17	......	00.99	
8036	18.453	20.3	19.7	......	49 22 06.39						
8059	21.6 6	19.4	20.4	......	48 36 38.72	+ 1 39.81	−0.09	+0.02	......	02.29	
8083	15.050	17.9	22.0	......	56 28 24.11						
8128	24,964	20.7	19.1	......	41 23 23.76	+ 5 07.96	−0.56	+0.09	......	01.42	
8206	20.178	18.8	21.7	0 12	20 37 55.01						
8273	12.057	21.0	19.0	......	67 06 23.72	+ 8 51.83	−0.20	+0.17	+0.02	01.18	
8311	23.650	21.0	19.0	......	73 42 31.28						
8324	16.821	18.0	22.0	......	24 26 36.73	− 3 32.13	−0.45	−0.07	......	01.35	
46	22.548	22.0	18.6	......	60 49 58.21						
67	18.432	19.4	21.0	......	37 16 19.18	− 2 07.86	+0.40	−0.03	......	01.22	
120	11.770	20.7	19.8	......	32 53 16.35						
175	29.705	21.0	19.7	......	65 27 19.94	− 9 17.11	+0.49	−0.17	......	01.35	
198	25.254	21.5	19.0	......	47 35 42.73						
219	16.125	20.0	20.6	......	50 16 50.77	+ 4 43.57	+0.42	+0.08	......	00.82	
239	26.263	18.5	22.0	......	60 25 56.65						
259	13.768	23.1	17.4	......	37 49 00.90	− 6 28.13	+0.49	−0.11	......	01.02	
Gr. 12-Yr. 73	15.462	20.1	20.5	......	67 06 23.92						
345	25.417	29.2	20.5	......	30 45 21.77	+ 5 09.23	−0.16	+0.10	......	02.01	
401	30.509	21.6	19.5	... ...	28 04 53.28						
438	10.886	19.5	21.7	......	69 36 51.95	+10 09.55	−0.02	+0.19	......	49 01 02.33	

Mean latitude (60 determinations), 49° 01′ 01.″42

$\epsilon = 0''.413$
$r = 0''.275$
$\epsilon_0 = 0''.053$
$r_0 = 0''.035$

1874.

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

Astronomical Station No. 19—North Fork of Milk River, 716 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.]

B. A. C. No.	Readings. Microm.	Readings. Level N.	Readings. Level S.	Readings. Merid. dist.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refrac.	Corrections. Red. to merid.	Latitude.	Remarks.
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6047	27. 507	15. 5	19. 0	....	72 12 43. 54						
6073	11. 014	18. 0	17. 0	....	26 04 21. 45	− 8 32. 32	−0. 56	−0. 17	....	48 59 59. 45	August 13.
6114	13. 263	16. 9	18. 6	....	76 58 47. 95						
6157	26. 162	18. 5	17. 0	....	20 47 49. 17	+ 6 40. 68	−0. 04	+0. 14	....	59. 34	
7320	22. 286	19. 0	18. 0	....	38 09 43. 76						
Gr. 7-Yr 2395	17. 546	17. 5	20. 5	....	59 45 22. 69	+ 2 27. 24	−0. 45	+0. 04	....	60. 05	
7377	29. 720	18. 5	19. 8	....	59 28 13. 09						
7398	10. 045	18. 6	20. 0	....	38 52 08. 70	−10 11. 16	−0. 60	−0. 18	....	58. 95	
7416	25. 470	18. 0	20. 7	....	62 03 12. 44						
7453	15. 070	20. 7	18. 4	....	36 07 32. 51	− 5 23. 06	−0. 09	−0. 10	....	59. 24	
7400	18. 189	19. 9	19. 1	....	45 59 14. 69						
7489	21. 317	18. 8	20. 6	....	52 03 57. 91	− 1 37. 17	−0. 22	−0. 02	....	58. 91	
7566	13. 187	19. 5	20. 7	....	37 42 31. 27						
7595	27. 686	20. 6	19. 7	....	60 12 27. 58	− 7 30. 38	−0. 07	−0. 13	....	60. 34	
7627	22. 261	19. 5	20. 8	....	25 20 07. 25						
7686	17. 447	21. 9	19. 0	....	72 34 51. 75	+ 2 29. 63	+0. 36	+0. 05	....	59. 54	
7755	17. 064	21. 0	20. 9	....	58 47 40. 01						
7765	23. 601	20. 6	21. 0	....	39. 05 31. 86	+ 3 23. 06	−0. 07	+0. 06	....	59. 00	
7820	12. 651	21. 5	20. 8	....	48 50 22. 07						
7882	27. 720	21. 4	21. 5	....	49 25 13. 21	− 7 48. 09	+0. 13	−0. 13	....	59. 56	
7907	8. 193	20. 9	22. 0	....	71 43 01. 04						
7945	30. 527	21. 8	21. 6	....	22 54 20. 29	+11 18. 23	−0. 20	+0. 23	....	58. 93	
7962	28. 237	22. 3	21. 1	....	41 17 18. 34						
8024	11. 938	21. 1	22. 9	....	56 25 46. 97	+ 8 26. 30	−0. 13	+0. 15	....	58. 97	
8036	19. 208	21. 9	22. 2	....	49 22 07. 69						
8059	21. 083	20. 7	23. 7	....	48 36 40. 01	+ 0 36. 50	−0. 74	+0. 01	....	59. 62	
8083	15. 475	21. 5	23. 0	....	76 28 25. 46						
8128	23. 341	22. 0	22. 9	....	41 23 24. 97	+ 1 04. 34	−0. 54	+0. 07	....	59. 08	
8206	27. 474	23. 4	22. 3	....	30 37 56. 07						
8273	12. 364	20. 7	25. 6	....	67 06 25. 06	+ 7 49. 36	−0. 85	+0. 15	....	59. 23	
8314	24. 599	22. 8	23. 6	....	73 42 32. 61						
8324	15. 760	20. 8	25. 7	....	24 26 35. 69	− 4 34. 57	−1. 27	−0. 09	....	59. 22	
46	23. 132	25. 2	21. 9	....	60 49 59. 50						
67	16. 985	21. 9	25. 4	....	37 16 20. 27	− 3 10. 94	−0. 01	−0. 05	....	58. 85	
120	10. 431	25. 5	22. 0	....	32 53 17. 39						
175	30. 353	21. 8	25. 8	....	65 27 21. 14	−10 19. 46	−0. 11	−0. 20	....	59. 50	
198	23. 895	21. 4	23. 0	....	47 35 43. 87						
219	16. 773	22. 3	25. 0	....	50 16 51. 90	+ 3 41. 23	−0. 29	+0. 06	....	58. 88	
239	27. 147	23. 5	24. 0	....	60 25 57. 79						
259	12. 669	23. 8	23. 8	....	37 40 01. 95	− 7 29. 73	−0. 11	−0. 13	....	48 59 59. 90	

Observations for Latitude.—Station No. 19—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″		° ′ ″	
Gr. 12-Yr. 73	15.943	22.6	25.1	....	67 06 25.17						
345	23.893	22.3	25.4	....	30 45 22.73	+ 4 06.95	−1.25	+0.68	....	48 59 59.73	
401	28.903	24.0	23.8	....	28 04 54.21						
438	11.313	23.3	24.3	....	69 36 52.98	+ 9 06.10	−0.18	+0.17	....	59.98	
5693	26.935	12.8	9.0	0 10	31 54 45.54						
5823	14.465	8.0	16.4	....	65 52 19.72	+ 6 27.36	−1.03	+0.12	+0.01	59.09	August 14.
5853	26.262	14.6	10.4	....	49 49 45.51						
5911	14.792	10.5	15.9	....	48 22 07.26	− 5 56.29	−0.27	−0.10	....	59.71	
6047	27.858	14.8	12.9	....	72 12 43.69						
6073	11.341	13.0	14.8	....	26 04 21.57	− 8 33.07	+0.02	−0.17	....	59.41	
6114	13.754	13.0	14.7	....	76 58 48.11						
6157	26.657	15.0	13.0	....	20 47 49.26	+ 6 40.81	+0.07	+0.11	....	59.70	
6206	12.392	12.8	15.6	....	79 59 00.73						
6245	26.920	14.7	13.9	....	17 45 54.69	+ 7 31.28	−0.45	+0.17	....	58.71	
6268	14.710	15.0	13.0	....	39 26 29.46						
6289	24.694	14.1	14.0	....	58 43 49.48	− 5 10.13	+0.47	−0.69	......	59.72	
6318	12.193	13.0	15.2	....	59 28 03.90						
6365	28.353	15.7	13.0	....	38 15 10.56	+ 8 21.98	+0.11	+0.15	....	59.47	
6421	20.210	14.0	14.7	....	49 17 42.19						
6476	20.211	14.8	14.0	....	48 42 15.59	+ 0 00.03	+0.02	0.00	....	58.94	
6553	18.267	16.0	13.0	....	32 18 22.04						
6586	22.680	13.7	16.0	....	65 46 11.07	− 2 17.08	+0.16	−0.04	....	59.59	
6624	23.277	14.0	15.9	....	40 07 51.88						
6681	17.890	14.9	15.5	....	57 46 32.47	+ 2 47.31	−0.56	+0.05	....	59.00	
6728	16.675	13.9	16.8	....	43 25 37.08						
6748	22.931	15.9	14.9	....	54 40 51.49	− 3 11.33	−0.42	−0.05	....	59.18	
6780	20.421	16.0	14.9	....	57 43 06.91						
6817	20.397	13.0	17.8	....	40 16 54.86	− 0 00.75	−0.83	0.00	....	59.31	
6830	14.958	14.9	15.9	....	47 36 33.30						
6865	25.159	13.0	17.7	....	50 33 59.62	− 5 16.87	−1.27	−0.08	....	58.21	
6937	15.321	14.6	15.9	....	36 28 18.76						
6970	25.244	16.0	14.6	....	61 41 56.68	− 5 08.24	+0.02	−0.09	....	59.11	
7024	17.430	16.0	14.8	....	61 51 33.65						
7073	23.411	13.9	16.9	....	36 02 13.41	+ 3 05.79	−0.44	+0.05	....	58.97	
5853	25.919	14.9	16.9	....	49 49 45.67						
5911	14.453	14.5	17.7	....	48 22 07.40	− 5 56.17	−1.16	−0.10	....	59.10	August 15.
6047	28.123	14.6	17.7	....	72 12 43.85						
6073	11.582	19.0	13.0	....	26 04 21.68	− 8 33.81	+0.65	−0.17	....	59.43	
6114	13.232	15.7	16.8	....	76 58 48.28						
6157	26.123	16.8	16.1	....	20 47 49.38	+ 6 40.42	−0.09	+0.11	....	59.31	
6206	12.811	15.9	17.1	....	79 59 00.91						
6245	27.323	17.1	16.4	....	17 45 51.80	+ 7 30.79	−0.11	+0.17	....	58.70	
6268	14.895	17.2	16.6	....	39 26 29.61						
6289	21.872	15.6	18.3	....	58 43 49.68	− 5 09.94	−0.47	−0.09	.....	59.17	
6318	11.996	15.1	19.0	....	59 28 01.10						
6365	28.181	18.9	16.4	....	38 15 10.71	+ 8 22.75	+0.31	+0.15	....	60.01	
6421	20.100	16.5	19.0	....	49 17 42.40						
6476	20.119	18.0	17.8	....	48 42 15.80	+ 0 00.59	−0.51	0.00	....	59.18	
6553	18.580	19.0	17.4	....	32 18 22.23						
6586	22.983	16.1	20.4	....	65 46 11.32	− 2 16.77	−0.[illegible]	0.01		48 59 59.[illegible]	

Observations for Latitude.—Station No. 19—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red to merid		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6624	23. 296	17. 3	19. 5	....	40 07 52. 14						
6681	17. 899	17. 8	19. 4	....	57 46 32. 74	+ 2 47. 65	−0. 85	+0. 05	....	48 59 59. 29	
6728	16. 821	17. 2	20. 1	....	43 25 37. 33						
6748	23. 141	21. 2	16. 4	....	54 40 51. 76	− 3 16. 32	+0. 42	−0. 05	....	58. 60	
6780	20. 603	19. 0	18. 8	....	57 43 07. 19						
6817	20. 532	19. 0	19. 1	....	40 16 55. 11	− 0 02. 21	+0. 02	0. 00	....	58. 96	
6830	15. 058	16. 7	20. 0	....	47 36 33. 56						
6865	25. 296	22. 0	17. 3	....	50 33 59. 89	− 5 18. 02	+0. 76	−0. 08	....	59. 38	
6937	15. 486	19. 1	20. 7	....	76 28 19. 01						
6970	25. 416	21. 1	18. 8	....	61 41 56. 99	− 5 08. 46	+0. 16	−0. 09	....	59. 61	
7024	17. 273	19. 0	21. 4	....	61 51 33. 99						
7073	23. 238	21. 2	19. 3	....	36 02 13. 69	+ 3 05. 29	−0. 11	+0. 05	....	59. 07	
7100	10. 540	21. 9	18. 8	....	42 45 55. 67						
7166	29. 568	18. 4	22. 4	....	55 33 46. 90	− 9 51. 07	−0. 20	−0. 18	....	59. 84	
7215	15. 100	19. 2	21. 6	....	57 07 47. 52						
7277	25. 839	20. 5	20. 7	....	40 41 05. 60	+ 5 33. 59	−0. 58	+0. 10	....	59. 67	
7320	22. 361	21. 5	20. 0	....	38 09 44. 29						
Gr. 7-Yr. 2395	17. 655	19. 7	21. 8	....	59 45 23. 31	+ 2 26. 18	−0. 13	+0. 04	....	59. 90	
7377	30. 404	17. 9	23. 8	....	59 28 13 74						
7398	10. 703	23. 1	18. 5	....	38 52 09. 24	−10 11. 97	−0. 29	−0. 18	....	59. 05	
7416	25 696	21. 2	20 4	....	62 03 13. 10						
7453	15. 286	20. 0	22. 0	....	36 07 33. 06	− 5 23. 37	−0. 27	−0. 10	....	59 34	
7480	19. 024	21. 3	20 5	....	45 59 15. 29						
7489	22. 166	19. 9	21. 8	....	52 03 58. 56	− 1 37. 60	−0. 25	−0. 02	....	59. 05	
7566	12. 955	20. 4	20 6	....	37 42 34. 82						
7595	27. 510	20. 0	20. 9	....	60 32 28. 25	− 7 32. 12	−0. 25	−0. 13	....	59. 03	
7627	22 497	19. 9	20. 6	....	25 20 07. 69						
7686	17. 692	19. 5	20. 4	....	72 34 52. 44	+ 2 29. 26	−0. 36	+0. 05	....	59. 01	
7755	17. 332	19. 6	20. 0	....	58 47 40. 70						
7765	23. 857	19. 8	19. 9	....	39 05 32. 42	+ 3 22. 69	−0. 11	+0. 06	....	59. 20	
7787	18. 587	17. 6	21. 9	....	52 01 36. 80						
7800	22. 559	21. 7	17. 7	....	45 54 15. 66	+ 2 03. 48	−0. 07	+0. 03	....	59. 67	
7820	13. 226	21. 7	17. 6	....	48 50 22. 68						
7882	28. 325	17. 7	22. 0	....	49 25 13. 85	− 7 49. 02	−0. 01	−0. 13	....	48 59 59. 08	

Mean latitude (62 determinations), 48° 59′ 59″.31.

$\varepsilon = \pm\ 0''.405$
$r = \pm\ 0''.270$
$\varepsilon_0 = \pm\ 0''.051$
$r_0 = \pm\ 0''.034$

UNITED STATES NORTHERN BOUNDARY.

Observations for Latitude.

[Astronomical Station No. 20—Chief Mountain Lake, 759 miles west of Pembina.—Observer, J. F. Gregory, Captain United States Engineers.—Zenith Telescope, Würdemann No. 20.—Chronometer, Negus Sidereal No. 1513.

B. A. C. No.	Readings.				Declination.	Corrections.				La itude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
6206	12.304	20.5	20.5	....	79 59 02.47						
6245	26.924	20.6	21.1	....	17 45 55.86	+ 7 34.14	−0.11	+0.17	....	49 00 03.36	August 23.
6268	14.936	19.8	22.4	....	39 26 31.12						
6289	24.796	22.1	20.1	....	58 43 51.38	− 5 06.28	−0.13	−0.09	....	04.75	
6318	11.820	22.1	20.2	....	59 28 05.84						
6365	28.126	19.0	24.0	....	38 15 12.36	+ 8 26.51	−0.69	+0.15	....	05.07	
6421	19.966	21.5	21.8	0 6	49 17 44.25						
6476	20.007	21.9	21.5	....	48 42 17.69	+ 0 01.27	+0.04	0.00	+0.01	02.27	Rejected.
6553	17.940	21.8	22.2	....	32 18 23.90						
6586	22.260	22.0	23.0	....	65 46 1[illegible].53	− 2 14.19	−0.31	−0.04	....	04.17	
6624	22.989	20.8	24.0	....	40 07 54.02						
6681	17.491	23.0	22.4	....	57 46 35.01	+ 2 50.78	−0.58	+0.05	....	04.77	
6728	16.777	21.5	24.1	....	43 25 39.43						
6748	22.997	26.2	19.9	....	54 40 54.09	− 3 13.21	+0.83	−0.05	....	04.33	
6780	20.160	24.1	21.8	....	57 43 09.58						
6817	20.175	22.1	24.0	....	40 16 57.22	+ 0 00.47	+0.09	0.00	....	03.96	
6830	14.701	24.0	22.1	....	47 36 35.85						
6865	24.861	23.0	24.0	....	50 34 02.31	− 5 15.60	+0.20	−0.08	....	03.60	
6937	14.923	23.0	24.6	....	36 28 21.13						
6970	24.804	26.1	21.3	....	61 41 59.62	− 5 06.93	+0.71	−0.09	....	04.06	
7100	10.803	24.0	23.9	0 12	42 45 58.17						
7166	29.773	24.0	25.0	....	55 53 49.60	− 9 49.27	−0.20	−0.18	+0.02	01.25	
6318	11.713	19.9	14.5	....	59 28 06.12						
6365	27.979	13.1	21.8	....	38 15 12.59	+ 8 25.27	−0.74	+0.15	....	04.03	August 25.
6421	20.178	16.9	18.4	....	49 17 44.53						
6476	20.261	18.7	16.8	....	48 42 18.00	+ 0 02.58	+0.09	0.00	....	03.94	
6553	18.278	17.9	17.8	....	32 18 24.16						
6586	22.618	17.8	18.5	....	65 46 13.92	− 2 14.81	−0.13	−0.01	......	01.06	
6624	23.153	15.7	20.6	....	40 07 54.34						
6681	17.724	21.0	16.0	....	57 46 35.42	+ 2 48.61	+0.02	+0.05	....	03.59	
6728	17.027	15.9	20.9	....	43 25 39.81						
6748	23.236	21.0	16.0	....	54 40 54.52	− 3 12.87	0.00	−0.05	....	04.24	
6780	20.540	18.0	19.0	....	57 43 10.03						
6817	20.543	18.0	19.0	....	40.16 57.61	+ 0 00.09	−0.45	0.00	......	03.46	
6830	14.949	17.2	19.9	....	47 36 36.28						
6865	25.124	19.9	17.2	....	50 34 02.75	− 5 16.07	0.00	−0.08	......	03.37	
6937	15.293	16.9	20.6	....	36 28 21.53						
6970	25.178	21.0	16.3	....	61 42 00.14	− 5 07.05	+0.22	−0.09	....	03.91	
7024	17.742	19.5	18.0	....	61 51 37.23						
7073	23.738	19.0	18.6	....	36 02 16.31	+ 3 06.25	+0.42	+0.05	.	49 00 03.49	

Observations for Latitude.—Station No. 20—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level. N.	Level. S.	Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
7100 7166	10.618 29.621	18.6 21.0	19.0 17.0	....	42 45 58.61 55 33 50.15	− 9 50.28	+0.80	−0.18	....	49 00 04.72	August 25.
7215 7277	14.974 25.756	18.4 20.2	19.8 18.1	....	57 07 50.84 40 41 08.55	+ 5 33.99	+0.16	+0.10	....	03.94	
7320 Gr. 7-Yr. 2395	22.365 17.644	19.0 21.0	19.8 18.0	....	28 09 47.18 59 45 26.81	+ 2 26.65	+0.49	+0.04	....	04.18	
7377 7398	30.478 10.797	19.0 20.5	20.0 18.6	....	59 28 17.27 38 52 12.22	−10 11.35	+0.20	−0.18	....	03.41	
7416 7433	25.629 15.230	20.0 20.0	19.5 19.8	....	62 03 16.73 36 07 35.92	− 5 23.02	+0.16	−0.10	....	03.36	
7480 7489	18.723 21.831	19.0 22.0	20.9 18.0	....	45 59 18.58 52 04 02.00	− 1 36.54	+0.47	−0.02	....	04.20	
7566 7595	12.939 27.453	20.1 21.0	19.8 19.2	....	37 42 37.83 60 32 31.93	− 7 31.47	+0.47	−0.13	....	03.75	
7627 7686	22.344 17.530	20.0 21.0	19.8 19.4	....	25 20 10.21 72 34 56.30	+ 2 29.54	+0.40	+0.05	....	03.24	
7755 7765	17.106 23.670	19.0 21.6	21.7 18.5	....	58 47 44.42 39 05 35.56	+ 3 23.90	+0.09	+0.06	....	04.04	
7787 7800	18.562 22.519	20.5 20.7	20.1 19.8	....	52 01 40.36 45 54 19.06	+ 2 02.92	+0.29	+0.03	....	02.95	
7820 7882	13.171 28.240	19.8 21.0	20.7 19.7	....	48 50 26.18 49 25 17.57	− 7 48.09	+0.09	−0.13	....	03.65	
7907 7945	9.096 30.964	19.8 20.7	21.0 19.9	....	74 43 05.64 22 51 23.20	+11 19.29	−0.09	+0.23	....	03.85	
7962 8024	28.475 12.160	19.4 21.2	20.9 19.5	....	41 17 22.08 56 25 51.28	+ 8 26.89	+0.04	+0.15	....	03.76	
8036 8050	19.589 20.782	21.0 19.0	19.8 21.4	....	49 22 11.80 48 36 44.09	+ 0 37.06	−0.27	+0.01	....	04.74	
8083 8128	16.072 23.950	19.6 20.9	21.0 19.6	....	56 28 29.75 41 23 28.76	+ 4 04.71	−0.02	+0.07	....	04.01	
8206 8273	29.612 13.507	19.6 21.1	21.3 20.1	....	30 37 59.35 67 06 29.38	+ 7 49.21	−0.16	+0.15	....	03.57	
8314 8334	24.841 16.017	20.0 20.5	21.4 20.7	....	73 42 36.93 24 26 40.53	− 4 34.10	−0.26	−0.09	....	04.18	
46 67	23.237 17.150	20.2 20.4	21.6 20.9	....	60 50 03.54 37 16 23.66	− 3 08.80	−0.42	−0.05	....	04.33	
120 175	10.671 30.757	19.8 21.0	21.4 21.0	....	32 53 20.57 65 27 25.03	−10 17.72	−0.36	−0.20	....	04.52	
198 213	22.877 16.629	19.0 21.1	22.6 20.2	0 18	47 35 47.42 50 16 55.49	+ 3 42.97	−0.60	+0.06	+0.04	03.93	
230 250	27.002 13.174	21.2 17.9	20.0 23.5	....	60 26 01.55 37 49 05.15	− 7 28.50	−0.98	−0.13	....	03.44	
Gr. 12 Yr. 73 315	16.274 23.273	19.9 20.1	21.9 21.5	....	67 06 29.09 30 45 25.59	+ 4 08.47	−0.76	+0.08	....	05.13	
401 438	29.607 11.965	20.8 20.1	22.1 22.0	....	28 01 50.92 69 36 59.35	+ 9 08.01	−0.49	+0.17	....	04.33	
471 487	13.895 19.097	19.9 20.0	22.0 21.9	....	48 04 48.31 47 59 20.49	− 1 16.54	−0.62	−0.02	....	04.32	
522 560	21.561 28.254	20.9 21.0	21.8 21.9	....	50 03 16.51 50 10 12.38	− 5 26.03	−0.67	−0.13	....	49 00 03.53	

Observations for Latitude.—Station No. 20—Continued.

B. A. C. No.	Readings.				Declination.	Corrections.				Latitude.	Remarks.
	Microm.	Level.		Merid. dist.		Microm.	Level.	Refrac.	Red. to merid.		
		N.	S.								
				m. s.	° ′ ″	′ ″	″	″	″	° ′ ″	
611	25.668	26.9	15.8	....	63 46 50.37						
656	15.790	14.1	28.0	....	34 23 34.48	− 5 06.84	−0.62	−0.09	....	49 00 04.87	August 25.
744	22.361	20.0	23.0	....	66 50 03.04						
752	18.360	22.0	20.5	....	31 11 14.07	− 2 04.28	−0.32	−0.04	....	03.91	
825	8.840	19.2	23.4	....	19 28 37.66						
896	31.493	23.1	19.7	....	78 54 58.00	−11 43.67	−0.18	−0.26	......	49 00 03.72	

Mean latitude (16 determinations), 4 .° 00″ 04″.00.

$\varepsilon = 0''.503$
$\tau = 0''.335$
$\varepsilon_0 = 0''.073$
$\tau_0 = 0''.049$

1872.

UNITED STATES NORTHERN BOUNDARY.

SEPTEMBER 12.

STATION, CAMP NO. 1, NEAR PEMBINA, DAK.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 7, by the eastern elongation of Polaris, Chronometer Negus **1514**, *sidereal.*

[Observer, W. J. Twining, Captain United States Engineers.]

A. R. of Polaris, $1^h\ 12^m\ 41^s.5$
δ of Polaris, $88°\ 37'\ 36''.7$
Assumed ϕ, $48°\ 59'\ 56''.5$

$\log\cot\delta = 8.3796706$
$\log\tan\phi = 0.0608220$
$\log\cos t_0 = 8.4404926$
$t_0 = 88°\ 25'\ 11''.8$
t_0 in time $= 5^h\ 53^m\ 40^s.8$
Chro. A. R. $= 1^h\ 12^m\ 37^s.5$
Chro. time of elong. $= 19^h\ 18^m\ 56^s.7$

$$\sin(z - z_0) = \cos\delta\sin(T - T_0)$$

$\log\operatorname{cosec}\delta = 0.0001248$
$\log\sin\phi = 9.8777735$
$\log\cos z_0 = 9.8778983$
$z_0 = 40°\ 58'\ 55''.2$

Note.—The notation and method adopted in this computation are derived from the article on the Zenith Telescope, page 360, Vol. II, Chauvenet's Spherical and Practical Astronomy.

Number.	Microm. readings.	Level. N.	Level. S.	T	$T - T_0$	$Z - Z_0$	Corrected for dr.	Combined with number—	Diff. of level.	Equiv. in microm.	Diff. of turns.	$Z - Z'$	Value of 1 rev.	v
				h. m. s.	m. s.	′ ″	′ ″					″	″	
1	−10.0	34.8	30.7	18 48 19.0	−30 37.7	−10 59.60	−10 59.60	21	+ .35	+ .0040	11.004	867.05	78.794	.119
2	9.5	35.7	29.8	50 11.8	28 41.9	10 18.39	10 18.41	22	− .70	− .0080	10.992	865.62	.750	.075
3	9.	35.8	29.9	52 01.3	26 52.1	9 38.26	9 38.30	23	− .20	− .0023	10.998	863.01	.472	.243
4	8.5	35.8	30.1	53 52.5	25 04.2	8 59.61	9 59.67	24	− .10	− .0011	10.999	864.68	.615	.060
5	8.	36.5	29.7	55 42.0	23 14.7	8 20.47	8 20.55	25	− .70	− .0080	10.992	864.48	.646	.029
6	7.5	35.5	31.0	18 57 31.8	21 21.9	7 41.19	7 41.29	26	+ .40	+ .0046	11.005	864.55	.563	.112
7	6.	35.9	31.7	19 03 01.0	15 55.7	5 43.25	5 43.41	27	+ .50	+ .0057	10.006	786.22	.570	.105
8	5.5	35.9	31.8	4 48.5	11 08.2	5 05.27	5 05.45	28	+ .55	+ .0063	10.006	786.07	.557	.118
9	5.	36.6	31.3	6 42.2	12 11.5	4 23.89	4 24.09	29	+ .20	+ .0023	10.002	784.38	.420	.255
10	4.5	36.6	31.4	8 28.7	10 28.0	3 45.66	3 45.88	30	− .10	− .0011	9.999	785.42	.551	.124
11	4.0	36.6	31.4	10 15.3	8 41.4	3 07.42	3 07.66	31	− .10	− .0011	9.999	788.45	.854	.179
12	3.5	36.4	32.0	12 00.5	6 47.2	2 26.35	2 26.61	32	− .15	− .0017	9.998	786.67	.680	.005
13	3.	36.6	31.9	13 56.8	7 59.9	1 47.79	1 48.05	33	− .20	− .0023	9.998	787.09	.727	.052
14	2.5	36.6	31.9	15 46.5	3 10.2	1 08.37	1 08.67	34	− .15	− .0017	9.998	787.52	.764	.089
15	2.	36.7	31.7	17 31.7	− 1 22.0	− 0 29.48	− 0 29.70	35	.00	.0000	10.000	788.12	.812	.137
16	1.5	36.8	31.9	19 27.0	+ 0 30.3	+ 0 10.89	+ 0 [illegible]	36	.00	.0000	10.000	787.36	.736	.061
17	1.	36.8	31.9	21 16.0	2 19.3	0 50.71	0 50.37	37	− .05	− .0006	9.999	786.96	.701	.026
18	− 0.5	36.8	31.9	23 05.2	4 08.5	1 29.32	1 28.91	38	− .10	− .0010	9.999	786.65	.673	.002
19	0.0	37.1	31.6	24 53.0	5 56.3	2 08.04	2 07.61	39	− .70	− .0080	9.992	787.45	.808	.133
20	+ 0.5	27.0	31.9	26 46.0	7 49.3	2 48.16	2 48.25	40	− .50	− .0057	9.994	787.59	78.803	.128
21	1.0	36.3	31.5	28 35.2	9 38.5	3 27.88	3 27.45							
22	1.5	36.2	31.7	30 26.0	11 29.3	4 07.66	4 07.21							
23	2.0	37.3	31.8	32 10.5	13 13.8	4 45.18	4 44.71							
24	2.5	37.3	31.8	34 02.8	15 05.1	5 25.5	5 25.01							
25	3.0	37.3	31.9	35 51.5	16 54.8	6 04.41	6 03.93							
26	3.5	37.3	32.0	37 41.8	18 45.1	6 43.79	6 43.26							
27	4.0	37.3	32.1	39 31.8	20 35.1	7 23.36	7 22.84							
28	4.5	37.3	32.1	41 17.5	22 20.8	8 01.19	8 00.62							
29	5.	37.5	31.8	43 08.5	24 11.8	8 40.88	8 40.21							
30	5.5	37.3	32.3	45 02.0	26 05.3	9 20.15	9 19.59							
31	6.0	37.5	32.5	46 54.0	27 57.3	10 01.12	10 00.79							
32	6.5	37.1	33.0	48 41.2	29 47.5	10 40.71	10 40.06							
33	7.	37.5	33.2	50 33.5	31 36.9	11 19.69	11 19.02							
34	7.5	37.5	32.5	52 25.6	33 28.9	11 59.54	11 58.85							
35	8.0	37.7	32.7	54 17.0	35 20.3	12 39.13	12 38.42							
36	8.5	37.7	32.8	56 08.0	37 11.3	13 18.61	13 17.91							
37	9.0	37.7	32.9	57 59.5	39 02.8	13 58.06	13 57.33							
38	9.5	37.7	33.0	19 59 52.0	40 55.3	14 36.36	14 35.59							
39	10.0	37.6	33.5	20 01 39.5	42 42.8	15 15.88	15 15.09							
40	10.5	37.6	33.5	20 03 35.0	+44 38.3	+15 56.65	+15 55.84							

Mean value of 1 turn Z. T. microm., $78''.675 \pm .018$

$\varepsilon = 0''.121$
$\tau = 0''.081$
$\varepsilon_0 = 0''.027$
$\tau_0 = 0''.018$

$Z - Z'$ = diff. of zenith distances.
Z = zenith distance at elongation.
$T - T_0$ = diff. of time from elongation.
T_0 = Chro. time of elongation.
dr = differential refraction.

1872.

UNITED STATES NORTHERN BOUNDARY.

September 21.

Station, Camp No. 1, near Pembina, Dak.

Observations to determine the value of one division of the level of Zenith Telescope Würdemann No. 7, in terms of the micrometer. Mark, cross-hairs of Zenith Telescope No. 11.

[Observer, W. J. Twining, Captain United States Engineers.]

No.	Microm. readings, first position.	Means.	Microm. readings, second position.	Means.	Level, first position.		Level, second position.		Mean change of level.	Mean change of microm.	1d of level in divisions of microm.	v	v v
					N.	S.	N.	S.					
1	23.582		24.071		10.0	64.8	54.5	20.2					
	.583		.057		10.2	64.7	54.4	20.2					
	.587	23.584	.066	24.065	10.2	64.9	54.0	20.4	44.3	48.1	1.0858	.0575	.003306
2	24.055		24.592		16.4	58.2	60.2	14.3					
	.075		.578		15.9	58.8	60.0	14.5					
	.077	24.069	.571	24.580	16.2	58.3	60.0	14.3	44.0	51.1	1.1591	.0158	.000250
3	24.571		24.982		18.1	56.0	54.0	20.2					
	.575		.993		18.3	55.8	54.0	20.2					
	.587	24.578	.987	24.987	18.3	55.9	53.8	20.2	35.6	40.9	1.1489	.0056	.000031
4	24.987		25.414		17.9	56.3	54.7	19.3					
	.996		.413		18.2	56.0	55.3	18.4					
	.996	24.993	.412	25.413	18.2	55.8	54.7	19.2	37.0	42.0	1.1351	.0082	.000067
5	24.995		25.392		18.8	55.0	54.0	19.2					
	.993		.406		18.3	55.3	53.9	19.7					
	.989	24.992	.395	25.398	18.3	55.2	54.0	19.5	35.5	40.6	1.1437	.0004	.000000
6	25.392		25.857		16.0	57.1	54.5	18.3					
	.405		.866		16.1	57.2	54.4	18.6					
	.400	25.399	.867	25.863	16.0	57.2	54.5	18.2	38.6	46.4	1.2002	.0569	.003237
7	25.848		26.275		16.2	56.3	53.3	19.0					
	.863		.269		16.2	56.2	53.2	19.1					
	.862	25.858	.278	26.274	16.1	56.8	53.3	18.8	37.3	41.6	1.1153	.0280	.000784
8	17.034		17.400		20.5	51.2	52.8	18.3					
	.039		.400		20.6	50.9	52.4	18.6					
	.038	17.037	.398	17.399	20.6	50.5	52.3	18.6	32.1	36.2	1.1277	.0156	.000243
9	17.402		17.765		18.3	52.2	49.3	21.0					
	.393		.772		18.7	52.0	49.3	21.1					
	.398	17.398	.766	17.768	18.3	52.1	49.3	21.0	30.9	37.0	1.1974	.0541	.002927
10	17.761		18.100		19.2	50.9	49.7	20.2					
	.769		.130		19.2	50.8	51.2	18.6					
	.772	17.767	.134	18.121	19.1	50.7	51.4	18.6	31.6	35.4	1.1203	.0230	.000529
*11	18.222		18.532		21.0	49.0	50.2	19.7					
	.233		.541		21.0	49.0	50.0	19.8					
	.242	18.232	.528	18.534	21.0	49.1	49.9	20.1	29.0	30.2	1.0114	......	....

Mean of 1^d level = $1^d.1133 \pm .0076$

$\varepsilon = 0^d.0356$
$\tau = 0^d.0240$
$\varepsilon_0 = 0^d.0113$
$\tau_0 = 0^d.0076$

1^d Z. T. Micro. = $0''.78675$ 1^d Z. T. Level = $0''.8995$

* Rejected.

1873.

UNITED STATES NORTHERN BOUNDARY.

June 15.

Station, Camp No. 2, 20 miles west of Pembina.

Observations to determine the value of one division of the level of Zenith Telescope Würdemann No. 20, in terms of the micrometer. Mark, cross-hairs of Transit Telescope No. 4.

[Observer, Lewis Boss.]

No.	Microm. readings, first position.	Means.	Microm. readings, second position.	Means.	Level, first position. N.	Level, first position. S.	Level, second position. N.	Level, second position. S.	Mean change of level.	Mean change of microm.	1d of level in divisions of microm.	v	vv
1	21.039 .029 .040	21.036	21.542 .539 .546	21.542	13.0 13.6 14.0	45.3 45.0 44.5	48.5 49.3 49.4	10.2 09.0 08.6	35.6	50.6	1.421	.019	.000361
2	21.543 .530 .540	21.538	22.131 .134 .128	22.131	08.0 08.2 08.4	50.1 49.8 49.2	51.2 52.0 52.1	06.5 05.8 05.4	43.7	59.3	1.357	.083	.006889
3	27.095 .095 .102	27.097	27.642 .658 .650	27.650	07.3 07.8 07.6	50.4 49.5 49.6	45.0 44.8 44.2	12.1 12.4 12.7	37.25	55.3	1.485	.045	.002025
4	26.761 .748 .746	26.752	27.389 .388 .383	27.387	05.2 05.0 05.1	51.8 51.9 51.9	49.2 49.1 49.2	07.1 07.4 07.0	44.45	63.5	1.429	.011	.000121
5	19.829 .820 .826	19.825	20.383 .392 .384	20.386	07.4 07.0 06.3	48.0 48.5 49.2	44.4 44.0 43.4	10.9 11.3 12.0	37.4	56.1	1.512	.072	.005184
6	20.368 .350 .364	20.361	20.886 .883 .898	20.889	07.3 06.0 05.5	48.1 49.4 49.6	45.0 44.6 43.8	10.2 10.8 11.3	38.2	52.8	1.382	.058	.003364
7	20.856 .852 .849	20.852	21.442 .437 .457	21.445	05.7 05.0 05.4	49.3 50.4 50.2	48.0 48.3 48.0	07.0 06.6 06.9	42.95	59.3	1.383	.057	.003249
8	21.436 .438 .440	21.438	21.989 .993 .976	21.986	10.0 09.5 09.0	45.0 45.4 46.0	48.3 48.3 48.1	06.4 06.5 06.7	38.85	54.8	1.411	.029	.000841
9	21.999 .992 .985	21.992	22.559 .558 .548	22.555	06.2 05.5 05.3	48.6 49.0 49.0	44.2 44.2 44.0	10.1 10.2 10.6	38.5	56.3	1.462	.022	.000484
10	22.540 .551 .552	22.548	23.058 .053 .064	23.058	07.9 07.6 07.7	46.4 46.7 46.7	42.9 42.7 42.8	11.4 11.5 11.5	35.1	51.0	1.453	.013	.000169
11	14.536 .523 .538	14.532	13.914 .905 .912	13.910	49.3 49.3 49.2	05.0 05.1 05.2	06.2 06.3 05.8	48.0 48.2 48.5	43.15	62.2	1.441	.001	.000001
12	13.908 .904 .898	13.903	13.416 .410 .413	13.413	43.4 43.2 43.1	10.5 10.7 10.8	10.4 10.4 09.8	43.3 43.3 44.0	32.9	49.0	1.489	.049	.002401
13	13.411 .412 .422	13.415	12.833 .824 .826	12.828	48.1 48.2 48.0	05.5 05.6 05.7	08.0 07.5 07.4	45.6 46.2 45.3	40.45	58.7	1.451	.011	.000121

Value of level—Continued.

No.	Microm. readings, first position.	Means.	Microm readings, second position.	Means.	Level, first position. N.	Level, first position. S.	Level, second position. N.	Level, second position. S.	Mean change of level.	Mean change of microm.	1[d] of level in divisions of microm.	v	vv
14	17.140		17.668		08.2	45.3	44.2	09.0					
	.151		.673		08.1	45.4	44.3	08.9					
	.147	17.146	.668	17.670	08.1	45.7	44.4	08.8	36.4	52.4	1.440	.000	.000000
15	24.826		25.305		07.0	46.0	40.0	12.9					
	.827		.316		07.3	45.8	40.0	12.8					
	.813	24.822	.309	25.310	07.1	46.0	39.9	13.0	32.95	48.8	1.481	.041	.001681
16	25.944		26.540		05.2	47.5	46.5	06.0					
	.938		.538		05.5	47.2	46.4	06.2					
	.949	25.944	.534	26.537	04.8	47.8	46.0	06.2	41.25	59.3	1.438	.002	.000004

Mean value of 1[d] of level in terms of micro, 1.4397.

$\varepsilon = .042$
$\tau = .028$
$\varepsilon_0 = .010$
$\tau_0 = .007$

1[d] of micro. = ″.62055
1[d] of level = ″.8936 ± .0043

1873.

UNITED STATES NORTHERN BOUNDARY.

June 13.

Station, Astronomical Camp No. 2.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 20, at the eastern elongation of Polaris, Chronometer Negus 1513, sidereal.

[Observer, W. J. Twining, Captain United States Engineers.]

A. R. of Polaris, $1^h\ 11^m\ 45^s.63$
δ of Polaris, $88°\ 37'\ 42''.1$
ϕ, $48°\ 59'\ 57''.0$

log cot δ = 8.379198
log tang ϕ = 0.060824
log cos t_0 = 8.440022
t_0 in time = $7^h\ 5^m\ 41^s.2$
A. R. = $1^h\ 11^m\ 45^s.6$
Sid. time of elong. = $19^h\ 18^m\ 04^s.4$
Chro. fast = $00^h\ 3^m\ 35^s.4$
Chro. time of elong. = $19^h\ 21^m\ 39^s.8$

$$\sin (z-z_0) = \cos d \sin T - T_0$$

log sin δ = 9.999875
log sin ϕ = 9.877774
log cos z_0 = 9.877899
z_0 = $40°\ 58'\ 55''.0$

Number.	Microm. readings.	Level. N.	Level. S.	T.	T − T₀	Z − Z₀	Combined with number—	Diff. of level.	Equiv. in microm. turns.	Diff. of turns.	Z − Z	Value of 1 rev.	v	v v
				h. m. s.	h. m. s.	″					″	″		
1	25.	28.8	32.8	18 59 02.0	−00 22 37.8	+186.74	19	+0.10	− .0014	9.0014	560.42	62.259	.184	33856
2	24.5	28.5	33.0	19 00 32.5	21 07.3	451.39	20	0.50	.0072	9.0072	558.76	62.035	40	1600
3	24.	28.7	32.8	1 57.5	19 42.3	423.50	21	0.05	.0007	9.0007	559.59	62.172	97	9409
4	23.5	28.5	33.0	3 25.0	18 14.8	392.08	22	0.80	.0115	9.0115	558.96	62.027	48	2304
5	23.	28.1	33.2	4 49.5	16 50.3	362.43	23	0.90	.0130	9.0130	559.39	62.065	10	100
6	22.5	28.7	32.9	6 21.0	15 18.8	329.66	24	0.25	.0036	9.0036	559.09	62.096	21	441
7	22.	29.0	33.0	7 47.5	13 52.3	298.66	25	0.66	.0086	9.0086	558.30	61.984	91	8281
8	21.5	28.7	33.2	9 09.5	12 30.3	269.27	26	+0.25	.0050	9.0050	559.47	62.138	63	3969
9	21.	29.0	32.9	10 37.5	11 02.3	237.71	27	−0.35	− .0504	8.9950	559.63	62.216	.141	19881
10	20.5	29.0	33.0	11 59.0	09 40.8	208.18	28	0.10	+ .0000	9.0000	561.03	62.337	.262	68644
11	20.	28.7	33.2	13 33.0	08 06.8	174.75	29	+0.60	.0086	9.0086	558.41	61.989	86	7396
12	19.5	29.0	32.9	14 57.5	06 42.3	144.13	30	0.35	.0050	9.0050	559.62	62.145	70	4900
13	19.	29.0	33.0	16 25.0	05 14.8	113.02	31	0.60	.0086	9.0086	559.15	62.068	07	49
14	18.5	28.6	33.3	17 51.5	03 48.3	81.97	32	0.35	.0050	9.0050	557.95	61.960	.115	13225
15	18.	28.8	33.1	19 17.0	02 22.7	51.24	33	0.95	.0137	9.0137	559.02	62.019	56	3136
16	17.5	28.8	33.0	20 45.5	−00 00 51.3	+ 19.50	34	0.75	.0108	9.0108	558.70	62.003	72	5184
17	17.	28.4	33.4	22 10.5	+00 00 20.7	− 11.02	35	0.75	.0108	9.0108	557.22	61.839	.236	55696
18	16.5	29.1	32.8	23 38.5	01 58.7	42.62	36	+0.85	+ .0122	9.0122	558.81	62.006	69	4761
19	16.	29.1	32.9	25 05.0	03 25.2	73.68								
20	15.5	28.9	32.4	26 30.5	04 50.7	104.37								
21	15.	29.0	33.0	27 57.5	06 17.7	135.60								
22	14.5	29.4	32.3	29 24.0	07 43.2	166.28								
23	14.	29.3	32.6	30 48.5	09 08.7	196.96								
24	13.5	29.5	33.2	32 19.0	10 39.2	229.13								
25	13.	29.5	32.3	33 44.5	12 03.7	259.73								
26	12.5	29.0	33.0	35 08.5	13 28.7	290.20								
27	12.	28.6	33.2	36 37.0	14 57.2	321.92								
28	11.5	29.0	33.0	38 02.5	16 22.7	352.55								
29	11.	29.4	32.7	39 29.5	17 49.7	383.69								
30	10.5	29.0	32.2	40 57.5	19 17.7	415.19								
31	10.	29.5	32.3	42 21.0	20 41.2	446.13								
32	9.5	29.0	33.0	43 47.5	22 07.7	475.98								
33	9.	29.8	32.2	45 16.5	23 36.7	507.78								
34	8.5	29.6	32.3	46 44.5	25 04.7	539.20								
35	8.	29.0	32.0	48 05.9	26 26.4	568.21								
36	7.5	30.0	32.0	49 39.0	+00 27 59.2	−601.13								

Mean 62″.075 ± .019

Mean, 62″.075
Corr. for refrac., ± 0″.031
Value of one turn of microm., 62″.044

$\varepsilon = 0''.118$
$r = 0''.079$
$\varepsilon_0 = 0''.028$
$r_0 = 0''.019$

1873.

UNITED STATES NORTHERN BOUNDARY.

JUNE 14.

STATION, ASTRONOMICAL CAMP NO. 2.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 20, at the eastern elongation of Polaris, Chronometer Negus 1513, sidereal.

[Observer, W. J. Twining, Captain United States Engineers.]

Assumed latitude, 48° 59′ 57″.0
A. R. of Polaris, $1^h\ 11^m\ 46^s.6$
δ of Polaris, 88° 37′ 42″.0

$\log \cot \delta = 8.379209$
$\log \tan \phi = 0.060824$
$\log \cos t_0 = 8.440033$
$t_0 =$ 88° 25′ 17″.8
t_0 in time $= -\ 5^h\ 53^m\ 41^s.2$
A. R. $=$ $1^h\ 11^m\ 46^s.6$
Sid. time of elong. $=$ $19^h\ 18^m\ 05^s.4$
Chro. fast $=$ $(0^h\ 3^m\ 35^s.0$
Chro. time of elong. $=$ $19^h\ 21^m\ 40^s.4$

$$\sin (Z - Z_0) = \cos d \sin (T - T_0)$$

$\log \sin \delta = 0.000125$
$\log \sin \phi = 9.877741$
$\log \cos z_0 = 9.877859$
$z_0 = 40°\ 58′\ 55″.0$

Number.	Microm. readings.	Level. N.	Level. S.	T	$T - T_0$	$Z - Z_0$	Combined with number—	Diff. of level.	Equiv. in microm. turns.	Diff. of turns.	$Z - Z'$	Value of 1 rev.	v	vv
				h. m. s.	m. s.	″					″	″		
1	29.	24.7	24.5	18 48 44.0	−32 56.4	−707.20	21	−.8	−.0115	9.9885	620.17	62.088	.012	144
2	28.5	24.3	29.7	50 10.5	31 29.9	676.65	22	.4	.0058	9.9942	621.04	62.140	40	160
3	28.	24.3	24.7	51 45.5	29 54.9	642.65	23	.35	.0050	9.9950	618.81	61.912	.188	35344
4	27.5	24.4	24.6	53 11.5	28 28.9	612.02	24	.4	.0058	9.9942	617.62	61.798	.302	91204
5	27.	24.4	24.6	54 33.5	27 06.9	582.79	25	.4	.0078	9.9942	620.52	62.088	12	144
6	26.5	24.3	24.6	55 59.0	25 41.4	552.30	26	.4	.0058	9.9942	621.62	62.198	98	9604
7	26.	24.3	24.5	57 22.5	24 17.9	522.49	27	1.05	.0151	9.9849	622.16	62.310	.210	44100
8	25.5	24.3	24.5	58 54.5	22 45.9	489.63	28	1.0	.0144	9.9856	620.53	62.143	43	1849
9	25.	24.0	25.0	19 00 21.5	21 18.9	458.54	29	.6	.0086	9.9914	621.56	62.210	.110	12100
10	24.5	24.0	24.9	01 50.5	19 49.9	426.71	30	.6	.0086	9.9914	620.05	62.058	42	1764
11	24.	24.0	24.8	03 15.0	18 25.4	396.48	31	.7	.0101	9.9899	620.13	62.076	24	576
12	23.5	24.0	25.0	04 46.5	16 53.9	363.72	32	.65	.0094	9.9906	617.32	61.790	.310	96100
13	23.	23.7	25.2	06 09.5	15 30.9	335.42	33	.35	.0050	9.9950	621.11	62.142	42	1764
14	22.5	24.0	24.9	07 34.5	14 05.9	303.54	34	.65	.0094	9.9906	622.74	62.333	.233	54289
15	22.0	24.0	25.0	09 04.0	12 36.4	271.45	35	.45	.0065	9.9935	621.27	62.167	67	4489
16	21.5	23.8	25.0	10 26.0	11 14.4	242.05	36	.30	.0043	9.9957	621.77	62.204	.104	10816
17	21.0	23.7	25.0	11 55.5	9 44.9	209.95	37	.30	.0043	9.9957	619.56	61.983	.117	13689
18	20.5	23.5	25.0	13 21.0	8 19.4	179.27	38	.15	.0022	9.9978	621.07	62.121	21	441
19	20.	23.5	25.0	14 47.5	6 52.9	148.23	39	.10	.0014	9.9986	620.78	62.087	13	169
20	19.5	23.5	24.9	16 14.0	5 26.4	117.19	40	−.10	−.0011	9.9986	621.36	62.145	45	2025
21	19.	23.4	24.8	17 28.0	4 02.4	87.03								
22	18.5	23.6	24.8	19 05.5	2 34.9	55.61								
23	18.	23.5	24.6	20 31.0	− 1 06.4	− 23.84								
24	17.5	23.5	24.5	21 56.0	+ 0 15.6	+ 5.60								
25	17.	23.5	24.5	23 25.5	1 45.1	37.73								
26	16.5	23.4	24.5	24 53.5	3 13.1	69.32								
27	16.	22.8	25.1	26 18.0	4 37.6	99.67								
28	15.5	22.9	25.1	27 45.0	6 04.6	130.80								
29	15.	22.8	25.0	29 11.5	7 34.1	163.02								
30	14.5	22.9	25.0	30 39.0	8 58.6	193.34								
31	14.	22.9	25.1	32 03.5	10 23.1	224.65								
32	13.5	22.8	25.1	33 27.0	11 46.6	253.60								
33	13.	22.9	25.1	34 56.5	13 16.1	285.69								
34	12.5	22.8	25.0	36 30.0	14 49.6	319.20								
35	12.	23.0	24.9	37 55.5	16 15.1	349.82								
36	11.5	23.0	24.8	39 19.0	17 38.6	379.72								
37	11.	23.0	24.9	40 42.5	19 02.1	409.61								
38	10.5	23.0	24.8	42 12.5	20 32.1	441.80								
39	10.	23.0	24.7	43 38.5	21 58.1	472.55								
40	9.5	23.0	24.6	19 45 07.0	+23 26.6	+504.17								

Mean 62″ 100 ± .021

Mean, 62″.0997
Corr. for refr., −″.0314
Value of one turn, 62″.068

$\varepsilon = 0.142$
$r = 0.094$
$\varepsilon_0 = 0.032$
$r_0 = 0.021$

Mean by weight of the two series—first taken June 13, second, June 14. Adopted value of one turn 62″.055 ± .014

1873.

UNITED STATES NORTHERN BOUNDARY.

JUNE 13.

STATION, CAMP NO. 3.

Observations for value of one division of level of Zenith Telescope No. 11, Würdemann, in terms of the micrometer.

[Observer, Lieut. J. F. Gregory.]

No. of observations	Readings.				Differences.		1 *d.*	*v*	*vv*
	Micrometer.		Level		Microm.	Level.			
	Successive.	Means.	N.	S.					
	t. d. 0 99.4 99.5 98.2	0 99.03	66.3	10.1					
1	1 81.5 83.5 1 80.0	1 81.7	18.0	58.3	82.7	48.25	1.714	+ .045	.0020
	1 81.3 82.9 78.2	1 80.8	62.0	14.5					
2	2 51.9 53.7 50.9	2 52.2	18.0	58.4	71.4	43.95	1.625	− .044	.0019
	2 53.1 52.5 50.4	2 52.0	66.9	10.0					
3	3 29.2 28.2 27.5	3 28.3	19.0	57.7	76.3	47.80	1.596	− .073	.0053
	3 27.0 28.2 31.2	3 28.8	65.1	12.0					
4	3 98.7 99.4 1 02.5	4 00.2	19.0	58.3	71.4	46.20	1.545	− .124	.0154
	3 99.1 4 01.9 3 99.3	4 00.1	68.0	09.6					
5	4 83.1 80.8 81.2	4 81.7	19.0	58.5	81.6	48.95	1.667	− .002	.0000
	4 82.2 80.5 81.6	4 81.4	62.0	15.7					
6	5 56.2 58.6 56.1	5 57.0	17.7	60.0	75.6	44.30	1.707	+ .038	.0011
	5 58.2 58.6 55.5	5 57.4	61.0	13.9					
7	6 39.3 38.3 37.7	6 38.4	19.0	58.6	81.0	41.85	1.806	+ .137	.0188
	6 38.0 34.8 38.7	6 36.8	61.0	11.1					
8	7 07.7 09.0 08.1	7 08.3	20.3	57.7	71.5	43.65	1.638	− .031	.0010

Observations for value of one division of level, &c.—Continued.

No. of observations.	Readings.				Differences.		1 d	v	vv
	Micrometer.		Level.		Microm.	Level.			
	Successive.	Means.	N.	S.					
	t *d.* 7 07.5 07.5 06.8	7 07.3	64.0	14.0					
9	7 85.3 88.0 88.2	7 87.2	17.7	60.3	79.9	46.3	1.726	+ .057	.0032
	7 86.3 87.9 86.9	7 87.0	63.0	15.0					
10	8 52.3 52.4 51.9	8 52.2	24.5	54.8	65.2	39.15	1.665	−0.004	.0000
	8 53.7 54.0 51.8	8 53.2	65.8	12.7					
11	9 26.8 29.0 27.1	9 27.6	21.0	57.3	74.4	44.70	1.661	− .005	.0000
	9 28.2 28.9 28.0	9 28.4	64.1	14.2					
12	10 07.0 09.0 07.5	10 07.8	19.7	58.5	79.4	44.35	1.790	+ .121	.0146
	10 08.2 06.1 10.2	10 08.2	63.0	15.4					
13	10 81.3 80.4 83.0	10 81.6	19.9	58.5	73.4	43.10	1.703	+ .034	.0012
	10 82.7 80.0 80.7	10 81.1	66.2	12.1					
14	11 62.2 59.8 60.0	11 60.7	19.7	58.6	79.6	46.50	1.712	+ .043	.0018
	11 60.0 60.9 68.9	11 63.3	65.0	13.4					
15	12 37.2 35.3 36.2	12 36.2	19.7	58.7	72.9	45.30	1.609	− .060	.0036
	12 37.4 36.8 36.8	12 37.0	66.0	12.0					
16	13 16.8 16.8 20.8	13 18.1	19.5	58.5	81.1	46.50	1.744	+ .075	.0056
	13 17.6 17.1 17.2	13 17.4	63.0	15.0					
17	13 98.8 14 01.5 13 99.9	14 00.1	17.0	60.9	82.7	45.95	1.800	+ .131	.0172
	14 03.4 01.2 02.5	14 02.4	60.0	18.0					
18	14 76.2 74.9 76.7	14 75.9	19.2	58.7	73.5	40.75	1.804	− .135	.0182

Observations for value of one division of level, &c.—Continued.

No. of observations.	Readings.				Differences.				
	Micrometer.		Level.		Microm.	Level.	1 *d.*	*v*	*v v*
	Successive.	Means.	N.	S.					
	t. d. 14 74.5 76.0 74.9	14 75.1	68.2	10.0					
19	15 48.2 47.9 46.0	15 47.4	22.2	55.7	72.3	45.85	1.577	− .092	.0085
	15 47.0 47.8 47.5	15 47.4	63.0	15.2					
20	16 18.7 17.6 19.9	16 18.7	20.5	57.6	71.3	42.05	1.680	+ .011	.0001
	16 03.0 00.7 02.2	16 02.0	58.6	19.7					
21	69.5 16 68.3 69.4	16 69.1	19.6	58.5	67.1	38.90	1.728	+ .059	.0035
	16 71.9 69.6 67.8	16 69.8	65.0	13.1					
22	17 37.3 37.9 36.0	17 37.1	22.7	55.3	67.3	42.25	1.593	− .076	.0058
	17 36.7 36.5 37.0	17 36.7	66.3	11.7					
23	18 11.5 10.4 12.0	18 11.3	21.3	56.5	74.6	44.90	1.661	− .008	.0001
	18 11.3 14.0 11.0	18 12.1	64.0	11.0					
24	18 87.9 86.2 91.0	18 88.4	19.5	58.5	76.3	44.50	1.715	+ .046	.0021
	18 91.5 90.0 91.1	18 90.9	[illegible]	15.4					
25	19 57.2 56.2 55.0	19 56.1	22.5	55.8	65.2	40.15	1.612	− .057	.0032
	19 57.1 54.3 55.8	19 55.7	65.0	13.5					
26	20 33.9 33.2 30.0	20 32.4	19.8	58.5	76.7	45.10	1.701	+ .032	.0010
	20 33.0 35.6 34.6	20 34.4	62.8	17.7					
27	21 04.4 03.7 03.0	21 03.7	20.0	58.2	69.3	42.65	1.625	− .044	.0019
	21 04.8 02.5 04.2	21 04.0	68.5	10.0					
28	21 82.2 80.3 82.5	21 81.7	20.0	58.5	77.7	48.50	1.602	− .067	.0045

Observations for value of one division of level, &c.—Continued.

No. of observations.	Readings. Micrometer. Successive.	Readings. Micrometer. Means.	Readings. Level. N.	Readings. Level. S.	Differences. Microm.	Differences. Level.	1 *d.*	*v*	*v v*
	t. *d.* 21 80.6 85.0 82.0	21 82.5	63.0	15.8					
29	22 62.4 60.9 63.2	22 62.2	20.0	58.5	79.7	42.85	1.860	+ .191	.0365
	22 60.0 62.6 60.8	22 61.1	68.1	10.7					
30	23 33.5 34.3 33.6	23 33.8	22.2	56.2	72.7	45.70	1.591	− .078	.0061
	23 32.4 34.3 34.5	23 33.7	64.0	14.9					
31	24 10.7 12.5 10.0	21 11.1	20.2	58.5	77.4	43.70	1.770	+ .101	.0102
	24 11.8 10.0 07.5	24 09.8	65.9	13.3					
32	24 87.8 86.8 87.8	24 87.5	20.2	58.6	77.7	45.50	1.708	+ .039	.0015
	21 87.8 88.9 90.0	24 88.9	62.0	17.0					
33	25 58.2 58.8 60.0	25 59.0	20.5	57.8	70.1	41.15	1.703	+ .034	.0012
	25 59.6 60.2 60.5	25 60.1	62.0	17.3					
34	26 21.2 20.8 19.7	26 20.6	24.2	55.0	60.5	37.75	1.603	− .066	.0049
	26 21.0 23.0 18.0	26 20.7	66.3	13.2					
35	26 88.7 89.9 89.2	26 89.3	23.2	56.0	68.6	42.95	1.597	− .072	.0052
	26 87.9 87.9 88.5	26 88.1	62.0	17.7					
36	27 48.2 47.4 46.7	27 47.4	24.3	55.1	59.3	37.55	1.571	− .098	.0096
	27 47.2 46.0 47.0	27 46.7	65.5	14.2					
37	28 13.2 13.5 14.9	28 13.9	24.1	55.7	67.2	41.45	1.621	− .048	.0023
	28 12.1 12.7 11.5	28 13.1	63.0	16.9					
38	28 74.9 75.4 74.5	28 74.9	24.3	55.5	61.8	38.65	1.599	− .070	.0049

Observations for value of one division of Level, &c.—Continued.

No. of observations.	Readings.				Differences.		1 d	r	rv
	Micrometer.		Level.		Microm.	Level.			
	Successive.	Means.	N.	S.					
	t. *d.*								
39	28 75.3 75.9 73.5 29 40.2 39.7 39.7	28 74.9 29 39.9	65.0 24.0	15.0 55.7	65.0	40.85	1.591	− .078	.0061
40	29 41.2 41.4 42.0 30 16.8 16.0 16.5	29 41.5 30 16.4	68.0 21.5	12.0 58.3	74.9	46.40	1.614	− .055	.0030
41	30 17.2 18.6 17.9 30 80.7 80.5 81.8	30 17.9 30 81.0	64.0 21.2	16.0 55.8	63.1	39.80	1.585	− .084	.0071
									.2400

$d = 1.6688 \pm .008$.

UNITED STATES NORTHERN BOUNDARY.

JUNE 14.

STATION, CAMP NO. 3.

Determination of value of one turn of the Micrometer, Zenith Telescope Würdemann No. 11, by observation of Polaris at eastern elongation.

[Observer, Captain J. F. Gregory, United States Engineers.]

$\phi = 49° 00' 02''$. Time of elong. by chron. 1481, 19ʰ 25ᵐ 28ˢ.0.

No. of observations.	Micrometer reading.	Level. N.	Level. S.	T	T − T₀	Z − Z₀	Combination of observat'ns.	Interval in micrometer revolutions.	Z − Z′	R	v
				h. m. s.	m. s.	″			″	″	
1	8.	39.0	42.0	18 52 58.5	− 32 29.5	+ 697.6	1 with 12	†5.477	404.0	73.763	.636
2	8.5	38.5	42.2	54 33.5	30 54.5	668.0	2 13	.477	411.2	75.079	.680
3	9.	38.3	42.3	56 12.2	29 15.8	628.8	3 14	.484	408.1	74.416	.017
4	9.5	37.3	42.5	57 58.2	27 29.8	590.9	4 15	.487	407.1	74.194	.205
5	10.	38.5	42.4	18 59 29.2	25 58.8	558.5	*[5 16	.475	413.3	75.489	1.090]
6	10.5	37.6	44.4	19 01 22.2	24 05.7	518.1	6 17	.498	409.7	74.510	111
7	11.	37.5	44.0	03 08.5	22 19.5	480.2	7 18	.508	408.0	74.074	.325
8	11.5	37.7	44.5	04 57.0	20 31.0	448.4	8 19	.499	406.8	73.966	.433
9	12.	38.4	44.0	06 39.3	18 48.7	404.8	9 20	.482	407.1	74.261	.138
10	12.5	37.5	44.0	08 20.5	17 07.5	368.5	10 21	.492	408.4	74.363	.036
11	13.	37.8	44.2	10 05.0	15 23.0	331.1	11 22	.497	407.8	74.186	.213
12	13.5	37.7	43.5	11 50.0	13 38.0	293.6	23 34	.482	406.9	74.225	.174
13	14.	37.3	44.0	13 32.5	11 55.5	256.8	24 35	.490	409.8	74.294	.105
14	14.5	37.8	43.7	15 13.2	10 14.8	220.7	25 36	.490	409.0	74.499	.100
15	15.	37.1	44.0	16 56.0	08 32.0	183.8	26 37	.488	409.3	74.581	.182
16	15.5	37.1	04.0	18 43.4	06 41.6	145.2	27 38	.492	407.8	74.253	.146
17	16.	37.0	44.0	20 26.2	05 01.8	108.4	28 39	.492	408.7	74.417	.018
18	16.5	37.8	43.4	22 06.7	03 21.3	72.2	29 40	.498	410.8	74.718	.319
19	17.	37.1	44.0	23 51.5	− 01 36.5	+ 34.6	30 41	.492	407.2	74.144	.255
20	17.5	36.7	44.5	25 34.5	+ 00 06.5	− 02.3	31 42	.488	407.4	74.235	.164
21	18.	36.8	44.2	27 19.0	01 51.0	39.9	32 43	.488	411.1	74.909	.510
22	18.5	37.3	44.0	29 01.7	03 33.7	76.7	33 44	5.486	407.1	74.207	.192
23	19.	36.7	44.5	30 46.5	05 18.5	114.3					
24	19.5	36.6	44.6	32 28.0	07 00.0	150.8					
25	20.	36.6	45.0	34 11.3	08 43.3	187.8					
26	20.5	36.6	44.7	35 51.5	10 23.5	223.8					
27	21.	36.4	44.9	37 36.0	12 08.0	261.3					
28	21.5	36.0	45.0	39 23.0	13 55.0	299.6					
29	22.	35.8	45.1	41 02.5	15 34.5	335.3					
30	22.5	35.8	45.2	42 51.0	17 23.0	374.1					
31	23.	36.0	45.0	44 30.5	19 02.5	409.4					
32	23.5	36.1	45.0	46 09.3	20 41.3	445.0					
33	24.	36.0	45.1	47 58.5	22 30.5	484.1					
34	24.5	35.7	45.6	49 42.3	24 14.3	521.2					
35	25.	36.0	45.2	51 27.2	25 59.2	558.6					
36	25.5	36.0	45.6	53 15.0	27 47.0	596.8					
37	26.	36.0	45.5	54 56.0	29 28.0	633.1					
38	26.5	36.0	45.5	56 37.2	31 09.2	669.1					
39	27.	35.6	45.6	19 58 27.2	32 59.2	708.3					
40	27.5	36.0	45.5	20 00 14.2	34 46.2	746.1					
41	28.	35.6	46.0	01 53.2	36 25.2	781.3					
42	28.5	35.6	46.0	03 33.3	28 05.3	816.8					
43	29.	35.7	46.0	05 24.3	39 56.3	856.1					
44	29.5	35.4	46.2	20 07 04.0	+ 41 36.9	− 891.2					

R = 74″.347
Corr. for ref. = − .036
Value of one turn = 74″.31 ± .003

* Rejected.

† This is the interval 5.5 revolutions corrected for the difference in the levels at the two observations.

1873.

UNITED STATES NORTHERN BOUNDARY.

JULY 19.

STATION, TURTLE MOUNTAIN DEPOT (EAST SIDE), DAK.

Observations to determine the value of one division of the level of Zenith Telescope Würdemann No. 11 in terms of the micrometer. Mark, cross-hairs of Transit Telescope No. 4.

[Observer, W. J. Twining, Captain United States Engineers.]

No.	Microm. readings, first position.	Means.	Microm. readings, second position.	Means.	Level, first position.		Level, second position.		Mean change of level.	Mean change of microm.	1d of level in divisions of microm.	v	vv
					N.	S.	N.	S.					
1	21.495		20.775		57.4	15.0	15.6	57.8					
	.488		.785		57.5	15.0	15.8	57.9					
	.483	21.489	.772	20.777	57.6	15.2	15.5	58.2	42.4	71.2	1.679	82	6724
2	19.900		20.602		16.9	57.2	57.7	15.8					
	.920		.631		16.8	57.1	57.6	15.9					
	.921		.616		17.0	57.1	57.8	15.9					
	.909	19.913	.616	20.616	16.9	57.0	57.7	15.8	41.0	70.3	1.715	46	2116
3	20.598		21.382		15.7	58.2	58.6	15.4					
	.593		.381		15.6	58.6	58.5	15.5					
	.587	20.593	.365	21.376	15.5	58.8	58.5	15.6	43.0	78.3	1.821	60	3600
4	21.357		22.098		15.9	58.8	57.5	17.3					
	.352		.096		16.1	58.8	57.6	17.3					
	.365	21.358	.096	22.097	16.2	58.7	57.7	17.5	41.4	73.9	1.785	24	576
5	22.098		22.825		19.3	56.4	59.9	16.6					
	.089		.808		19.3	56.8	60.0	16.7					
	.103	22.097	.807	22.813	19.2	56.9	60.0	16.7	40.4	71.6	1.772	11	121
6	22.811		23.496		19.8	57.2	58.6	18.2					
	.807		.506		19.9	57.3	58.5	18.2					
	.805	22.808	.503	23.502	19.9	57.4	58.6	18.2	38.9	69.4	1.784	23	529
7	23.467		24.265		16.0	61.3	58.7	18.5					
	.491		.263		16.0	61.4	58.7	18.6					
	.497	23.485	.266	24.265	15.8	61.8	58.8	18.6	42.9	78.0	1.818	57	3249
8	24.252		24.939		20.9	56.9	60.9	16.8					
	.256		.947		21.0	56.9	60.9	16.8					
	.250	24.259	.941	24.942	21.3	56.9	61.0	16.8	39.9	68.3	1.712	49	2401
9	24.920		25.690		18.5	59.5	61.0	16.8					
	.942		.713		18.5	59.6	61.1	16.7					
	.938	....	.696	25.700	18.3	59.6	60.8	16.9	42.7	76.7	1.796	35	1225
10	25.703		26.450		18.0	59.9	60.8	16.6					
	.714		.463		17.9	60.1	60.9	16.5					
	.713	25.710	.458	26.457	17.9	60.0	61.0	16.5	44.3	74.7	1.725	36	1296

1 div. of level = 1.761 div. microm.

ε = .049
r = .033
ε_0 = .016
r_0 = .010

UNITED STATES NORTHERN BOUNDARY.

JULY 18.

STATION, TURTLE MOUNTAIN DEPOT (EAST SIDE), DAK.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 11, by the eastern elongation of Polaris; Chronometer 1513 Negus.

[Observer, W. J. Twining, Captain United States Engineers.]

A. R. of Polaris, $1^h\ 12^m\ 17^s.5$
δ of Polaris, $88°\ 37'\ 43''.3$
Assumed ϕ, $49°\ 03'\ 17''.0$

$\log \cot \delta = 8.3790045$
$\log \tan \phi = 0.0616748$
$\log \cos t_0 = 8.4107693$
$t_0 = 88°\ 25'\ 08''.2$
t_0 in time $= 5^h\ 53^m\ 40^s.5$
A. R. $= 1^h\ 12^m\ 17^s.5$
Sid. time of elong. $= 19^h\ 18^m\ 37^s.0$
Chronometer corr. $= 0^h\ 12^m\ 25^s.8$
Chro. time elong. $= 19^h\ 31^m\ 02^s.8$

$$\sin (Z - Z_0) = \cos \delta \sin (T - T_0)$$

$\log \sin \delta = 9.9998756$
$\log \sin \phi = 9.8781401$
$\log \cos z_0 = 9.8782645$
$z_0 = 40°\ 55'\ 34''.8$

Number.	Microm readings.	Level. N.	Level. S.	T	$T - T_0$	$Z - Z_0$	Combined with number—	Diff. of level.	Equiv. in microm. turns.	Diff. of turns.	$Z - Z'$	Value of 1 rev.	v	vv
				h. m. s.	m. s.	"					"	"		
1	28.	30.5	35.8	19 01 55.5	−29 07.3	−625.55	22	−1.50	.0264	10.4736	780.85	74.554	.210	44100
2	27.5	30.3	36.3	03 41.5	27 31.3	587.78	23	1.05	.0185	.4815	779.11	.335	9	81
3	27.	30.0	36.5	05 26.0	25 36.8	550.52	24	1.05	.0185	.4815	779.89	.406	62	3844
4	26.5	30.0	36.5	07 09.5	23 53.3	513.58	25	1.05	.0185	.4815	780.06	.423	79	6241
5	26.	30.0	36.5	08 54.0	22 10.8	476.98	26	1.05	.0185	.4815	780.01	.418	74	5476
6	25.5	29.8	36.7	10 31.5	20 28.3	440.34	27	1.45	.0225	.4745	780.99	.561	.217	47089
7	25.	29.8	36.9	12 20.0	18 42.8	402.61	28	1.25	.0220	.4784	780.49	.488	.144	20736
8	24.5	29.8	36.9	14 04.0	16 58.8	365.39	29	1.20	.0211	.4789	779.77	.413	69	4761
9	24.	29.9	37.0	15 50.5	15 12.3	327.25	30	1.25	.0220	.4780	778.10	.260	84	7056
10	23.5	29.9	37.1	17 34.0	13 28.8	290.17	31	1.25	.0220	.4780	778.54	.302	42	1764
11	23.	30.0	37.1	19 15.5	11 47.3	253.79	32	1.30	.0229	.4771	779.12	.364	20	400
12	22.5	29.8	37.3	20 59.0	10 03.8	216.08	33	1.15	.0202	.4798	779.29	.413	69	4761
13	22.	29.7	37.4	22 42.5	8 20.3	178.12	34	1.00	.0176	.4824	778.34	.252	92	8464
14	21.5	29.7	37.6	24 27.5	6 35.3	141.88	35	.90	.0158	.4842	779.14	.316	28	784
15	21.	29.8	37.6	26 09.0	4 53.8	105.46	36	1.05	.0185	.4815	778.30	.255	89	7921
16	20.5	29.7	37.6	27 53.0	3 09.8	68.13	37	.60	.0106	.4894	778.82	.248	96	9216
17	20.	29.8	37.7	29 37.5	− 1 25.3	− 30.62	38	.55	.0097	.4903	778.95	.254	90	8100
18	19.5	29.8	37.6	31 20.0	+ 0 17.2	+ 6.17	39	.55	.0097	.4903	779.39	.296	48	2304
19	19.	29.6	37.8	33 03.0	2 00.2	43.15	40	.90	.0158	.4842	779.07	.309	35	1225
20	18.5	29.6	38.0	34 48.5	3 45.7	81.02	41	.85	.0150	.4850	777.81	.183	.161	25921
21	18.	29.6	38.0	36 30.5	5 27.7	117.62	42	−0.75	− .0132	10.4868	777.77	.166	.178	31684
22	17.5	29.6	37.9	38 15.5	7 12.7	155.30								
23	17.	29.7	37.8	39 56.0	8 53.2	191.36								
24	16.5	29.6	38.2	41 42.0	10 39.2	229.37								
25	16.	29.6	38.2	43 25.5	12 22.7	266.48								
26	15.5	29.6	38.2	45 07.5	14 04.7	303.03								
27	15.	29.0	38.8	46 52.5	15 49.7	340.65								
28	14.5	29.1	38.7	48 36.5	17 33.7	377.88								
29	14.	29.1	38.6	50 18.5	19 15.7	414.38								
30	13.5	29.1	38.7	52 00.5	20 57.7	450.85								
31	13.	29.1	38.8	53 45.5	22 42.7	488.37								
32	12.5	29.1	38.8	55 29.0	24 26.2	525.33								
33	12.	29.1	38.9	57 13.5	26 10.7	562.61								
34	11.5	29.2	38.9	19 58 59.0	27 56.2	600.22								
35	11.	29.2	38.9	20 00 43.0	29 40.2	637.26								
36	10.5	29.1	39.0	02 23.0	31 20.2	672.84								
37	10.	29.5	38.6	04 09.5	33 06.7	710.69								
38	9.5	29.5	38.5	05 55.5	34 52.7	748.33								
39	9.	29.6	38.5	07 40.5	36 37.7	785.76								
40	8.5	29.1	39.1	09 24.0	38 21.2	822.22								
41	8.	29.1	39.2	11 07.5	40 04.7	858.83								
42	7.5	29.2	39.1	20 12 51.0	+41 48.2	895.39								

Mean value of one turn, 74''.344 ± .016

Mean, 74''.344
Corr. for refrac., ''.036
Value of one turn of microm., 74''.308

$\varepsilon = 0''.110$
$r = 0''.073$
$\varepsilon_0 = 0''.024$
$r_0 = 0''.016$

UNITED STATES NORTHERN BOUNDARY.

JUNE 18.5.

FORT BUFORD, DAKOTA.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 20; Chronometer Negus No. 1513, eastern elongation of Polaris.

[Observer, J. F. Gregory, Captain United States Engineers.]

Chronometer-time of elongation, 19ʰ 18ᵐ 12ˢ.

No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	15 rev. interval.	v
	h. m. s.	*s.*	*s.*	*h. m. s.*		*h. m. s.*	*s.*	*s.*	*h. m. s.*	*s.*	*s.*
1	18 38 40.0	+ 11.8	+ 0.6	18 38 52.4	31	19 22 21.9	0.	− 0.7	19 22 21.2	2608.8	3.7
2	40 07.9	10.5	+ 0.7	40 19.1	32	23 50.5	0.	0.8	23 49.7	10.6	5.5
3	41 38.0	9.3	+ 0.7	41 48.0	33	25 16.3	0.	1.1	25 15.2	07.2	2.1
4	43 06.2	8.3	− 0.4	43 14.1	34	26 44.9	− 0.1	1.1	26 43.7	09.6	4.5
5	44 32.8	7.3	+ 0.7	44 40.8	35	28 10.6	0.2	1.1	28 09.3	08.5	3.4
6	46 00.8	6.3	+ 0.4	46 07.5	36	29 37.0	0.2	1.2	29 35.6	08.1	3.0
7	47 27.6	5.5	+ 0.6	47 33.7	37	31 03.9	0.4	1.2	31 02.3	08.6	3.5
8	48 54.3	4.7	+ 0.9	48 59.9	38	32 33.4	0.5	1.2	32 31.7	11.8	6.7
9	50 24.0	4.1	0.0	50 28.1	39	33 59.0	0.8	1.2	33 57.0	08.9	3.8
10	51 51.3	3.4	0.0	51 54.7	40	35 27.0	1.0	1.4	35 24.6	09.9	4.8
11	53 20.6	2.9	0.0	53 23.5	41	36 52.6	1.3	1.4	36 49.9	06.4	1.3
12	54 48.0	2.4	+ 0.4	54 50.8	42	38 20.7	1.5	1.4	38 17.8	07.0	1.9
13	56 13.7	2.0	+ 0.1	56 15.8	43	39 46.0	1.9	1.4	39 42.7	06.9	1.8
14	57 43.4	1.6	+ 0.1	57 45.1	44	41 13.8	2.3	1.4	41 10.1	05.0	0.1
15	18 59 10.0	1.3	+ 0.1	18 59 11.4	45	42 40.0	2.8	1.4	42 35.8	01.4	0.7
16	19 00 38.4	1.0	+ 0.2	19 00 39.6	46	44 09.4	3.3	1.4	44 04.7	05.1	0.0
17	02 04.4	0.8	+ 0.2	02 05.4	47	45 35.4	3.9	1.4	45 30.1	04.7	0.4
18	04 33.5	0.6	− 0.2	03 33.9	48	47 07.9	4.5	1.4	46 56.0	02.1	3.0
19	05 00.0	0.4	− 0.5	04 59.9	49	48 29.0	5.3	2.1	48 21.6	01.7	3.4
20	06 27.7	0.3	− 0.5	06 27.5	50	49 57.5	6.1	1.9	49 49.5	02.0	3.1
21	07 52.3	0.2	0.0	07 52.5	51	51 25.0	7.0	1.9	51 16.1	2603.6	1.5
22	09 23.3	+ 0.1	− 0.4	09 23.0	52	52 52.8	8.0	1.9	52 42.9	2599.9	5.2
23	10 49.0	0.	− 0.4	10 48.6	53	54 19.7	9.0	2.1	54 08.6	2600.0	5.1
24	12 16.8	0.	− 0.4	12 16.4	54	55 49.1	10.1	2.1	55 36.9	00.5	4.6
25	13 41.9	0.	− 0.4	13 41.5	55	57 11.7	11.3	1.8	57 01.6	00.1	5.0
26	15 08.6	0.	− 1.2	15 07.4	56	19 58 45.0	12.7	1.6	58 30.7	03.3	1.8
27	16 35.0	0.	− 0.2	16 34.8	57	20 00 13.6	14.1	1.6	19 59 57.9	03.1	2.0
28	18 03.5	0.	− 0.1	18 03.4	58	01 41.5	15.6	1.6	20 01 24.3	00.9	4.2
29	19 29.0	0.	− 0.1	19 28.9	59	03 08.6	17.3	1.5	02 49.8	00.9	4.2
30	19 20 56.0	0.	− 0.2	19 20 55.8	60	20 04 38.3	− 19.0	− 1.5	20 04 17.8	2602.0	3.1

LEVEL OBSERVATIONS.

No	N.	S.	No.	N.	S
	d.	*d.*		*d.*	*d.*
1	18.6	19.1	27	19.7	19.5
2	18.5	19.1	28	19.6	19.5
4	19.0	18.7	30	19.8	19.6
5	18.6	19.2	31	20.0	19.4
6	18.8	19.1	33	20.2	19.3
7	18.7	19.2	34	20.3	19.4
8	18.6	19.3	36	20.5	19.5
9	19.0	19.0	40	20.6	19.5
12	18.8	19.1	47	20.7	19.5
13	19.0	19.1	49	21.0	19.3
16	19.0	19.2	50	21.0	19.5
18	19.3	19.1	53	21.1	19.4
19	19.5	19.1	55	21.0	19.6
21	19.2	19.2	56	21.0	19.7
22	19.6	19.3	59	21.0	19.8
25	20.5	19.5			

1st contact at *T* 35.0 } Value of one division of level, 0".893.
60th contact at *T* 5 5 }

Mean, 2605ˢ.05 ± .438
log 3.4158161
log 15 cos δ 8.3772074
log val one turn, 1.7930235
val. one turn, 62".0904
Correction for refraction, − 0".0315
Corrected value one turn, 62".059 ± .010.

Mean value adopted, giving the determination of June 18, double weight, 62".126.

1874.

UNITED STATES NORTHERN BOUNDARY.

JUNE 14.5.

FORT BUFORD, DAKOTA.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 20, elongation of B. A. C. No. 240 (eastern), Chronometer Negus 1513, sidereal.

[Observer, J. F. Gregory, Captain United States Engineers.]

Chronometer-time of elongation, 18h 56m 20s.

B. A. C. 240, apparent place, June 14.5, 1874, A. R., 0h 48m 59s.2; δ 88° 20′ 36″.

No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	15 rev. interval.	v
	h. m. s.	s.	s.	h. m. s.		h. m. s.	s.	s.	h. m. s.	s.	s.
1	18 36 05.0	+ 1.6	− 1.3	18 36 05.3	31	19 11 58.0	− .7	+ .7	19 11 58.0	2152.7	2.0
2	37 15.5	1.3	1.3	37 15.5	32	13 10.5	.9	0.7	13 10.3	51.8	4.1
3	38 27.0	1.1	1.3	38 26.8	33	14 23.0	1.1	1.1	14 23.0	56.2	5.5
4	39 38.0	.9	1.3	39 37.6	34	15 33.5	1.3	1.2	15 33.4	55.8	5.1
5	40 51.5	.7	1.3	40 50.9	35	16 46.0	1.6	.8	16 45.2	54.3	3.6
6	41 59.0	.5	1.3	41 58.2	36	17 55.5	1.9	1.0	17 54.6	56.4	5.7
7	43 16.0	.4	1.3	43 15.1	37	19 08.0	2.2	.0	19 06.8	51.7	1.0
8	44 28.0	.3	1.3	44 27.0	38	20 21.0	2.6	.0	20 19.4	52.4	1.7
9	45 38.0	.2	1.1	45 37.1	39	21 32.0	3.1	.0	21 29.9	52.8	2.1
10	46 49.0	.1	1.0	46 48.1	40	22 45.0	3.5	.0	22 42.5	54.4	3.7
11	48 01.5	+ .1	0.8	48 00.8	41	23 56.0	4.0	.0	23 53.0	52.2	1.5
12	49 14.5	.0	0.8	49 13.7	42	25 08.0	4.5	.0	25 05.5	50.8	.1
13	50 29.0	.0	1.0	50 28.0	43	26 20.0	5.1	.0	26 15.9	47.9	2.8
14	51 41.0	.0	0.9	51 40.1	44	27 34.5	5.8	.0	27 28.7	49.6	1.1
15	52 48.0	.0	0.7	52 47.3	45	28 46.5	6.4	.0	28 41.1	53.8	3.1
16	54 02.5	.0	1.2	54 01.3	46	29 58.0	7.2	.0	29 51.8	51.5	.8
17	55 15.5	.0	.8	55 14.7	47	31 11.0	8.1	.0	31 03.9	49.2	1.5
18	56 25.0	.0	.0	56 24.2	48	32 22.0	8.9	.0	32 14.1	49.9	.8
19	57 36.5	.0	.0	57 35.7	49	33 36.5	9.8	1.0	33 27.7	52.0	1.3
20	18 58 48.0	.0	.8	18 58 47.2	50	34 48.0	10.8	2.0	34 39.2	52.0	1.3
21	19 00 02.0	.0	.4	19 00 01.6	51	36 01.0	11.9	1.5	35 50.6	49.0	1.7
22	01 13.0	.0	− .4	01 13.4	52	37 12.5	13.0	2.5	37 02.0	48.6	2.1
23	02 28.0	.0	+ .3	02 28.3	53	38 25.5	14.2	2.5	38 13.8	45.5	5.2
24	03 39.0	.0	.4	03 39.4	54	39 39.0	15.4	2.3	39 25.9	46.5	4.2
25	04 48.5	− .1	.7	04 49.1	55	40 50.5	16.8	2.5	40 36.2	47.1	3.6
26	05 59.0	.2	.7	05 59.5	56	42 05.0	18.2	2.5	41 49.3	49.8	0.9
27	07 15.0	.2	.3	07 15.1	57	43 16.5	19.6	2.5	42 59.4	44.3	6.4
28	08 23.5	.3	.7	08 23.9	58	44 32.0	21.4	2.5	44 13.1	49.2	1.5
29	09 36.0	.4	.7	09 36.3	59	45 44.0	23.0	2.5	45 23.5	47.2	3.5
30	19 10 49.0	− .5	+ .7	19 10 49.2	60	19 46 55.5	− 24.7	+ 2.9	19 46 33.7	2144.5	6.2

LEVEL OBSERVATIONS.

No.	N.	S.	No.	N.	S.	No.	N.	S.
	d.	d.		d.	d.		d.	d.
1	25.0	23.7	23	24.2	24.5	52	23.3	25.7
9	24.9	23.8	24	24.1	24.5	54	23.5	25.7
10	24.9	23.9	25	24.0	24.7	55	23.3	25.7
11	24.8	24.0	27	24.1	24.4	59	23.3	25.9
13	24.9	23.9	28	24.0	24.7	60	23.2	26.0
14	24.8	23.9	33	23.9	25.0			
15	24.7	24.0	34	23.8	25.0			
16	25.0	23.8	35	24.0	24.8			
17	24.8	24.0	36	24.0	25.0			
21	24.5	24.1	50	23.6	25.5			
22	24.1	24.5	51	23.8	25.3			

1st contact at T 34.5 }
6 th contact at T 4.5 } Value of one division of level, 0″.893.

Mean, 2150s.74 ± .412
log, 3.3325879
log 15 cos δ, 8.4612336

log value one turn, 1.7938215
value one turn, 62″.2045
Correction for ref., −0″.0315
Value of one turn corrected, 62″.173 ± .012

1874.

UNITED STATES NORTHERN BOUNDARY.

JUNE 15.5.

FORT BUFORD, DAKOTA.

Observations to determine the value of one turn of the micrometer of Zenith Telescope Würdemann No. 20, Chronometer Negus 1513, eastern elongation of Polaris.

[Observer, J. F. Gregory, Captain United States Engineers.]

Chronometer-time of elongation, 19h 18m 10s.

No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	No.	Chronom. time.	Correction to motion in vertical.	Correction for level.	Corrected time.	12 rev. interval.	v
	h. m. s.	s.	s.	h. m. s.		h. m. s.	s.	s.	h. m. s.	s.	s.
1	18 33 12.0	+ 17.3	− 1.2	18 33 28.1	25	19 08 19.8	+ .2	+ .6	19 08 20.6	2092.5	3.3
2	34 39.6	15.7	1.1	34 54.2	26	09 47.0	.1	.5	09 47.6	93.4	4.2
3	36 07.7	14.1	1.2	36 20.6	27	11 13.4	0.	.5	11 13.9	93.3	4.1
4	37 35.6	12.7	1.9	37 46.4	28	12 43.0	0.	.7	12 43.7	97.3	8.1
5	39 09.0	11.3	2.2	39 18.1	29	14 08.2	0.	.8	14 09.0	90.9	1.7
6	40 37.4	10.0	2.4	40 45.0	30	15 33.0	0.	1.1	15 34.1	89.1	.1
7	42 04.7	9.0	2.4	42 11.3	31	16 58.2	0.	1.1	16 59.3	88.0	1.2
8	43 30.6	8.0	2.1	43 36.5	32	18 27.5	0.	1.0	18 28.5	92.0	2.8
9	44 57.5	6.9	2.1	45 02.3	33	19 54.0	0.	1.0	19 55.0	92.7	3.5
10	46 27.0	6.0	1.8	46 31.2	34	21 21.4	0.	1.1	21 22.5	91.3	2.1
11	47 54.7	5.2	1.7	47 58.2	35	22 47.6	0.	1.2	22 48.8	90.6	1.4
12	49 23.6	4.5	1.7	49 26.4	36	24 15.6	0.	1.0	24 16.6	90.2	1.0
13	50 51.2	3.8	1.7	50 53.3	37	25 41.3	0.	1.0	25 42.3	89.0	.2
14	52 16.8	3.3	1.7	52 18.4	38	27 07.8	− .1	1.1	27 08.8	90.4	1.2
15	53 47.5	2.7	1.7	53 48.5	39	28 35.0	.2	.9	28 35.7	87.2	2.0
16	55 15.6	2.3	1.7	55 16.2	40	30 03.7	.3	1.5	30 04.9	88.7	.5
17	56 39.5	1.9	1.4	56 40.0	41	31 29.6	.4	1.7	31 30.9	90.9	1.7
18	58 13.8	1.5	1.4	58 13.9	42	32 58.2	.6	1.8	32 59.4	85.5	3.7
19	18 59 36.0	1.2	− .4	18 59 36.8	43	34 22.4	.8	1.8	34 23.4	86.6	2.6
20	19 01 04.3	.9	+ .2	19 01 05.4	44	35 48.1	1.0	1.8	35 48.9	83.5	5.7
21	02 32.0	.7	+ .4	02 33.1	45	37 16.4	1.3	1.8	37 16.9	83.8	5.4
22	03 58.5	.5	− .3	03 58.7	46	38 45.8	1.7	1.8	38 45.9	87.2	2.0
23	05 27.6	.4	+ .4	05 28.4	47	40 11.3	2.0	2.1	40 11.4	83.0	6.2
24	19 06 54.5	+ .2	+ .6	19 06 55.3	48	19 41 39.2	− 2.4	+ 2.1	19 41 38.9	2083.6	5.6

LEVEL OBSERVATIONS.

No.	N.	S.	No.	N.	S.
1	20.0	19.0	30	19.4	20.3
2	19.9	19.0	32	19.7	20.5
3	20.0	19.0	34	19.7	20.6
4	20.2	18.7	35	19.6	20.6
5	20.3	18.5	37	19.8	20.6
6	20.4	18.5	38	19.7	20.6
7	20.1	18.5	39	19.8	20.5
8	20.4	18.7	40	19.7	20.9
9	20.4	18.7	41	19.6	21.0
10	20.4	19.0	4[illegible]	19.5	21.2
17	20.3	19.2			
19	20.1	19.8			
20	19.8	20.0			
21	19.7	20.0			
22	20.0	19.8			
23	19.7	20.0			
24	19.5	20.0			
26	19.6	20.0			
28	19.5	20.1			

1st contact at T 36.0 } Value of one division of level 0".892.
4th contact at T 12.5 }

Mean,	2089.2
log,	3.3199800
log 15,	1.1760913
log cos δ,	8.3772074
	2.8[illegible]32787
log 12,	1.0791812
log value of one turn,	1.7940975
value one turn,	62".244
Correction for ref.,	− 0".032
True value one turn,	62".212 ± 0".015

UNITED STATES NORTHERN BOUNDARY.

Determination of Chronometer corrections of Chronometer Negus Sidereal 1514, by Transit Observations.

At Station No. 1, Initial Point near Pembina, Dak.

Date.	*Objects.*	*Correction to 1514.*
Sept. 12.4.	θ Cygni, α Cephei, ξ Aquarii, ε Pegasi, 79 Draconis, α Aquarii, θ Aquarii, π Aquarii, 9 Drac	−3s.73
Sept. 18.5.	κ Aquilæ, γ Aquilæ, κ Cephei, Gr. 3241, 12-Yr. 1879, α Cephei, α Aquarii, 32 Urs. Maj., 9 Drac., ι Cephei, α Pegasi	−1s.55
Sept. 26.5.	ω Piscium, 4 Drac., α Cassiop., ε Piscium	−0s.42
Sept. 28.4.	α Cygni, μ Aquarii, σ² Urs. Maj., 1 Drac., ξ Aquarii, ε Pegasi, α Aquarii, 226 Cephei	−0s.86

At Station No. 2, East (Lake of Woods).

Oct. 24.4.	θ Aquarii, α Pegasi, ο Cephei, λ Drac., Gr. 4163, γ Pegasi, 21 Cassiop., ε Piscium	+8m 24s.54

SEXTANT TIME.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	Correction to 1514.
				h. m. s.	° ′ ″	*h. m. s.*	*h. m. s.*
Fort Pembina	Aug. 21	Sun	B. 188 m. s...	−1 20 11.6	48 56 45	6 28 55	−1 20 18.8
Fort Pembina	Aug. 22	Sun	B. 188 m. s...	11.9	....	....	17.5
Fort Pembina	Aug. 23	Sun	B. 188 m. s...	10.4	....	....	16.5
Fort Pembina	Aug. 26	α Ophiuchi.... α Pegasi	N. 1514 sid ..	08.6	....	....	13.9
Fort Pembina	Aug. 29	Sun	B. 188 m. s...	10.5	....	....	−1 20 08.4
Fort Pembina	Sept. 1	Sun	B. 188 m. s ..	−1 20 09.4	48 56 45	6 28 55	−1 19 58.9
N. W. Angle	Oct. 10	α Andromedæ... α Lyræ	N. 1514 sid ..	+ 8 37.7	49 22 26	6 20 [37]	+ 8 37.7
Station No. 2 East	Oct. 14	Sun	N. 1319 m. s .	−6 16 46.4	48 59 45	6 21 07	+ 8 16.3
Station No. 2 East	Oct. 16	Sun	N. 1514 sid ..	+ 8 22.6	48 59 45	6 21 07	+ 8 22.1
Station No. 2 East	Oct. 22	α Tauri .... α Pegasi	N. 1514 sid ..	+ 8 26.2	48 59 45	6 21 07	+ 8 26.2
N. W. Angle	Nov. 2, a. m.	Sun	N. 1319 m. s	−6 15 06.2	49 22 20	6 20 [37]	+ 9 08.8
N. W. Angle	Nov. 4, a. m.	Sun	N. 1319 m. s	−6 14 57.0	49 22 20	6 20 [37]	+ 9 11.6

1873.

UNITED STATES NORTHERN BOUNDARY.

Determination of chronometer corrections and resulting corrections of Sidereal Chronometer Negus 1481, used with Zenith Telescope for determination of Latitude.

SEXTANT.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	Correction to 1481.
				m. s.	° ′ ″	h. m. s.	m. s.
Station No. 2	June 10	Sun	N. 1319 m. s.	+ 1 50.4	49 00 04	6 30 41	− 6 00.0
Station No. 3	June 12	Sun	N. 1319 m. s.	+ 0 34.5	49 00 05	6 32 02	− 7 21.1
Station No. 3	June 13	Sun	N. 1319 m. s.	+ 0 35.0	....	....	− 7 22.4
Station No. 3	June 14	Sun	N. 1319 m. s.	+ 0 36.8	....	....	− 7 21.8
Station No. 3	June 15	Sun	N. 1319 m. s.	+ 0 40.8	....	....	− 7 21.8
Station No. 3	June 16, p. m.	Sun	N. 1319 m. s.	+ 0 44.9	....	....	− 7 26.6
Station No. 4	June 17, p. m.	Sun	N. 1319 m. s.	+ 0 46.5	49 00 05	6 32 02	− 7 25.6
Station No. 5	June 25	α Lyræ α Bootis	N. 1319 m. s.	− 2 37.3	49 00 00	6 35 39	....
Station No. 5	June 26.2	α Lyræ α Bootis	N. 1319 m. s.	− 2 33.3	....	....	....
Station No. 5	June 26	Sun	N. 1319 m. s.	− 2 35.7	....	....	−11 14.1
Station No. 5	June 29	Sun	N. 1319 m. s.	− 2 29.8	....	....	−11 16.7
Station No. 5	June 30	Sun	N. 1319 m. s.	− 2 31.5	....	....	−11 20.0
Station No. 5	July 1, a. m.	Sun	N. 1319 m. s.	− 2 31.3	....	....	−11 19.4
Station No. 5	July 2, a. m.	Sun	N. 1319 m. s.	− 2 30.3	....	....	−11 19.5
Station No. 5	July 3, a. m.	Sun	N. 1319 m. s.	− 2 32.4	....	....	−11 20.4
Station No. 5	July 6	Sun	N. 1319 m. s.	− 2 22.2	....	....	−11 23.1
Station No. 5	July 7, a. m.	Sun	N. 1319 m. s.	− 2 18.9	....	....	−11 23.7
Station No. 5	July 8, a. m.	Sun	N. 1319 m. s.	− 2 19.1	....	....	−11 23.5
Station No. 5	July 9	Sun	N. 1319 m. s.	− 2 17.3	....	....	−11 21.1
Station No. 5	July 10, a. m.	Sun	N. 1319 m. s.	− 2 16.0	....	....	−11 25.2
Station No. 5	July 11, p. m.	Sun	N. 1319 m. s.	− 2 13.9	....	....	−11 25.9
Station No. 5	July 12	Sun	N. 1319 m. s.	− 2 11.8	....	....	−11 27.5
Station No. 5	July 13, a. m.	Sun	N. 1319 m. s.	− 2 14.9	....	....	−11 28.2
Station No. 5	July 14, a. m.	Sun	N. 1319 m. s.	− 2 12.9	....	....	−11 30.0
Station No. 5	July 15, a. m.	Sun	N. 1319 m. s.	− 2 12.6	49 00 00	6 35 39	−11 31.4
Turtle Mountain Depot	July 22	α Aquilæ α Bootis	N. 1319 m. s.	− 4 55.3	49 03 14	6 39 22	....
Temporary Camp	July 28	α Aquilæ	N. 1319 m. s.	−11 28.4	49 05 00	6 44 [32]	
Station No. 7	July 30	Sun	N. 1319 m. s.	−12 07.5	49 01 50	6 45 52	−22 03.5
Station No. 7	Aug. 1	Sun	N. 1319 m. s.	−12 01.8	....	....	−22 05.5
Station No. 7	Aug. 2	Sun	N. 1319 m. s.	−11 58.5	....	....	−22 05.3
Station No. 7	Aug. 6	Sun	N. 1319 m. s.	−11 55.3	....	....	−22 11.8

Sextant Time—Continued.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	Correction to 1481.
				m. s.	° ′ ″	*h. m. s.*	*m. s.*
Station No. 7	Aug. 7	Sun	N. 1319 m. s	−11 54.0	49 01 50	6 45 52	−22 13.6
Station No. 9	Aug. 18	Sun	N. 1319 m. s	−18 21.2	48 58 18	6 52 44	−29 17.6
Station No. 9	Aug. 19	Sun	N. 1319 m. s	−18 17.3	....	....	−29 19.7
Station No. 9	Aug. 29	Sun	N. 1319 m. s	−17 52.3	....	....	−29 31.6
Station No. 9	Aug. 30	Sun	N. 1319 m. s	−17 50.1	....	....	−29 32.1
Station No. 9	Aug. 31, a. m.	Sun	N. 1319 m. s	−17 49.0	48 58 18	6 52 44	−29 33.9
Temporary Camp	Sept. 1, p. m.	Sun	N. 1319 m. s	−19 16.1	49 01 30	6 54 [27]	−31 05.0
Near camp	Sept. 3, p. m.	Sun	N. 1319 m. s	−20 24.0	48 58 00	6 55 [30]	−32 20.8
Station No. 10	Sept. 4	α Bootis	N. 1319 m. s	−21 10.8	49 00 40	6 56 22	−33 11.5
Station No. 10	Sept. 5, a. m.	Sun	N. 1319 m. s	−21 [13.0]	....	....	−33 [16.3]
Station No. 10	Sept. 6	Sun	N. 1319 m. s	−21 06.6	....	....	−33 12.3
Station No. 10	Sept. 7, a. m.	Sun	N. 1319 m. s	−21 04.4	49 00 40	6 56 22	−33 12.7
Camp near No. 10	Sept. 8	Sun	N. 1319 m. s	−20 09.2	48 58 30	6 55 [30]	−32 21.0
Near No 10	Sept. 9	Sun	N. 1319 m. s	−20 06.8	48 58 30	6 55 [20]	−32 22.5
Stony Creek	Sept. 12, p. m.	Sun	N. 1319 m. s	−24 12.1	49 01 00	6 58 [32]	....
Station No. 11	Sept. 14, p. m.	Sun	N. 1319 m. s	−35 02.5	49 00 55	7 00 49	....
Station No. 11	Sept. 14	α Bootis	N. 1481 sid	−37 40.8	49 00 55	....	−37 40.8
Station No. 11	Sept. 15	Sun	N. 1319 m. s	−25 06.9	49 00 10	....	−37 46.7
Station No. 11	Sept. 16	Sun	N. 1319 m. s	−21 59.2	....	....	−37 41.5
Station No. 11	Sept. 16	α Bootis	N. 1481 sid	−37 39.8	....	....	−37 39.8
Station No. 11	Sept. 17	α Bootis α Andromedæ	N. 1481 sid	−37 42.5	49 00 10	7 00 49	−37 42.5
Station No. 12	Sept. 20	α Bootis	N. 1481 sid	−41 37.7	49 00 00	7 04 50	−41 37.7
Station No. 12	Sept. 21	Sun	N. 1319 m. s	−28 39.0	48 59 30	....	−41 40.1
Station No. 12	Sept. 22	Sun	N. 1319 m. s	−28 34.0	....	....	−41 37.6
Station No. 12	Sept. 22.5	Sun	N. 1319 m. s	−27 58.6	48 59 30	7 01 50	−41 25.6
Temporary Camp	Oct. 6	α Lyræ α Andromedæ	N. 1481 sid	−28 05.3	49 02 40	6 51 [50]	−28 05.3

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UNITED STATES NORTHERN BOUNDARY.

Determination of chronometer corrections and resulting corrections of Sidereal Chronometer Negus 1513, used with Zenith Telescope for determination of Latitude.

SEXTANT.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	Correction to 1513.
				h. m. s.	° ′ ″	*h. m. s.*	*m. s.*
Fort Pembina	June 2	Sun	N. 1319 m. s	+ 3 25.9	48 56 45	6 28 55	− 1 48.8
Fort Pembina	June 3	α Aquilæ α Bootis	N. 1514 sid	+ 0 30.5	....	....	....
Fort Pembina	June 4	Sun	N. 1319 m. s	+ 3 24.9	48 56 45	6 28 55	− 1 48.0
Near Fort Pembina	June 8	Sun	N. 1319 m. s	+ 3 33.8	48 56 51	6 28 55	− 1 50.4
Near Fort Pembina	June 9	β Leonis α Aquilæ	N. 1514 sid	+ 0 28.5	48 56 51	6 28 55	− 1 51.2
Camp No. 2	June 10.4	β Leonis α Lyræ	N. 1514 sid	− 1 17.2	49 00 04	6 30 41	− 3 36.7
Camp No. 2	June 10.5	Sun	B. 188 m. s	−1 17 30.7	49 00 04	6 30 41	− 3 36.5
Camp No. 2	June 13	α Aquilæ α Bootis	B. 188 m. s.	−1 17 20.9	49 00 04	6 30 41	− 3 35.7
Camp No. 2	June 16	Sun	B. 188 m. s	−1 17 31.1	49 00 04	6 30 41	− 3 37.0
Camp No. 2	June 19	α Aquilæ β Leonis	B. 188 m. s	−1 17 31.7	49 00 04	6 30 41	− 3 37.6
Temporary Camp	June 23	Sun	B. 188 m. s	−1 19 47.3	48 58 45	6 32 58	− 5 54.3
Camp No. 4	June 23	α Aquilæ α Bootis	N. 1513 sid	− 6 00.4	48 59 53	6 33 04	− 6 00.4
Camp No. 4	June 26.5	Sun	B. 188 m. s	−1 19 52.5	48 59 52	6 33 04	− 6 03.0
Camp No. 4	June 29	Sun	B. 188 m. s	−1 19 55.5	48 59 52	6 33 04	− 6 05.5
Camp No. 5	July 9	Sun	B. 188 m. s	−1 22 29.2	48 59 58	6 35 39	− 8 39.4
Turtle Mountain Depot	July 13.5	Sun	B. 188 m. s	−1 26 14.7	49 03 15	6 39 22	−12 24.4
Turtle Mountain Depot	July 18	Sun α Aquilæ α Bootis	B. 188 m. s	−1 26 19.1	49 03 15	6 39 22	−12 25.8
Turtle Mountain Depot	July 23	Sun	B. 188 m. s	−1 26 26.3	49 03 15	6 39 22	−12 27.8
Temporary Camp	July 25	α Aquilæ α Bootis	N. 1513 sid	− 14 38.0	49 02 14	6 41 ?1	−14 38.0
Station No. 6	July 26.5	Sun α Andromedæ	B. 188 m. s	−1 29 08.9	48 59 45	6 42 04	−15 09.2
Station No. 6	July 29	α Aquilæ α Bootis	B. 188 m. s	−1 29 10.9	48 59 42	6 42 04	−15 09.8
Station No. 6	Aug. 1	α Aquilæ α Bootis	B. 188 m. s	−1 29 12.6	48 59 42	6 42 04	−15 09.4
Station No. 6	Aug. 5	β Pegasi α Bootis	B. 188 m. s	−1 29 14.3	48 59 42	6 42 04	−15 11.4
Station No. 6	Aug. 8	β Pegasi α Bootis	B. 188 m. s	−1 29 15.7	48 59 42	6 42 04	−15 12.4
Station No. 8	Aug. 16.45	Sun α Bootis α Andromedæ	B. 188 m. s	−1 36 56.6	49 01 02	6 49 45	−22 50.1

Sextant Time—Continued.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	Correction to 1513.
				h. m. s.	° ′ ″	*h. m. s.*	*m. s.*
Station No. 8	Aug. 20.4	Sun α Bootis α Andromedæ	B. 188 m. s. N. 1513 sid	−1 36 57.9	49 01 02	6 49 45	−22 50.1
Station No. 8	Aug. 26.4	α Bootis α Andromedæ β Pegasi	B. 188 m. s.	−1 36 54.2	49 01 02	6 49 45	−22 47.4
Wood End Depot Camp	Aug. 28.3	α Bootis α Andromedæ	N. 1513 sid	— 25 00.6	49 01 36	6 51 58	−25 00.6
Wood End Depot Camp	Sept. 6	α Bootis α Andromedæ	N. 1513 sid	— 24 55.4	49 01 36	6 51 58	−24 55.4

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Determination of Chronometer corrections, and correction of Chronometer Negus 1513, *whenever used in Latitude work, 49th parallel.*

SEXTANT.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	1513 correction.
				m. s.	° ′ ″	*h. m. s.*	*m. s.*
Fort Buford	June 15	Sun	N. 1319 m. s.	+20 03.2	47 59 07	6 55 52	
Fort Buford	June 16	Sun	N. 1319 m. s.	+20 06.5			
Fort Buford	June 18	Sun	N. 1319 m. s.	+20 08.0			
Fort Buford	June 18	α Aquilæ α Bootis	N. 1481 sid.	−38 43.8			
Fort Buford	June 20	Sun	N. 1319 m. s.	+20 09.6			
Big Muddy	June 22	Sun	N. 1319 m. s.	+17 50.8	48 09 10	6 58 18	
Frenchman's Point	June 25	Sun	N. 1319 m. s.	+16 39.8	48 08 38	6 59 35	
Quaking Ash	June 26	Sun	N. 1319 m. s.	+15 36.2	48 07 58	7 00 40	
Little Porcupine Creek	June 28	α Aquilæ α Bootis	N. 1513 sid.	− 8 08.1	48 04 55	7 04 02	−08 08.1
Buggy Creek	June 30	Sun	N. 1319 m. s.	+10 00.9	48 16 18	7 06 23	
Rocky Creek	July 2	Sun	N. 1319 m. s.	+ 8 29.8	48 29 37	7 07 58	
Prairie	July 3	Sun	N. 1319 m. s.	+ 8 10.0	48 42 50	7 08 20	
Fort Turnay	July 4	α Cygni α Bootis	N. 1513 sid.	−12 53.4	48 41 05	7 08 47	−12 53.4
Station No. 13	July 5	α Cygni α Bootis	N. 1513 sid.	−13 42.7	48 58 08	7 09 35	−13 42.7
Station No. 13	July 8	α Cygni α Bootis	N. 1513 sid.	−13 42.0	48 58 08	7 09 35	−13 42.0
Station No. 14	July 10	Sun	N. 1319 m. s.	+ 3 52.7	49 00 03	7 12 52	−16 59.3
Station No. 14	July 11	Sun	N. 1319 m. s.	+ 3 52.7	49 00 03	7 12 52	−16 58.7
Station No. 14	July 12	α Cygni α Bootis	N. 1513 sid.	−16 58.4	49 00 03	7 12 52	−16 58.4
Station No. 15	July 15	α Cygni α Bootis	N. 1319 m. s.	− 0 46.4	49 00 03	7 17 06	−21 44.3
Station No. 15	July 20	α Cygni α Bootis	N. 1513 sid.	−21 46.4	49 00 03	7 17 36	−21 46.4
Station No. 16	July 22	Sun	N. 1319 m. s.	− 3 43.4	48 59 55	7 20 41	−24 49.9
Station No. 16	July 25	α Cygni α Bootis	N. 1319 m. s.	− 3 41.2	48 59 55	7 20 41	−24 50.2
Temporary Station, near No. 17	July 27	α Bootis	N. 1513 sid.	−27 38.3	48 56 24	....	−27 38.3
Station No. 17	July 29	Sun	N. 1319 m. s.	− 7 39.9	48 59 06	7 24 44	−28 55.3
Station No. 17	Aug. 2	Sun	N. 1319 m. s.	− 7 34.1	48 59 07	7 24 44	−29 00.5
Sweet Grass Depot	Aug. 4	Sun	N. 1513 sid.	−30 26.9	49 01 13	7 26 10	−30 26.9
Station No. 18	Aug. 8	Sun	N. 1319 m. s.	−10 48.7	49 01 00	7 28 03	−32 24.8

Sextant Time—Continued.

Station.	Date.	Objects.	Chronometer used.	Observed correction.	Latitude.	Longitude.	1515 correction.
				m. s.	° ′ ″	*h. m. s.*	*m. s.*
Station No. 19	Aug. 13	Sun	N. 1319 m. s.	−14 33.6	49 00 00	7 31 55	−36 19.0
Station near No. 20	Aug. 18	α Bootis α Andromedæ	N. 1513 sid.	−40 04.5	49 03 02	7 35 33	−40 04.5
Station near No. 20	Aug. 19	α Bootis α Andromedæ	N. 1513 sid.	−40 05.8	49 03 02	7 35 33	−40 05.8
Station No. 20	Aug. 23	Sun	N. 1513 sid.	−40 06.7	49 00 00	7 35 33	−40 06.7
Station No. 20	Aug. 25	Sun	N. 1513 sid.	−40 09.2	49 00 04	7 35 33	−40 09.2
Sweet Grass Depot, No. 2	Sept. 1	α Bootis α Andromedæ	N. 1513 sid.	−30 49.4	49 01 08	7 26 09	−30 49.4
Fort Benton	Sept. 10	α Andromedæ α Cor. Bor. α Ophiuchi	N. 1513 sid.	−27 21.2	47 48 50	7 22 39	−27 21.2

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Declinations adopted in reducing observations for Latitude.

B. A. C. No.	Declinations.			Proper motion.	B. A. C. No.	Declinations.			Proper motion.
	°	′	″	″		°	′	″	″
6553	32	18	05.05	+ 0.018	8344	60	30	35.40	− 0.046
6586	65	15	51.78	+ 0.007	8366	60	36	03.66	− 0.035
6624	40	07	37.06	....	46	60	49	18.20	− 0.045
6681	57	46	11.75	+ 0.007	67	37	15	34.15	− 0.007
6728	43	25	14.20	− 0.044	120	32	52	29.42	− 0.051
6748	54	40	27.53	+ 0.134	175	65	26	42.51	+ 0.050
6780	57	42	43.81	− 0.007	198	47	35	00.36	− 0.000
6817	40	16	31.70	....	219	50	16	09.92	− 0.03
6937	36	27	51.06	+ 0.031					
6970	61	41	28.95	+ 0.049	239	60	25	17.69	+ 0.146
					259	37	48	16.18	+ 0.018
7024	61	51	05.11	+ 0.015	12-Yr. 73	67	05	45.39	− 0.015
7073	36	01	12.79	+ 0.018	345	39	44	36.35	− 0.000
7100	42	45	22.04	+ 0.053	401	22	01	06.32	− 0.112
7166	55	33	16.22	− 0.074					
7215	57	07	15.66	− 0.245	438	69	36	16.50	− 0.064
					474	48	04	04.39	− 0.053
7277	40	40	31.33	− 0.022	487	47	58	43.05	− 0.100
7345	47	08	05.22	+ 0.069	522	50	02	34.31	− 0.022
7448	51	06	26.96	....	560	50	09	31.05	− 0.040
7480	45	58	37.16	− 0.106					
7489	52	03	20.60	− 0.026	611	63	46	13.75	+ 0.02
					656	34	22	50.86	− 0.026
7505	37	57	39.56	+ 0.096	744	66	40	29.07	− 0.007
7605	60	05	56.87	− 0.030	752	31	13	31.05	− 0.036
7636	55	36	34.35	− 0.020	825	19	27	52.53	− 0.049
7679	42	11	49.83	− 0.003					
7755	58	46	59.91	− 0.043	896	78	54	31.62	− 0.015
					979	77	15	37.25	− 0.006
7765	39	04	48.10	+ 0.011	999	20	34	06.72	− 0.068
7787	52	00	55.40	− 0.038	1101	31	15	02.09	− 0.030
7800	45	53	32.54	− 0.042	1127	66	17	48.78	− 0.107
7820	48	40	40.45	− 0.035					
7882	49	14	30.28	− 0.042	1203	62	41	37.13	− 0.025
					1228	35	25	15.26	− 0.019
7962	41	16	34.03	− 0.04	1254	50	00	03.91	− 0.068
8024	56	25	01.79	− 0.01	1257	48	04	53.39	− 0.026
8036	49	21	23.34	+ 0.1295					
8059	48	35	54.90	+ 0.1170					
8083	56	27	42.37	+ 0.2685					
8128	41	22	28.86	+ 0.003					
8206	50	37	08.11	− 0.021					
8273	67	05	11.43	0.006					
8314	73	41	54.20	− 0.011					
8324	24	25	48.12	....					

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Declinations adopted in reducing observations for Latitude.

B. A. C. No.	Declination. ° ′ ″	Proper motion. ″	B. A. C. No.	Declination. ° ′ ″	Proper motion. ″
4804	50 21 49.84	− .131	7605	60 06 13.22	− .015
4827	47 20 37.33	− .027	7627	25 19 42.37	− .0075
4897	38 20 07.99	+ .122	7686	72 31 32.19	− .1675
4918	59 48 39.80	+ .108	7755	58 47 18.30	− .031
4937	50 08 55.05	− .232	7765	39 05 07.44	− .026
4974	48 08 59.40	+ .053	7787	52 01 13.30	− .010
5026	38 44 29.73	− .019	7800	45 53 51.29	− .010
5097	59 21 42.43	+ .032	7820	48 49 58.64	− .0225
5271	42 48 27.63	+ .586	7882	49 24 49.59	+ .004
5313	55 06 33.40	+ .103	7962	41 16 53.26	− .001
5415	58 16 10.11	+ .675	8024	56 25 23.56	− .030
5460	40 00 48.42	− .033	8036	49 21 43.35	+ .149
5502	55 29 39.82	− .013	8059	48 36 15.55	+ .1185
5523	42 09 45.66	+ .040	8083	56 28 02.16	+ .269
5545	69 02 33.80	+ .020	8128	41 22 59.17	+ .011
5624	28 35 28.73	+ .031	8206	30 37 28.13	− .016
5644	42 27 58.60	− .029	8273	67 06 04.42	− .006
5658	55 38 07.53	− .031	8314	73 42 13.23	− .0025
5693	31 54 46.89	− .056	8324	24 26 07.77	− .043
5823	65 52 16.19	+ .031	8344	60 30 55.46	− .036
5853	49 49 42.35	+ .053	8366	60 36 24.40	− .003
5911	48 22 02.80	− .028	46	60 49 38.22	− .020
6047	72 12 37.29	− .279	67	37 15 53.51	− .055
6073	26 04 18.19	− .010	120	32 52 49.48	+ .024
6114	76 58 40.49	+ .235	175	65 27 01.57	− .038
6157	20 47 46.51	− .020	198	47 35 20.11	.000
6268	39 26 21.56	+ .005	219	50 16 29.01	− .040
6289	58 43 39.93	+ .055	239	60 25 37.25	+ .146
6318	59 27 53.95	+ .023	259	37 48 35.84	+ .0165
6365	38 16 01.35	+ .038	12-Yr. 73	67 06 04.70	− .015
6421	49 17 30.01	+ .001	345	30 44 54.95	− .016
6476	48 42 04.99	− .143	401	28 04 26.00	− .089
6553	32 18 10.48	+ .018	438	69 36 36.28	− .047
6586	65 45 57.76	+ .007	471	48 04 23.47	− .021
6624	40 07 38.74	+ .003	487	47 59 01.86	− .125
6681	57 46 18.78	− .0174	522	50 02 52.55	− .028
6728	43 25 22.03	− .044	560	50 09 49.02	− .051
6748	54 40 35.81	+ .134	611	63 46 31.05	+ .0035
6780	57 42 51.54	− .056	656	34 23 07.59	− .048
6817	40 16 39.15	− .037	744	66 49 46.32	− .0035
6937	36 28 01.47	+ .031	752	31 13 47.28	− .038
6970	61 41 39.74	+ .049	825	19 28 08.03	− .054
7024	61 51 16.11	+ .019	896	78 54 46.44	− .015
7073	36 01 54.70	− .019	979	77 15 51.10	− .066
7100	42 45 36.32	+ .073	999	20 34 19.85	− .081
7166	55 33 27.80	− .0675	1029	25 12 12.39	− .103
7215	57 07 28.45	− .245	1067	72 54 46.50	− .039
7277	49 49 44.75	− .026	1101	31 15 13.75	− .040
7320	38 09 22.77	− .013	1127	66 48 00.56	− .094
7-Yr. 2395	59 45 03.29	− .036	1203	62 41 48.87	+ .012
7377	59 27 53.22	− .017	1228	35 25 25.93	− .011
7398	33 51 47.05	− .023	1254	50 00 14.32	.040
7416	62 02 52.52	+ .031	1287	4 05 02.41	.038
7453	36 07 10.53	− .019			
7480	45 58 52.89	+ .106			
7489	42 03 36.98	− .001			
7505	37 57 55.78	+ .085			

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Declinations adopted in reducing observations for Latitude.

B. A. C. No.	Declination.	Proper motion.	B. A. C. No.	Declination.	Proper motion.
	° ′ ″	″		° ′ ″	″
5115	61 06 19.30	− .028	7595	60 32 23.18	− .020
5178	37 02 45.88	+ .007	7605	60 06 29.82	− .015
5271	42 48 17.32	+ .586	7627	25 19 59.15	− .0075
5313	55 06 23.08	+ .103	7686	72 34 49.28	− .1675
5415	58 16 00.65	− .0675	7755	58 47 35.94	− .031
5460	40 00 39.84	− .0143	7765	39 05 25.14	− .026
5502	55 29 31.46	− .013	7787	52 01 31.23	− .010
5523	42 09 37.58	+ .040	7800	45 54 09.30	− .010
5545	69 02 26.08	+ .0252	7830	48 50 16.77	− .0225
5624	28 35 21.90	+ .031	7852	49 25 08.14	− .004
5644	42 27 51.91	− .0289	7907	74 42 59.80	− .003
5658	55 38 01.06	− .0304	7945	22 54 11.01	− .024
5693	31 54 41.53	− .0128	7962	41 17 11.96	− .0018
5823	65 52 11.14	+ .0138	8024	56 25 43.43	− .0055
5853	49 49 38.29	+ .056	8036	49 22 02.84	+ .149
5911	48 22 00.19	− .016	8059	48 36 35.08	+ .1185
6017	72 12 35.82	− .2691	8083	56 28 21.95	+ .2685
6073	26 04 17.03	− .0096	8128	41 22 18.83	+ .041
6114	76 58 40.21	+ .235	8206	30 37 47.97	− .016
6157	20 47 46.10	− .020	8273	67 06 24.40	− .0063
6206	79 58 53.27	+ .087	8314	73 42 33.26	− .0025
6215	17 45 51.80	− .031	8324	21 26 27.77	− .043
6268	39 26 23.13	+ .002	8341	60 31 15.47	− .036
6289	58 43 41.76	+ .032	8366	60 36 44.45	− .003
6318	59 27 56.21	+ .0182	46	60 49 58.24	− .020
6365	38 15 01.23	+ .0092	67	37 16 13.51	− .053
6421	49 17 35.00	+ .00695	120	32 53 09.41	+ .024
6476	48 42 08.54	− .1349	175	65 27 21.36	− .038
6553	32 18 16.08	+ .0222	198	47 35 59.92	− .003
6586	35 46 03.89	+ .017	219	50 16 45.72	− .040
6624	40 07 15.29	+ .09262	239	60 25 57.05	+ .146
6681	57 46 25.37	− .0178	250	37 48 55.44	+ .0165
6728	43 25 30.23	+ .0035	7 Yr. 73	67 06 23.98	− .015
6748	54 40 44.31	+ .1106	345	30 45 14.21	− .016
6780	57 43 00.02	− .056	401	28 04 44.92	− .059
6817	40 16 48.08	− .037	433	49 36 55.02	− .047
6830	47 36 26.38	− .012	474	48 04 42.02	− .021
6865	51 33 52.72	+ .011	487	47 50 20.25	− .125
6957	36 22 11.97	.0318	522	50 03 10.87	− .006
6970	61 41 51.29	− .047	560	50 10 06.99	− .051
7024	61 51 27.45	+ .019	611	63 46 48.69	+ .0035
7073	36 02 06.51	− .019	656	34 23 24.82	− .048
7100	12 45 48.51	.073	744	66 40 02.81	− .0035
7166	55 33 40.34	− .0675	752	31 14 03.67	− .038
7215	57 07 41.25	− .245	825	19 28 23.60	− .054
7277	40 41 58.43	− .026	836	78 55 01.24	− .015
7320	38 00 37.01	+ .0128	979	77 16 04.87	− .066
7 Yr. 2285	50 45 17.44	− .036	999	20 34 33.47	− .081
7374	53 28 07.94	− .017	1020	25 12 25.64	− .103
7398	38 52 01.96	− .023	1067	72 54 59.46	− .039
7416	62 03 07.66	+ .031	1101	31 15 26.07	− .040
7453	36 07 25.58	− .025	1127	66 48 12.39	− .094
7480	45 59 08.49	+ .102	1203	62 41 59.93	+ .012
7489	52 03 52.37	− .0103	1228	35 25 36.64	− .011
7505	37 58 11.76	+ .085	1254	50 00 24.52	− .040
7566	37 42 27.40	+ .002	1287	48 05 12.00	− .038

1874.

UNITED STATES NORTHERN BOUNDARY.

Preliminary computations relating to Observations made at Fort Buford, Dak., to determine the value of one revolution of micrometer of Zenith Telescope Würdemann No. 20.

Reduction of B. A. C. 240 from mean place 1850 to apparent place June 14.5, 1874.

FORMULÆ.

$$\tan \tfrac{1}{2}(z' + z) = \tan \tfrac{1}{2}(\psi' - \psi) \cos \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)$$

$$\tfrac{1}{2}(z' - z) = \frac{\tfrac{1}{2}(\varepsilon_1' - \varepsilon_1)}{\text{tang } \tfrac{1}{2}(\psi' - \psi) \sin \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)}$$

$$\sin \tfrac{1}{2}\theta = \sin \tfrac{1}{2}(\psi' - \psi) \sin \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)$$

$$p = \sin \theta (\tan \delta + \tan \tfrac{1}{2}\theta \cos A)$$

$$(A' - A) = \frac{p \sin A}{1 - p \cos A}$$

$$\tan \tfrac{1}{2}(\delta' - \delta) = \tan \tfrac{1}{2}\theta \frac{\cos \tfrac{1}{2}(A' + A)}{\cos \tfrac{1}{2}(A' - A)}$$

$$\varepsilon_1 = 23^\circ\ 27'\ 54''.2384 \qquad \psi = 41'\ 58''.72$$
$$\varepsilon_1' = 23^\circ\ 27'\ 54''.2602 \qquad \psi' = 62'\ 07''.51$$

$$\log \tan \tfrac{1}{2}(\psi' - \psi) = 7.466900$$
$$\log \cos \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1) = 9.962512$$
$$\log \tan \tfrac{1}{2}(z' + z) = 7.429412$$
$$\tfrac{1}{2}(z' + z) = 9'\ 14''.42$$

$$\log \tfrac{1}{2}(\varepsilon_1' - \varepsilon_1) \quad 8.037426\ n$$
$$\left.\begin{array}{r}\log \tan \tfrac{1}{2}(\psi' - \psi) \\ \log \sin \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)\end{array}\right\} = 7.066990 \qquad \begin{array}{r}7.466900 \\ 9.600090\end{array}$$
$$\log \tfrac{1}{2}(z' - z) = 0.970436\ n$$
$$\tfrac{1}{2}(z' - z) = -9''.34$$

$$z' = 9'\ 05''.08$$
$$z = 9'\ 23''.76$$

$$\log \sin \tfrac{1}{2}(\psi' - \psi) = 7.466898$$
$$\log \sin \tfrac{1}{2}(\varepsilon_1' + \varepsilon_1) = 9.600090$$
$$\log \sin \tfrac{1}{2}\theta = 7.066988$$
$$\tfrac{1}{2}\theta = 4'\ 00''.5$$

		Nat. No.
$\tan \delta =$		32.108
$\log \tan \tfrac{1}{2}\theta =$	7.066988	
$\log \cos A =$	9.991508	
	7.058496	.001
		32.109

$$A = a + z + \theta$$

$a =$	$00^h\ 44^m\ 32^s.41$
$=$	$11^\circ\ 08'\ 06''$
$z = +$	$9'\ 24''$
$\theta = +$	$07''$
$A =$	$11^\circ\ 17'\ 37''$
$A' - A =$	$00^\circ\ 54'\ 24''$

$$\log \tan \tfrac{1}{2}\theta = 7.066988$$
$$\log \cos \tfrac{1}{2}(A' + A) = 9.990808$$
$$\log \sec \tfrac{1}{2}(A' - A) = 0.000014$$
$$\tan \tfrac{1}{2}(d' - d) = 7.057810$$
$$\tfrac{1}{2}(\delta' - \delta) = 3'\ 55''.63$$
$$\delta' - \delta = +7'\ 51''.3$$
$$\mu' = 0''.5$$
$$\delta' - \delta = +7'\ 50''.8$$

$$\delta = 88^\circ\ 12'\ 58''.2$$
$$\delta' = 88^\circ\ 20'\ 49''.0$$

$$\log 32.109 = 1.506627$$
$$\log \sin \theta = 7.367720$$
$$\log p = 8.874347$$
$$\log \sin A = 9.291894$$
$$\text{a. c. } \log (1 - p \cos A) = 0.033120$$
$$\log \tan (A' - A) = 8.199361$$
$$(A' - A) = 0^\circ\ 54'\ 24''$$

$$a = A' + z' - \theta \left\{\begin{array}{rr} A' = & 12^\circ\ 12'\ 01'' \\ z' = + & 09'\ 05''.1 \\ -\theta = - & 09''.8 \end{array}\right.$$

$a =$	$12^\circ\ 20'\ 56''.3$
$=$	$00^h\ 49^m\ 23^s.75$
$\tau \mu' = +$	$2^s.78$
$a' =$	$00^h\ 49^m\ 26^s.53$
Mean 1874.0 =	$12^\circ\ 21'\ 38''.0$

Formulæ for apparent A. R. and δ:

$$a' - \delta = f + \tau \mu + g \sin (G + a) \frac{\tan \delta}{15} + h \sin (H + a) \frac{\sec \delta}{15} \text{ (in time)}$$

$$\delta' - \delta = \tau \mu' + g \cos (G + a) + h \cos (H + a) \sin \delta + i \cos \delta \text{ (in arc)}$$

June 14.5: $\delta\ 88^\circ\ 20'\ 36''$ — A. R. $= 12^\circ\ 14'\ 48'' = 00^h\ 48^m\ 59^s.2$

Zen. dist. and chron. time of elongation computed by formulæ as follows:

$t_e = \cot \delta \tan \phi \qquad G_2 = \text{cosec } \delta \sin \phi \qquad T_e = \text{(time elong.)} = \text{A. R.} - \text{(chron. corr'n)} - t_e$

Microm. values computed by formulæ as follows:

z'' = seconds of arc in direction of vertical from elongation, t = diff. of elong. and time of observation.

$z'' = \dfrac{\cos \delta \sin t}{\sin 1''}$, for which may be written $z'' = 15 \cos. \delta\ [t - \tfrac{1}{6}(15 \sin 1'')^2 t^3]$, in which t is in seconds of time.

$\tfrac{1}{6}(15 \sin 1'')^2 t^3$ = "corr'n to motion in vertical". Corr'n for level, $\pm [\tfrac{1}{2}(n - s) - \tfrac{1}{2}(n_0 - s_0)] \dfrac{6}{15 \cos \delta}$

SUMMARY OF ASTRONOMICAL STATIONS OBSERVED BY THE BRITISH ASTRONOMICAL PARTIES.

No.	Position.	Observer.	Latitude.	No. of pairs.	No. of observations.	Probable error, single observation.	Probable error, final result.
			° ′ ″				″
1 A	Northwest angle.......	Anderson..............	49 22 19.137	33	66	....	.131
1	Lake of the Woods.....	Galwey	48 59 47.451	43	93	....	.088
2	Pine River	Featherstonhaugh	49 00 28.39	42	66	....	.109
3	West Roseau	Galwey	48 59 54.399	35	78	....	.101
4	Red River	Featherstonhaugh	49 00 00.95	31	77	....	.093
5	Pointe Michel.........	Galwey	48 59 57.274	26	74	....	.14
6	Pembina Mountains.....	Featherstonhaugh	49 00 03.272	41	93	....	.104
9	Sleepy Hollow.........	Galwey	49 00 14.183	38	92	....	.089
10	Turtle Mountain east ..	Featherstonhaugh	48 59 57.25	40	86	....	.103
12	Souris River 1st	Galwey	49 00 17.701	39	92	....	.07
14	Souris River 2d.......	.... do	48 59 58.963	49	97	....	.11
16	Short Creek	Featherstonhaugh	49 00 28.41	47	99	....	.107
18	Coteau	Galwey	49 00 51.462	38	91	....	.07
20	....	Featherstonhaugh	49 00 04.658	34	70	....	.093
22	Porcupine River	Galwey	48 59 59.615	35	78	....	.097
24	Little Rocky Creek.....	Featherstonhaugh	48 59 49.521	37	69	....	.081
26	Cottonwood Coulé	Galwey	49 01 00.123	33	87	....	.076
28	....	Featherstonhaugh	48 48 44.237	35	66	....	.058
30	West Fork	Galwey	48 59 55.985	36	80	....	.064
32	Milk River	Featherstonhaugh	48 59 48.274	40	65	....	.067
34	West Butte............	Galwey	49 09 12.068	40	85	....	.052
36	Milk River	Featherstonhaugh	48 59 58.667	34	68	....	.067
38	Chief Mountain........	Galwey	49 00 01.019	41	83	....	.051
39	Belly River...........	Featherstonhaugh	49 04 03.48	28	76	....	.092

Abstract of Appendix C to report of Capt. W. J. Twining, Chief Astronomer.

ALTITUDES OF ASTRONOMICAL CAMPS, &c.

Camps, &c.	Latitude.	Longitude west of Greenwich.	Above Station No. 1.	Above sea.	Location of camp.
	° ′ ″		*Feet.*	*Feet.*	
Station No. 1	49 00 00	97 13 54.5	....	788.0	Boundary-line, west bank of Red River.
Station No. 2 east	49 00 00	95 17	246.3	1034.2	On boundary-line, at Lake of the Woods.
Station No. 3 east	49 00 00	....	168.6	956.6	On boundary-line, 16 miles east of Red River.
Station No. 4 east	49 00 00	96 47	206.6	994.6	On boundary-line, 20.5 miles east of Red River.
Station northwest angle	49 22 20	95 09	252.5	1040.5	Transit post near landing, Northwest Angle, Lake of the Woods.
Lake of the Woods.....	49 00 00	....	243.4	1031.4	Water surface—mean of Station No. 2 and Northwest Angle.

Abstract of Appendix C, &c.—Continued.

ALTITUDES OF ASTRONOMICAL CAMPS, &c.

Camps.	Latitude of camps.	Longitude west of Greenwich.	Above Wood End, Camp No. 1.	Above Wood End, Camp No. 2.	Above sea means.	Location of camp.
	° ′ ″	° ′ ″				
Red River......	49 00 00.00	97 13 51.5	....	....	748.0	Red River at Pembina.
Fort Pembina ...	....	....	....	....	790.0	Barometer at Fort Pembina.
Station No. 2	49 00 00.00	97 40 25.4	....	....	813.7	Near Pembina River.
Station No. 3	49 00 00.00	98 00 33.4	....	....	1030.1	East slope of Pembina Mountains.
Station No. 4	48 59 51.55	98 16 06.8	......	....	1531.0	West slope of Pembina Mountains.
Station No. 5	49 00 00.00	98 51 52.9	....	....	1552.2	Long River.
Station No. 6	48 59 53.76	100 31 15.7	......	....	2093.0	West slope of Turtle Mountain.
Station No. 7	49 01 48.76	101 28 05.4	....	....	1615.0	On South Antler Creek.
Station No. 8	49 01 01.63	102 26 28.2	....	....	1985.4	Pool on prairie.
Wood End, No. 1.	....	....	....	....	1817.3	On Mouse River.
Wood End, No. 2.	....	....	....	....	1745.3	Do.
Station No. 9	48 58 10.29	103 11 14.7	....	....	1980.7	Do.
Station No. 10 ...	49 00 44.73	104 05 37.9	377.5	....	2145.5	In Coteau of the Missouri.
Station No. 11 ...	49 01 09.11	105 12 26.0	717.6	....	2532.6	Camp at Bully Spring.
Station No. 12 ...	48 59 28.90	106 12 39.5	......	1131.0	2861.8	Near Poplar River.

Camps, &c	Latitude.	Longitude west of Greenwich.	Above Fort Benton.	Above sea.	Location of camp.
	° ′ ″	° ′ ″			
Fort Benton......	47 48 50.00	110 39 48.0	....	2674.0	On Missouri River.
Station No. 13	48 58 09.10	107 23 53.8	192.0	2866.0	Right bank of Frenchman's Creek.
Station No. 14	49 00 02.95	108 13 15.5	267.8	2941.8	Pool on prairie.
Station No. 15	49 00 01.86	109 24 11.5	100.0	2770.0	East Fork of Milk River.
Station No. 16	48 59 55.39	110 10 26.7	148.7	2822.7	Milk River lakes.
Station No. 17	48 59 06.30	111 11 10.2	1049.0	3723.2	Near East Butte, Sweetgrass Hills.
British depot	....	....	1063.4	3737.4	Near Sweetgrass Hills.
United States camp	49 01 08.40	....	1086.3	3760.3	Do.
British mound.	49 00 00.00	....	1654.3	4328.3	British West Butte astronomical station.
Do.	49 00 00.00	....	1620.0	4294.0	7,124 feet west of above.
Station No. 18	49 01 01.42	112 00 51.7	827.2	3501.2	Red River (branch of Milk River).
Station No. 19	48 59 59.31	112 58 58.5	1641.3	4315.3	North Fork of Milk River.
Station No. 20	49 00 04.00	....	1539.4	4213.4	West shore of Chief Mountain Lake.

CONNECTION OF ASTRONOMICAL STATIONS.

DETAILS OF UNITED STATES TANGENT LINES.

UNITED STATES TANGENT No. 1.

Winter 1873–'74.

From Joint Astronomical Station at Red River to British Astronomical Station, Lieutenant Galwey, at West Roseau.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8 in. No. 71.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuths.
					° ′ ″
November 6	Initial point 61.3 feet north of 49°.	5,280 feet west of instrument.	8	δ Ursæ Minoris... W. E..	270 01 09.0
			8	51 Cephei .. near E. E..	06.4
			8	Polaris ... near U. C..	02.0
			8	Polaris ... near U. C..	08.3
			32	Mean	270 01 06.3

The tangent prolonged to the west passed through a point 1.7 feet south of the mark.

The mounds on this tangent were built before azimuth observations were taken at the eastern extremity.

These observations gave the error of the tangent in azimuth 1′ 32″, the line running south of east. This error was corrected in placing the iron pillars.

STATION ERROR.

Computed offset due to 108,011 feet		320.2
Initial point was north of 49°	61.3	
To keep in cutting, offset was made to south	35.	
		26.3
		293.9
The measured offset		166.1
Station error, West Roseau Astronomical Station, south.		127.8

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Error of initial point.	Change of line.	Final offset.	Remarks.
	M.	*Ch.*	*Lks*	*Feet.*	+	−	−	+		
	1	00	00	5,280	0.8	6.2	61.3	.....	66.7 south.	Iron pillar, west 385 feet.
	2	00	00	10,560	3.1	12.4	61.3	.....	70.6 south.	Do.
	3	00	00	15,840	6.9	18.7	61.3	.....	73.1 south.	Do.
	4	00	00	21,120	12.2	24.9	61.3	......	74.0 south.	Do.
	5	00	00	26,400	19.1	31.2	61.3	......	73.4 south.	Do.
	6	00	00	31,680	27.6	37.4	61.3	......	71.1 south.	Do.
	7	00	00	36,960	37.5	43.6	61.3	.....	67.4 south.	Do.
	8	00	00	42,240	49.0	49.9	61.3	.....	62.2 south.	Do.
	9	00	00	47,520	62.0	55.2	61.3	.....	54.5 south.	Do.
	10	00	00	52,800	76.5	62.4	61.3	.....	47.2 south.	Do.
	11	00	00	58,080	92.6	68.6	61.3	25.0	12.3 south.	Do.
	12	00	00	63,360	110.2	74.8	61.3	25.0	0.9 south.	Do.
	13	00	00	68,640	129.3	81.1	61.3	25.0	11.9 north.	Do.
	14	00	00	73,920	150.0	87.3	61.3	25.0	26.4 north.	Do.
	15	00	00	79,200	172.2	93.5	61.3	25.0	42.4 north.	Do.
	16	00	00	84,480	195.9	99.7	61.3	35.0	69.9 north.	Do.
	17	00	00	89,760	220.5	106.0	61.3	35.0	88.2 north.	Do.
	18	00	00	95,040	248.0	112.3	61.3	35.0	109.4 north.	Do.
	19	00	00	100,320	276.3	118.5	61.3	35.0	131.5 north.	Do.
	20	00	00	105,600	306.1	124.7	61.3	35.0	155.1 north.	Do.
	20	36	53	108,011	320.2	127.8	61.3	35.0	166.1 north.	Do.

UNITED STATES TANGENT No. 2.

WINTER 1873–'74.

From West Roseau Astronomical Station to Pine Ridge Astronomical Station.

This tangent was run in three parts. First part, from West Roseau Astronomical Station to Point D'Orme; second part, from Point D'Orme to Forty-mile Station; third part, from Forty-mile Station to Pine Ridge Astronomical Station.

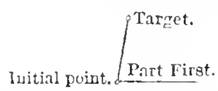
[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 71.]

PART FIRST.—AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Nov. 21	3.9 feet north of 49°....	About 1 mile north	10	β Cephei ....W. E..	4 52 10.3
Nov. 21			10	Polaris...........U. C..	51 59.8
Nov. 21			10	51 Cephei ....E. E..	51 38.5
Nov. 21			10	δ Ursæ Minoris ...W. E..	51 12.8
Nov. 25			10	Polaris....before U. C..	50 47.7
Nov. 27			10	Polaris......near L. C..	52 32.5
			60	Mean................	4 51 43.6

The above azimuth is that of the Target from the initial point of Part First, Tangent No. 2.

	°	′	″
The mean of 50 angles between the Target and Tangent No. 2	85	08	54.5
Mean azimuth of mark	4	51	43.6
Azimuth of the tangent	90	00	38.1



PART SECOND.—AZIMUTHS.

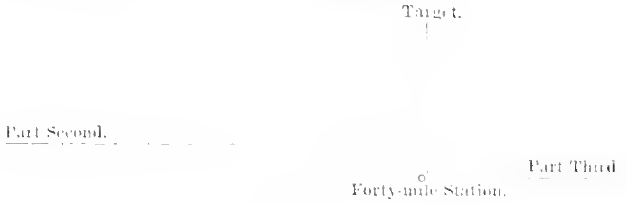
Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Dec. 5	Initial point of Part 2, on post established by A. L. Russell.	East of instrument 4,591 feet, and in center of cutting.	10	Polaris........... L. C..	90 00 19.8
Dec. 2			10	Polaris........... U. C..	01 39.3
Dec. 5			10	1 Draconis.........W. E..	00 29.8
Dec. 5			10	Polaris............U. C..	00 48.9
Dec. 5			10	Polaris............U. C..	01 11.2
Dec. 5			10	γ Cephei...........W. E..	00 59.7
Dec. 6			10	Polaris............U. C..	01 12.7
			8	δ Ursæ Minoris....W. E..	01 23.7
			78	Mean	90 01 00 6

This mean is the azimuth of the Part Second of Tangent 2.	
Mean of 67 angles between Tangent No. 2 and Target	89 57 29.7
Azimuth of Target	00 03 30.9
Mean of 85 angles between Part First and Target	89 48 44.2
Part First started south	38.1
	270 14 08.6
True azimuth at 69,709 feet	270 13 50.6
Error in running the line	18.0

United States Tangent No. 2—Continued.

PART THIRD.—AZIMUTHS.

Date	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Dec. 9	Terminus of Part 3, 10m 05s.27 east of Pembina.	Center of cutting, 1 mile east.	10	ξ Ursæ Minoris ... U. C..	89 43 64.8
Dec. 9			10	Polaris......near U. C..	43 62.9
Dec. 9			10	γ^2 Ursæ Minoris ....U. C..	42 51.5
Dec. 12			10	1 Draconis ....E. E..	43 51.5
Dec. 12			5	δ Ursæ Minoris ..W. E..	43 63.6
Dec. 12			10	51 Cephei .... E. E..	43 14.5
Dec. 12			10	β Cephei ......W. E..	43 00.6
Dec. 12			10	β Ursæ Minoris ....L. C..	42 44.3
Dec. 12			10	Polaris......near U. C..	43 05.5
Dec. 12			6	λ Draconis ....L. C..	43 25.4
Dec. 12			10	γ^2 Ursæ Minoris ....L. C..	43 47.9
Dec. 12			10	Polaris.......... U. C..	43 35.3
			111	Mean................	89 43 29.0
	The above mean is the azimuth of Part Third.				
	Mean of 57 angles between Tangent, Part Third, and Target				89 34 50.6
					08 38.4
	Mean of 57 angles between Part Second and Target				90 00 54.7
	Azimuth of Part Second				270 07 43.7
	True azimuth at distance of 33,827 feet..				270 06 24.
	Azimuth too great at Forty-mile Station				01 19.7
	Azimuth too great at Point D'Orme				1 00.6
	Error in running line				19.1



PINE RIDGE.—AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Dec. 20	35 feet south of Initial Point.	On tangent, west of instrument.	5	λ Draconis .... L. C.	270 00 17.3
			5	9 Camelopardalis .. E. E.	35.8
			5	α Ursæ Majoris .... L. C.	44.5
			5	Polaris ....U. C.	11.6
			5	Polaris ....L. C.	270 00 48.4
			5	τ Draconis .... W. E.	269 59 53.0
			5	δ Ursæ Minoris .. W. E.	00 78.5
			35	Mean	270 00 37.0
	The mean is the azimuth of the Tangent at the Terminal Point.				
	Azimuth of Tangent at Forty-mile Station				269 13 29.0
	Azimuth due to distance [illegible] feet..				269 13 24.2
					4.8
	Azimuth of Tangent Terminal Point				270 00 37.0
	Azimuth error in running line				32.2

NOTE.—This tangent was traced during the winter of 1872-'73 by the English commission and was in three parts. The first was from West Roseau to Point D'Orme, run by Captain Featherstonhaugh, R. E. At Point D'Orme was a meridian connecting this part with Part Second from Point D'Orme to near the Forty-mile Station, which was run by Mr. A. L. Russell, surveyor, N. A. B. C.

At Forty-mile Station was a meridian connecting Parts Second and Third, the latter being run from Pine Ridge Astronomical Station westward by Captain Featherstonhaugh, R. E.

Lieutenant Greene made use of the English cuttings through the timber. Observations for azimuth being difficult to obtain owing to cloudy weather and extreme cold, one azimuth was determined at each point, while the other was determined by repetition of angles.

United States Tangent No. 2—Continued.

STATION ERROR.

	Feet.	*Feet.*
Part First.................length, 69,709.2		
Computed offset..........................	133.4	
Initial Point north of 49°	3.9	
Terminal Point south of 49°	129.5	
Measured offset between Parts 1 and 2..................	316.8	
Part Second.................length, 33,827.6		
Initial Point north of 49°	187.3	
Computed offset..........................	31.3	
Terminal Point north of 49°		156.0
Part Third.................length, 87,914.6		
Initial Point, Pine Ridge north of 49°	59.6	
Computed offset..........................	212.2	
Terminal Point south of 49°	152.6	
Measured offset between Parts 2 and 3..................	371.6	
Terminal Point of Part Second, north of 49°		219.0
Station error of West Roseau, north		63.0

NOTE.—This is the station error given by the tangent without taking its azimuth into consideration, and is used correctly in computing the intermediate offsets to the parallel, since the offsets are measured from the tangent itself as run. It is, however, not the true station error.

Part First deviates to the south of the true tangent 49".3, which in a length of 69,709.2 ft. gives	16.6 south.	
Part Second deviates to the south 1' 12".3, which in a length of 33,827.6 ft. gives	15.3 south.	
Part Third deviates to the south 23".7, which in a length of 87,914.6 ft. gives	10.1 south.	
The tangent, if continuous, would then have been still farther to the north of Pine Ridge		42.0
And the true station error is West Roseau, north..................		105.0

TANGENT LINE (PART FIRST) AND MOUNDS.

Distances from Red River Station.			Distances from Initial Point.	Computed offset.	Station error.	Error of Initial Point.	Final offset.	Remarks.
M.	*Ch.*	*Lks.*	*Feet.*	+	−	−		
20	26	53	00	....	....	....	....	
21	00	00	2,869	0.2	0.9	3.9	4.6 south.	Iron pillar, west 3.5 feet.
22	00	00	8,149	1.8	2.6	3.9	4.7 south..	Do.
23	00	00	13,429	5.0	4.4	3.9	3.3 south..	Do.
24	00	00	18,709	9.6	6.1	3.9	0.4 south..	Do.
25	00	00	23,989	15.8	7.9	3.9	4.0 north..	Do.
26	00	00	29,269	23.0	9.6	3.9	10.1 north..	Do.
27	00	00	34,549	32.7	11.3	3.9	17.5 north..	Do.
28	00	00	39,829	43.5	13.1	3.9	26.5 north..	Do.
29	00	00	45,109	55.8	14.8	3.9	37.1 north..	Do.
30	00	00	50,389	69.7	16.6	3.9	49.2 north..	Do.
31	00	00	55,669	85.2	18.3	3.9	63.0 north..	Do.
32	00	00	60,949	102.0	20.0	3.9	78.1 north..	Do.
33	00	00	66,229	120.3	21.8	3.9	94.6 north..	Do.
33	52	73	69,709.2	133.4	23.0	3.9	106.5 north..	

United States Tangent No. 2—Continued.

TANGENT LINE (PART SECOND) AND MOUNDS.

Distances from Red River Station.	Distances from Initial Point.	Computed offset.	Station error.	Error of Initial Point.	Final offset.	Remarks.
M. Ch. Lks.	*Feet.*	+	−	−		
34 00 00	1,800	0.1	0.6	210.3	210.8 south..	Earth mound, 10′ × 6′.
35 00 00	7,080	1.0	2.3	210.3	211.6 south..	Do.
36 00 00	12,360	3.5	4.1	210.3	210.9 south..	Do.
37 00 00	17,640	7.6	5.8	210.3	208.5 south..	Do.
38 00 00	22,920	13.2	7.6	210.3	204.7 south..	Do.
39 00 00	28,200	20.3	9.3	210.3	199.3 south..	Do.
40 00 00	33,480	29.0	11.0	210.3	192.3 south..	Do.
40 05 27	33,827.6	31.3	11.1	210.3	190.1 south..	

TANGENT LINE (PART THIRD) AND MOUNDS.

	Feet.
Distance between Parts 2 and 3 at meridian of Forty-mile Station.............	371.6
Computed offset from Part Second to 49°	190.1
Offset from Part Third to 49°	181.5

Distances from Red River Station.	Distances from Initial Point.	Computed offset.	Station error.	Error of Initial Point.	Final offset.	Remarks.
M. Ch. Lks.	*Feet.*	+	+	−		
40 05 27	87,915	212.2	28.9	59.6	181.5 north .	
41 00 00	82,982	189.1	27.2	59.6	156.7 north..	Earth mound, 10′ × 6′.
42 00 00	77,702	165.7	25.4	59.6	131.5 north .	Do.
43 00 00	72,422	143.9	23.6	59.6	107.9 north..	Do.
44 00 00	67,142	123.7	21.9	59.6	86.0 north..	Do.
45 00 00	61,862	104.2	20.1	59.6	64.7 north..	Do.
46 00 00	56,582	87.8	18.4	59.6	46.6 north..	Mound of tamarack poles driven into swamp.
47 00 00	51,302	72.3	16.7	59.6	29.4 north..	Do.
48 00 00	46,022	58.1	14.9	59.6	13.4 north..	Do.
49 00 00	40,742	45.6	13.2	59.6	0.8 south..	Do.
50 00 00	35,462	34.5	11.4	59.6	13.7 south..	Do.
51 00 00	30,182	25.0	9.7	59.6	24.9 south..	Do.
52 00 00	24,902	17.0	8.0	59.6	34.6 south..	Do.
53 00 00	19,622	10.6	6.2	59.6	42.8 south..	Do.
54 00 00	14,342	5.6	4.5	59.6	49.5 south..	Do.
55 00 00	9,062	2.3	2.7	59.6	51.6 south..	Earth mound, 10′ × 6′.
56 00 00	3,782	0.4	1.0	59.6	58.2 south..	Do.
56 57 31	....	.....	....	.....	....	

UNITED STATES TANGENT No. 3.

WINTER 1873-'74.

From Pine Ridge to Lake of the Woods.

This tangent was traced and cut through the woods during the winter of 1872-'73, by the British Commission, and is in two parts. Part Second, from Pine Ridge eastward for a distance of 14 miles 3 382 feet. At the latter point a meridian connected Parts Second and First, which started at the Lake of the Woods Astronomical Station, and was run westward 17 miles 1,373 feet. The parallel being marked by mile-posts by the English parties from the Lake of the Woods Station, this tangent was not traced by the parties of Lieutenant Greene who observed for azimuth at Pine Ridge, Lake of the Woods, and the branch of East Roseau River where the two parts join.

AZIMUTHS.—AT PINE RIDGE—INITIAL POINT PART 2.

Date.	Position of instrument.	Position of mark.	No. of readings	Star.	Azimuth.
					° ′ ″
Dec. 20	3.5 feet south of Initial Point, Tangent No. 3.	On tangent west of instrument.	5	λ Draconis........L. C..	270 00 17.3
			5	9 Camelopardalis . E. E..	35.8
			5	α Ursæ Majoris...L. C..	44.5
			5	Polaris .... U. C..	41.6
			5	Polaris .... U. C..	270 00 48.4
			5	τ Draconis ......W. E..	269 59 53.0
			5	δ Ursæ Minoris..W. E..	60 78.5
			35	Mean	270 00 37.0
	This mean is the azimuth of the mark placed west of the instrument, at Pine Ridge. A point was determined east of the Initial Point on the prolongation of this line with an azimuth of				90 00 37.
	The distance between this point and the Thirty-one Mile stake from the Lake of the Woods Station was 4.9 feet, which, at the distance of 4,755 feet, gives an azimuth of 1′ 02″.5....				1 02.5
	Which gives the azimuth of the English Tangent........				89 59 34.5

Difference between the English and United States determination of Azimuth Tangent north of east, 25″.5.

AZIMUTHS.—AT EAST ROSEAU—PARTS FIRST AND SECOND.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 71.]

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Dec. 26	Terminal point of Second part.	On tangent, about 1 mile west of instrument	5	Polaris .... L. C	270 14 30.5 (Tel. direct.)
Dec. 27			5	δ Ursæ Minoris. W. E..	13 57.0
Dec. 29			5	α Ursæ Majoris. L. C..	14 10.2
Dec. 29			5	δ Ursæ Minoris W. E	13 52.6
Dec. 29			5	Polaris .... L. C	14 43.8
Dec. 29			5	Polaris ....W. E..	14 13.7
Dec. 26			5	Polaris ....L. C..	15 34.0 (Tel. rev.)
Dec. 29			5	Polaris ......W. E..	15 25.1
Dec. 29			5	λ Draconis ......L. C..	16 05.1
Dec. 29			5	51 Cephei .... E. E..	16 28.7
			50	Mean	270 15 04.0
	True azimuth at a distance of 77,302 feet				270 14 35.6
	Difference in azimuth—United States determination—Tangent south of east				28.4
	Tangent started, north of east				25.5

These differences being small and in opposite directions, the English Tangent is considered straight and its azimuth correct.

United States Tangent No. 3.—Tangent Line.—Continued.

AZIMUTHS.—AT LAKE OF THE WOODS STATION.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Dec. 31	On astronomical post marking 49°.	Two miles west of instrument.	10	51 Cephei ....E. E..	269 59 26.5
			10	δ Ursæ Minoris W. E..	03.2
			20	Mean	269 59 14.8
	Difference in azimuth between the United States and English determinations—tangent south of west, Initial Point Part First				45.2
	Initial Point Part Second, azimuth observed				270 15 04.0
	Mean of 20 angles between Part Second and meridian				90 17 22.9
	Azimuth of meridian				179 57 41.1
	Supplement of mean of 20 angles between meridian and Part First				90 14 12.7
	Azimuth of Part First, Terminal Point				89 43 28.4
	True azimuth at distance 91,133 feet				89 42 48.0
	Difference in United States and English determinations—Tangent north of west				40.4

UNITED STATES TANGENT No. 1.

1873.

From Joint Astronomical Station No. 1 to Joint Astronomical Station No. 2.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 71.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Nov. 6	Initial Point 61.3 feet north of 49°.	5,280 feet west of instrument.	8	δ Ursæ Minoris W. E.	270 01 09.0
			8	51 Cephei ... near E. E.	06.4
			8	Polaris ... near U. C.	02.0
			8	Polaris .. near U. C.	0[illegible].3
			32	Mean	270 01 06.3

Tangent was run on this azimuth.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
June 17	Station 33, 20m	1,320 feet west	4	32 Camelopardalis. W. E.	269 41 42.3
			8	Polaris .... E. E.	64.1
			12	Mean	53.2 ± 3″.7
	Azimuth determined from a series of repetitions from Tangent No. 2				34.0
	Mean				269 41 43.6
	Tangent started north				1 06.3
					269 40 37.3
	Azimuth due to distance 105,600 feet				269 40 04.8
	Error of tangent, north				32.5

STATION ERROR.

	Feet.
Chained distance from Station 34 of Tangent to joint mound 49°	259.4
Tangent started north of 49°	61.3
	320.7
Computed offset for distance of 106,277 feet	310.1
	10.6
Owing to the uncertainty of the azimuth of this tangent it was agreed to accept Lieutenant Galwey's azimuth as correct. His tangent started 29″ south of this, which solving the spherical triangle, gives the distance between the tangents at Station 34, 22.3 feet. The actual distance is 21.4 feet. The mean line is south of this tangent at Station 34	21.8
Giving the station error of Astronomical Station at Michell, north	32.4

United States Tangent No. 1—Continued..

TANGENT LINE.

Stations.	Distances.				Computed offset	Constant.	Station error.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	−	+		
1									Initial Point.
2	0	66	06	4,360					
	1	00	00	5,280	0.8	61.3	0.5	60.0 south.	Iron pillar, west 385 feet.
3	1	17	32	6,423					
4	1	54	10	8,851					
5	1	79	61	10,534					
	2	00	00	10,560	3.1	61.3	1.0	57.2 south.	Iron pillar, west 385 feet
6	2	37	71	13,049					
	3	00	00	15,840	6.9	61.3	1.6	52.8 south.	Iron pillar, west 385 feet
7	3	34	09	18,090					
8	3	79	18	21,066					
	4	00	00	21,120	12.2	61.3	2.1	47.0 south.	Iron pillar, west 385 feet.
9	4	39	00	23,694					
10	4	79	32	26,355					
	5	00	00	26,400	19.1	61.3	2.6	39.6 south.	Iron pillar, west 385 feet.
11	5	38	88	28,966					
12	6	00	00	31,680	27.5	61.3	3.1	30.7 south.	
14	6	79	65	36,937	......	....	.....	....	Iron pillar, west 385 feet.
	7	06	00	36,960	37.5	61.3	3.7	20.1 south.	
15	7	79	63	42,216					
	8	00	00	42,240	49.0	61.3	4.2	8.1 south.	Iron pillar, west 385 feet.
	9	00	00	47,520	62.0	61.3	4.7	5.4 north.	Iron pillar, west 385 feet.
16	9	01	25	47,603					
17	10	00	00	52,800	76.5	61.3	5.2	20.4 north.	Iron pillar, west 385 feet.
18	10	40	00	55,440					
19	11	00	00	58,080	92.6	61.3	5.8	37.1 north.	Iron pillar, west 385 feet.
20	11	40	00	60,720					
21	12	00	00	63,360	110.2	61.3	6.3	55.2 north.	Iron pillar, west 385 feet.
22	12	40	00	66,000					
23	13	00	00	68,640	129.3	61.3	6.8	74.8 north.	Iron pillar, west 385 feet.
24	13	40	00	71,280					
25	14	00	00	73,920	150.0	61.3	7.3	96.0 north.	Iron pillar, west 385 feet.
26	14	40	00	76,560					
27	15	00	00	79,200	172.2	61.3	7.9	118.8 north.	Iron pillar, west 385 feet.
28	15	40	00	81,840					
29	16	00	00	84,480	195.9	61.3	8.4	143.0 north.	Iron pillar, west 385 feet.
30	17	00	00	89,760	220.5	61.3	8.9	168.1 north.	Iron pillar, west 385 feet.
31	18	00	00	95,040	248.0	61.3	9.4	196.1 north.	Iron pillar, west 385 feet.
32	19	00	00	100,320	276.3	61.3	10.0	225.0 north.	Iron pillar, west 385 feet.
33	20	00	00	105,600	306.1	61.3	10.5	255.3 north.	Iron pillar, west 385 feet.
34	20	10	26	106,277	310.1	61.3	10.6	259.4 north.	Meridian of Joint Astronomical Station.

UNITED STATES TANGENT No. 2.

1873.

From Joint Astronomical Station at Michel to Joint Astronomical Station at Pembina Mountain East.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8 in. No. 71.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuths.
June 14	46.5 feet north of 49°	3,154.7 feet west.	Polaris	270 01 55.7
			British determination	55.1
			Mean	270 01 55.4

The tangent was run through a point 20.88 inches south of the mark and prolonged to meridian of Astronomical Station, Pembina Mountain East.

The difference between the British and United States tangents at this point was inappreciable. The azimuth was checked at the terminal point by Lieutenant Galwey, R. E.

STATION ERROR.

Lieutenant Galwey, R. E., gives the Station Error, Station Pembina Mountain East—south 55.05 feet.

OFFSETS TO PARALLEL.

For list of offsets and position of mounds and iron pillars, see Lieutenant Galwey's report.

UNITED STATES TANGENT No. 3.

1873.

From United States Astronomical Station No. 4 (Captain Twining), East to Pembina River crossing.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
July 4	Initial Point 49°	4447.8 W	8	32 Camelopardalis .. W. E.	270 03 40.6
			8	β Cephei .. E. E.	4 20.7
			8	Polaris .. E. E.	4 03.1
			8	γ Cephei .. E. E.	4 00.0
			8	β Ursæ Minoris .. W. E.	4 15.5
			40	Mean	270 04 04.0 ± 2″.7

Mark was moved 5.3 feet south, and tangent run through that point.

TANGENT LINE AND MOUNDS.

Stations.	Distances M. Ch. Lks.	Distances Feet.	Computed offset.	Constant.	Station error.	Final offset to mound.	Remarks.
			+				
0							Initial Point, iron pillar 520 feet east.
1	00 66 66	4,400					
2	1 40 00	7,920	1.8			1.8 north.	Iron pillar.
3	3 02 42	16,000	7.0			7.0 north.	Earth mound, 12′ × 5′.
......	3 17 54	16,998					Pembina River.

UNITED STATES TANGENT No. 4.

1873.

From United States Astronomical Station No. 4 (Assistant Lewis Boss), west side of Pembina Mountain, to Long River, United States Astronomical Station No. 5 (Lieutenant Gregory).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 4	Initial point 49°	4,447.8 W	8	32 Camelopardalis .... W. E.	270 03 40.6
			8	β Cephei .... E. E.	4 20.7
			8	Polaris .... E. E.	4 03.1
			8	γ Cephei .... E. E.	4 00.0
			8	β Ursæ Minoris ..... W. E.	4 15.5
			40	Mean	270 01 04.0 ± 2″.7

Mark was moved south 5.3 feet, and tangent run through that point.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 9	Station No. 27	Station No. 26	8	β Cephei .... E. E.	89 31 17.2
			8	Polaris .... E. E.	24.6
			8	γ Cephei .... E. E.	20.4
			24	Mean	89 31 20.6 ± 2″.4
	Azimuth due to distance, 155,410. feet				89 30 39.5
	Error in running the line				41 1

There being no reason to suspect an error at any station, this total error of 41″.1 is distributed at the rate of 1″.62 at each station. The accumulated error, in feet, arising from each individual error in pointing, is calculated separately for 15, 21, 25, 26, 27, 28, 29, and 29½ miles. At the other stations it is interpolated from these and placed in the column headed "Error of line," and is subtractive.

STATION ERROR.

	Feet
Chained distance from Station No. 27 to Astronomical Mound 49°	565.2
Computed offset for distance, 155,100 feet	660.0
	94.8
Error of Line, due to azimuth deviation	12.0
United States Astronomical Station No. 5, south	82.8

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Error of line.	Station error.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*		−	−		
0									Initial Point.
1	0	67	38	4,447					
2	2	08	40	11,114	3.1	0.3	5.9	2.8 south	Earth mound.
3	3	00	00	15,840	6.9	0.4	8.5	2.0 south	Do.
4	4	21	34	22,528	13.9	0.5	11.4	2.0 north	Do.
5	5	07	98.5	26,926.5	19.8	0.6	11.3	4.9 north	Do.
6	6	50	47	35,009	33.6	0.8	18.6	14.2 north	Do.

United States Tangent No. 4—Continued.

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Error of line.	Station error.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	—	—		
7	7	61	49	41,018	46.2	1.0	21.8	23.4 north..	Earth mound.
8	8	46	99	45,341	56.4	1.2	24.1	31.1 north..	Do.
9	9	11	18	48,256	63.9	1.4	25.7	36.8 north .	Do.
10	10	05	58.2	53,168.2	77.6	1.6	28.4	47.6 north.	Do.
11	10	60	67	56,801	88.6	1.8	30.0	56.8 north .	Do.
	11	00	00	58,080	92.6	1.9	31.0	59.7 north..	Do.
12	12	41	59	66,105	119.9	2.2	35.2	82.5 north..	Do.
13	13	69	35	73,217					
	14	00	00	73,920	150.0	2.5	39.5	108.0 north..	Earth mound.
14	15	07	41	79,689	174.3	2.9	42.6	128.8 north..	Do.
	16	00	09	84,480	195.9	3.0	45.1	147.8 north..	Do.
15	17	04	68	90,069	222.7	3.4	48.1	171.2 north..	Do.
16	17	77	68	94,887	246.7	3.6	50.6	192.5 north .	Stone mound, 12′ × 5′.
17	18	71	79	99,976	274.5	4.2	53.3	217.0 north..	Earth mound, 8′ × 3′.
18	19	51	72.5	103,713.5					
19	20	08	91	106,188	309.6	5.0	56.7	247.9 north..	Earth mound, 18′ × 7′.
20	21	31	62.8	112,967.8					
21	22	03	53	116,393	371.7	5.8	60.8	205.1 north..	Earth moand, 16′ × 6′.
22	22	43	87.3	119,055.3					
	23	00	00	121,440	403.4	6.3	64.9	332.2 north .	Earth mound, 8′ × 3′.
23	24	01	67	127,028	443.0	7.1	67.9	368.0 north..	Do.
	25	00	00	132,000	478.3	7.6	70.5	400.2 north..	Earth mound, 16′ × 6′.
24	25	46	23.5	135,051.5					
25	25	79	67	137,258					
	26	00	00	137,280	517.4	8.2	73.3	435.9 north .	Earth mound, 16′ + 6′.
	27	00	00	142,560	557.9	9.2	76.1	472.6 north..	Earth mound, 8′ × 3′.
26	27	20	44	143,909	568.5	9.4	76.8	482.3 north..	Earth mound, 16′ × 6′.
	28	00	00	147,840	600.0	10.4	78.9	510.7 north..	Earth mound, 8′ × 3′.
	29	00	00	153,120	643.7	11.5	81.7	550.5 north..	Do
27	29	30	00	155,100	660.0	12.0	82.8	565.2 north..	Lieutenant Gregory's Meridian.

On the parallel established by the above mounds iron pillars were placed, in 1875, by Capt. J. F. Gregory, United States Engineers, as follows:

Distance from Initial Point of Tangent No. 4.

M.	*Ch.*
1	72.12
3	72.12
5	72.12
7	72.12
9	72.12
11	72.12
13	72.12
15	72.12
17	72.12
19	72.12
21	72.12
23	72.12
25	72.12
27	72.12

UNITED STATES TANGENT No. 5.

1873.

From United States Astronomical Station No. 5 (Lieutenant Gregory) to Astronomical Station at Sleepy Hollow (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit, Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 16 } July 18 }	Initial Point, 49°	3,468 feet west	8	β Cephei ... E.	270 00 17.5
			8	β Cephei ... E.	11.6
			8	γ Cephei ... E.	18.2
			8	β Ursæ Minoris ... W.	270 00 35.4
			8	Polaris ... E.	269 59 43.8
			40	Mean	270 00 13.3 ± 2″.6

The mark was moved south 0.3 feet and the tangent run through it.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 21 } July 22 }	Station 12	Station 11	8	β Ursæ Minoris ... W.	89 41 38.1
			8	γ^2 Ursæ Minoris ... W.	42 25.6
			8	Polaris ... E.	41 45.6
			8	γ Cephei ... E.	42 26.4
			32	Mean	89 42 02.4 ± 2″.7
Azimuth due to distance 95,112 feet					89 42 03.9
Error of Line					01.5

STATION ERROR.

	Feet.
Chained distance from Station 13 to Astronomical Mound on 49°	93.75
Computed offset for distance of 96,760 feet	257.
Sleepy Hollow Astronomical Mound, 49°, south	163.25

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	—	—		
0	0	00	00	0	0.0	0.0	0.0	Initial Point, mound of Astronomical Station No. 5.
1	0	52	55	3,468	0.3	4.8	4.5 south	Stone mound, 6′ × 4′.
2	1	30	76	7,310				
3	3	36	86	18,274	8.8	31.0	22.2 south	Stone mound, 13′ × 7′.
4	4	76	15	26,146				
5	5	54	50	29,997	24.7	50.6	25.9 south	Stone mound, 13′ × 7′
6	7	58	50	40,821	45.7	66.8	21.1 south	Do.
7	10	63	57	56,986	89.2	96.3	7.1 south	Do.
8	11	41	84	69,839	100.9	102.8	1.9 south	Stone mound, 10′ × 6′.
9	13	52	23	72,086	142.4	119.2	23.2 north	Earth mound, 16′ × 7′.
10	15	61	06	83,230	190.2	138.7	51.5 north	Do.
11	17	40	42	92,428				
12	18	01	09	95,112	248.5	157.1	91.4 north	Earth mound, 10′ × 5′.
13	18	26	09	96,762	257.0	163.3	93.7 north	Terminal Point, Sleepy Hollow meridian.

On the parallel established by the above mounds, iron pillars were placed, in 1875, by Capt. J. F. Gregory, United States Engineers, as follows:

Distance from Initial Point of United States Tangent No. 5.

M.	*Ch.*
2	42.14
4	42.14
5	42.15

UNITED STATES TANGENT No. 6.

1873.

From United States Astronomical Station No. 6, at Turtle Mountain West (Captain Twining), eastward into Turtle Mountain.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTH.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 1	2.2 feet north of 49°, and 1,678 feet east of meridian of United States Astronomical Station No. 6.	8,123 feet west of meridian of United States Astronomical Station No. 6.	8	Polaris .... E..	269 50 59.6
			8	32 Camelopardalis ...... W..	58.4
			8	β Ursæ Minoris ... . W..	49.2
			8	γ² Ursæ Minoris .... W..	47.3
			8	γ Cephei .... E..	23.3
			40	Mean..................	269 50 47.6 ± 3″.2

The tangent was run through a point 26.2 feet north of the mark.
The Station Error as given by the English is, United States Astronomical Station No. 6 North, 100.76 feet.
The tangent line was cut through the woods. The following are the stations:

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Constant error.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	−	−		
0	0	25	42	1,678					
1	0	75	45	4,980					
2	2	39	63	13,176					
3	2	68	50	15,081	6.3	8.4	2.2	4.3 south ..	Earth mound.
4	3	23	07	17,363					
5	3	64	88	20,122					
6	4	24	45	22,734					
7	4	57	23	24,897	16.9	13.9	2.2	0.8 north .	Earth mound.
8	5	27	72	28,230					
9	8	22	65	43,735	52.3	24.3	2.2	25.8 north ..	Earth mound.
10	8	31	57	44,324					
11	8	58	76	46,118					
13	9	20	30	48,860					
14	10	32	78	54,963					

UNITED STATES TANGENT No. 7.

1873.

From United States Astronomical Station No. 6, at Turtle Mountain West (Captain Twining), to British Astronomical Station at first crossing Mouse River (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Wurdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 1	2.2 feet north of 49°, and 1,678 feet east of meridian of United States Astronomical Station No. 6	8,123 feet west of the meridian of United States Astronomical Station No. 6.	8	Polaris .... E..	269 50 59.6
			8	32 Camelopardalis ...... W..	58.4
			8	β Ursæ Minoris ...... W..	49.2
			8	γ² Ursæ Minoris .... W..	47.3
			8	γ Cephei...... .... E..	23.3
			40	Mean	269 50 47.6 ± 3″.2

The tangent was run through a point 26.2 feet north of mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 5	Station 9 of Tangent ..	Station 8 of Tangent...	8	Polaris .... E..	89 41 23.8
			8	32 Camelopardalis ...... W..	33.3
			8	γ² Ursæ Minoris .. ....W..	36.8
			8	γ Cephei................ E..	17.9
			32	Mean	89 41 27.9 ± 2″.8
Azimuth due to distance 96,604 + 1,678 = 98,282 feet					89 41 28.2
Error of Tangent Line					60.3

STATION ERROR.

The chained distance from Station 10 of Tangent to British Astronomical Parallel is	396.
Tangent started north	2.2
	398.2
Computed offset for distance, 105,095 feet..	303.2
	95.0

This 95.0 feet is used, without error, in determining the offsets to intermediate mounds; but it is not the true Station Error, because the tangent did not make an angle of 90° with Captain Twining's meridian, but with a meridian 1,678 feet east of the Astronomical Station. Taking the initial point of the tangent on the meridian of United States Astronomical Station No. 6, the computed offset is 312.9

The measured offset is 396 feet + 2.2 feet 398.2

Station Error of British Astronomical Station, first crossing Mouse River, north 85.3

TANGENT LINE AND MOUNDS.

Stations.	Distances. M	Ch.	Lks.	Feet	Computed offset.	Station error.	Constant error.	Final offset to mound.	Remarks.
					+	+	—		
0				1,678	..	..		....	Initial Point of line.
0	....	.		0,000	.		..	....	Initial Point of chaining, meridian of United States Astronomical Station No. 6.
1				... .	..	..	.	....	
2									
3	4	76	01	26,139	18.7	23.6	2.2	40.1 north.	Stone mound, 16′ × 7′.
4	6	25	64	33,372					
5	8	61	39	46,292	58.8	41.8	2.2	98.1	Do.
6	11	15	26	59,087	95.8	53.1	2.2	145.0	Do.
7	14	13	86	74,835	162.0	69.1	2.2	229.2	Do.
8	17	14	30	90,704	227.0	82.2	2.2	307.0	Do.
9	18	23	70	96,604	256.4	87.1	2.2	341.6	Do.
10	19	72	35	105,095	303.2	95.0	2.2	396.0	Terminal Point, Astronomical Station.

UNITED STATES TANGENT No. 8.

1873.

From United States Astronomical Station No. 7, at South Antler Creek (Lieutenant Gregory), to British Astronomical Station at second crossing Mouse River (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 26	49° Mound	2,040.7 feet east of 49° Mound.	8	Polaris ... E.	89 47 07.3
			8	β Ursæ Minoris ... W.	35.9
			8	γ^2 Ursæ Minoris ... W.	37.1
			24	Mean	89 47 26.8 ± 2″.1

The mark was moved south 7.5 feet and tangent run through that point.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 29	Station 9	Station 8	8	Polaris ... E.	89 41 30.8
			8	β Ursæ Minoris ... W.	32.2
			8	γ^2 Ursæ Minoris ... W.	38.8
			8	ξ Ursæ Minoris ... W.	22.6
			8	γ Cephei ... E	28.4
			40	Mean	89 41 30.6 ± 1″.2
	Azimuth due to distance 107,698 feet				89 39 41.4
	Error of line to north				1 49.2

STATION ERROR.

A strong southerly gale was blowing at Stations 0, 1, and 2, turning the telescope to the north. The error of 109″.2 is distributed at these three stations, or 36″.5 at each, and the result of each separate erorr is calculated and subtracted from the station error of 221 feet given by the line as run. The sum of these errors is 58 feet.

	Feet.
Chained distance from Station 11 to Astronomical Mound 49°	148.0
Computed offset due to distance 119,576.8 feet	369.0
	221.0
	58.0
British Astronomical Station south	163.0

United States Tangent No. 8—Continued.

TANGENT LINE AND MOUNDS.

Stations.	Distances.		Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	M. Ch. Lks.	*Feet.*	+	−	+		
0	....	....	....	....	....	....	Initial Point, meridian of United States Astronomical Station No. 7.
1	0 10 17	671	....	....	....	....	
2	2 11 73	11,334	3.5	21.3	....	17.8 south..	Stone mound, 10′ × 6′.
3	4 64 75	25,393	16.2	47.8	....	31.6 south..	Do.
4	7 40 03	39,601	43.0	74.9	....	31.9 south..	Earth mound, 10′ × 6′.
5	9 65 41	51,837	73.6	97.9	....	24.3 south..	Stone mound, 10′ × 6′.
6	13 57 24	72,418	143.9	136.8	....	7.1 north .	Earth mound, 12′ × 6′.
7	16 65 49	84,842	197.6	160.3	....	37.3 north..	Stone mound, 10′ × 6′.
8	18 72 77	99,843	....	....	....	....	
9	20 31 79	107,698	318.4	203.7	....	114.7 north..	Do.
10	21 03 08	111,083	....	....	....	....	
11	22 51 77	119,577	369.0	221.0	....	148.0 north..	Terminal Point, meridian of British Astronomical Station.

Error at—	Feet.
Station 2 ..	1.6 south.
Station 3....	1.2 north.
Station 4....	3.5 north.
Station 5....	5.9 north.
Station 6...	9.7 north.
Station 7...	12.0 north.
Station 9...	16.2 north.

NOTE.—In revising these notes in 1875 an error was discovered in the computed offset at Station 11, which should be 392.7 instead of 369.0 feet. This makes the mounds erroneously built as in the column to the right. Owing to the uncertainty in the azimuth, the station error of 163.3 feet south is not disturbed.

UNITED STATES TANGENT No. 9.

1873.

From United States Astronomical Station No. 8 (Captain Twining), to British Astronomical Station at Short Creek (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 1	49° Mound	5,711 feet west	8	Polaris ... E	269 49 17.9
			8	β Ursæ Minoris ... W	20.8
			8	γ^2 Ursæ Minoris ... W	45.9
			24	Mean	269 49 28.2 ± 3″.1

Tangent was run through a point 17.5 feet north of the Mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 5	Station 9	Station 10	8	Polaris ... E	269 43 11.0
			8	β Ursæ Minoris ... W	43 16.8
			8	γ^2 Ursæ Minoris ... W	42 52.1
			8	γ Cephei ... E	43 40.7
			32	Mean	269 43 15.1 ± 2″.7
	Azimuth due to distance, 89,079 feet				269 43 11.1
	Error in line				4.0

STATION ERROR.

	Feet.
Chained distance from Station 10 to British Astronomical Mound 49°	420.2
Computed offset for a length of 94,410 feet	244.6
Station error, British Astronomical Station north	175.6

TANGENT LINE AND MOUNDS.

Stations.	Distances. M. Ch. Lks.	Distances. Feet.	Computed offset. +	Station error. +	Error of initial point.	Final offset to mound.	Remarks.
0							Initial Point, meridian Astronomical Station No. 8.
1	1 06 53	5,711					
2	2 06 59	10,995					
3	4 34 48	23,396	15.0	43.6		58.6 north	Stone mound, 8′ × 6′.
4	6 21 40	33,092	31.1	61.6		92.7 north	Earth mound, 14′ × 6′.
5	9 13 20	48,392	64.3	90.0		154.3 north	Stone mound, 8′ × 6′.
6	9 65 09	51,816					
7	11 54 14	61,653	104.3	114.8		219.1 north	Earth mound, 10′ × 6′.
8	14 54 45	77,514	164.9	143.1		308.0 north	Stone mound, 10′ × 6′.
9	16 69 68	89,079	218.0	165.7		383.7 north	Earth mound, 15′ × 7′.
10	17 70 46	94,410	244.6	175.6		420.2 north	Meridian British Astronomical Station.

UNITED STATES TANGENT No. 10.

1873.

From United States Astronomical Station No. 9 (Lieutenant Gregory) to British Astronomical Station, at Grand Coteau (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 9	49° parallel	3025.3 feet west	8	Polaris .... E..	270 00 12.5
			8	β Ursæ Minoris. ...... W..	12.1
			8	γ² Ursæ Minoris. .... W..	30.8
			8	γ Cephei .... E..	07.8
			32	Mean	270 00 15.8 ± 1″.9

Tangent was run through a point 0.3 feet south of mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 15	Station 9	Station 8	8	Polaris .... E..	89 42 43.3
			8	β Ursæ Minoris ...... W.	41 38.9
			8	γ² Ursæ Minoris. .... W..	41 56.3
			8	γ Cephei .... E.	42 01.8
			32	Mean	89 42 05.1 ± 1″.9
Tangent started with an azimuth of					2.1
					89 42 07.2
Azimuth due to distance, 93,928 feet					89 42 17.4
Error of line to south .... (This error was taken as the sum of the errors of observation at both stations.)					10.2

STATION ERROR.

	Feet.
The effect of the azimuth error in feet at the terminal point is	2.7
The chained distance from station 10 of tangent to British astronomical mound	185.0
	182.3
Computed offset for a length of 94,799 feet	246.7
Station error of British Astronomical Station, south	64.4

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Final offset to mound.	Remarks.
	M.	Ch.	Lks.	Feet	+	−		
0	......	......	......	......	......	......	......	Initial point, meridian of Astronomical Station.
1	0	45	83	3,025		......	......	
2	2	46	55	13,632	5.1	8.9	3.8 south	Earth mound, 20′ × 9′.
3	5	04	13	26,672	19.6	17.3	2.3 north	Do.
4	8	40	21	44,894		......	......	
5	9	50	82	50,874	71.0	33.1	37.9 north	Earth mound, 16′ × 6′.
6	12	37	61	65,841	......	......	......	
7	13	08	82	69,222	131.1	45.0	86.1 north	Do.
8	15	25	71	80,897	179.6	54.6	125.0 north.	Stone mound, 11′ × 5′.
9	17	63	15	93,928	......		......	
10	17	77	55	94,865.2	246.7	61.7	185.0 north	Terminal point, meridian of British Astronomical Station.

UNITED STATES TANGENT No. 11.

1873.

From United States Astronomical Station No. 10 at Mid Coteau (Lieutenant Gregory) to British Astronomical Station (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 18.	10 feet north of 49° mound.	14,164 feet west	8	Polaris .... E..	269 57 40.7
			8	β Ursæ Minoris........ W..	17.2
			8	γ^2 Ursæ Minoris........ W..	23.8
			8	γ Cephei .... E..	22.8
			32	Mean	269 57 26.1 ± 1″.7

Tangent was run through a point 10.7 feet north of the mark.

Owing to stormy and cloudy nights it was impossible to obtain azimuth observations at the terminal point, either while there, on the way west, or returning east. The initial point of the succeeding British tangent was not definitely marked, so that it was impossible to compare the azimuth with the British meridian or tangent.

STATION ERROR.

	Feet.
Chained distance from Station 12 of tangent to British astronomical mound 49°	134.5
Line started north	10.0
	144.5
Computed offset for a length of 137,356 feet...........	518.2
Station error of British Astronomical Station, south	373.7

TANGENT LINE AND MOUNDS.

Stations.	Distances.		Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	M. Ch. Lks.	Feet.	+	−	−		
0	....	....	......	......	......	....	Initial point, meridian Astronomical Station No. 10.
1	2 54 60	14,164	5.5	38.6	10	43.1 south..	Earth mound, 14′ × 6′.
2	5 04 82	26,718	19.6	72.6	10	63.0 south..	Stone mound, 10′ × 6′.
3	7 20 41	38,307	40.3	104.2	10	73.9 south	Do.
4	9 79 73	52,783	76.5	143.6	10	77.1 south.	Earth mound, 14′ × 6′.
5	12 67 50	67,815	126.2	184.4	10	68.2 south.	Do.
6	14 23 80	75,490	......	......	......	....	
7	16 54 87	88,101	213.1	239.6	10	36.5 south..	Do.
8	20 52 51	109,066	326.6	296.7	10	19.9 north.	Stone mound, 10′ × 6′.
9	22 04 14	116,433	......	......	......	....	
10	23 40 15	124,090	422.7	337.5	10	75.2 north..	Do.
11	25 15 58	133,028	......	......	......	....	
12	26 01 16	137,356	518.2	373.7	10	134.5 north..	Terminal point, meridian British Astronomical Station.

UNITED STATES TANGENT No. 12.

1873.

From United States Astronomical Station No. 11, at Bully Spring (Lieutenant Gregory) to British Astronomical Station at Porcupine Creek (Lieutenant Galwey).

[Observer, F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Sept. 30	1,637 west and 9.2 feet north of 49° mound.	56.15 feet east of instrument.	8	Polaris .... E	89 58 00.2
			8	β Ursæ Minoris .... W	58 01.3
			8	ξ Ursæ Minoris .... W	57 54.2
			24	Mean	89 57 58.6 ± 2″.4
	Azimuth of true tangent at distance 1,637 feet				89 59 41.5
					1 42.9

Tangent was run through a point 2 8 feet south of mark.
The sky was cloudy and it was impossible to obtain azimuth observations at terminal point.

STATION ERROR.

	Feet.
Chained distance from Station 10 of tangent to British astronomical mound	549.7
Tangent started north	9.2
	558.9
Computed offset for a length of 117,229 feet	377.2
Station error of British Astronomical Station, north	181.7

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	+	−		
0	....			....	....	....	....	....	Initial point, meridian of United States Astronomical Station No. 11.
1	0	24	80	1,637	0.0	2.5	9.2	6.7 south..	Stone mound, 9′×6′.
2	3	27	00	17,622	8.5	27.3	9.2	26.6 north..	Earth mound, 10′×6′.
3	6	40	33	31,341	32.4	53.2	9.2	76.4 north..	Do.
...	9	40	00	50,160	69.1	77.8	9.2	137.7 north..	Do.
4	12	14	23	64,299	....	....	....	....	
5	12	50	51	66,694	....	....	....	....	Do.
6	13	27	91	70,482	136.4	109.3	9.2	236.5 north..	Do.
7	16	29	85	86,450	205.2	133.9	9.2	329.9 north..	Do.
8	17	22	83	91,267	....	....	....	....	
9	20	68	91	110,148	333.0	170.8	9.2	494.6 north..	Do.
10	22	16	20	117,229	377.2	181.7	9.2	549.7 north..	Terminal point, meridian British Astronomical Station.

UNITED STATES TANGENT No. 13.

1874.

From United States Astronomical Station No. 12 (Captain Gregory) to British Astronomical Station, Little Rocky Creek (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
June 30	20 feet south of United States Astronomical Mound, 49°.	10,430 feet west of instrument.	10	Polaris..............E..	269 51 31.1
			10	β Cephei..............E..	50 36.4
			10	γ Cephei..............E..	51 07.0
			10	γ² Ursæ Minoris........W..	51 14.8
			40	Mean................	269 51 07.3 ± 4″.2

Tangent was run through a point 26 feet 10.3 inches north of mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 4	Station 11 of tangent....	Station 10 of tangent....	10	β Cephei.............. E.	89 33 50.7
			10	Polaris..............E..	47.0
			10	β Ursæ Minoris........W.	47.8
			10	γ² Ursæ Minoris ...... W..	45.4
			40	Mean	89 33 47.7 ± 1″.8
True azimuth at distance 135,852 feet					89 34 23.9
Error of line to the south .... (This error is taken to be the sum of the errors of the azimuth observations at the extremities; *i. e.*, the whole line ran south 18″.1, which gives Station 11 an error of 11.9 feet.)					36.2

STATION ERROR.

		Feet.
The chained offset to mound from station 11 of tangent		772.5
The computed offset for a distance of 135,852 feet..........................		506.7
		265.8
The initial point was south	20.	
	11.9	31.9
Station error, British Astronomical Station north..........................		233.9

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Error of initial point.	Error of azimuth.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	+	+	+		
1				....	......	......	......	......	.. ..	Stone mound, 15′×6′.
2	1	77	58	10,400	2.9	17.9	20.0	0.9	41.7 north .	Earth mound, 12′×7′.
3	4	23	93	22,699	14.1	39.0	20.0	2.0	75.1 north..	Do.
	6	04	85	32,000	28.1	55.0	20.0	2.9	106.0 north	Do.
4	8	14	50	43,197	51.2	74.3	20.0	3.8	149.3 north.	Do.
6	13	12	63	69,474	132.6	112.6	20.0	6.2	271.4 north..	Do.
7	14	21	55	75,342	155.7	129.5	20.0	6.8	312.0 north..	Stone mound 10′×6′
8	17	28	67	91,652	230.3	157.6	20.0	8.1	416.0 north.	Do.
9	21	47	35	114,005	356.8	196.1	20.0	10.1	583.0 north..	Earth mound, 12′×7′.
10	24	03	95	126,981	442.7	218.4	20.0	11.2	692.3 north.	Stone mound, 10′×6′.
11	25	58	36	135,852	506.7	233.9	20.0	11.9	772.5 north.	Meridian of British Astronomical Station.

UNITED STATES TANGENT No. 14.

1874.

From United States Astronomical Station No. 13 (Captain Gregory) to British Astronomical Station (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No of readings.	Star.	Azimuth.
					° ′ ″
July 8	348 feet east and 11.4 feet north of United States Astronomical Mound 492.	11,825 feet west of instrument.	10	Polaris .... E..	268 10 31.0
			10	β Cephei .... E..	24.2
			10	γ Cephei .... E..	52.2
			10	β Ursæ Minoris ....W..	46.2
			10	γ² Ursæ Minoris ....W..	41.2
			50	Mean	268 10 39.0 ± 1″.2
	A line perpendicular to the meridian through the mound would have an azimuth at the initial point of				270 00 03.9
	The mark was then soath of the tangent				1 49 24.9

The tangent was run through a point 376.5 feet north of the mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star	Azimuth.
					° ′ ″
July 10	Station 7................	Station 6	10	Polaris .... E.	89 42 67.9
			10	γ Cephei ....E.	70.6
			10	β Ursæ Minoris .. .... W.	57.6
			10	γ² Ursæ Minoris........W.	57.0
			40	Mean	89 44 03.3 ± 1″.2
	True azimuth at a distance 87,873 feet				89 43 24.7
					38.6

Tangent north 38″.6. This error is taken to be the sum of the errors of the azimuth observations at both extremities, *i. e.*, the whole line ran north 19″.3, which gives at Station 7 an error of 8.3 feet north.

STATION ERROR.

The chained offset to the mound from Station 7.........		349.0
The computed offset to the mound from Station 7........		212.0
		137.0
The initial point was north	11.4	
The error of azimuth was north	8.3	19.7
Station error of British Astronomical Station north		156.7

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Error of initial point.	Error of azimuth.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks*	*Feet.*	+	+	−	−		
2	2	28	66	12,452	4.3	22.3	11.4	1.1	14.1 north	Stone mound 10′ × 6′.
3	6	37	20	34,135	32.0	60.9	11.4	3.2	78.3 north	Do.
	9	49	68	50,799	70.9	90.6	11.4	4.8	145.3 north	Do.
4	12	35	30	65,690	118.5	117.1	11.4	6.2	218.0 north	Do.
5	14	35	82	76,284	159.7	136.0	11.4	7.1	277.2 north	Do.
7	16	51	41	87,873	212.0	156.7	11.4	8.3	349.0 north	Do.

UNITED STATES TANGENT No. 15.

1874.

From United States Astronomical Station No. 14 (Captain Gregory) to British Astronomical Station (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 12	20 feet north of mound 49°.	11,352.5 feet west of instrument.	10	Polaris .... E ..	271 57 51. 6
			10	γ Cephei .... E ..	54. 1
			10	β Ursæ Minoris .... W ..	35. 4
			10	γ^2 Ursæ Minoris .... W ..	44. 4
			40	Mean	271 57 46. 4 ± 2″.0

Tangent line was run through a point 389 feet south of mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 17	Station 10...............	Station 11...............	10	Polaris .... E ..	269 35 30. 2
			10	γ^2 Cephei .... E ..	28. 6
			10	β Ursæ Minoris .... W ..	75. 2
			10	γ^2 Ursæ Minoris .... W ..	62. 5
			40	Mean	269 35 49. 1 ± 3″.5
	True azimuth due to distance 130,975 feet..............................				269 35 18. 0
	Error of line to north				31. 1

This error was made in sighting from Station 8 to Station 10, a distance of 7½ miles, and gives Station 10, north of true tangent 6.2 feet, Station 11, north of true tangent 6.4 feet.

STATION ERROR.

		Feet.
The chained offset to mound at Station 11		394. 3
The computed offset to mound at Station 11		564. 5
		170. 2
The initial point was north	20. 0	
The error of azimuth...................................	6. 4	26. 4
Station error of British Astronomical Station, south........		143. 8

TANGENT LINE AND MOUNDS.

Stations.	Distances.				Computed offset.	Station error.	Error of initial point.	Error of azimuth.	Final offset to mound.	Remarks.
	M.	*Ch.*	*Lks.*	*Feet.*	+	−	−	−		
3	3	42	56	18, 649	9. 6	18. 6	20. 0	....	29. 0 south	Stone mound, 10′ × 6′.
5	8	38	58	44, 786	55. 0	44. 8	20. 0	......	9. 8 south	Do.
6	10	62	97	56, 956	89. 1	57. 0	20. 0	......	12. 1 north	Do.
7	13	02	52	68, 806	129. 1	68. 9	20. 0	....	40. 2 north	Do.
8	17	49	48	93, 026	237. 5	93. 0	20. 0	....	124. 5 north .	Do.
	20	46	62	108, 677	324. 3	108. 7	20. 0	....	195. 6 north .	Do.
10	24	64	47	130, 975	471. 1	131. 0	20. 0	6. 2	313. 9 north .	Do.
11	27	12	71	143, 399	564. 5	143. 8	20. 0	6. 4	394. 3 north .	Do.

UNITED STATES TANGENT No. 16.

1874.

This Tangent was in two parts, both starting at United States Astronomical Station No. 15, at the East Fork of Milk River; one part, east 8.5 miles, connecting with Captain Featherstonhaugh's Tangent, the other, west 13.3 miles, to Lieutenant Galwey's station on the West Fork.

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 21	877 feet west and 123.2 feet north of the mound.	14,124 feet east of the instrument.	10	Polaris .... E ..	88 19 48.3
			10	γ Cephei .... E ..	52.4
			10	β Ursæ Minoris .... W .	48.4
			10	γ² Ursæ Minoris .... W ..	57.4
			40	Mean..................	88 19 51.6 ± 0″.6
	The azimuth at this point of a perpendicular to the meridian of Captain Gregory's Astronomical Mound				89 59 50.1
					1 39 58.5

The tangent line was run through a point 411 feet south of mark.
No azimuth observations were taken at the eastern extremity.
No azimuth observations were taken at the western extremity, the sky being cloudy. The tangent was checked in azimuth on Lieutenant Galwey's meridian and found correct within 10″.

STATION ERROR EAST.

	Feet.
Initial point, north	123.2
Computed offset for distance 44,793 feet	55.1
United States determination of 49°, south	68.1
Distance from extremity to British determination of 49°, south	507.0
Station error United States Station, north	538.9

STATION ERROR WEST.

Computed offset due to distance 70,052 feet	134.7
Initial point, north	123.2
United States determination of 49°, north of tangent	11.5
Actual offset to mound, south	155.2
Station error British Station, south	166.7

United States Tangent No. 16—Continued.

TANGENT LINE (EAST) AND MOUNDS.

Stations.	Distances.		Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	M. Ch. Lks.	*Feet*	+	−	−		
4	6 37 59	34, 161	32. 0	166. 4	123. 2	197. 6 south .	Stone and earth mound, 10′×6′.
2	2 40 71	13, 247	4. 1	41. 2	123. 2	160. 3 south .	Stone mound, 10′×6′.

TANGENT LINE (WEST) AND MOUNDS.

Stations.	Distances.		Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	M. Ch. Lks.	*Feet.*	+	−	−		
2	1 66 38	9, 661	2. 6	23. 0	123. 2	143. 6 south .	Stone mound, 10′×6′.
4	4 21 78	22, 557	14. 0	53. 0	123. 2	162. 2 south .	Do.
	7 17 83	38, 137	39. 9	90. 8	123. 2	174. 1 south .	Do.
6	9 08 95	48, 111	63. 6	114. 5	123. 2	174. 1 south .	Earth mound, 12′×7′.
8	13 21 40	70, 052	134. 7	166. 7	123. 2	155. 2 south .	Meridian British Astronomical Station.

UNITED STATES TANGENT No. 17.

1874.

From United States Astronomical Station No. 16 (Captain Gregory) to British Astronomical Station (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
July 25	34.5 feet north of 49° ...	12,104 feet west of instrument.	10	Polaris .... E ..	268 43 42.0
			10	β Ursæ Minoris .... W ..	52.0
			10	γ^2 Ursæ Minoris .... W ..	52.8
			30	Mean	268 43 48.9 ± 1″.0

Tangent line run through a point 268.25 feet north of the mark.

	° ′ ″
Station 6 of the tangent was on the meridian of the terminal point of a tangent run east by Captain Featherstonhaugh. The azimuth was checked here by putting a stake on United States tangent, on the meridian of next British tangent stake, measuring the distance between the two tangents at each point. By these means the azimuth of the United States tangent was found to be	89 34 16.2
True azimuth for 133,810 feet	89 34 46.0
Azimuth error	29.8

	Feet.
Length of Captain Featherstonhaugh's tangent is	21,450
Length of Lieutenant Greene's tangent is	112,360
Total length of tangent	133,810

STATION ERROR.

	Feet.	
At Station 6, the distance from United States tangent to British determination of 49°		32.7
The initial point was north of 49°	34.5	
The computed offset for 112,360 feet	346.6	
Distance from United States tangent to United States determination of 49°		312.1
Station error, British Astronomical Station, south		279.4

TANGENT LINE AND MOUNDS.

Stations.	Distance.	Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks
	Feet.	+	−	−		
3	16,082	7.4	33.6	34.5	60.7 south ..	Earth and stone mound, 10′ × 6′.
A	32,250	28.5	67.3	34.5	73.3 south .	Do.
4	45,749	57.6	95.6	34.5	72.5 south .	Stone mound, 10′ × 6′.
5	70,364	135.9	147.0	34.5	45.6 south .	No mound built.
6	112,360	317.3	231.6	34.5	78.2 north .	British mound.

UNITED STATES TANGENT No. 18.

1874.

From United States Astronomical Station No. 17 (Captain Gregory) to British Astronomical Station (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 2	42.3 feet south and 1,479 feet east of United States astronomical mound.	10,677 feet west of instrument.	10	Polaris......... E..	270 04 03.7
			10	β Ursæ Minoris.. W..	02.3
			10	γ^2 Ursæ Minoris.. W..	04.5
			30	Mean...........	270 04 03.5 ± 1″.1
The azimuth at this point of a perpendicular to the meridian of United States astronomical mound.					270 00 17.3
					3 46.2

Tangent run through a point 13.3 feet south of mark.
Total length of tangent is 89,636 feet.

STATION ERROR.

	Feet.
Chained offset from United States tangent to British Astronomical Station 49°, north	4.0
Computed offset for distance, 89,636 feet	220.6
Initial point, south	42.3
Station error of British Astronomical Station, south	266.9

TANGENT LINE AND MOUNDS.

Station.	Distance.	Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks
	Feet.	+	−	+		
A	18,269	9.2	54.8	42.3	3.3 south ..	Stone mound, 10′ × 6′.
4	37,085	37.8	112.2	42.3	31.1 south..	Do.
5	58,305	93.3	175.5	42.3	39.9 south ..	Do.
7	82,500	186.9	245.6	42.3	16.4 south...	Do.
8	89,636	220.6	266.9	42.3	4.0 south...	British astronomical mound—Meridian.

UNITED STATES TANGENT No. 19.

1874.

From United States Astronomical Station No. 18 (Captain Gregory) to British Astronomical Station (Captain Featherstonhaugh).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8-in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 9	125.3 feet north and 174.0 feet west of United States astronomical mound.	18,324 feet west of instrument.	10	β Ursæ Minoris .. W..	270 34 20.4
			10	β Cephei .... E ..	41.5
			10	γ Cephei .... E ..	34.0
			30	Mean............	270 34 32.0 ± 1″.16
	Azimuth at this point of the perpendicular to the meridian through the astronomical mound..				269 59 58.1
					34 33.9

Tangent was run through a point 184.3 feet south of mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 13	Terminal point of tangent on meridian of British astronomical mound 49°.	On tangent............	10	Polaris .... E ..	89 36 15.6
			10	γ Cephei .... E .	01.2
			10	β Ursæ Minoris.. W..	30.3
			5	γ² Ursæ Minoris.. W..	26.8
			35	Mean	89 36 18.5 ± 1″.43
	Computed azimuth				89 35 27.9
	Error of line				50.6

STATION ERROR.

The British ran east 16,834.6 feet, from a point 13 feet east and 11 feet south of British astronomical mound 49°.

	Feet.	Feet.
Lieutenant Greene's chaining....................	113,251.0	
British	16,834.6	
British initial point, east....................	13.0	
Total length of tangent	130,098.6	
The measured offset, north		604.9
Initial point, south....................		125.3
		479.6
Computed offset due to distance, north		464.6
Station error, British Astronomical Station, south		15.0

TANGENT LINE AND MOUNDS.

Stations.	Distances.	Computed offset.	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	Feet.	+	+	+		
2	18,498	9.4	2.1	125.3	136.8 north.	Stone mound, 10′×6.
A	41,840	48.0	4.8	125.3	178.1 north.	Do.
B	58,857	95.4	6.7	125.3	227.4 north..	Do.
C	74,708	153.2	8.5	125.3	287.0 north..	Do.
D	89,035	217.5	10.2	125.3	353.0 north	Do.
...	100,000	274.5	11.5	125.3	411.3 north.	Do.
9	130,098.6	464.6	15.0	125.3	604.9 north..	Meridian British Astronomical Station.

UNITED STATES TANGENT No. 20.

1874.

From United States Astronomical Station No. 19 (Captain Gregory) to British Astronomical Station (Lieutenant Galwey).

[Observer, Lieut. F. V. Greene.—Transit Würdemann 8 in. No. 87.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 14	3.4 feet south and 124 feet east of United States astronomical mound.	17,720 feet west of instrument.	10	γ Cephei..........E..	269 58 28.1
			10	Polaris.......... E..	38.9
			10	β Ursæ Minoris ..W..	02.3
			10	γ² Ursæ Minoris ..W..	12.3
			40	Mean............	269 58 20.4 ± 1″.6
	Azimuth at this point of a perpendicular to the meridian through the astronomical mound ..				269 59 58.5
					1 38.1

Tangent was run through a point 8.5 feet north of the mark.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
Aug. 30	152.1 feet east and 124.1 feet south of British astronomical mound.	Station 5 of tangent....	10	γ Cephei .... E..	89 38 41.7
			6	Polaris .... E..	53.3
			16	Mean	89 38 47.5 ± 1″.7
	Azimuth due to distance, 112,562 feet.				89 38 46.4
	Error of line..............				1.1
	Total length of tangent 112,714 feet.				

STATION ERROR.

	Feet.
Chained distance from United States tangent to British determination 49°...	124.1
Computed offset for distance 112,714 feet..........	348.7
	224.6
Initial point	3.4
Station error, British Astronomical Station, south	228.0

TANGENT LINE AND MOUNDS.

Stations.	Distances.	Computed offset	Station error.	Error of initial point.	Final offset to mound.	Remarks.
	Feet.	+	−	+		
1	17,720	8.6	35.8	3.4	23.8 south ..	Stone mound, 10′ × 6′.
A	36,620	36.8	73.9	3.4	53.7 south...	Stone mound, 12′ × 6′.
2	56,072	86.3	113.1	3.4	23.4 south...	Stone mound, 11′ × 7′.
D	71,212	139.2	143.8	3.4	1.2 south...	Stone mound, 11′ × 8′.
F	85,350	200.0	172.3	3.4	31.1 north...	Stone mound, 12′ × 7′.
5	105,986	308.4	214.1	3.4	97.7 north ..	Stone mound, 12′ × 6′.
6	112,562	......	......	......	....	Terminal point of tangent.
...	112,714	......	......	......	....	British Astronomical Station meridian.

CONNECTION OF ASTRONOMICAL STATIONS.

DETAILS OF BRITISH TANGENT LINES AND MOUNDS, COMPILED FROM THE RECORD-BOOKS OF CAPT. A. FEATHERSTONHAUGH, R. E., AND LIEUT. W. J. GALWEY, R. E.

BRITISH TANGENT No. 1.

1872.

From Lake of the Woods to Pine Ridge Astronomical Station.

[Troughton & Sims Transit Theodolite F. O. No. 1.—In two parts: Part First, Lake of the Woods to East Rosean River, observer Colonel Forrest; Part Second, Pine Ridge to East Roseau River, observer A. Featherstonhaugh, R. E.]

AZIMUTHS.—PART FIRST.

[The azimuth of Part First was checked by W. J. Galwey, R. E.]

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
1873. Feb. 24	At Terminal Point, 17 miles 1372.8 feet from Lake of Woods.	At 17-mile point	α Ursæ Minoris	89 41 47.
			α Ursæ Majoris...........	43.
			β Ursæ Minoris	57.
			Mean	89 41 49.
	True azimuth			89 42 50.
	Error in azimuth.........			1 01

The tangent was run through a point (1,372.8 feet × sin 1′ 01″ =) 4.9 inches south of the mark, to within three miles of the Lake of the Woods, and found correct.

AZIMUTHS.—PART SECOND

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
1872. Nov. 6	53.125 chains west of Astronomical Station.	66.35 chains west of instrument.	51 Cephei	269 59 00.93
			51 Cephei	58 48.96
			Mean	269 58 54.95

The tangent was prolonged on the correct azimuth to East Roseau River. No record of this.

STATION ERROR.

	Feet.
Part Second started north	77.
Offset due to distance	164
Part Second south of 49°	87.
Part Second north of Part First	528.66
	615.66
Offset from Part First due to distance..............	227.66
Station error Pine Ridge Astronomical Station, north	388.

British Tangent No. 1—Continued.

PART FIRST.—OFFSETS TO PARALLEL.

Distance from initial point in miles.	Computed offset in feet.	Station error in feet.	Final offset in feet.	Remarks.
	+	+		
1	00.765	12.17	12.935 north..	No post was fixed, there being no firm ground.
2	03.06	24.36	27.42 north..	
3	06.89	36.53	43.42 north..	Earth mound.
4	12.24	48.70	60.94 north..	
5	19.13	60.87	80.00 north..	Earth mound.
6	27.55	73.04	100.59 north..	
7	37.50	85.21	122.71 north..	
8	48.98	97.38	146.36 north..	
9	61.99	109.54	171.53 north..	Iron pillar.
10	76.53	121.71	198.24 north..	
11	92.57	133.88	226.45 north..	
12	110.20	146.05	256.25 north..	Earth mound.
13	129.34	158.22	287.56 north..	
14	150.00	170.39	320.39 north..	
15	172.20	182.56	354.76 north..	Earth mound.
16	195.92	194.73	390.65 north..	
17	220.53	206.90	427.43 north..	Iron pillar.
17.26	227.66	210.00	437.66 north..	Post fixed by A. Featherstonhaugh, R. E.

PART SECOND.—OFFSETS TO PARALLEL.

Distance from Lake of the Woods.	Distance from Pine Ridge.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.	*M. Ch.*	+	−	−		
18 20.80	....	142.4	166.0	77.0	100.6 south...	Earth mound.
21 00.00	10 72.05 east...	90.94	132.58	77.0	118.6 south...	Iron pillar.
24 15.48	7 56.57 east...	45.48	93.71	77.0	125.3 south...	Earth mound.
25 68.04	6 04.01 east...	28.00	73.59	77.0	122.6 south...	Iron pillar.
29 00.00	2 72.05 east...	06.44	35.27	77.0	105.8 south...	Earth mound.
30 00.00	1 72.05 east...	02.76	23.11	77.0	97.3 south...	
32 51.54	0 79.49 west ..	....	....	....	....	

BRITISH TANGENT No. 2.

1873.

From Joint Astronomical Station No. 1, at Red River, to Joint Astronomical Station No. 2, at Pointe Michel.

[Observer, Lieut. W. J. Galwey, R. E.—Transit Theodolite 7-in. F. O. No. 3.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
May 29	Instrument on azimuth post	West of instrument 3,572.5 feet.	....	Polaris	270 00 36.9
			....	Polaris	23.1
			....	Polaris	19.0
			....	α Ursæ Majoris	04.6
			....	δ Ursæ Minoris	04.3
				Mean........	270 00 17.6

Tangent was run through a point (3,572.5 ft. × sin 17″.6) 3.6 in. south of the mark.
The tangent was checked at Pointe Michel by repeating the angle between it and the Michel meridian.
Result: Tangent running north 14″.8.

STATION ERROR.

	Feet.
Measured distance from terminal point of tangent to 49°	280.79
Tangent started north.............	61.25
	342.04
Offset due to distance 20 m. 675 ft	310.07
Station error	31.97
Station error by Lieutenant Greene's tangent	32.64
Mean station error, Michel north	32.3

Mounds were built by Lieutenant Greene. (See his report, page 208.)

BRITISH TANGENT No. 3.

1873.

From Joint Astronomical Station No. 2, at Michel, to Join Astronomical Station No. 3, Pembina Mountain, east.

[Troughton & Sims Transit Theodolite, 7-in. F. O. No. 3.—Observer, W. J. Galwey, R.E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
					° ′ ″
June 15	Instrument on astronomical meridian.	3,154.7 feet west of instrument.	4	Polaris	270 01 55. 1
				United States determination.	55. 7
				Mean	270 01 55. 4
	Tangent was run through point 20.88 inches south of the mark.				
	At Joint Astronomical Station, Pembina Mountain east, the angle between the tangent and the astronomical meridian of Captain Featherstonhaugh gave the azimuth of tangent				89 45 24. 3
	True azimuth due to distance				89 44 48. 3
	Azimuth error to north				36. 0

This error was considered cumulative, and was distributed at each station proportionally to its distance from Michel.

STATION ERROR.

	Feet.
The adjusted tangent was at Pembina Mountain, south of 49°	76. 6
Error of initial point north	46. 5
	123. 1
Offset due to distance	178. 15
Station error Pembina Mountain Astronomical Station, south	55. 05

OFFSET TO PARALLEL.

Distance from Pembina.		Distance from initial point in feet.	Computed offset in feet.	Station error in feet.	Azimuth error in feet.	Error of initial point in feet.	Final offset in feet.
M.	*Ch.*		+	—	—	—	
21	00	4, 603	0. 59	3. 1	0. 05	46. 5	49. 06 south.
22	00	9, 883	2. 68	6. 7	0. 17	46. 5	50. 69 south.
23	00	15, 163	6. 31	10. 3	0. 35	46. 5	50. 85 south.
24	00	20, 443	11. 48	13. 9	0. 58	46. 5	49. 51 south.
25	00	25, 723	18. 17	17. 5	0. 87	46. 5	46. 70 south.
26	13. 84	31, 916	29. 16	21. 7	1. 31	46. 5	40. 34 south.
27	00	36, 283	36. 14	24. 7	1. 63	46. 5	36. 69 south.
28	00	41, 563	47. 42	28. 3	2. 09	46. 5	29. 47 south.
29	00	46, 843	60. 24	31. 9	2. 62	46. 5	20. 77 south.
30	00	52, 123	74. 58	35. 5	3. 26	46. 5	10. 68 south.
31	00	57, 403	90. 46	39. 1	3. 96	46. 5	00. 90 north.
32	00	62, 683	107. 88	42. 7	4. 74	46. 5	13. 93 north.
33	00	67, 963	126. 8	46. 3	5. 56	46. 5	28. 44 north.
34	00	73, 243	147. 26	49. 9	6. 37	46. 5	44. 49 north.
35	00	78, 523	169. 26	53. 5	7. 24	46. 5	62. 02 north.

Note.—The iron monuments were subsequently erected at points 583 links west of the above points.

BRITISH TANGENT No. 4.

1873.

From Pembina Mountain east to Pembina River, connecting with Lieutenant Greene's Tangent from Pembina Mountain west.

[Troughton & Sims Transit Theodolite F. O. No. 1.—Observer, A. Feathorstonhaugh, R. E.]

AZIMUTHS.

The azimuth at initial point was determined by observing an assumed meridian with an astronomical transit and reading a series of angles between this meridian and the tangent as follows:

	Face right.	*Face left.*
	89 59 37. 5	89 59 52. 5
	25.	50.
	52. 5	40.
	27. 5	40.
	45.	35.
		45.
		60.
		40.
		27. 5
Means,	89 59 37. 5	89 59 43. 4

Mean of above means	89 59 40. 45
Observed azimuth of meridian	00 00 09. 2
Azimuth of tangent	270 00 28. 75

The tangent was run through a point 12.45 inches north of the mark to Pembina River. A line connecting with this tangent was run east, from Pembina Mountain west, by Lieutenant Greene.

The parallel was marked without station error, near the last picket of Lieutenant Greene's line. It was agreed to consider this the true 49°.

STATION ERROR.

	Feet.
Measured offset from Lieutenant Greene's tangent to 49°	00. 68
Error of initial point south	16. 94
	17. 62
Offset due to distance 8 miles 2,985 feet	56. 12
Station error, Pembina Mountain west, south	73. 74

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Chs.	+	−	+		
1 00.	0. 8	8. 6	16. 9	9. 1 north.	
1 65. 51	2. 5	15. 5	16. 9	3. 9 north.	
3 00.	6. 8	25. 7	16. 9	2. 0 south.	
4 37. 20	15. 2	38. 1	16. 9	6. 0 south.	
5 00.	19. 1	43. 5	16. 9	7. 5 south.	
6 00.	27. 5	51. 6	16. 9	7. 2 south.	
7 19. 46	40. 1	61. 8	16. 9	4. 8 south.	
8 00.	48. 9	68. 8	16. 9	3. 0 south.	
8 45. 81	56. 8	73. 7	16. 9	0. 0 south.	

BRITISH TANGENT No. 5.

1873.

From Sleepy Hollow Astronomical Station to Astronomical Station Turtle Mountain east.

[Troughton & Sims 7-in. Transit Theodolite F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.	Weight.
				° ′ ″	
July 5	Instrument on meridian of Astronomical Station at Sleepy Hollow.	2,300 feet west of instrument.	γ Cephei	270 06 17. 29	1
			Polaris	32. 29	2
				270 06 27. 3	

The tangent was run through a point (2,300 × sin 6′ 27″.3) = 51.78 in. south of the mark to a point 12 miles west, when azimuth observations were taken with the following result:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.	Weight.
				° ′ ″	
July 13	Instrument on tangent	Mark on tangent	Polaris	89 48 02. 7	
	True azimuth			89 47 52. 4	
	Azimuth error, neglected as inappreciable			10. 3	

The tangent was run to Astronomical Station at Turtle Mountain east, where the azimuth was examined by Captain Featherstonhaugh and an error of 7″ found, which was neglected.

STATION ERROR.

	Feet.
Measured offset at terminal point of tangent to 49°	110. 78
Error of initial point north	52. 16
	162. 94
Offset due to distance, 20.3733 miles	322. 19
Station error, Turtle Mountain east, Astronomical Station south	159. 25

OFFSETS TO PARALLEL.

Distance from initial point in chains.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
	+	−	−	
80. 00	0. 77	7. 76	52. 16	59. 15 south.
160. 00	3. 06	15. 52	52. 16	64. 62 south.
240. 00	6. 89	23. 28	52. 16	68. 55 south.
320. 00	12. 24	31. 04	52. 16	70. 96 south.
410. 48	20. 15	39. 83	52. 16	71. 84 south.
453. 17	21. 56	43. 97	52. 16	71. 57 south.
560. 00	37. 50	54. 33	52. 16	68. 99 south.
658. 06	51. 79	63. 84	52. 16	64. 21 south.
771. 29	71. 14	74. 83	52. 16	55. 85 south.
880. 00	92. 57	85. 33	52. 16	44. 97 south.
933. 61	104. 23	90. 58	52. 16	38. 51 south.
1, 016. 64	123. 88	98. 63	52. 16	26. 91 south.
1, 094. 77	143. 33	106. 21	52. 16	15. 04 south.
1, 200. 00	172. 20	116. 42	52. 16	03. 62 north.
1, 273. 78	194. 03	123. 57	52. 16	18. 30 north.
1, 387. 90	230. 36	134. 66	52. 16	43. 54 north.
1, 480. 00	261. 94	143. 59	52. 16	66. 19 north.
1, 540. 05	283. 62	149. 34	52. 16	88. 12 north.
1, 641. 41	322. 19	159. 25	52. 16	110. 78 north.

Note.—The parallel between Sleepy Hollow and Turtle Mountain was subsequently marked by mounds 9 feet in diameter and 6 feet high, with berme and trench, at the following distances from initial point: 240.00 chains, 453.17 chains, 658.06 chains, 933.61 chains, 1,200.00 chains, and 1,480.00 chains. All other mounds were destroyed.

BRITISH TANGENT No. 6.

1873.

From Turtle Mountain East toward Turtle Mountain West.

[Troughton & Sims Transit Theodolite F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

The azimuth at initial point was determined by a series of angles between the meridian of astronomical transit and the tangent as follows:

	Face right.	*Face left.*
	° ′ ″	° ′ ″
	89 58 50	89 59 02.5
	59 05	58 52.5
	59 15	59 05
	58 50	59 00
	58 57.5	
Means,	89 58 59.5	89 59 00

	° ′ ″
Mean of above means	89 58 59.75
Azimuth of meridian	359 59 03.85
Azimuth of tangent	270 00 04.1

The tangent was prolonged on this azimuth about 24 miles, where it was connected with Lieutenant Greene's tangent run east from Turtle Mountain west. Azimuth observations were here taken by Mr. King, with following results:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
....	On tangent	On tangent	Polaris	89 36 19.75
			δ Ursæ Minoris	35 06.20
			51 Cephei	34 56.75
			β Cephei	35 55.75
			Mean	89 35 34.65
	True azimuth			89 36 17
	Error in azimuth ...			42.35

	M. Ch.
The length of Captain Featherstonhaugh's tangent was	23 65.03
The length of Lieutenant Greene's tangent was	10 32.78
Distance between stations, Turtle Mountain east and Turtle Mountain west	34 17.81

STATION ERROR.

	Feet.
Measured offset from Lieutenant Greene's line to 49°	82.89
Measured offset from British tangent to United States tangent	451.64
49th parallel north of British tangent, by United States determination	534.53
49th parallel north of British tangent, by offset due to distance	433.77
Station error, Turtle Mountain west *north* of Turtle Mountain east	100.76

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Final offset in feet.	Remarks.
M. Ch.				
3 00.0	6.8	12.7	19.5 north.	
5 78.73	25.1	24.3	49.4 north.	
9 00.0	62.0	38.0	100.0 north.	
11 22.67	97.5	47.6	145.1 north.	
13 00.0	172.2	63.4	235.6 north.	
17 75.10	246.3	75.8	322.1 north.	
21 00.0	337.5	88.8	426.3 north.	
23 67.11	433.8	100.7	534.5 north.	

NOTE.—A post was placed in the interior of each mound, being sunk 3 feet in the ground and marked 49°. In the autumn of 1874 an iron tablet was buried 3 feet in the ground 10 feet east of each mound.

BRITISH TANGENT No. 7.

1873.

From first Crossing, Mouse River, to South Antler Creek.

[Troughton & Sims Astronomical Transit and 7-in. Transit Theodolite F. O. No. 3.—Observer W. J. Galwey, R. E.]

AZIMUTHS.

At the initial point of tangent Troughton & Sims astronomical transit was mounted in the meridian of zenith telescope and its azimuth found to be	[illegible]
The mark was placed on the tangent, approximately, and the angle between it and the zenith telescope meridian repeated, giving the mean of seven repetitions	[illegible]
The azimuth of mark through which tangent was run	[illegible]

The tangent was prolonged a distance of [illegible] chains, when, encountering timber, an offset was made to the south to avoid it. The original tangent was regained at [illegible] chains and prolonged to 974.[illegible] chains. Here azimuth observations were taken as follows:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
Aug. 1	On tangent	On tangent	Polaris	[illegible]
			...do	[illegible]
			Mean	[illegible]
True azimuth				[illegible]
Azimuth error				[illegible]

This tangent was corrected for this error in azimuth and prolonged to the meridian of South Antler Creek Astronomical Station.

STATION ERROR.

	Feet.
Measured offset from terminal point of tangent to 49°	[illegible]
Error of initial point north	[illegible]
	[illegible]
Offset due to distance	[illegible]
Station error South Antler Creek Astronomical Station south	[illegible]

OFFSETS TO PARALLEL.

Distance from initial point in miles.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
3	[illegible]	4.75	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]
9	61.99	*12.34	[illegible]	[illegible] south.
12	110.[illegible]	*15.12	[illegible]	14.[illegible] north.
15	[illegible]	23.9[illegible]	[illegible]	[illegible] north.
18	[illegible]	[illegible]	[illegible]	141.41 north.
21	3[illegible]7.51	33.46	[illegible]	[illegible] north.

Note.—The parallel was marked at 3-mile intervals by a square stake, 4 by 4 inches and 2 feet long, driven into the ground 9 inches and having XLIX cut deep in it. A conical mound of earth was [illegible] with the stake in the center [illegible] base, 5 feet high, [illegible] feet broad at base, with berme 2 feet and trench [illegible] feet wide. The exterior of the mound was carefully revetted with sods.

* A correction of − 1 foot is to be applied. The mounds at these points were built with this error.

BRITISH TANGENT No. 8.

1873.

From Astronomical Station Second Crossing, Mouse River, to United States Astronomical Station No. 8.

[Troughton & Sims 7-in. Transit Theodolite F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
Aug. 11	Initial point of tangent on meridian of Astronomical Station.	1,542.2 ft. west of instrument	Polaris	270 01 13.97
			do	22.12
			do	23.77
			do	31.65
			Mean	270 01 23.4

Tangent was run through a point (1,542.2 ft. × sin 1′ 23″.4 =) 7.5 in. south of the mark to 10m.945 where azimuth observations were taken as follows:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
Aug. 18	On tangent	On tangent, 1,558.8 ft. west of instrument.	Polaris	269 48 59.9
			do	57.5
			Mean	269 48 58.7
	True azimuth			269 49 06.1
	Azimuth error			7.4

The mark was moved (1,558.8 ft. × sin 7″.4 =) 6 in. north and line continued to terminal point.

STATION ERROR.

	Feet.
Measured offset from terminal point of tangent to 49°	297.66
Error of initial point, north	26.83
	324.49
Computed offset due to distance 21m.587	356.65
Station error, United States Astronomical Station, south	32.16

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset, in feet.
Miles.	+	−	−	
3	6.89	4.47	26.83	24.41 south.
6.	27.55	8.91	26.83	8.22 south.
9.066	62.91	13.50	26.83	22.58 north.
12.	110.20	17.87	26.83	65.50 north.
15.156	176.23	22.58	26.83	126.82 north.
18.	247.97	26.81	26.83	194.33 north.

Note.—The form and marking of the mounds were in every respect similar to those on the tangent from first crossing Mouse River to South Antler Creek.

BRITISH TANGENT No. 9.

1873.

From Short Creek Astronomical Station to United States Astronomical Station No. 9.

[Troughton & Sims Transit Theodolite F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

	° ′ ″
A mark was placed on the approximate tangent and the angle between it and the zenith-telescope meridian, the azimuth of which was observed with astronomical transit, was measured, giving the mean of several series	89 59 37.5
Azimuth of meridian	359 59 56.42
Azimuth of tangent	270 00 19.92
The tangent was run through a point (2,432.7 ft. × sin 19″.92 =) 2.4 in. south of the mark to 679.24 chains, where another meridian was established as above, and a series of angles read to the tangent eastward, giving a mean angle	89 55 10.00
Azimuth of meridian	359 56 16.75
Azimuth of tangent	89 51 26.75
Azimuth due to distance	89 51 41.00
Azimuth error	14.25

This error was not corrected, and the tangent continued to terminal point with the astronomical transit, the theodolite being out of order.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	205.8
Error of initial point north	19.8
	225.6
Error due to azimuth deviation of 14″	4.95
	220.65
Computed offset due to distance, 16 miles 03.62 chains	196.68
Station error of United States Astronomical Station, north	24.0

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Correction for azimuth in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.	+	+	+	−		
2 55.80	5.6	4.0	1.0	19.8	9.2 south..	Mound, 12½ 6′.
5 75.18	27.0	8.9	2.1	19.8	18.2 north..	Do.
9 15.00	64.5	13.8	3.3	19.8	61.9 north..	Do.
12 58.78	124.1	19.1	4.6	19.8	128.0 north..	Do.
16 03.62	196.7	24.0	4.9	19.8	205.8 north..	Do.

Note.—Iron tablets were buried near the mounds in 1874.

BRITISH TANGENT No. 10.

1873.

From Grand Coteau to Mid Coteau.

[Tronghton & Sims 7-in. Transit Theodolite, F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
Sept. 1	On meridian of Astronomical Station.	2,862.2 feet west of instrument.	Polaris	269 50 30.9
			.. do	29.3
			...do	30.1
			.. do	37.6
			Mean	269 50 32.0

Tangent was run through a point (2,862′.2 × sin 9′ 28″ =) 7 ft. 10.5 in. north of the mark and prolonged to the terminal point at Mid Coteau.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	642.51
Error of initial point, north	46.13
	688.64
Computed offset for a distance 23.24475 miles.................	413.49
Station error, Mid Cotean astronomical station, north	275.15

OFFSETS TO PARALLEL.

Distance from initial point in chains.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
	+	+	−	
204.4	5.00	30.25	46.13	10.88 south
410.36	20.137	60.72	46.13	34.73 north
629.19	47.341	93.1	46.13	94.31 north
911.0	99.901	135.24	46.13	189.01 north
1,211.62	175.553	179.28	46.13	308.70 north
1,454.85	253.11	215.27	46.13	422.25 north
1,712.64	350.76	253.42	46.13	558.05 north
1,859.48	413.49	275.15	46.13	642.51 north

Note.—The form and marking of the mounds were, in every respect, similar to those on the tangent from 1st crossing, Mouse River, to South Antler Creek.

BRITISH TANGENT No. 11.

1873.

From British Astronomical Station to Astronomical Station near Bully Spring.

[Troughton & Sims Transit Theodolite F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

	° ′ ″
The azimuth, at the initial point, of a mark placed approximately on the tangent, 4,343.4 feet distant, was determined from a series of readings of the angle between the mark and the zenith telescope meridian, the azimuth of which was determined with Astronomical Transit F. O. No. 1 to be......	360 06 41.30
Mean of readings of angle......	89 59 26.25
Azimuth of mark......	90 06 20.55
To get on the true tangent, the mark should be moved north, or the instrument south (4,343.4 ft. × sin 6′ 20″.55 =) 8.01 ft. The tangent had been started from a point 8.58 ft. south of observing post, using the same mark for a back sight. The tangent was consequently in error $\sin^{-1}\frac{8.58 - 8.01 = 0.57}{4,343.4}$ = 27″. southing; *i. e.*, the azimuth of the tangent, as started, was......	269 59 33.00
The line was prolonged on this azimuth 1,141.17 chains, when the azimuth was checked in the same manner as above.	
Azimuth of observed meridian......	359 57 23.53
Mean reading of angle between meridian and tangent......	90 11 44.16
Azimuth of tangent......	89 45 39.37
Computed azimuth due to distance......	89 45 48.00
Azimuth error, south......	8.63
Azimuth error, south at initial point......	27.00
Mean azimuth error, south to this point, *i. e.* 1,141.17 chains......	17.81
This error in azimuth was considered cumulative.	
Beyond Pyramid Creek the ground was very broken, the line crossing a range of hills about 5 miles distant. To convey signal so far being difficult, a mark, approximately in line, was placed on this range. The mean angle between this mark and the meridian observed above was......	89 49 31.25
Azimuth of meridian......	359 57 23.53
Azimuth of mark......	89 46 54.78
Azimuth of mark due to distance, 1,141.17 chains......	89 45 48.00
Azimuth of mark in error......	1 06.78

The line was prolonged on this erroneous azimuth 826.19 chains to the meridian of Bully Springs Astronomical Station, making a total length of tangent 1,968.06 chains. The azimuth was not again tested.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49......	693.00
Error of initial point, south......	130.68
	562.32
Azimuth error up to 1,141.17 chains......	− 6.14
Azimuth error beyond 1,141.17 chains......	+ 17.82
Computed offset due to distance, 24 miles 48.06 chains......	− 462.66
Station error, Bully Springs Station, north......	111.34

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Correction for azimuth in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.	+	+		+		
2 79.03	6.8	13.5	+ 1.4	130.7	152.4 north	Earth mound, 14′ × 6′.
5 43.35	23.5	25.1	+ 2.5	130.7	181.8 north	Do.
8 60.00	58.6	39.6	+ 4.0	130.7	232.9 north	Do.
10 44.54	85.3	47.8	+ 4.8	130.7	268.6 north	Do.
14 21.17	155.7	64.6	+ 6.1	130.7	357.1 north	Do.
18 00.46	248.1	81.5	− 0.3	130.7	460.0 north	Do.
21 02.76	338.6	95.2	− 5.5	130.7	559.0 north	Stone mound, 12′ × 6′.
24 48.06	462.7	111.3	− 11.7	130.7	693.0 north	Astronomical mound, Bully Spring.

Note.—Mounds made of earth are faced with sod.

BRITISH TANGENT No. 12.

1873.

From East Poplar River to West Poplar River.

[Troughton & Sims 7-in. Transit Theodolite F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
Sept. 16	On meridian of astronomical station ..	2,848.5 feet west of instrument	Polaris..........	270 00 38.8
			...do	34.8
			...do	26.9
			Mean	270 00 33.5

Tangent was run through a point (2,848.5 feet × sin 33.5 inches =) 5.5 inches south of the mark to the terminal point.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	281.82
Error of initial point, south..	38.40
	243.42
Computed offset due to distance 23.4315 miles	420.20
Station error, West Poplar River Astronomical Station, south.........	176.78

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
Miles.	+	−	+	
3.	6.89	22.63	38.4	22.66 north.
5.9475	27.41	45.11	38.4	20.70 north.
9.	61.99	67.90	38.4	32.49 north.
12.	110.20	90.53	38.4	58.07 north.
15.	172.20	113.17	38.4	97.43 north.
17.825	234.16	131.80	38.4	146.76 north.
21.	337.51	158.43	38.4	217.48 north.
23.4315	420.20	176.78	38.4	281.82 north.

Note.—The tangent having been run under very favorable circumstances, and time pressing, its azimuth was not checked at the terminal point.

BRITISH TANGENT No. 13.

1874.

From Little Rocky Creek to Frenchman's Creek.

[Troughton & Sims Transit Theodolite F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

	° ′ ″
The azimuth of a mark placed approximately on the tangent west of the initial point was determined from a series of readings of the angle between the mark and the zenith telescope meridian, the azimuth of which was observed with astronomical transit F. O. No. 1, and found to be	00 00 16.3
Mean reading of angle between meridian and mark	90 00 05.78
Azimuth of mark	270 00 10.52

The tangent was run on this azimuth from the initial point 18.075 chains, south of 49° for a distance of 647.58 chains; here the line was shifted north 16.7 chains, and the new line continued to the west side of Frenchman's Creek.

The terminal point of British tangent was connected with the United States astronomical mound (49°) by a United States traverse.

		Chains.
Length of British tangent		2066.33
Departure of United States traverse		193.65
	M. Chs.	
Total distance between astronomical stations	28 19.98 =	2259.98

STATION ERROR.

	Feet.
The station error was determined by Lieutenant Greene to be Frenchman's Creek Station, *i. e.*, United States Astronomical Station No. 13 north	46.2

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.	+	+	+		
0 00.00	0.0	0.0	1193.0	1193.0 north..	Earth mound, 6′×14′.
2 63.61	5.9	4.6	1193.0	1203.5 north..	Rock mound, 6′×10′.
5 40.22	23.1	9.0	1193.0	1225.1 north..	Do.
8 55.81	57.9	14.2	88.8	160.9 north..	Do.
12 29.00	116.8	20.2	88.8	225.8 north..	Do.
14 42.68	161.7	23.7	88.8	274.2 north..	Do.
19 29.62	287.1	31.7	88.8	407.6 north..	Do.
22 27.71	382.1	36.6	88.8	507.5 north..	Earth mound, 6′×12′.
25 66.33	511.5	42.3	88.8	642.6 north..	Rock mound, 6′×10′.

Note.—The azimuth deviation being small (10″.52) was neglected, but it is practically included in the station error. Iron tablets were uniformly 10 feet east of the eastern base of the mound and two feet below the surface of the ground.

BRITISH TANGENT No. 14.

1874.

From Cottonwood Creek to United States Astronomical Station No. 14.

[Troughton & Sims, 7-in. Transit Theodolite, F. O., No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
July 1	On meridian of astronomical station.	1,495.2 feet west of instrument.	Polaris	270 00 03.5
			...do	269 59 58.4
			...do	270 00 07.8
			...do	270 00 13.0
			Mean	270 00 05.7

The tangent was prolonged on this erroneous azimuth to 12.5-mile point, where azimuth observations were taken as follows:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
July 3	On tangent	On tangent	Polaris	269 47 35.1
				49.3
				269 47 42.2
	True azimuth			269 47 29.5
	Error, which was neglected as inappreciable			12.7
	Error at initial point			5.7
	Error in running the line			7.0

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	298.75
Error of initial point, south	21.72
	277.03
Computed offset due to distance, 20 miles 3,993 feet	329.74
Station error, United States Astronomical Station No. 14, south	52.71

OFFSETS TO PARALLEL.

Distance from initial point in chains.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset, in feet.
	+	−	+	
240.00	6.89	7.62	21.72	20.99 north.
480.00	27.55	15.24	21.72	34.03 north.
720.00	61.99	22.85	21.72	60.86 north.
960.00	110.20	30.47	21.72	101.45 north.
1,200.00	172.20	38.09	21.72	155.83 north.
1,440.00	247.97	45.71	21.72	223.98 north.

Note.—Circular stone mounds 10 feet in diameter and 6 feet high, having a berme 2 feet wide, trench 1.5 feet wide and 1 foot deep, were erected at the distances from initial point of tangent given above. An iron tablet was sunk 6 inches in center of each mound, marking the exact determination of 49° parallel. An iron tablet was also sunk 18 inches in the ground, 15 feet east of the center of the mound.

BRITISH TANGENT No. 15.

1874.

From Astronomical Station No. 28 to Astronomical Station No. 29, East Fork.

[Troughton & Sims Astronomical Transit F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

	° ′ ″
The azimuth of a mark placed approximately on the tangent west of the initial point was determined from a series of readings of the angle between the mark and the zenith telescope meridian, the azimuth of which was observed with astronomical transit F. O. No. 1 and found to be	180 01 43.93
Mean reading of angle between meridian and mark	89 59 26.86
Azimuth of mark	270 01 10.79
The tangent was run on this azimuth 1451.58 chains, when azimuth observations were taken on Polaris with a 7-in. theodolite F. O. No. 2.	
Mean of two observations on Polaris	89 43 31.75
True azimuth	89 41 55.00
Error in azimuth, north	1 36.75
Error in azimuth, north, at initial point	1 10.76
Error in azimuth in running	26.01
The mean azimuth of the whole line was assumed	270 01 18.00
	Chains.
The British tangent at distance west of initial point	= 1451.58
Met United States tangent running east at distance from East Fork	678.58
Giving total length of tangent, 26 miles 50.16 chains	= 2130.16

STATION ERROR.

	Feet.
Lieutenant Greene, in his report, gives station error of East Fork Station, north	438.9

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Azimuth error in feet.	Error of initial point in feet.	Final off-set in feet.	Remarks.
M. Ch.	+	+	−	+		
0 00.00	0.0	0.0	0.0	15.0	15.0 north..	Rock mound, 6′×12′.
3 00.00	6.9	49.4	6.0	15.0	65.3 north..	Rock mound, 6′×10′.
5 58.83	25.2	94.5	11.5	15.0	123.2 north..	Do.
8 75.35	61.2	147.3	17.8	15.0	205.7 north..	Do.
11 53.69	104.2	192.4	23.3	15.0	288.3 north..	Do.
15 12.00	175.6	249.7	30.2	15.0	410.1 north..	Do.
17 08.03	223.6	281.9	34.1	15.0	486.4 north.	Do.

Note.—Iron tablets were buried at a uniform distance of 10 feet east of the eastern bases of the mounds, and at a depth of 2 feet in the ground.

BRITISH TANGENT No. 16.

1874.

From West Fork Milk River to United States Astronomical Station No. 16.

[Troughton & Sims 7-in. Transit Theodolite F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
July 14	On meridian of astronomical station.	2,050.9 feet west of instrument	Polaris	269 59 11.88
			...do	19.72
			...do	15.08
			...do	16.12
			Mean	269 59 15.7

The tangent was run through a point (2,050.9 feet × sin 44″.3 =) 5.5 inches north of the mark and prolonged to terminal point where azimuth observations were taken, as follows:

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
July 20	On tangent	On tangent	Polaris	89 38 41.66
			..do	50.28
			..do	45.99
			..do	48.24
			Mean	89 38 47.3
	True azimuth			89 38 18.2
	Azimuth error			29.1

No correction was made for this error in azimuth, it being considered cumulative.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	145.00
Error of initial point, south	6.46
	138.54
Computed offset for distance 21 miles 59.29 chains	361.76
Station error, United States Astronomical Station No. 16, south	223.22

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
Chains.	+	−	+	
240.00	6.89	30.80	6.46	17.45 south.
480.00	27.55	61.60	6.46	27.59 south.
720.00	61.99	92.40	6.46	23.95 south.
960.00	110.20	123.21	6.46	6.55 south.
1200.00	172.20	154.01	6.46	24.65 north.
1440.00	247.97	184.81	6.46	69.62 north.

Note.—Circular stone mounds 10 feet in diameter and 6 feet high, having a berme 2 feet wide, trench 1.5 feet wide and 1 foot deep, were erected at distances from initial point of tangent given above.

An iron tablet was sunk 6 inches in center of each mound, marking the exact determination of 49° parallel.

An iron tablet was also sunk 18 inches in the ground, 15 feet east from the center of the mound.

BRITISH TANGENT No. 17.

1874.

From British Astronomical Station near Milk River to Astronomical Station East Butte.

[Troughton & Sims Astronomical Transit F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

This tangent was prolonged eastward 325 chains to connect the United States tangent from Milk River Lake's Station, and was run westward 19 miles 60.22 chains, when it joined United States tangent from East Butte eastward.

	° ′ ″
The azimuth of a mark placed approximately on the tangent east of the initial point was determined from a series of readings of the angle between the mark and the zenith telescope meridian, the azimuth of which was found with astronomical transit to be	00 00 27.26
Mean angle to tangent east	89 59 48.75
Azimuth of mark	90 00 16.01

The tangent east was run on this azimuth, and its connection with United States tangent, and resulting station error, are given in Lieutenant Greene's report.

The tangent west was run on the same azimuth to its terminus, where azimuth observations were taken with Troughton & Sims 7-in. Theodolite F. O. No. 2 on Polaris at various hour angles, as follows:

	Face right.	*Face left.*
	° ′ ″	° ′ ″
	89 41 21.0	89 41 08.0
	41 13.0	23.0
	41 08.0	18.5
	40 57.5	18.0
Means,	89 41 09.9	89 41 16.9

	° ′ ″
General mean	89 41 13.4
True azimuth	89 40 20.0
Error in azimuth, north	53.4
Error in azimuth, north, at initial point	16.01
Error in azimuth, north, in running	37.39
The adopted azimuth error for the whole line was north	34.62

	M. Ch.
Length of British tangent west	19 60.22
Length of United States tangent east	73.38
Total length of tangent	20 53.60

STATION ERROR.

Lieutenant Greene gives station error East Butte Station, south, 470.9 feet.

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Azimuth error in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.	+	−	−	−		
W. 00 00.00	00.0	00.0	00.0	58.7	58.7 south	Rock mound, 6′ × 12′.
3 45.04	9.7	81.2	3.2	58.7	133.4 south	Rock mound, 6′ × 10′.
6 01.81	27.7	137.2	5.4	58.7	173.6 south	Do.
9 04.21	62.7	206.3	8.1	58.7	210.4 south	Do.
11 73.89	108.8	271.7	10.7	58.7	232.3 south	Do.
13 08.25	186.2	355.5	11.6	58.7	239.6 south	Do.
18 25.27	256.6	417.3	16.4	58.7	235.8 south	Do.

Note.—An iron tablet was buried 2 feet in the ground 10 feet east of the base of each mound.

BRITISH TANGENT No. 18.

1874.

From West Butte to United States Astronomical Station No. 18.

Troughton & Sims 7 in. Transit Theodolite, F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTHS.

The azimuth at initial point was determined by repeating the angle between the mark and the meridian of astronomical transit.

	° ′ ″
Mean of four sets of angles between mark and meridian of astronomical transit	90 00 05.0
Correction for level	3.0
	90 00 08.0
Azimuth of meridian	359 59 50.7
Azimuth of mark	269 59 42.7

The tangent was prolonged on this azimuth to its terminal point, where azimuth observations were taken as follows:

Position of instrument.	Position of mark.	Star.	Azimuth.
			° ′ ″
On tangent at terminal point	Approximately on the meridian.	Polaris	359 38 56.73
		..do	55.93
		..do	53.63
		Mean	359 38 55.4
Mean angle between approximate meridian and tangent			89 59 52.5
Azimuth of tangent			89 38 47.9
True azimuth			89 39 27.2
Azimuth error			39.3
Azimuth error at initial point			17.3
Azimuth error in running tangent			22.0

No correction made for either of these errors.

STATION ERROR.

	Feet.
Measured offset from terminal point to 49°	965.5
Error of initial point, north	99.53
	1,064.83
Computed offset for distance 20 miles 53.90 chains	327.11
Station error, astronomical station, north	737.72

OFFSET TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
Chains.	+	+	−	
246.22	7.25	109.82	99.33	17.74 north.
486.07	28.25	216.81	99.33	145.73 north.
729.96	63.72	325.60	99.33	289.99 north.
960.00	110.20	428.20	99.33	439.07 north.
1,200.00	172.80	545.25	99.33	608.12 north.
1,457.54	251.05	650.13	99.33	804.85 north.

Note.—Circular stone mounds were built on this tangent similar to those built on tangents Nos. 14 and 18.

BRITISH TANGENT No. 19.

1874.

From South Branch Milk River to North Branch Milk River.

[Troughton and Sims Astronomical Transit F. O. No. 1.—Observer, A. Featherstonhaugh, R. E.]

AZIMUTHS.

The line was started on an approximate azimuth of 270° and prolonged 586.09 chains where azimuth observations were taken on Polaris near eastern elongation, as follows:

	Face right.	*Face left.*
	° ′ ″	° ′ ″
	89 54 19.6	89 53 58.6
	54 11.6	50.6
	53 58.6	49.6
	54 09.6	56.6
		54.6
		52.6
		57.6
Mean,	89 54 09.8	89 53 54.3

	° ′ ″
General mean	89 54 02
True azimuth	89 52 41
Error in azimuth, north	1 21

The line was continued on this azimuth to its terminal point where azimuth observations on Polaris at various hour angles gave following results:

	Face right.	*Face left.*
	° ′ ″	° ′ ″
	89 44 25	89 44 05
	24	07
	28	16
	27	21
Mean,	89 44 26	89 44 12

	° ′ ″
General mean	89 44 19
True azimuth	89 40 41
Error in azimuth, north	3 38
Previous error in azimuth, north	1 21
Previous error in azimuth in running	2 17

This error is attributed to the nature of the ground, which rendered very short sights necessary. The deviation in azimuth is taken as 1′ 21″ north for the first part of the line, *i. e.*, 586.09 chains, and as 1′ 21″ + ½ (2′ 17″) = 2′ 30″ north for the rest of the line.

The tangent was prolonged east from South Branch Milk River to connect United States tangent with Astronomical Station No. 36—azimuth deviation north 1′ 21″.

	Ch.
Total distance between Astronomical Station No. 35 and Astronomical Station No. 36	1,971.19
Total distance between Astronomical Station No. 36 and Astronomical Station No. 37	1,550.82

STATION ERRORS.

	Feet.
Astronomical Station No. 36 north of Astronomical Station No. 35	15.0
Astronomical Station No. 37 south of Astronomical Station No. 36	66.0

OFFSETS TO PARALLEL.

Distance from initial point.	Computed offset in feet.	Station error in feet.	Azimuth error in feet.	Error of initial point in feet.	Final offset in feet.	Remarks.
M. Ch.						
E. 3 15.07	7.8	1.9	6.7	11.0	23.6 north	Rock mound 6′ × 10′.
00 00.00	0.0	0.0	0.0	11.0	11.0 north	Rock mound 6′ × 12′.
W. 2 59.42	5.7	9.3	5.7	11.0	1.7 north	Rock mound 6′ × 10′.
5 73.31	26.8	20.1	12.4	11.0	5.3 north	Do.
8 73.34	60.9	30.4	21.3	11.0	20.3 north	Do.
13 20.26	134.4	45.1	38.0	11.0	62.4 north	Do.
16 29.22	203.5	55.6	49.9	11.0	110.3 north	Do.
....	......	......	......	......	171.3 north	

Note.—An iron tablet was buried 2 feet in the ground 10 feet east of the base of each mound

BRITISH TANGENT No. 20.

1874.

From Chief Mountain Astronomical Station to Belly River Astronomical Station.

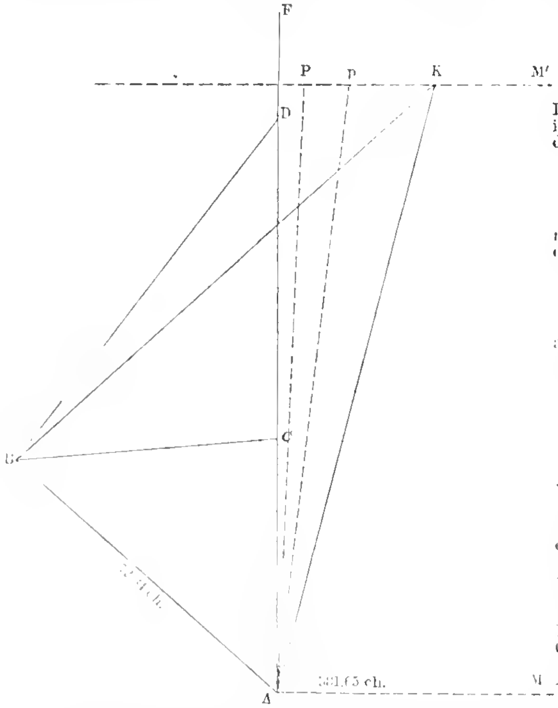
[Troughton & Sims 7-in. Transit Theodolite F. O. No. 3.—Observer, W. J. Galwey, R. E.]

AZIMUTH.

Date.	Position of instrument.	Position of mark.	Star.	Azimuth.
				° ′ ″
Aug. 13	On meridian of astronomical station.	4,596.2 feet west of instrument.	Polaris	269 54 26.35
			Do	23.45
			Do	31.45
			Do	31.05
			Mean	269 54 28.1

The tangent was run through a point (4,596.2 ft. × sin 5′ 31″.9) 7 ft. 4.5 in. to north of the mark.

The tangent was run to 617.03 ch. from initial point. The chaining was carried on to a point A (see diagram) from which a true base-line, A B, was measured, and the distances of the points C and D determined by triangulation. The chaining was continued from D to F, the terminal point of tangent. The underbrush, dead-fall, and standing timber being so dense as to give no hope of connecting with Captain Featherstonhaugh's astronomical station on Belly River by means of the tangent a point, K, in trigonometrical connection with his station was established and observed from points A and B.



To find position of K with respect to A:

Angle B A K = 69° 47′ 16″.9
Angle A B K = 94° 48′ 51″.3
Angle B A C = 52° 35′ 15″.4

Let K M′ and A M be meridians passing through A and K, and A P be perpendicular, drawn from A to A M; *p* the intersection of a small circle, *i. e.* a parallel of latitude drawn through A. The point K is north of A.

The distance K p = K P − p P
The angle F A K = 69° 47′ 16″.9 − 52° 35′ 15″.4
= 17° 12′ 01″.5

A F makes an angle with meridian A M of 90° + 59″.75, multiplied by distance in miles of point A from point of departure.

$$\therefore \text{angle F A M} = 90^\circ + 59''.75 \times \frac{381.65}{80}$$
$$= 90^\circ + 4' 45'' = 90^\circ 4' 45''$$

The perpendicular at A, *i. e.* A P, makes with A K an angle = 90° − M A K = 90° − (90° 4′ 45″ − 17° 12′ 01″.5.)
= 17° 07′ 16″.5

K P = A K sin 17° 7′ 16″.5

$$\text{A K} = \text{A B}\frac{\sin \text{A B K}}{\sin \text{A K B}} =$$
$$= 72.34\frac{\sin 94^\circ 48' 51''.3}{\sin 15^\circ 23' 51''.8} = 251.49 \text{ ch.}$$

$$\therefore \text{K P} = 72.34\frac{\sin 94^\circ 48' 51''.3}{\sin 15^\circ 23' 51''.8}\sin 17^\circ 7' 16''.5 = 79.925 \text{ ch.}$$

A P = A K cos 17° 7′ 16″.5 = 259.46 ch.

P p = offset to parallel due to distance from A considered as initial point = 8.05 ft.

K is north of A 79.925 ch. × 66 − 8.05 ft. = 5,275.05 ft. − 8.05 ft. = 5,267 ft.

To find position of A with respect to 49° parallel:

	Feet.
Initial point of tangent north of 49° parallel	18.07
Offset from A due to distance, 381.65 ch.	17.42
A north of 49° parallel	.65

∴ K is north of English determination of 49°, 5,267 ft. + .65 ft. = 5,267.65 ft.
Distance of K from initial point along tangent is 381.65 ch. + 259.40 ch. = 641.11 ch

British Tangent No. 20—Continued.

1874.

STATION ERROR.

		Feet.
By Captain Featherstonhaugh's triangulation *K* is north of his determination of 49° parallel 83.919 chains.......	=	5,538.65
By Lieutenant Galwey *K* is north of 49° parallel...		5,267.65
Astronomical Station at Belly River south of Chief Mountain Astronomical Station................................		271.00
		Chains.
The meridian of *K* (diagram on previous page) was east of the meridian of Captain Featherstonhaugh's astronomical mound at Belly River, measured on the tangent..		211.42
Distance of *K* from initial point, along the tangent..		641.11
Total distance from Chief Mountain Astronomical Station to astronomical mound at Belly River		852.53

OFFSETS TO PARALLEL.

Distance from initial point in chains.	Computed offset in feet.	Station error in feet.	Error of initial point in feet.	Final offset in feet.
	+	−	−	
243.45	7.09	77.37	18.07	88.35 south.
445.15	23.70	141.48	18.07	135.85 south.
853.53	89.94	271.00	18.07	199.13 south.

Note. -Circular stone mounds, 10 feet diameter and 6 feet high, with berme 2 feet wide and trench 18″×12″, were erected at above distances from initial point. That at 852.53 chains was Captain Featherstonhaugh's astronomical mound, and was built by him. An iron tablet marking exact determination of parallel was sunk 6 inches in the ground in center of mound. No tablets were placed outside the mounds except at astronomical mound.

TRIANGULATION.

To connect Belly River Astronomical Station with 49th Parallel and Rocky Mountain Astronomical Station.

[Observer, A. Featherstonhaugh, R. E.]

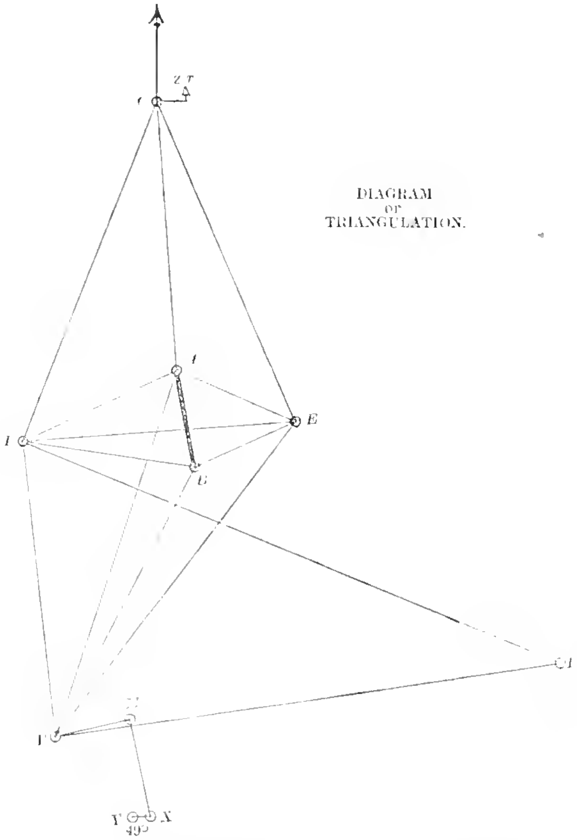


DIAGRAM OF TRIANGULATION.

ABSTRACT OF TRIANGLES.

Triangle.	Angle.	Observed angle. ° ′ ″	Correction. ″	Reduced angle. ° ′ ″
A B D	*B A D*	71 27 55. 84		71 28 00
	A B D	72 35 26. 7	− 5. 3	72 35 38
	A D B	35 56 22. 16		35 56 22
A B E	*A B E*	72 27 13. 3		72 27 07
	A E B	53 08 24. 58	+17. 04	53 08 17
	B A E	54 24 39. 16		54 24 36
D E A	*D E A*	31 33 50		31 33 50
	A D E	22 33 21. 8	−13. 2	22 33 30
	E A D	125 52 35		125 52 40
A C D	*A C D*	25 43 54. 87		25 43 42
	A D C	40 22 17. 4	+36. 85	40 22 05
	D A C	113 54 24. 58		113 54 13
D C E	*D C E*	44 31 13. 62		44 31 36
	D E C	72 32 49. 17	+22	72 32 42
	C D E	62 55 49. 2		62 55 42
D E P	*D E P*	47 19 35		47 19 35
	P D E	88 16 49. 4	+ 1. 9	88 16 49
	E P D	44 23 37. 5		44 23 36
D P B	*D P B*	35 02 16. 6		35 02 24
	D B P	70 03 17. 64	−26. 76	70 03 26
	P D B	74 53 59		74 54 10
D A P	*D A P*	43 55 00. 84		43 55 15
	A P D	25 13 55. 85	−12. 13	25 14 09
	A D P	110 50 21. 2		110 50 36
A C E	*A C E*	18 47 48. 74		18 47 53
	C A E	120 13 00. 42	−11. 67	120 13 04
	C E A	40 58 59. 17		40 59 03
A P E	*A P E*	19 09 41. 67		19 09 28
	E A P	81 57 24. 16	+40. 83	81 57 21
	A E P	78 53 25		78 53 11
D P K	*P D K*	61 36 25		61 36 25
	D P K	88 25 58	(*)	88 25 58
	D K P	29 57 37		29 57 37

MEASUREMENT FROM THE ZENITH TELESCOPE TO THE 49TH PARALLEL OF LATITUDE.

		Chains.
Measured dis. *C* south of zen. tel. = .75″	=	1. 152
P south of *C* by triangulation		332. 169
Offset to parallel for westing of *P* from *C*		0. 004
		332. 165

log 332.165 = 2.5213539
log ρ sin 1″ (feet)
For mid. lat. between *P* and *C* = 2. 0058361

0. 5155178
log 66 1. 8195439

2. 3350617

	″
P south of *C*	216. 303
C south of zen. tel.	0. 75
P south of zen. tel.	217. 053
Zen. tel. north of 49°	243. 48
P north of 49°	26. 427

log 26.427 = 1. 42205
log number of feet in 1″ = 2. 00579
A C log 66 = 8. 18045

1. 60829 *P* north of 49°. Chains. 40. 578

P M = 43.2 chains. log = 1. 63548   1. 63548
log sin az. = 9. 99191   9. 28157

1. 62739   0. 91705

	Chains.	Chains.	
	Easting 42. 403	8. 261	Northing
P north of 49°		40. 578	
M north of 49°		48. 839	
log		1. 68876	
log cos azimuth *M X*		9. 99102	
Diff.		1. 69774	
Cor. number	=	49. 863	

Note.—The distance, 49.863 chains, was measured along *M X*. The point falling in a hollow a site for the mound was selected at *Y* 1.34 chains west of *X*. A stone mound, 6 feet by 12 feet was built at *Y*. An iron tablet was buried 2 feet in the ground 10 feet east of the base of the mound.

* Last not observed.

TRIANGULATION—Continued.

Side.	Length	Azimuth	Latitude.	Departure.
	Chains.	° ′ ″	*Chains.*	*Chains.*
A B	57.097	169 51 01.37	S. 56.203	E. 10.062
A D	92.826	241 18 57.27		
B D	92.236	277 15 23.37		
A E	68.043	115 26 22.21		
B E	58.033	62 18 05.21		
D E (1)	143.69			
D E (2)	143.715			
D E (mean)	143.702	83 52 51.88		
C D	195.49	210 57 03.79	S. 182.564	W. 69.901
C E	182.47	156 25 33.88	S. 167.245	E. 72.9768
A C (1)	138.499			
A C (2)	138.489			
A C (mean)	138.495	175 13 21.79	S. 138.012	E. 11.534
P D (1)	151.028			
P D (2)	151.024			
P D (3)	151.015			
P D (mean)	151.022	172 09 33.37	S. 149.600	E. 20.601
P A (1)	203.477			
P A (2)	203.452			
P A (mean)	203.461	197 23 42.27	S. 194.167	W. 69.8304
P E (1)	205.30			
P E (2)	205.319			
P E (mean)	205.31	216 33 16.88	S. 164.923	W. 122.281
P B	155.103	207 12 07.03	S. 137.949	W. 70.902
P K	266.03	80 35 31.37	N. 43.486	E. 262.451

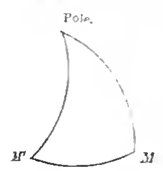
Station.	Latitude.	Departure.
	Chains.	*Chains.*
C	00.000	00.000
	S. 182.564	W. 69.901
D	S. 182.564	W. 69.901
	S. 149.600	E. 20.601
P (1)	S. 332.164	W. 49.300
C	00.000	00.000
	S. 138.012	E. 11.534
A	S. 138.012	E. 11.534
	S. 194.167	W. 69.8304
P (2)	S. 332.179	W. 49.296
C	00.000	00.000
	S. 138.012	E. 11.534
A	S. 138.012	E. 11.534
	S. 56.203	E. 10.062
B	S. 194.215	E. 21.596
	S. 137.949	W. 70.902
P (3)	S. 332.164	W. 49.306
C	00.000	00.000
	S. 167.245	E. 72.9768
E	S. 167.245	E. 72.9768
	S. 164.923	W. 122.281
P (4)	S. 332.168	W. 49.304
P (1)	S. 332.164	W. 49.300
P (2)	S. .179	W. .296
P (3)	S. .164	W. .306
P (4)	S. .168	W. .304
P (mean)	S. 332.169	W. 49.304
Y	00.000	00.000
		E. 1.34
X	00.000	E. 1.34
	N. 48.839	W. 10.0 8
M	N. 48.839	W. 8.698
	S. 8.261	W. 42.403
P	N. 40.578	W. 51.101
	N. 43.486	E. 262.451
**K*	N. 84.064	E. 211.350

* This is the *K* referred to by Lieutenant Galwey in his report.

NOTES ON GEODETIC FORMULÆ.

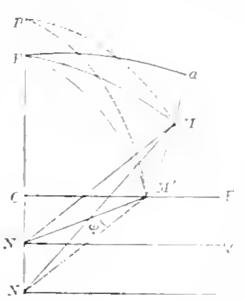
BY LIEUT. F. V. GREENE.

The formulæ used in obtaining the offsets from the tangent to the parallel are simply modifications of the general formulæ for geodetic latitudes, longitudes, and azimuths. The general problem is, *given* the latitude and longitude of M, the length of $M\,M'$ and its azimuth at M; *required* the latitude and longitude of M', and the azimuth of $M\,M'$ at M'.



If the earth were a perfect sphere, the solution of the spherical triangle, of which three parts are given, would afford the desired result exactly; and the early geographers used this solution, taking as a radius of the terrestrial sphere the radius of curvature, as accurately as their knowledge of the earth's figure gave it, at the middle point of $M\,M'$. The error was not so large as would at first appear, being only about two feet in fifty miles.

In the measurement of the French arc of meridian, however, more accurate formulæ were devised—that is, to the formulæ, as derived above, were applied corrections necessitated by the spheroidal figure of the earth. And in deducing the formulæ, instead of using Napier's Analogies directly, formulæ derived from these were used, in which the values of sines, cosines, &c., were expressed in the form of a series. This is really only an approximation "of indefinite accuracy," but in its application it gives results numerically more accurate than the direct formulæ, owing to the imperfection of the tables of logarithmic sines, &c., for very small arcs.



The corrections on account of spheroidal figure will be readily apparent from the accompanying figure. Let M and M' be the two points, and P the pole of the earth: $N\,M$ the normal at M, and p the pole of a sphere with that radius; $M'\,N'$ the normal at M': $P\,a$ the meridian from which longitudes are reckoned. Now the solution by spherical trigonometry gives for colatitude of M' the arc $p\,M' = p\,N'\,M'$; but the true colatitude is the angle $p\,N\,M'$, being the angle between the normal at M' and the axis. The difference between the two is the angle $N'\,M'\,N = \nu$.

There is, evidently, no correction to the longitude for the angle $M\,p\,M' = M\,P\,M'$, since each is the angle cut from two planes by a plane perpendicular to their intersection.

The correction to the azimuth is the difference between the angle $p\ M'\ M$ and $P\ M'\ M$. This correction can always be neglected, being equal to less than one-tenth of a second in a hundred miles.

The general formulæ are then as follows (neglecting terms beyond second order, which can be done for distances less than fifty miles):*

$$(a)\quad H - H' = (u \cos Z + \tfrac{1}{2}\, u^2 \sin 1'' \sin^2 Z \tan H)\,(1 + e^2 \cos^2 H)$$

$$(b)\quad P' - P = \frac{u \sin Z}{\cos H} - \tfrac{1}{2}\, u^2 \sin 1'' \sin 2\,Z \frac{\tan H}{\cos H}$$

$$(c)\quad Z' - Z = 180^\circ - u \sin Z \tan H + \tfrac{1}{4}\, u^2 \sin 1'' \sin 2\,Z\,(1 + 2 \tan^2 H)$$

in which $u = \dfrac{K\,(1 - e^2 \sin^2 H)^{\frac{1}{2}}}{a \sin 1''} = K \dfrac{1}{N \sin 1''}$

and N = Normal or radius of curvature

H and H' = Latitudes.

P and P' = Longitudes.

Z and Z' = Azimuths.

For our special case, $\left\{ \begin{array}{l} Z = 270^\circ \\ H = \ \ 49^\circ \end{array} \right\}$ and the formulæ become

$$(a')\quad H - H' = K^2 \frac{\tan H\,(1 + e^2 \cos^2 H)^{\frac{1}{2}}}{2\,N^2 \sin 1''} = K^2\,C \ldots\ldots\ldots \log C = 2.4383317$$

$$(b')\quad P' - P = K \frac{1}{N \sin 1'' \cos H} = K\,C' \ldots\ldots\ldots \log C' = 9.0302614$$

$$(c')\quad Z' = 90^\circ - K \frac{\tan H}{N \sin 1''} = 90^\circ - K\,C'' \ldots\ldots \log C'' = 9.0080412$$

Of these logarithms the first is the logarithm of C, in feet, obtained by multiplying C in arc by 101.34, the value of one second of latitude at 49°. The others are in arc.

From these simple formulæ, by substituting for K the length of tangent in feet, we can form a table of offsets and azimuths for the argument K. In the table used in the field, the arguments were miles and thousands of feet; between the latter it was easy to interpolate. A portion of this table is here given.

* See Puissant, Traité de Géodésie (edition 1819), livre III, chapitre XV. In addition to the solution indicated above, he gives a very elegant method, first proposed by Legendre, which employs the differential calculus. Each of the required quantities is necessarily a function of the length of $M\ M$. These functions are developed by Maclaurin's theorem, and for the differential co-efficients are substituted their values in terms of the circular functions. The resulting formulæ are the same as those given above, after applying the spheroidal correction for latitude.

OFFSETS AND AZIMUTHS.

Miles.	*K.*	*H — H'.*	*Z'.*		
	Feet.	*Feet.*	°	″	′
	1000	.03	89	59	48.7
	2000	.11			37.4
	3000	.24			26.1
	4000	.44			14.8
	5000	.69			03.5
1	5280	.76			00.2
	6000	.99		58	52.1
	7000	1.34			40.9
	8000	1.76			29.6
	9000	2.22			18.3
	10000	2.74			07.0
2	10560	3.06			00.5
3	15840	6.88		57	00.7
4	21120	12.24		56	00.9
5	26400	19.12		55	01.2
10	52800	76.49		50	02.4
15	79200	172.10		45	03.6
20	105600	305.96		40	04.8
25	132000	478.06		35	06.0
30	158400	688.40		30	07.2

In this connection, it is a matter of some interest to see how much numerical error would result from neglecting the spheroidal corrections.

These results are shown in the accompanying table, in which the column O contains the accurate offsets, and O_1 those derived from the formulæ, neglecting spheroidal corrections.

Miles.	*O.*	*O_1.*
5	19.12	19.07
10	76.49	76.27
15	172.10	171.61
20	305.96	305.08

The formulæ used in the British Ordnance Survey are derived by solving the spherical triangle by Napier's Analogies, and then introducing the correction to the latitude in the form of a series. Their general form is as follows, the letters representing the same quantities as before:—

$$\tan \tfrac{1}{2}\,(Z' + \zeta + P) = \frac{\cos \tfrac{1}{2}\,(90^\circ - H - \theta)}{\cos \tfrac{1}{2}\,(90^\circ - H + \theta)} \cot \tfrac{1}{2}\,Z$$

$$\tan \tfrac{1}{2}\,(Z' + \zeta - P) = \frac{\sin \tfrac{1}{2}\,(90^\circ - H - \theta)}{\sin \tfrac{1}{2}\,(90^\circ - H + \theta)} \cot \tfrac{1}{2}\,Z$$

$$\lambda' - \lambda = \frac{K}{R}\,\frac{\sin\frac{1}{2}(Z' + \zeta - Z)}{\sin\frac{1}{2}(Z' + \zeta + Z)}\left(1 + \frac{\theta^2}{12}\cos^2\tfrac{1}{2}(Z' - Z)\right)$$

$$\theta = \frac{K}{N}\left(1 + \frac{1}{6}\,\frac{e^2\,\theta^2}{1 - e^2}\cos^2 H \cos^2 Z\right)$$

$$\zeta = \tfrac{1}{4}\,\frac{e^2\,\theta^2}{1 - e^2}\cos^2 H \sin 2\,Z$$

For $\left\{\begin{matrix} Z = 90^\circ \\ H = 49^\circ \end{matrix}\right\}$ these reduce to

$$\tan\tfrac{1}{2}(Z' + P) = \frac{\cos\frac{1}{2}\left(41^\circ - \frac{K}{N}\right)}{\cos\frac{1}{2}\left(41^\circ + \frac{K}{N}\right)}$$

$$\tan\tfrac{1}{2}(Z' - P) = \frac{\sin\frac{1}{2}\left(41^\circ - \frac{K}{N}\right)}{\sin\frac{1}{2}\left(41^\circ + \frac{K}{N}\right)}$$

$$\lambda' - \lambda = \frac{K}{R}\,\frac{\sin\frac{1}{2}(Z' - 90^\circ)}{\sin\frac{1}{2}(Z' + 90^\circ)}\left(1 + \left(\frac{K}{N}\right)^2 \frac{\cos^2\frac{1}{2}(Z' - 90^\circ)}{12}\right)$$

For general purposes of geodetic calculation, these formulæ are as convenient as those given by Puissant; but for our special purposes they are extremely inconvenient, for the variable quantity K, or length of tangent, does not appear as a factor, but as part of a factor, and all three equations must be solved to obtain a single offset, whereas, as we have seen, with Puissant's formulæ only one equation need be solved, viz, $H - H' = K^2\,C$. The numerical result is exactly the same, in both cases.

CHAPTER V.

THE MEAN AND ASTRONOMICAL PARALLEL.

An astronomical parallel of latitude is the line of intersection of the surface of the earth by a cone whose apex is at the center of normals and whose elements make an angle with the axis of the earth equal to the complement of the latitude.

The earth being considered a spheroid or an ellipsoid of revolution, each parallel of latitude is mathematically a circle. But owing to irregularities of elevation in the surface, the parallel is actually a curve of irregular curvature, approximating, however, very closely, in its general course, to a circle. Rejecting instrumental and local errors, such a curve would be determined by fixing each point astronomically. If the connection between successive astronomical stations on a given parallel of latitude were made by tangents to a small circle, the resulting errors would be very great, depending on the relative altitude of the stations and the latitude. As, however, in practice, the stations are connected by tangents to a great circle, the resulting errors are insignificant and may be neglected. It is manifestly the true and the only possible parallel of latitude, although not a mathematical figure. For purposes of geodetic computation, it must be referred to a uniform sea-level, when it becomes a circle. For all ordinary purposes, this may be assumed as the true shape.

In marking a parallel of latitude on the actual surface of the earth, another and most serious difficulty is at once encountered in the anomalous deflections of the plumb-line, due to local attractions. All astronomical determinations are referred, by means of the level, to the direction of the resultant force of gravity. If, then, this direction is affected by the protrusion above the surface of mountain-masses, or by variations in the density of the earth's crust below the surface, each astronomical determination will be in error by the amount of such deflection. Science affords only approximate methods of correcting these errors, and they of such difficult and doubtful application as to be of no practical use, except in extreme cases, and for exceptional purposes. In a triangulation, the relation of the various points depends solely on the measurement of horizontal angles, and is not appreciably affected by local disturbances, though the whole system will be in error by the amount of the error in position of the astronomical station to which it is referred.

If, therefore, it were desired to lay out upon the surface of the earth a mathematical circle of latitude, the relative positions would be made to depend upon a series of triangles, referred to a measured base and a mean astronomical position. But in the definition of a circle of latitude for the purposes of a boundary, practical rather than mathematical considerations determine the methods to be followed. The ruling conditions may be briefly stated. The boundary must be clearly defined by visible monuments, and the positions of these marks must be such that, in case of their loss, the points can be easily and accurately recovered. The only simple method of recovery is by astronomical observation, and since the local deflections of the plumb-line are supposed not to vary for long periods of time, the process is easy and accurate.

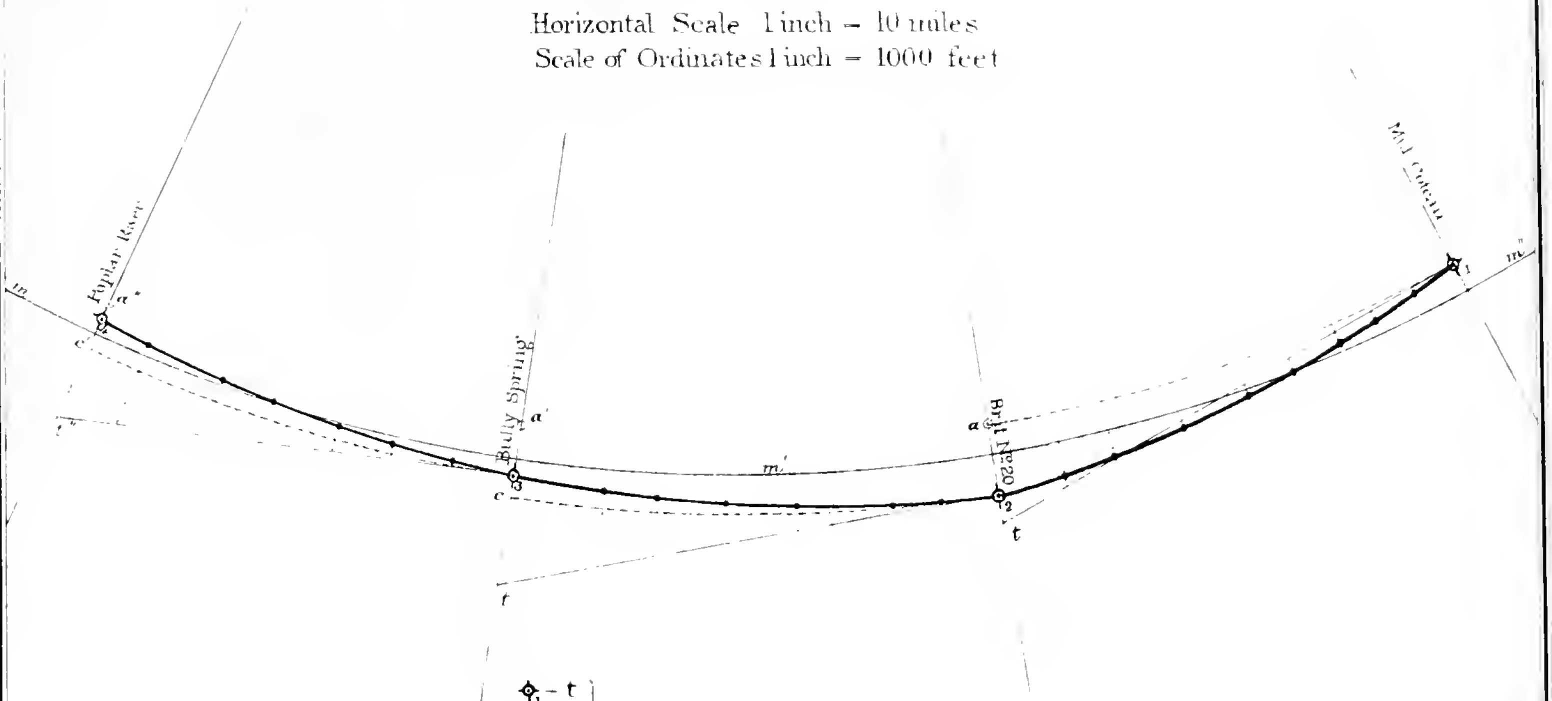
At the time of the organization of this joint commission, the chief astronomers of the English and United States commissions were in accord in this view, that the parallel of latitude, as defined by astronomical observation at successive points, was, for the purpose required, a true parallel, and the only one that would fulfill the practical condition of being readily recovered. The question as presented, and which at the time gave rise to much discussion, was whether to define upon the ground an astronomical parallel of latitude, as above described, or a uniform line depending upon the mean of the astronomical stations. The recommendation of the chief astronomers was based on the following grounds: 1st, that the portion of the parallel of 49° included within the operations of the commission, being only about one-twentieth of the entire circle of latitude, was not sufficient to fix, with any mathematical accuracy, the true position of the mean line

DIAGRAM

showing

METHOD OF TRACING PARALLEL.

Horizontal Scale 1 inch = 10 miles
Scale of Ordinates 1 inch = 1000 feet



$\phi_1 - t$, $\phi_2 - t'$, $\phi_4 - c$ } *Tangent lines*

$\phi_1 - \phi_4$ *Parallel as marked by mounds*

$\phi_1 - a$, $\phi_2 - c$, $\phi_3 - c'$ } *Parallels of the Astronomical Stations*

m, m', m" *Mean Parallel*

STATIONS	DISTANCES	STATION ERRORS		FROM MEAN PARALLEL
Mid Coteau				180.0 ft N
	26 m 014			
Brit No 20		373.7 ft S	14.35 ft per mile	193.7 S
	24 m 601			
Bully Spring		111.5 N	4.53 " "	82.2 S
	22 m 202			
Poplar River		181.7 N	8.18 " "	99.5 N

of 49°, and that, therefore, if such a parallel were described, depending on the mean of the astronomical stations, no known point of the boundary would be in latitude 49°; 2d, that as the amplitude of the arcs included between the mean and the astronomical parallels, would in many cases be very considerable, grave errors and complications might arise in the subsequent recovery of any lost portion of the boundary; 3d, that the definition of a mean line would involve a readjustment of the whole boundary, after the first careful survey should have been completed, and consequently a very considerable increase of expense, without any practical benefit accruing; 4th, that for every purpose except that of geodetic computation, a parallel consisting of points determined astronomically (instrumental errors aside) is a true parallel of latitude, and, therefore, fulfills the stipulations of the treaty under which the joint commission was organized.

These views were accepted by the commissioners, and the following scheme adopted for the definition of the boundary: Astronomical positions were to be determined at approximate intervals of twenty miles. These stations were to be connected by tracing upon the ground tangents to the prime vertical circles at each successive point. From these tangents, checked and corrected for errors of azimuth, the calculated offsets to the small circle of latitude were to be measured at convenient intervals, varying from one to three miles. From the last-measured offset the relative station-error was to be found, and distributed between the stations in the ratio of the distances.

From this method it results that the boundary-line, as actually traced, is an irregular curve, affected at each astronomical station by instrumental errors and by the local deflections of the plumb-line, but making the closest probable approximation, at every point, to a true astronomical parallel.

In the accompanying diagram I have attempted to explain, by a graphic representation, the amount of the discrepancies between the line actually defined and a mean line, and to show approximately the probable causes of relative errors indicated. I have also added to this report a table of azimuths, showing the actual direction from each monument to the next succeeding one going west (see page 35 to page 40).

As this is a subject with which comparatively few persons are familiar, a short statement of the amount of such relative errors in other geodetic work, and of the methods by which it has been attempted to correct them, will not be out of place; after which will naturally follow the application of the general theory to the case in hand. (For full and complete discussion, see Encyclopedia of Astronomy, Airy; English Ordnance Survey, Clarke; Figure of the Earth, Pratt, fourth edition.)

Local deflections of the plumb-line, due to the attraction of comparatively small masses, is argued from the general law of attractions, from direct experiment, and from the lack of agreement between the astronomical and geodetic determinations of the relation of points on the earth's surface, as developed in the measurement of certain meridional arcs, which discrepancies exceed in amount any possible instrumental error or error of calculation.

The first experiments on local deflection were directed toward the determination of the mean density of the earth. In the progress of this investigation at Shehallein, Scotland, an anomalous deflection, amounting to 11″.6, was found between two stations on opposite sides of the mountain. Various other measures of deflection were obtained at different times by similar methods, but none of any reliable accuracy until, in investigating the form of the earth by the measurement of meridional arcs, relative errors which could not be reconciled were found to exist between most, if not all, of the astronomical points. Even in this case the absolute deflections were not found, since each station was referred to the mean of all by a mean curve which reduced the sum of the errors to a minimum, and which, therefore, only approximately satisfied the conditions—that is, the method would not detect constant or uniformly varying errors.

In the three great measured arcs the local errors due to deflection vary from —3″.384 to +4″.826 in the Anglo-Gallic, from —2″.429 to +3″.809 in the Russian, and from —3″.155 to +3″.122 in the Indian arc, showing an extreme range of 8″.210, 6″.238, and 6″.277, respectively (Pratt's Figure of the Earth). As each second of arc represents about one hundred and one feet, the discrepancies are quite apparent, and are readily detected by geodetic methods of any tolerable accuracy. Other and much larger relative errors have been discovered, amounting to 20″, 30″, and even 40″

(Airy's Figure of the Earth, Encyclopedia of Astronomy), though the data in these extreme cases are not entirely reliable.

The fact of local deflections being established, the attention of mathematicians was turned to the investigation of the causes and probable corrections. In this much ingenuity has been displayed, but with very small results. Starting with the general law that every particle of matter attracts each other particle with a force varying directly with the mass and inversely with the square of the distance, the attraction of masses of mathematical forms on distant particles was found by dividing mountain-ranges and other elevations into volumes bearing known mathematical relations; the probable deflection of the plumb-line due to such causes was found for different distances, on the supposition that the mean density of the large volumes was uniform for different parts of the earth's crust. Thus, it was found that at the northern station of the great Indian arc the attraction of the Himalayas should cause a deflection of 28″, which should decrease at the next two principal stations by 15″.9 and 21″.1, respectively, while the deficiency of matter in the ocean should produce similar northern deflections. These calculations were not absolute, since the contour of the mountains and of the ocean-bed was only approximately known, but the approximations were supposed to be sufficiently close. It was found, however, that the actual deflections were much smaller than those given by calculation, and that, in many cases, the deflection was toward the ocean. The explanation of this lies in the varying density of the earth's crust. The facts discovered indicate that the density is greatest in the depressed, and less in the elevated portions. This follows naturally, although in reality independent of any special theory, from the fluid hypothesis of the earth's formation. The process of cooling from the surface inward was accompanied by a corresponding contraction and increase of density. From this contraction resulted enormous strains on the interior fluid portion, which were relieved by fractures of the crust and the upheaval of mountain-ranges. While the thickness of the solid portion is now so great as to prevent general catastrophes, such as very probably occurred in earlier times, yet there still remain vast molten masses inclosed within the crust, which from time to time give evidence of their presence by volcanic eruptions.

From this theory of the gradual cooling and contraction of the earth's crust, the attraction of the plumb-line toward the ocean naturally follows, since the density would be greatest beneath the depressed basins into which the waters of the seas gradually flowed.

In calculating the deflections of the plumb-line due to visible mountain-masses, it has been found that the calculated relative errors very largely exceed those derived from the observations and geodetic connections. From this, a deficiency of matter beneath the mountain-ranges was at once inferred, either resulting from vacant spaces or from a decreased density. The latter supposition recommends itself as the most probable, and most in accord with the accepted theory of the gradual consolidation of the earth's crust. The effect of a very slight deficiency in density on the direction of the plumb is strikingly shown by the subjoined table, taken from Pratt's Figure of the Earth:—

Deflections caused by an excess or defect of matter prevailing through a semi cubic space 200 miles in each horizontal side and 100 miles deep, the density of the excess or defect being $\frac{1}{100}$ of the earth's density at the center of the semi-cubic space.

	Distance of the mid-point of the semi-cubic space from the station, measured along the chord, in miles.			
	400	600	800	1,000
When that center is 50 miles deep	1″.77	0″.81	0″.46	0″.29

From this we see at once how great the local disturbance from this cause may be, and over what immense distances the appreciable effects may extend. It also, as a natural consequence, indicates that every effort to calculate the amount of the errors resulting from local deflections must be confined to localities where the immediate effect of large visible masses, near at hand, will greatly exceed in amount the resultant of all the distant disturbing forces.

The accompanying sketches will illustrate sufficiently the amount of the local deflections along the northern boundary, from the Lake of the Woods to the Rocky Mountains, and will make clear to land-surveyors, and others who may have occasion to close their work on this line, the cause of the constant changes in the azimuths, which, unless perfectly understood, might at some time give much trouble in adjusting their work.

The first diagram, showing the "method of tracing the parallel," gives the actual line, as adjusted and marked, between the astronomical stations at the Mid-Coteau and at the Poplar River, including two intermediate stations, the heavy line being the boundary, as marked, and the light continuous line the relative position of the mean parallel of latitude, deduced from the entire series of forty-one stations between the Lake of the Woods and the summit of the Rocky Mountains. The remaining lines show the method of connecting the stations, the calculated offsets, and the manner of distributing the relative errors in latitude due to local deflections of the plumb-line. This discrepancy between succeeding astronomical points I have been in the habit of designating as the "Station-error."

From the attached table, it will be seen that the station-errors affect the azimuths between different stations by a variable quantity, but in every case by an amount sufficient to be easily appreciable with ordinary surveying instruments.

In regard to the accuracy of the instrumental line, a few words of explanation will be sufficient to indicate at about what amount the limit of error for the astronomical and other instrumental work may be fixed.

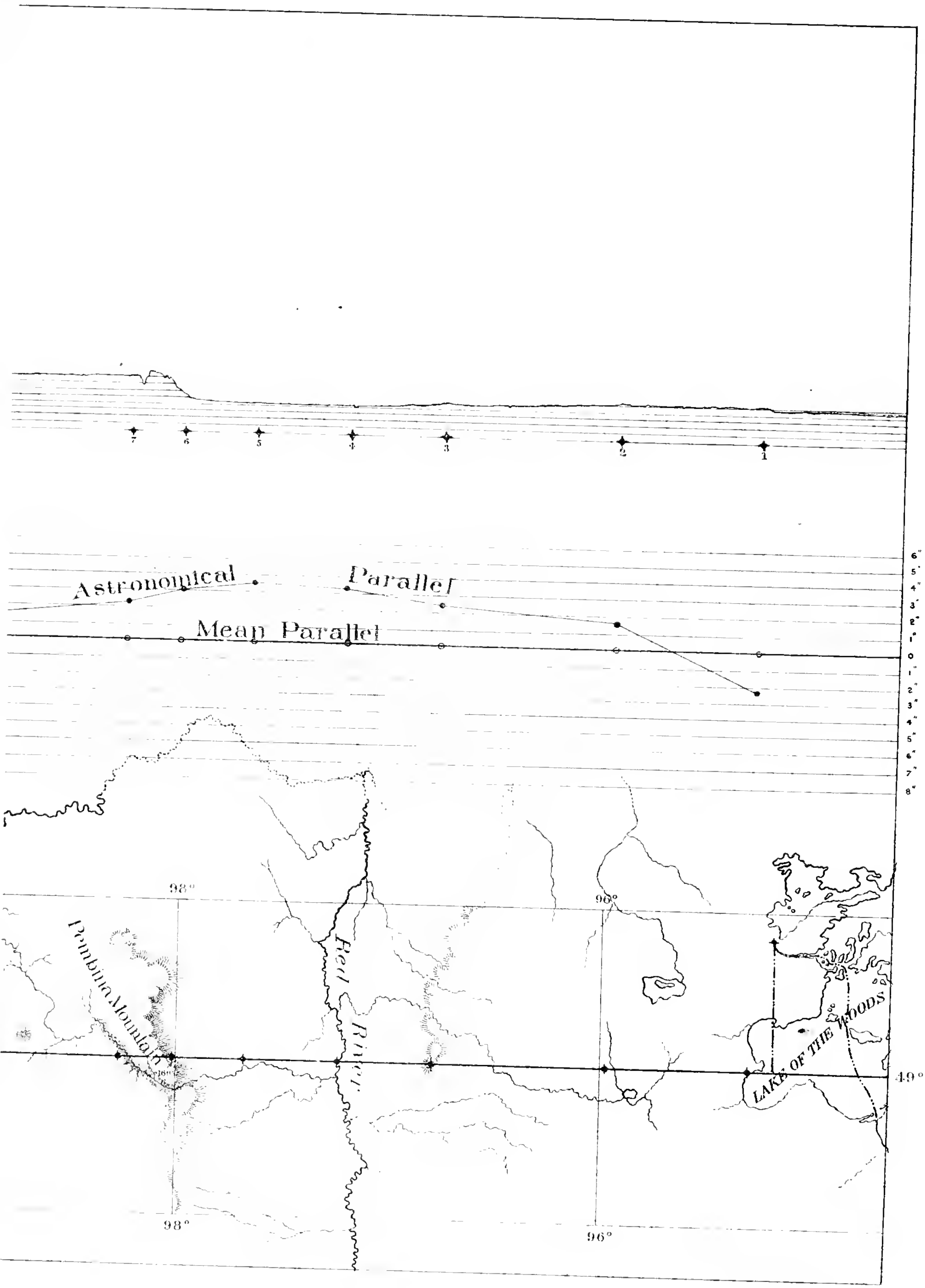
Of the forty-one astronomical stations, four were observed jointly by the two commissions, the difference in the determinations in each case being thirty-two feet, twenty-nine feet, seven feet, and twenty-seven feet, respectively. As those were the first stations observed, and as the general quality of the work constantly improved, it is probable that if the others had been observed jointly, a very considerable reduction in the average discrepancies would have been found. Of the remaining stations, seventeen were observed by the United States, nineteen by the English astronomers, and one jointly by the Northwestern Boundary Commission. The mean of the probable errors of the British stations was $\pm''.088$, and of those of the United States $\pm''.059$. The average of the probable errors is then a fraction over seven feet. Although such mathematical probable errors are more or less fallacious owing to the fact that constant errors are not included, still they give a fair measure of the general character of the work done, and offer sufficient ground for the conclusion that, if re-observed, the difference in any one case would hardly exceed twenty-five feet, while a general mean would probably not exceed seven feet.

From an examination of the geodetic connections, it will be seen that the mean error of the connecting tangents, in azimuth, is about 14″, which would imply an error of connection between the stations of nine feet.

In agreements between the chief astronomers of the joint commission in beginning the work, the limit of error was supposed to be less than fifty feet in the astronomical positions and the geodetic connection between two neighboring stations. From the results of the work this may safely be taken as the extreme limit, while the average errors, everything included, will doubtless be much smaller. Assuming, then, that the limiting error is fifty feet, we find that the supposition will account for less than one-fourth of the average station-error, which, as will be seen by reference to Table A, amounts to 2″.146, or about two hundred and seventeen feet, each station being referred to the mean of all, or less than one-sixteenth of the extreme deflection, as shown at station 34.

To illustrate this matter more fully, I have prepared the accompanying diagram, showing the "relative errors of astronomical stations in latitude, resulting from local deflections of the plumb-line." It must be borne in mind that in tracing a parallel by observed latitudes, only one component of the deflection is detected—that is, the component in the direction north and south—since that in the direction east and west depends on a determination of longitude more accurate than is compatible with the economic interests of such a survey. The diagram referred to shows: 1st. A profile of the line; 2d. The relation of each astronomical position to the mean parallel; 3d. The topography, so far as known, extending for half a degree on either side. It is scarcely necessary to say that beyond five miles, which was the limit of actual survey, the contours are only approximately known.

In examining the profile, the first general fact which strikes the eye is that from the lowest point of the basin of the Red River to the foot of the Rocky Mountains, a distance of about seven hundred and forty miles, there is a gradual rise of about 3,425 feet, or an average of 4.6 feet to the mile.



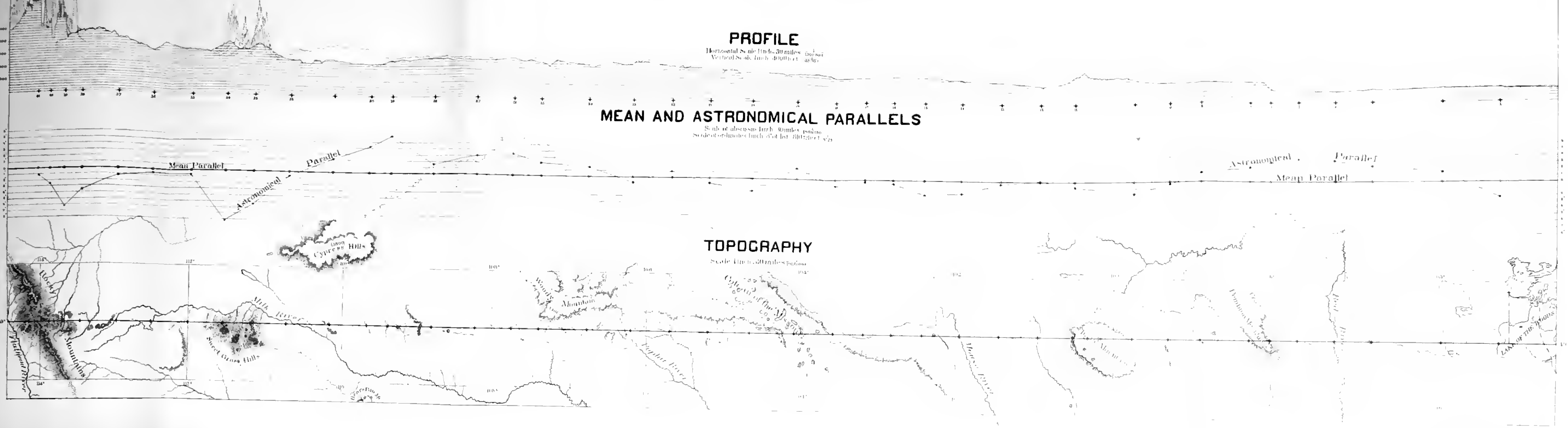
7
6
5
4
3
2
1
Astronomical Parallel
Mean Parallel
6"
5"
4"
3"
2"
1"
0
1"
2"
3"
4"
5"
6"
7"
8"
98°
96°
Pembina Mountain
Red River
LAKE OF THE WOODS
49°

But this profile is not drawn along the axis of greatest slope. The axial line of the Coteau of the Missouri extends from northwest to southeast, making nearly an angle of 45° with the meridian. As this Coteau consists of a mass of drift deposited by icebergs grounding against the inclined plane when in a state of submergence, it necessarily represents very nearly the line of equal altitude, from which it follows that the line of greatest slope is in a direction from southwest to northeast. The general direction of the base of the Rocky Mountains also conforms to this view. It is then evident that, taking into account both the large mountain-masses and the general slope of the comparatively level country, the deflections should be found toward the southwest, and increasing from east to west, and that the mean parallel, as determined from these stations, probably dips to the south at the western end.

In considering the line more in detail, the effect of purely local attractions is at once seen, strongly predominating over the supposed general direction of the deflection. Beginning at station No. 1 on the Lake of the Woods, the station-errors accumulate rapidly toward the north, reaching a maximum at No. 5. This curious effect is probably due to one of two causes, or perhaps in part to both. The first is the difference in the density of the substratum extending from station 1 to station 4 (Dawson's report on the geology along the forty-ninth parallel, a case very similar to the anomalous deflection observed at Moscow, and attributed by Pratt to the presence of a dike of increased density beneath the surface), while a second cause may be found in an increased density of the strata underlying the system of lakes to the north, represented by lakes Manitoba and Winnipeg. Going west, these effects diminish, while that of the high plateau of Northern Dakota is sensibly felt, so that at station 9 the line is again in its normal position, and so remains, with slight variations, due to local irregularities, as far as station 23. From this point the attraction of the high divide between the Milk River and the waters of the Saskatchewan makes itself felt, increasing to a maximum at station 29, south of the Cypress Hills. Here the enormous intrusive masses of the three buttes produce a violent disturbing effect, drawing the astronomical parallel to the south, at an average rate of fourteen feet to the mile, for a distance of one hundred miles, reaching

UNITED STATES NORTHERN BOUNDARY COMMISSION

DIAGRAM
to illustrate the
RELATIVE ERRORS OF ASTRONOMICAL STATIONS IN LATITUDE
resulting from
LOCAL DEFLECTIONS OF THE PLUMB LINE



the most southerly point of the boundary at station 34, which was situated immediately to the northwest of the West Butte, on the slope of the foot-hills. Relieved from the attraction of the butte, stations 35, 36, and 37 are again found nearly on the mean line. Stations 38 and 39 show, by a marked deflection to the south, the effect of the attraction of the Chief Mountain, a vast precipitous mass lying five miles south of the line, and rising to a height of 8,000 feet above the sea. The extreme deflection at 39 was probably due also, in some degree, to the general mass of the mountain-range. The connections on 40 and 41 are not sufficiently accurate to give a just basis of comparison, but as these stations were both in the midst of the main range, the deflections would probably be found to be anomalous.

The data for computing the amount of the local attractions along this line are very insufficient, except in the case of the station 34, at the West Butte. As a matter of scientific interest, I append a table of the actual and calculated deflections, as computed by Lieut. F. V. Greene, with an explanation of the methods employed. (See page 402.)

W. J. TWINING,

Captain of Engineers, Chief Astronomer.

APPENDIX A

TO

REPORT OF CAPT. W. J. TWINING,

CORPS OF ENGINEERS,

CHIEF ASTRONOMER.

REPORT OF CAPT. JAMES F. GREGORY, CORPS OF ENGINEERS, UNITED STATES ARMY.

OFFICE UNITED STATES NORTHERN BOUNDARY COMMISSION,
Washington, D. C., June 20, 1876.

CAPTAIN: I have the honor to submit herewith my report of the operations conducted under my charge upon the Survey of the United States Northern Boundary line, from the Lake of the Woods to the Rocky Mountains.

Very respectfully, your obedient servant,

JAMES F. GREGORY,
Captain of Engineers.

Capt. W. J. TWINING,
Corps of Engineers, United States Army,
Chief Astronomer, United States Northern Boundary Commission.

PRELIMINARY.

I was detailed for duty upon this work by Special Orders No. 131, War Department, Adjutant-General's Office, June 7, 1872, and accordingly reported in person to the Adjutant-General of the Army, and by subsequent orders from the same authority, by letter, to the honorable the Secretary of State. In accordance with instructions from the Assistant Secretary of State then Acting Secretary, I reported for duty with the United States Northern Boundary Commission, to Maj. F. U. Farquhar, Corps of Engineers, then Chief Astronomer, since which time I have been continuously on duty with the Commission.

The following report comprises a general description, by seasons, of the movements and operations of parties which were under my charge, and detailed descriptions of astronomical, geodetic, and barometric work performed by myself, or under my direction, with appended tabulated records and results.

In the season reports I have merely mentioned the general movements of my parties during the time that I was in company with the Chief Astronomer, and acting under his immediate direction, and have noticed more at length similar movements and operations when performed under my own direction, when acting independently under his general instructions.

During the winter succeeding each season's work in the field, I have been engaged in the office of the Commission in supervising and aiding in the computation and compilation of field records and results, and in the preparation of materials, and such computations as were desirable and necessary for the field-work of the succeeding seasons.

SEASON OF 1872.

The latter part of June, and the most of July, 1872, were spent in Washington, in making preparations for field-service, procuring, examining, and preparing for transportation the usual expeditionary outfit of instruments, text-books, note-books, &c., and making such computations as it was desirable to have done in advance of the field-work.

In the latter part of July I was assigned by Major Farquhar to the immediate charge of the geodetic and topographical department of the survey, with Lieut. F. V. Greene and Mr. F. von Schrader as assistants, and directed to proceed to Saint Paul, Minn.

Lieutenant Greene was sent by Major Farquhar in charge of the instruments, &c., via the Great Lakes, Northern Pacific Railroad, and Red River, to Fort Pembina, Dak., with instructions to report to me there, and Mr. von Schrader was directed to report to me, at Saint Paul, on the 5th of August.

My party was organized at Saint Paul, and went, in company with the several parties of the Commission, to Fort Abercrombie, Dak., and thence, after obtaining our wagon-transportation, camp-equipage, rations, and forage, to Fort Pembina, where we arrived on the 5th of September.

Camp was pitched at the boundary-line on the west bank of the Red River on the 7th, and the interval between that date and the 30th was employed in making topographical surveys of the country adjacent to the boundary-line, the Red River, and the Pembina River.

I may here remark that the autumn of 1872 was an exceptionally mild one for Northern Dakota. The equinoctial storm, which lasted nearly four days (September 22d to the 26th), was very severe and cold, but it was succeeded by three weeks of delightful weather, and the Red River did not close to navigation until the 12th of November.

On the 1st of October, by Major Farquhar's direction, I divided my party, equipage, &c., into two parts, and intrusted the larger proportion to the charge of Lieutenant Greene, with instructions to continue the line and topographical work eastward from the Red River, until he should join his work with that of the English parties, who were to work westward from the Lake of the Woods. He had reached Pointe d'Orme on the Roseau River, thirty miles east of the Red River, on the 5th of November, when he was recalled by a dispatch from Major Farquhar, which directed him to return to Fort Pembina, and report to me there.

On the 2d of October Major Farquhar, Captain Twining with his astronomical party, and myself, with five men of my party, started for the Northwest Angle of the Lake of the Woods, via Winnipeg, Manitoba.

We arrived at the Angle on the 9th, and remained there until the last of October. (For description of work performed there, see special paper on Northwest Angle.)

I left the Angle, in company with Major Farquhar, on the 31st of October, and arrived at Pointe de Chêne, eighty miles from the Angle, on the 3d of November. At this point Major Farquhar procured special transportation for himself, and left for Fort Pembina, leaving me with instructions to follow, as rapidly as possible, with the wagon-train.

I reached Fort Pembina on the 8th instant, with the animals in a much exhausted condition, owing to scanty forage and the very bad condition of the roads. On one day, the 5th, because of the almost bottomless mud, we made but eleven miles, although the wagons were light, and we were on the road from daylight until three hours after dark.

At Fort Pembina I received written instructions from Major Farquhar to await the arrival of Lieutenant Greene, to store at the post such equipage, instruments, &c., as would be needed there the next season, to procure such rations and forage as were necessary, and then to bring the entire train to Fort Abercrombie, where the animals were to be wintered.

Lieutenant Greene arrived on the 10th, and the southward march was begun on the 12th, and finished on the 19th; distance from Pembina one hundred and eighty miles.

The *personnel*, besides myself and party, were Lieut. O. D. Ladley, quartermaster, Mr. J. E. Bangs, acting secretary, and Dr. Hatch, surgeon of the Commission.

The transportation consisted of thirteen six-mule Army-wagons, three four-mule spring-wagons, and seven or eight spare mules.

On the second day out we were overtaken by a very severe snow-storm of two days' duration, which was succeeded by bitter cold winds, with the thermometer, much of the time, below zero, and as the men were not provided with suitable winter clothing, they experienced much discomfort, though none were seriously frozen. Several of the animals gave out on the march, but they were all, finally, brought in safety to Fort Abercrombie.

From Fort Abercrombie, after turning over to the care of the Quartermaster, Lieutenant Ladley, the train, equipage, &c., we proceeded by rail to Saint Paul, where the men of the party were paid off, and discharged on the 21st of November.

The office of the Commission was established for the winter at Detroit, Mich., where the usual routine of office-work was begun about the 1st of December.

SEASON OF 1873.

For the season of 1873 I was assigned, by the Chief Astronomer, to the charge of one of the two astronomical parties which were sent into the field that year. The party was organized, as in the preceding season, at Saint Paul, and proceeded, in company with the other parties of the Commission, by rail and steamboat, to Fort Pembina, Dak., where we arrived on the 1st of June.

During a week that we remained at Pembina on account of the non-arrival of our wagon-train, which was hindered in its progress from Fort Abercrombie by the high water in the streams tributary to the Red River, we were engaged in general preparations for the field, obtaining materials, rations, &c., observing for values of instrumental constants of zenith telescope, and completing organization of parties.

Upon marching from Pembina, June 9, the organization of my party, which was retained throughout the season, was as follows: Mr. E. L. Mark, computer, Mr. O. S. Wilson, recorder, a foreman, an observatory attendant and meteorological observer, a cook, waiter, three laborers, a mounted man to serve as scout and messenger, and five teamsters.

For transportation of party, instruments, equipage, and generally twenty to thirty days' rations and forage, I had one four-mule spring-wagon, three six-mule Army-wagons, one two-mule Minnesota wagon, and a horse for myself.

The general plan of work proposed for the astronomical parties, contemplated the occupation of stations on the boundary-line, at intervals of twenty miles, more or less, alternately by parties of the British and United States Commissions, and throughout the season this scheme was adhered to, with two exceptions, viz: United States stations Nos. 4 and 5 were consecutive stations, as were the British stations at Sleepy Hollow and East Turtle Mountain.

I began astronomical work at Station No. 3, East Pembina Mountain, on the 12th of June, observed successively at Stations Nos. 5, 7, 9, 10, 11, and 12, and completed the astronomical work of the season, at the latter station, on the 30th of September.

During the season all of the zenith telescope observations, both for latitude and values of instrumental constants, were made by myself and recorded by Mr. Wilson, as were also sextant observations for time and latitude in camp and upon the march, until we reached station No. 9; after that time most of the sextant work was done by Mr. Wilson.

The meteorological observations were made, under my supervision, by

William Batson, an ex-United States soldier, and an intelligent and efficient man.

Upon the march, while I was engaged in selecting routes for travel, and in the details of advancing the train rapidly and without accident, Assistants Mark and Wilson were employed in making reconnaissance surveys of the trail, by means of the compass and odometer.

All computations both in camp and upon the march were made by Mr. Mark, assisted, at times, by myself and Mr. Wilson.

The United States stations were occupied alternately by the two astronomical parties, from No. 2 to No 9. Upon completing work at the latter station, August 29, I received instructions from the Chief Astronomer to proceed westward, and occupy, at least, three more stations, and to so adjust the distances between them that the last one should be, at least, four hundred miles west of the initial Red River station. This work was accomplished, and the last station, No. 12, four hundred and eight and a quarter miles west of the Red River station, completed on the 30th of September, and the Chief Astronomer's camp, at Wood End depot, was reached, on the return march, October 6.

During the latter part of the season we were much troubled to obtain water and wood sufficient for cooking purposes. Wood End depot, on the Mouse River, was the last locality, going westward, where there was any timber, in the vicinity of the boundary-line, until we reached Station No. 11, and for that distance, one hundred and eighteen miles, wood was carried in the wagons. In the ravines, near Station No. 11, there were small groves of stunted trees, whence was drawn the supply which, economically used, and eked out by occasional supplies of the prairie-traveler's fuel, *bois des vâches*, lasted us during the remainder of our work until our return to Station No. 11, where a new store was laid in for use on the return march to Wood End depot.

The water-supply, after leaving the upper waters of the Mouse River, sixteen miles west of Station No. 9, was scant and precarious, as we had no information of the nature of the country before us. Through the "Coteau of the Missouri" we were entirely dependent upon the supply furnished by surface-pools, and those containing fresh water were of infrequent occur-

rence. There were many containing alkaline water, some of them large enough to be called lakes; but the water usually held such large quantities of salts that animals could not drink it. We were frequently compelled to use water sufficiently alkaline to be altogether disgusting to the taste, and the best of the fresh water found was full of insect life and vegetable matter. At Station No. 10 I was obliged to divide my party, and leaving the major portion of it and all of the animals in camp near a pool of surface-water, in charge of the officer commanding the military escort, to establish the station at a point ten miles farther west. I took with me for the purpose my assistants, three men, and ten soldiers, and had cooked provisions and water sent us, daily, from the main camp. At Station No. 12 I was obliged to adopt the same plan, and, leaving the main camp at a spring, which is the source of one of the tributaries of the Poplar River, to establish the station six miles farther westward. Near Station No. 11 I fortunately found a living spring with an ample supply of good water, which the men of my party at once christened "Bully Spring," and this name I have continued in the official record.

On the 23d of September, when the work at Station No. 12 was about half done, there began a furious snow-storm, which continued, almost without interruption, until the 29th, during which time the daily minimum thermometer reading varied from +14° to +34°.

The storm began with mingled rain and snow, which froze upon the grass, and made it impossible for the animals to get much nourishment. The forage-ration was short, and from this time until their arrival at Wood End depot they had only a daily allowance of three pounds, half of which was either flour or hard-bread. They were consequently much exhausted, and, to make matters worse, we found, upon our eastward march, the whole Coteau country a black desert, as the prairie-fires had passed over it, leaving only here and there, around the edges of what had been water-pools, small patches of dried grass containing little or no nutriment. We lost, however, but two animals, and they belonged to the escort transportation.

We arrived at Wood End depot on the 6th of October, and thence, in company with the Chief Astronomer's party, marched via Fort Totten to

Jamestown, Dak., where the transportation, equipage, &c., was turned over to the quartermaster, the parties proceeding by rail to Saint Paul.

From the second crossing of the boundary-line with the Mouse River, reckoning from the east, a reconnaissance survey was made of the trail to Fort Totten, and also from the latter place to Fort Seward, the former distance being one hundred and seventy and the latter eighty-one miles.

The military escort to my party was commanded during the entire season by Lieut. (now Capt.) C. O. Bradley, Twentieth United States Infantry. His command consisted, at first, of fourteen enlisted men, of Company K of his regiment. This force was increased by four privates of the Seventh Cavalry, on the 9th of August, and again, by six privates of Company K, Twentieth Infantry, on the 30th of August.

My relations, both official and personal, with Captain Bradley were always of the most pleasant kind, and I have to thank him and the soldiers of his command, not only for the faithful performance of legitimate duty as military escort, but more especially for frequent aid in helping along the work. In the latter part of the season a few days' delay would have prevented the completion of the work to the point proposed, and these days were saved to me by the assistance willingly rendered by the soldiers in gathering stones and building the mounds which mark the parallel at the stations.

Mr. Wilson was detached from my party at Fort Totten and attached to the line and topographical party, which, under Lieutenant Greene, was to work during the winter from the Red River eastward. Mr. Mark accompanied me to the office at Detroit, but soon after left the service of the Commission. The rest of the party were paid off and discharged upon our arrival at Saint Paul on the 28th of October.

SEASON OF 1874.

From the experience of the preceding season, in regard to the relative rapidity with which the various parties of the survey could accomplish their work, it was believed by the Chief Astronomer and myself that one astronomical party, with an organization somewhat stronger than that of my party of the preceding season, would be able to accomplish, in the allotted time, what astronomical work remained to be done, and to keep it at all times in advance of that of the line and topographical parties. But one astronomical party was therefore placed in the field, to the charge of which I was assigned, with Mr. Lewis Boss and Mr. A. J. Edgerton as assistants.

In order, however, that no untoward accident to the *personnel*, or instrumental outfit of my party, should compass a failure to attain the purposes of the expedition, the Chief Astronomer kept with him a complete instrumental outfit, a copy of the ephemeris, text and note books, and, in fact, the means of organizing another astronomical party; but, fortunately, the contingencies provided for did not arise, and the one party accomplished in ample time all of the work expected of it.

At Saint Paul, as in the preceding seasons, I employed the men of my party, and with them, in company with the other parties of the survey, left Saint Paul on the 4th of June, proceeding by rail and steamboat, via Bismarck, Dak., to Fort Buford, Dak., where we arrived on the 13th of June.

At Fort Buford, pending the completion of arrangements for field-service of the transportation for our own parties and the military escort, I observed with the zenith telescope for latitude, and also for the values of the instrumental constants of the instrument used. The results are given in the astronomical report.

My party comprised during the season, besides myself and assistants, one foreman, two cooks, one waiter, five laborers, six teamsters, and one scout. Dr. Elliott Coues, United States Army, Surgeon and Naturalist of the Commission, and three laborers, who were under his especial direction, were attached to my party during the entire season, for our mutual convenience of transportation, supply, and protection.

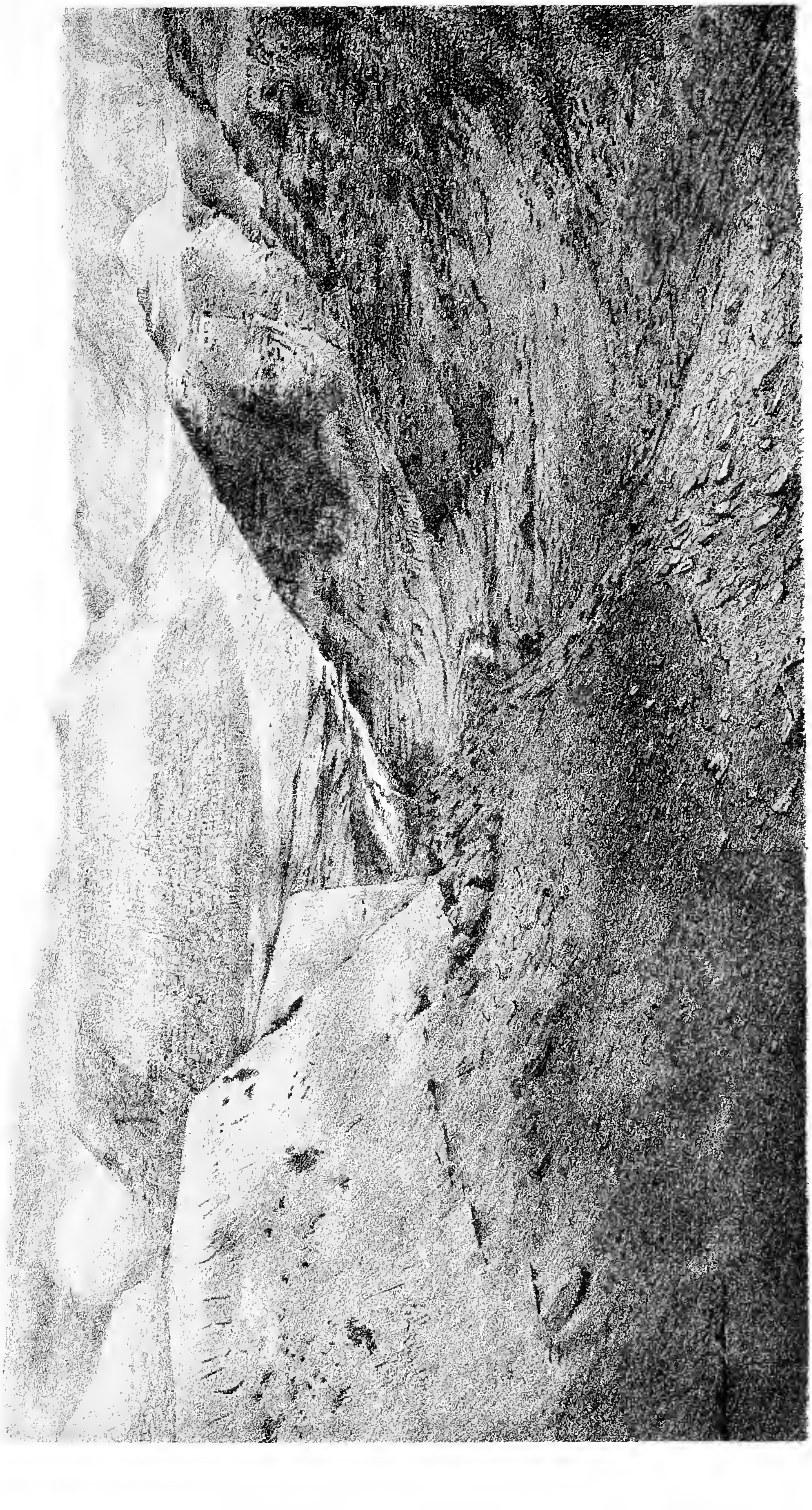
An assistant to Dr. Coues also joined the party at the Sweetgrass Hills, on the 5th of August. For transportation of the whole, instruments, equipage, &c., and from thirty to forty days' rations and forage, I had one four-mule spring-wagon, three six-mule Army-wagons, two two-mule Minnesota wagons, a horse and buckboard for Dr. Coues, and a horse for myself. The horse ridden by my scout, George Boyd, was his personal property, but was foraged with the train-animals

The military escort assigned to accompany my party consisted of

Company D, Sixth United States Infantry, about forty men, and three Indian scouts, commanded by Capt. Montgomery Bryant, Sixth Infantry (now Major Fourteenth Infantry), with Lieut. F. W. Thibaut, Sixth Infantry, second in command. This escort remained with my party from the time of leaving Fort Buford until we reached the Sweetgrass Hills depot, on our return from the Rocky Mountains.

On the 21st of June, the entire expedition and the military escort left Fort Buford, taking the Fort Peck trail, along the north bank of the Missouri River. We were delayed two days at the Big Muddy River, which, because of the deep mud on the bottom and along the banks, was not fordable. A crib and trestle bridge was constructed across it, on the 23d and 24th, by my own and Lieutenant Greene's parties, and the train crossed on the 25th. On the 26th, Lieutenant Greene's party and escort left the main column, to strike the boundary-line near the point where his last season's work terminated. The main column arrived, July 1, at a point on the north bank of the Milk River, in longitude about 106° 53′, and nearly opposite an old trading-post known as "Tom Campbell's houses," where I left it with my party, escort, and a contract wagon-train from Fort Buford, which was carrying rations and forage with which to form a depot of supplies on or near the boundary-line.

My objective point was on the boundary-line, about the usual distance between United States stations (forty miles) west of Station No. 12, the last station occupied in 1873. I therefore turned northward, July 2, from the main trail, and essayed to march along the east bank of Rocky Creek, as the general course of that stream appeared to be from the northwest, hoping, in case it did not lead us far enough to the westward, that we might be able to cross it near the boundary-line. I soon found, however, that we were getting into a country of bad-lands, impracticable for wagons, and therefore turned about, and followed the stream down to a practicable crossing near its forks. Thence, we marched across the broken country which is the dividing ridge between the Rocky and Frenchman's Creeks, to the east bank of the latter. As it was impossible to reach the bed of Frenchman's Creek in the vicinity of the point where we approached the bluffs, and as an inspection revealed the same rough bad-lands for several miles farther



north, I turned southward again, and made for the known crossing about three miles below the trading-post, Fort N J. Turnay. It was fortunate that we did so, as I afterward learned from the topographical parties that there was no practicable crossing for more than thirty miles, up-stream, from Fort Turnay.

The valley, or rather gulch, of Frenchman's Creek varies from one to two miles in width, and is abruptly terminated, on both sides, by ragged, steep hills, similar in character to those of the bad-lands south of the Missouri River. The bottom is comparatively level, and through it the stream winds sinuously. The creek, at ordinary stages of water, is about fifty yards wide, and has a rapid current, probably of about two miles an hour. The water is clear, but very unpleasantly alkaline, and at low stages of water is so strongly impregnated with salts as to be entirely unfit for use. We found Fort Turnay, which was a log structure, comprising storehouse and dwelling, occupied by two independent traders. They informed me that they were so much annoyed, and subjected to so much loss of property, by raids upon them by Indians, and were also kept so much upon the alert for their personal safety, that they purposed burning the buildings and leaving the country, which purpose was, I believe, carried into effect later in the season. Only the day before our arrival, a party of Sioux, from Fort Peck, had been entertained by them at a propitiatory feast, after which the guests displayed their gratitude for favors received by running off nine of the eleven horses belonging to their hosts. The two horses left were abandoned only because they were too much broken down to keep up with the rapid movements of the party.

We left Fort Turnay on the 5th of July, and arrived at a pool of water near the boundary-line the same evening. The weather had been intensely hot every day during our march from the Milk River, and water very scarce. The last day's march was twenty-five miles long, without water, and the thermometer at 105°, in the shade, at 3 p. m. Men and animals were, therefore, much fatigued upon arrival in camp, and eagerly sought the much-needed repose.

On July 6, according to instructions received from the Chief Astronomer, I adjusted accounts with Mr. Leighton, owner of the wagon-train which had accompanied us with supplies from Fort Buford, and sent back to Fort Turnay, to be stored until we could send for them, such rations and forage as I was unable to carry in my wagons.

Astronomical work was begun at Station No. 13 on the 6th, and finished on the 8th, on which date the march westward along the boundary-line was begun.

From this time forward until our arrival at the Sweetgrass Hills depot, August 3, the weather was favorable for astronomical work, and Stations Nos. 14, 15, 16, and 17 were successively established.

The country over which we had traveled from Station No. 13 had been very dry, and much of it alkaline in character. Water was scarce, and usually unpleasantly alkaline. We had found no wood along the line, and were therefore obliged to place our dependence for fuel upon buffalo-chips, which were everywhere abundant. At the East Fork, however, I obtained a load of wood by sending twelve miles down the fork to a small grove of cottonwood-trees, and this lasted us until our arrival at the depot camp, eked out, as before, by "*bois des vâches*."

On the 13th of July, while on the march from Station No. 15 to No. 16, my scout, George Boyd, aided by the Indian scouts, killed the first buffalo we had seen—a lone old bull. After that date we frequently saw small bands, and at times, when we got to close quarters with them, killed more perhaps than our needs justified. Upon our return from the Rocky Mountains to the Sweetgrass Hills, the plains and the eastern slopes of the hills were literally black with the creatures, and for days, upon our march toward Fort Benton, the plains presented a similar appearance, for nearly 180 degrees of the horizon, from the north around by the east.

The buffalo find every pool of water existing upon the prairie, and are in the habit of standing in them to rid themselves of the flies which are their peculiar pests. Wherever, therefore, the buffalo had preceded us we found the pools were mud-holes, which were loaded with buffalo *excreta*. Sometimes the water which we were compelled to drink, even of pools large enough to be called ponds or small lakes, was so impregnated with buffalo-urine as to partake of its color, and to be altogether disgusting to the stomach.

Between Station No. 15 and the Milk River we saw various camps and hunting-parties of Indians, supposed to be Sioux, and my scout, Boyd, had several interviews with bands of Assiniboines, but we were not, at any time, molested by them.

Upon arrival at the Sweetgrass Hills depot it became necessary to make some repairs to my wagons, which had become much shrunken by the continued dry weather. The 4th and 5th of August were therefore spent in resetting tires and reshoeing the animals.

The march westward was resumed on the 6th of August, and Stations Nos. 18, 19, and 20 were, thereafter, successively established. Work at the latter station, which was the last one of the survey, was completed on the 26th of August

There had been, therefore, between the 6th of July and the 26th of August, eight astronomical stations established, and three hundred and fifty-four miles marched. The average number of hours that we were in camp near stations was eighty-nine, and the average length of march for every day, excluding those at stations and the depot, was 18.6 miles, the shortest march being four, and the longest thirty-four miles.

Camp at Chief Mountain Lake was broken, and the march eastward, to join the Chief Astronomer's party at the Sweetgrass Hills depot, begun on the 27th, and finished on the 31st of August.

At this point the military escort was relieved from duty with my party, as they were to march back to their station at Fort Buford, and we were to go to Fort Benton, and thence, by Mackinac boats, down the Missouri River to Bismarck. I desire to express my sense of grateful appreciation to Major Bryant for the kind cheerfulness with which the movements of his command were always made to correspond with those which I deemed necessary for my party.

On the 4th of September, in company with the parties of the Commissioner and Chief Astronomer, we left the boundary-line to march to Fort Benton, arriving at the latter place on the 8th instant. A reconnaissance survey of the route traveled was made by Mr. Boss, the initial point being fixed, by triangulation, from the astronomical station near the Sweetgrass Hills depot, and the terminal points at Fort Benton by sextant observations.

The distance traveled between the two points was one hundred and fourteen miles.

At Fort Benton we were joined by Lieutenant Greene's parties, which had come from the boundary-line via Fort Shaw. The transportation, camp-equipage, &c., of the parties was turned over to the quartermaster of the Commission for transportation to Fort Shaw, and the parties, save those men who desired to remain in Montana, and were paid off and discharged at Fort Benton, embarked on the 12th of September, in Mackinac boats, to row down the Missouri River to Bismarck.

There were six boats, with an officer or assistant in charge of each, and the Chief Astronomer in charge of the whole. The crews and freight were so divided as to give about equal loads to the boats, and as nearly as possible equal power for propulsion. We arrived at Fort Buford on the 23d, and at Bismarck on the 30th of September. The distance, by river, from Benton to Bismarck, as determined by the astronomically-checked boat survey make by Lieutenant Greene's parties, is eight hundred and five miles. The same distance is popularly supposed to be, from the estimates of steamboat-men, one thousand two hundred and fifty-six miles.

We left Bismarck, by the Northern Pacific Railroad, October 2, and arrived in Saint Paul October 3, where, as in previous seasons, the men of the party were paid off and discharged. The officers and assistants thence proceeded to Washington, where the usual routine of office-work was resumed.

In closing this report, I desire to make mention of the admirable manner in which all duties required of them were performed by my assistants during the whole progress of the survey. Especially am I indebted to Mr. Boss and Mr. Wilson, not only for cheerful performance of the duties devolved upon them, but also for zeal in the furtherance of the work which was equaled only by the discretion and accuracy with which their work was done.

I desire also to mention my foreman, William Batson, who, by the exercise of an acute intelligence and untiring energy, relieved me of much personal responsibility, and contributed not a little to the harmony and comfort of my parties.

SEASON OF 1875

A portion of the United States Northern boundary-line which lies across the valley of the Red River, and extends some distance beyond its eastern and western limits, is marked at even-mile intervals (with one exception, which will be hereafter noted) by cast-iron pillars, of which alternate ones were placed in position by parties of the British and United States Commissions, respectively. Those of the British Commission were placed in 1874, and to place those of the United States Commission, I went, under instructions from the Chief Astronomer, to the boundary-line, in the summer of 1875.

The United States pillars were made at Detroit, Mich., upon the same general plan and specifications as those which mark our Northeastern boundary-line, differing from the latter only in the inscriptions upon them. They are hollow iron castings, three-eighths of an inch in thickness, in the form of a truncated pyramid, eight feet high, eight inches square at bottom, four inches square at top, with solid pyramidal cap, and an octagonal flange, one inch in thickness, at bottom. Upon opposite faces are cast, in letters two inches high, the inscriptions "Convention of London," and "October 20, 1818." The inscriptions begin about four and a half feet above the base, and read upward. The interiors are filled with well-seasoned cedar posts, sawed to fit, and securely spiked, through spike-holes cast in the pillars for the purpose. The average weight of the pillars, when completed and painted, was two hundred and eighty-five pounds.

I arrived at Detroit August 3, inspected the pillars upon completion, and, finding them all perfect and according to specifications, shipped them, on the 8th instant, via the Great Lakes and Northern Pacific Railroad, to Moorhead, Minn. I then went by rail to Saint Paul, where I employed a foreman, obtained such equipage and materials as were necessary for a working party, and left for Moorhead upon the receipt, August 15, of telegraphic advices that the pillars would arrive there the next day. From Moorhead, I shipped the pillars, equipage, &c., and myself took passage, August 16, on the steamboat Dakota, for Pembina. Owing to the low stage of water in the Red River, we were so frequently grounded on bars and rapids that we did not arrive at our destination until the 25th instant.

At Pembina I organized a working party by employing four additional men and three teams, and began setting the pillars on the 2d of September.

The similar pillars which had been placed by the British parties the preceding autumn, were at two-mile intervals, reckoning eastward and westward from the point of intersection of the boundary-line with the principal meridian of the Dominion province of Manitoba, and my instructions were to place the United States pillars midway between them, in order that the intervals between pillars should be even miles. The mounds erected when the survey of this portion of the boundary-line was made, in 1873, were at even-mile intervals, reckoning eastward and westward from the initial astronomical station, No. 1, on the west bank of the Red River. The principal meridian of Manitoba crossed the boundary-line five chains eighty-three links, or 384.8 feet west of the mound nearest it, and, therefore, each pillar was to be placed the same distance west of its corresponding mound. The sites for them had been marked, over a portion of the line, by the parties which placed the British pillars, with a peg and a small earth mound. When the pegs were found intact the pillars were there placed; if they were missing, or when, as on the line eastward from Roseau Ridge to Roseau River, no sites had been marked, they were established with theodolite and chain, by means of the distance mentioned and the direction given by the adjacent mound and the next iron pillar.

From the Red River eastward to the twenty-mile point, the mounds were in erroneous positions, owing to an error made in the field-calculations, which was discovered and corrected in the subsequent office-computations. They were north of the line proportionally to the distances from the east and west ends of the tangents to the point of junction, the greatest error being 16.9 feet at the ten-mile point. (For details see Lieutenant Greene's report "Details of Tangents.") The errors were corrected, and all of the iron pillars placed in their proper positions.

The pillars were all set four feet in the ground, with their inscription-faces to the north and south, and the earth around them well settled. They were placed in their exact sites by means of stakes north and south and east and west of the pegs marking their sites; upon which alignment was made in the two directions, before and during the time that they were being secured by bowlders and earth.

There were seventeen pillars set east, and forty-three west of the Red River; the most easterly and most westerly being, respectively, 53 miles 55.19 chains and 170 miles 55.19 chains west of the astronomical station at the Lake of the Woods (No. 1 east). The intervening ones are all at their proper intervals, with two exceptions, viz, an extra pillar was placed in the mound marking the initial point of the survey near the Red River (Station No. 1), and the pillar next west of the Pembina River was set in the mound 134 miles 32.07 chains west of the Lake of the Woods station. This latter site was selected for two reasons: first, on account of its conspicuous position, on the crest of the high ridge west of the river; and second, because it would have been at a great expense of time and labor to have carried it, by hand, down the precipitous bluffs, to an obscure position in the gulch below.

The work was completed, and the men and teams of the party paid off and discharged on the 7th of October. From the 2d of September to the latter date, we were accompanied by a military escort, detailed by order of Brigadier-General Terry, commanding Department of Dakota, consisting of twelve enlisted men of the Twentieth Infantry, from the garrison of Fort Pembina, commanded by Lieut. C. H. Low of the same regiment. To Lieutenant Low and his men I am indebted for much assistance in expediting the work.

Upon my return to Pembina, I found instructions from the Chief Astronomer, directing me to proceed to the Northwest Angle of the Lake of the Woods, for purposes which are detailed in a special paper concerning that locality. I accordingly left Pembina on the 8th of October, proceeded by stage to Winnipeg, Manitoba, and thence, by special conveyance, to my destination, and having performed the duty with which I was charged, returned to Pembina, on the 15th; and after adjusting the business affairs of the Commission there and at Saint Paul, I returned to Washington on the 2d of November.

ASTRONOMY.

The latitudes of all of the astronomical stations were determined by observations, with the zenith telescope, of the differences of nearly equal meridian zenith distances of stars, north and south of the zenith. This method and instrument are now in such general use that only such description of them is necessary as will explain the features and circumstances peculiar to our work.

INSTRUMENTS.

The zenith telescopes used were Nos. 9, 11, and 20, Würdemann. Nos. 9 and 11 were of twenty-five inches focal length, of small magnifying power, and were considerably worn by use upon the survey of our Northwestern boundary-line, from the Pacific Ocean to the summit of the Rocky Mountains.

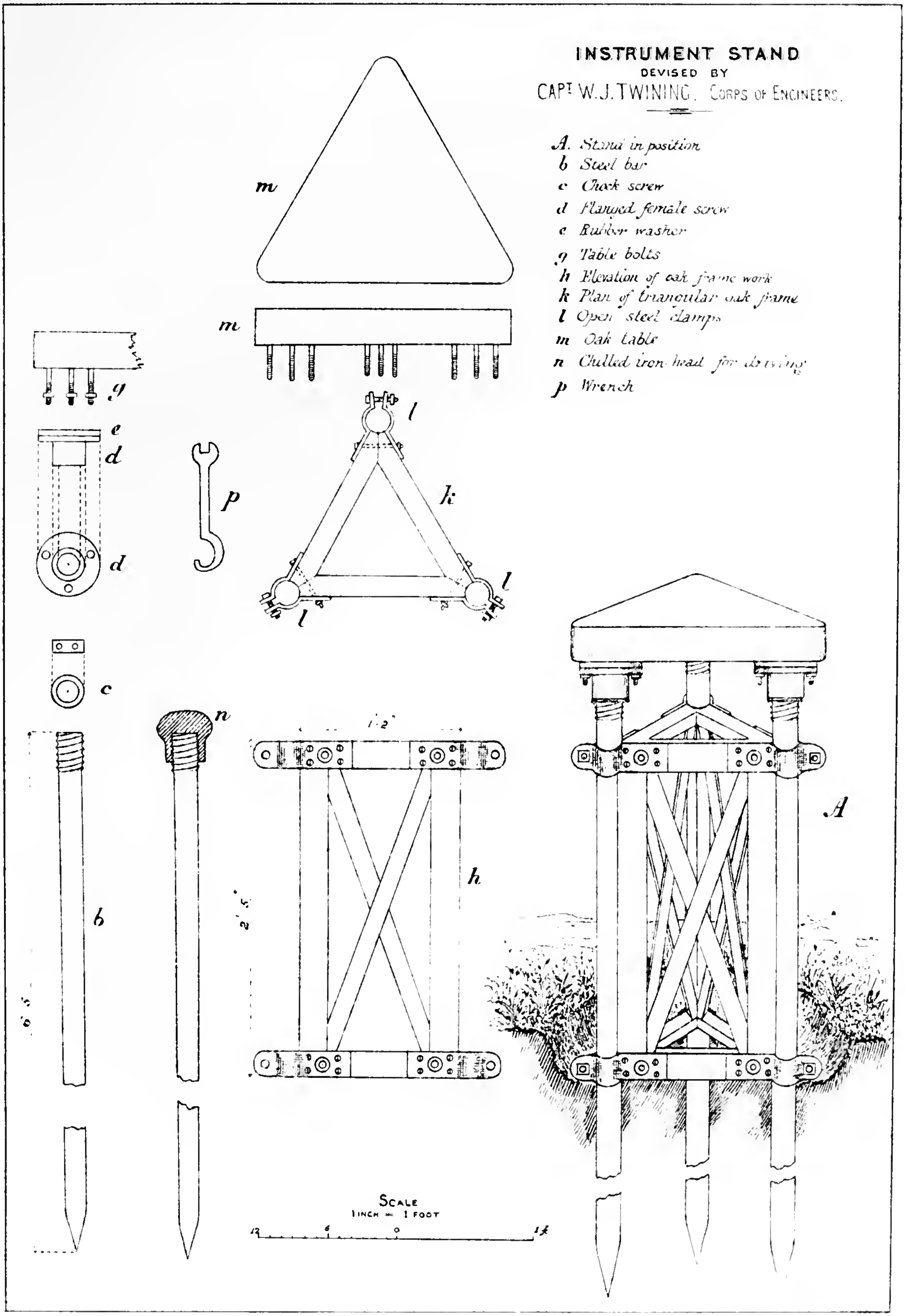
No. 20 was a new instrument, made for the Commission in 1872 and '73, of thirty-two inches focal length, and a magnifying power of sixty diameters.

No. 9 was used by Captain Twining, at Stations Nos. 1 and 1 east, and with it good results were obtained.

No. 11 was used by myself, at Stations Nos. 3, 7, and 9, and found to be entirely unreliable. It was afterward discovered that during the time of observations at Station No. 3, the telescope was loose upon its horizontal axis. Though this fault was afterward remedied, an irredeemable one was the badly-ground level attached to the telescope, which would often suddenly indicate large changes in the adjustments that could not be detected by means of the striding-level. The instrument was, in fact, faulty to a degree that rendered the attainment of precise results with it impossible. It was soon discarded and replaced by No. 20, which was used at sixteen stations and at Fort Buford, and found to be, in all respects, a perfect instrument.

INSTRUMENT-STANDS.

From the beginning of the work up to Station No. 5, the instruments were mounted upon wooden posts, about twenty inches in diameter and six feet long, sunk four feet in the ground. Well-seasoned logs were selected,


INSTRUMENT STAND
DEVISED BY
CAPT. W. J. TWINING, CORPS OF ENGINEERS.
A. Stand in position
b Steel bar
c Chock screw
d Flanged female screw
e Rubber washer
g Table bolts
h Elevation of oak frame work
k Plan of triangular oak frame
l Open steel clamps
m Oak table
n Chilled iron head for driving
p Wrench
SCALE
1 INCH = 1 FOOT

and the portion above ground painted to prevent swelling, shrinking, and twisting with atmospheric changes. They served their purpose very well, but as our field of labor was, for the most part, a treeless country, it was very desirable to have some sort of a stand which could be conveniently transported from station to station. Such an one was devised by Captain Twining, and manufactured to his order at the Detroit Locomotive Works. Three pointed steel bars, two inches in diameter and six and a half feet long, were driven four and a half feet into the ground, and formed a part of a rigid system, with a braced triangular frame-work of oak, twenty-nine inches high, whose horizontal section was an isosoles triangle, of about fourteen inches base. The connection between the bars and frame-work was effected by open steel clamps at top and bottom of the frame-work, which were closed by bolts and nuts, after the bars were driven.

The table, which was a solid triangular piece of oak, three inches thick, was joined to the bars by means of bolts attached to its bottom, three for each bar, and intermediate flanged female screws, with bolt-holes, which fitted the corresponding male screws upon the bar-heads.

Between these flanged screws and the table-bottom were placed soft-rubber washers, to allow the table to be brought to a firm bearing, by means of the bolts and nuts, when the top surfaces of the flanges were not in the same plane, or any of them not parallel to the bottom of the surface of the table.

On the bars, below the flanged female screws, were brass check-screws, which worked against the former, and held them firmly in position.

To place the stand in position, the top soil was first removed from a triangular space a little larger than the table of the stand. The frame-work was then placed upon the hard soil, the bars inserted in the open clamps, and driven with iron-bound wooden malls of twenty-five pounds weight.

The bar-heads were protected during the driving by chilled-iron heads, temporarily screwed on. These were then removed, the clamps tightened, and the table screwed down. The whole was then covered with a blanket bag, to protect the metal from the effects of sudden changes of temperature, and consequent disturbance of the adjustments of the surmounting instrument

In hard and gravelly soils the bars were driven with considerable difficulty, sinking slowly under the impulses given by the twenty-five pound malls, swung by stalwart men, but in no instance was I unable to use the stand by reason of not being able to sink the bars. Small bowlders struck, were either broken or forced aside, and sometimes the bars themselves were slightly sprung, not effecting, however, any damage. In a few cases large bowlders were struck, necessitating the choice of another position for the stand.

I used this stand at thirteen stations, and found it to be sufficiently stable, much more convenient to work around than a post, and there was no settling.

The labor of placing and removal was much less than with posts, and could be accomplished in half the time.

I think, however, that the bars would answer their purpose as well if they were made but five feet long; they would then have to be driven only three feet in the ground, which would afford ample stability, while the labor of driving them, and of digging them out, would be greatly lessened.

At Station No. 20, the instrument was mounted upon a structure of limestone slabs and small pieces of rock. As each slab had uneven surfaces, and was of varying thickness, its points of support were three small stones of selected sizes, so placed on the slab below as to make the top surface of the supported slab as nearly level as possible.

Although the arrangement answered tolerably well, it was neither as stable nor as convenient as our instrument-stand. The latter I was unable to transport up Chief Mountain Lake, and was, therefore, compelled to supply its place in any manner that I best could.

SEXTANTS.

The sextants used were Nos. 1452 and 1455, Stackpole & Bro. They were purchased by the Commission, and possess some peculiarities which were made from designs by Professor Harkness, United States Navy. They are of six-inch radius, are graduated to 10′, and read by vernier to 10″. The vernier-plate is beveled, and the attached reading-microscope is inclined to the limb in the direction of the graduation-lines, an arrangement which I do not consider desirable, especially for night-work. A finding-level is attached to the index-bar, which is a great convenience to inexperienced observers.

An eye-piece shade, with several glasses of various depths of the same color, was found to be a decided convenience for use in sun-observations, obviating the use of the shades of the index and horizon glasses, and, therefore, eliminating the possibilities of errors arising from different refractions by those shades.

The instruments were well made, and were, on the whole, very satisfactory.

Mr. Boss made an extended series of investigations in 1873 to obtain the corrections for eccentricity of No. 1452. They consisted of comparisons of observed angular distances of stars with the same distances computed. As the results obtained do not elsewhere appear, they are here tabulated.

Corrections due to eccentricity—Sextant, 1452, Stackpole & Bro.

At—	Corrections.	At—	Corrections.	
°	"	°	"	
10	— 0.5	80	— 11.2	For angles not given the correction is obtained by interpolation.
20	— 1.3	90	— 13.6	
30	— 2.3	100	— 16.1	
40	— 3.6	110	— 18.9	
50	— 5.2	120	— 21.7	
60	— 7.0	130	— 24.7	
70	— 8.0	140	— 27.7	

CHRONOMETERS.

The chronometers used by my party in 1873 were Negus break-circuit sidereal No. 1481; Bond sidereal No. 235; Negus mean solar No. 1319.

In 1874 I had Negus break-circuit sidereal No. 1513 instead of 1481, the others being the same.

The break-circuit chronometers were swung in gimbals, and the others were in leather cases. They were usually packed for transportation in a cotton-lined box, and were carried in the spring instrument-wagon.

Their performances were quite satisfactory, as may be ascertained by reference to the special paper on chronometer performances.

ASTRONOMICAL TRANSITS.

I carried, during the season of 1873, astronomical transit No. 30, Würdemann, and, in 1874, No. 4, Würdemann. These were little used. A few observations for instrumental constants and time were made at Station No. 7.

MANNER OF WORK.

It was customary, when upon the march, to make daily observations with the sextant for time and latitude; sometimes of the sun, but oftener of well-known stars.

When marching over portions of the country which were not afterward to be surveyed by the topographical parties, daily observations were made, when practicable, of stars east and west for time, and north and south for latitude. By means of the prismatic compass and odometer as full reconnaissance-notes as possible were made of the trail between points of astronomical observation.

When marching along the boundary-line the same care as to survey of route, &c., was not exercised, as this was to be the field of the topographical parties, and only such notes of bearings and distances were kept as would enable us, at any time, to know our approximate position with reference to points upon the boundary-line; chronometers were, however, usually compared daily, at noon, both in camp and upon the march.

When it happened that we arrived before noon in the vicinity of a proposed astronomical station, a halt was made in sufficient time to take circummeridian observations of the sun for latitude, for which the corresponding time-observations were made when the sun had attained an hour-angle great enough to give sufficiently accurate results.

To make these observations, and to compute the latitude from the data so obtained, and the longitude from the compass and odometer record of march from the preceding station, or the chronometers, usually involved a delay of two and a half or three hours.

From the position so established, it was easy to proceed, by compass and odometer, to a point near the 49th parallel, and at the proper distance from the preceding station.

In case of arrival in such vicinity after noon, it was necessary to go into camp and await the result of night observations. In several instances, however, I was spared this delay through the courtesy of the Chief Astronomer of the British Commission, who had driven pickets upon which were recorded the results of observations made by him while on reconnaissance expeditions, thus affording me fixed points on which to base trail-surveys.

A site for camp and the observatory was then selected as near the 49th parallel as the necessities of camp life, such as proximity to water and grass, would pemrit, and the zenith telescope was prepared for use. I rarely found it possible to put the instrument in perfect adjustment until after sundown, because of the rapid changes in temperature which occurred during the latter part of the afternoon. The difference between the highest temperature on July 6, 1874, and the lowest on the succeeding night was 56°.3; in many instances the changes inside of twenty-four hours were as much as 40° to 50°.

The instrument was placed in the meridian by means of an observation of Polaris at any convenient even minute of time, for which the azimuth of the star was computed in advance.

It was rarely necessary to repeat this adjustment at any station, though a convenient test of its accuracy was afforded by eye comparison with the micrometer comb-scale of the distances from mid-wire of stars observed at culmination. If these distances, so estimated, did not exceed three micrometer turns (one turn $=62''$), the adjustment was considered satisfactory; if unsatisfactory, it could be repeated in about twenty minutes' time.

In latitude observations the star bisection was always perfected at the instant of culmination, which time, as well as that of each even ten seconds and the last even five seconds of the preceding half minute, was called by the recorder, who had before him the chronometer, and the computed chronometer time of culmination on the programme arranged for the night.

Chronometer corrections were ascertained by means of sextant observations east and west.

The observations of each night were computed the following morning; frequently those of the last night at a station were computed as fast as taken.

On the day following the first night's work the distance on the meridian from the center of the instrument to the 49th parallel, as given by the mean of the results, was carefully measured, and a picket driven there (in latitude 49°: 1″ of latitude = 101.34 feet). The teams were then employed during the remainder of the days at the station in hauling stone for the mound to this picket.

When the requisite number of results were obtained, and the final latitude deduced, the difference between it and the result of the first night's work was laid off on the ground, north or south, from the picket before mentioned, and another picket driven, around which was piled the stone for the mound which marks the boundary-line.

The mounds were conical in form, and varied in dimensions with the comparative difficulty experienced in obtaining stones. The smallest was about five feet high, and eight feet in diameter at base, and the largest eight feet high, and sixteen feet in diameter at base.

When timber was obtainable there was usually a post sunk three feet in the ground, around which the mound was built; otherwise the top soil was removed and a circle of small bowlders laid around a central stone used in the place of the picket. This was then covered with earth and the mound piled upon it.

Upon completion of the mound, which was usually before noon of the day succeeding the last night's work at a station, camp was broken and the march begun for the next station.

BLANK FORMS.

The blank forms used for computations in the field were so convenient that I deem them worthy of preservation, and to that end attach specimens hereto:

1. Time by single altitude.
2. Latitude by Polaris off meridian.
3. Latitude by circummeridian altitudes.
4. Programme for zenith-telescope observations.
5. Comparison of chronometers.
6. Record and reduction of zenith-telescope observations.

Nos. 1, 2, 3, and 4 were arranged in blocks of one hundred forms, from which each form was detached for file as computations upon it were completed. No. 5 was in book-form of half quires; the specimen shown is one-half of one page.

No. 6 was in book-form of four quires; the specimens shown are the headings of opposite pages.

RESULTS.

There are appended hereto complete records of the astronomical stations. They are in order as follows:—

1. Star Catalogues, 1872, '73, '74.
2. Latitude determinations with the zenith telescope.
3. Instrumental constants.
4. Abstract of chronometer records.
5. Results at British astronomical stations.
6. Reconnaissance-positions.

The large number of independent observations made with the sextant for time and latitude, are not appended. They, alone, would make a considerable volume, and are not considered essential to a faithful presentation of the record.

STAR CATALOGUES.

The star lists comprise all stars used for observation with the zenith telescope. Their designating numbers are those of the British Association Catalogue, and the mean declinations and proper motions those adopted for the year. The list for 1872 was used at but two stations, No. 1 and No. 1 east. The mean declinations were derived from the catalogues of the Greenwich observatory. The mean declinations for 1873 and 1874 were obtained by homogeneous reduction, according to the method of Argelander, from all reliable authorities obtainable. This has been the work of Mr. Lewis Boss, to whom great credit is due for the correct and altogether admirable manner in which his work has been performed. As he is engaged in the preparation of an elaborate report upon the subject of these star places, I will not enlarge upon them here, and will only add, that a careful examination of the latitude results obtained, and of the residuals of each pair of stars, referred to the mean latitudes of the several stations, affords ample evidence to warrant the conclusion that the errors of determination are almost wholly those of observation, including, of course, instrumental errors, and that the mean places of the stars may be considered as very nearly approaching absolute accuracy.

The lists for 1873 and 1874 comprise one hundred and twenty-four and one hundred and twenty-eight stars, respectively, in declination from $+17° 45' 52''$ to $79° 58' 55''$, and in right ascension from $13^h 22^m$ to $4^h 05^m$, which were the hours of possible observation during the field-seasons.

The ephemeris, as constructed for use in the field, consisted of:—

1st. Table of mean places for the year; R. A. from any reliable authority; annual precession and proper motion. Logarithms of the constants $a' \; b' \; c' \; d'$, corresponding to Bessel's formulæ and notation for reduction from mean to apparent place.

2d. Logarithms of day numbers for the day and sidereal hours specified, computed for a mean longitude of the stations.

3d. Table of apparent places, for every five days of the probable time of field-work.

This time, in 1873, was from May 20 to October 22, and in 1874, from June 21 to October 12.

Declinations for other dates than those given in the table, were obtained by interpolation, the difference between a declination so obtained, and one directly reduced, being inappreciable.

LATITUDE RESULTS

The final result for the latitude of each station is the arithmetical mean of all of the determinations at that station, without regard to time of observation or the pairs of stars observed. This method was chosen, because the probable error of declination is so far inside of that of observation as to render weighting, not only a work of unnecessary refinement, but positively undesirable. For the same reason, it is believed that the final accuracy is about the same at stations, so far as it depends upon the number of different pairs of stars observed.

At no station has the time of observation covered a period of less than two entire nights. In those instances, when there were two or three nights of observation, the number of observations made on the several nights were nearly the same, and the mean result given is nearly that of the mean of the results taken by nights. At those stations where there was a greater number of nights' work, the numbers of observations of the several nights do greatly vary, and it would be manifestly unfair to give, for the final result, the mean of the nights' results, unless less weight were given to the night of few observations, and this is practically done by taking the mean of all the results.

There have been no results rejected by arbitrary selection. At each station, Peirce's Criterion for the rejection of doubtful observations was applied to the results, before striking the final mean. While there is much doubt of the actual utility of the application of such mathematical criterion when the results are in the hands of a competent and judicious computer, it nevertheless gives some standard rule for computers to follow, and affords means of comparing results obtained by different observers, which would not be comparable if results were rejected at will. It also dissipates doubts which might arise as to the constant good judgment of a computer in selecting results for rejection, especially under the pressure of necessary haste in completing the computations, which always obtained in our field work.

INSTRUMENTAL CONSTANTS.

Observations for the value of level divisions and micrometer turns of each zenith telescope, were made once or twice each season that such instrument was used, except that the value obtained for the level of zenith telescope No. 20, in 1873, was used in 1874. The permanent marks used in the level-value determinations were either the crosswires of astronomical transits or transit theodolites.

For value of micrometer turns, observations were made upon a circumpolar star, usually Polaris, near elongation.

For zenith telescope No. 20, those used in 1874 depend upon three series of observations: two of Polaris, and one of B. A. C. No. 240, made at Fort Buford.

I desired to reobserve for the constant values of No. 20, but there were no occasions, during the season of 1874, when such observations would have been practicable, that the time was not employed in latitude work, or that I was not too much fatigued, by such work, to make the results of value. It was not considered of sufficient importance to justify a night's delay for the purpose, as the latitude results demonstrated, by accompanying results obtained from pairs of stars with large and small differences of zenith distances, that the micrometer values used were amply good.

No corrections for run of micrometer, or for variations in the value of micrometer-turns for changes of temperature, have been applied, the investigations of these errors being considered more curious than useful in their relation to field-astronomy.

The following synoptical table explains the general character of the latitude-work

The results of observations at all the stations of 1873 and 1874 are included between the limits here given, except those of Nos. 3, 7, and 9, which were determined with the poor instrument (No. 11) before described, and which, though not absolutely bad, are not comparable with the rest of the work.

	1873.			1874.		
	Seconds of arc.	No. of determinations.	Station number.	Seconds of arc.	No. of determinations.	Station number.
	″			″		
Greatest extreme range of results at any station	3.43	66	10	2.68	75	16
Least extreme range of results at any station	2.28	59	12	1.83	60	18
Greatest probable error of single determination	0.457	66	10	0.393	47	20
Least probable error of single determination	0.324	82	5	0.228	62	15
Greatest probable error of final result	0.056	66	10	0.049	47	20
Least probable error of final result	0.037	82	5	0.029	62	15

Number of independent determinations of latitude with zenith telescope: 1873 .. 561; 1874 .. 520

Number of same rejected by criterion: 1873 .. 11; 1874 .. 3

No star forms a compound of more than one pair, and the results show that it is better that each pair should be separately observed; that is, that several pairs should not be grouped for the same setting.

In the computations for probable error, the residuals are the differences between the arithmetical means of all of the determinations and the individual determinations; which is the method usually, but not universally, adhered to in like field work.

RESULTS AT BRITISH STATIONS.

The appended list of results obtained at the British astronomical stations is compiled from the record of the British Commission furnished the United States Commission. (See page 198.)

The declinations of stars used by the astronomers of the British Commission were taken from the publications of the Greenwich Observatory, and the individual results obtained were combined by weights.

RECONNAISSANCE POSITIONS.

In the following table are given the astronomical positions of points on line of march from Fort Buford to the boundary-line at Station No. 13. The latitude of Fort Buford was determined, by myself, with zenith telescope No. 20. The large probable error of final result is accounted for by the facts that there were but twenty determinations, by observation of eleven pairs of stars, and that the declinations of these stars were from other sources than our own catalogue, which did not contain stars of suitable declination for that latitude.

The other positions given are from sextant observations by my assistant, Mr. Lewis Boss.

Positions.	Latitude.				Longitude.		
	°	′	″	″	°	′	″
Fort Buford (flag-staff)	47	59	15.58	± 0.192	103	58	00
Big Muddy River	48	09	10		104	54	25.5
Frenchman's Point (Missouri River)	48	08	38		104	53	46.5
Poplar River (or Quaking Ash River)	48	07	58		105	09	52.5
Little Porcupine River	48	04	55		106	00	28.5
Buggy Creek	48	16	18		106	35	46.5
Rocky Creek	48	29	37		106	59	33
Lake Boyd	48	42	50		107	01	51
Fort Turnay (Frenchman's Creek)	48	44	05		107	11	45

HYPSOMETRY AND METEOROLOGY.

The vertical element of the survey along the boundary-line depends upon the barometric determinations of the altitudes of astronomical camps, &c., upon which, as bases, are adjusted and closed the vertical surveys of the topographical parties.

The instruments used in this connection by each astronomical party were two cistern-barometers, Green, two aneroid barometers, two psychrometers, one maximum and one minimum thermometer, one black-bulb thermometer.

Those under my care were in constant use from the Red River to the Rocky Mountains, and, with the exception of the black-bulb thermometer, which was broken early in the first season and never replaced, were safely carried through all of the vicissitudes incident to two years' service in the field, a piece of good fortune rarely equaled in the histories of these fragile instruments.

The practice at astronomical camps was to record daily at 7 a. m., 2 p. m., and 9 p. m. the readings of the barometers, attached thermometers, and psychrometer, the extra barometers being read for the purpose of detecting any change of instrumental errors which might occur, and also to afford the means of continuing the record, reduced to the same zero, in case of accident to the standard barometer.

General meteorological phenomena were noted three times daily, and the maximum and minimum thermometers were read at 7 a. m. and 9 p. m.

The computations of the altitudes of all stations have been made by comparison of daily means with the daily means of synchronous observations made at a permanent station.

For the season of 1873 the permanent station was Fort Pembina, Dak., where the record was kept by an observer employed by the Commission.

For season of 1874 comparison was made with the record of the United States Signal-Service station at Fort Benton, Montana, a copy of which, for the time of our field-service, was furnished, upon application, by the Chief Signal-Officer of the Army.

The formulæ and tables employed in the reduction may be found in

Williamson's treatise on the "Use of the Barometer, &c.", Professional Papers Corps of Engineers, No. 15, and "are those of Plantamour (Guyot's tables D, 72–79), rearranged and adapted to English measures."

The reductions have been made by daily means, and each result thus obtained given equal weight in the final result. In those cases where, for lack of a sufficient number of daily means, single observations have been admitted, much less weight than that given a daily mean has been accorded them—generally about one-quarter.

No corrections for abnormal and horary oscillations of the weight of the atmosphere have been applied, as we had no sufficiently-extended series of observations made under circumstances favorable for the purpose of deducing these corrections. The only hourly series attempted was recorded at Captain Twining's camp, at Wood End Depot, September 23 to 30, 1873, and that time was, unfortunately, the period of the severe equinoctial storm of that year.

The great horizontal distances between barometers compared introduces an element of uncertainty in the results, on account of the different local conditions to which the two instruments may be subject at corresponding times of observations. This source of error would be practically eliminated in cases of long-extended series of observations, because abnormal results would be indicated by comparison with a large number of results, and might be rejected, or, if admitted, they would have little weight in the general result, by reason of comparatively small numbers.

This condition obtained at few of our stations, as, in the majority of cases, the determinations depend upon a small number of daily means, and necessarily so, because the time allowed for barometric observation at any station was strictly limited to that required for the purpose of astronomical observation.

The barometric heights of the eight astronomical stations of 1874 have been reduced by comparison with three Signal-Service stations. The results are given in the following table:—

Station.	Above Fort Pembina.	Above Fort Benton.	Below Cheyenne.	Altitude referred to Fort Pembina.	Altitude referred to Fort Benton.	Altitude referred to Cheyenne.	Locality of station.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	
No. 13........	2,094	192	3,201	2,884	2,866	2,857	Frenchman's Creek, west bank.
No. 14...... ..	2,240	268	3,039	3,030	2,942	3,019	Pool on prairie.
No. 15...... .	1,937	100	3,240	2,727	2,770	2,818	East Fork Milk River.
No. 16.........	1,929	149	3. 165	2,719	2,823	2,893	Milk River lakes.
No. 17........	2,898	1,049	2,262	3,688	3,723	3,795	East Butte Sweetgrass Hills.
No. 18.........	2,624	827	2,583	3,414	3,501	3,475	Red River, west bank.
No. 19.........	3,754	1,641	1,641	4,343	4,315	4,417	North Fork Milk River.
No. 20.........	3,586	1,539	1,726	4,375	4,213	4,331	Chief Mountain Lake.

	Feet.
Fort Pembina above sea............	760
Cheyenne above sea............	6,058
Fort Benton above sea............	2,674

The results obtained by reference to Fort Benton are those accepted for the altitudes of these stations, and are considered the most reliable, because the horizontal distances between stations compared are much less than in the other cases, and the general climatic and local conditions more nearly similar.

Apppended is a table giving the altitudes of thirty-two positions, on or near the boundary-line, with verbal description of location, latitude, and longitude, and height above station of comparison and above the sea.

Also, record of each station, and of station of comparison, and the work of reduction.

The records at stations Nos. 2, 4, 6, 8, Wood End Depot, Lake of the Woods, and Northwest Angle were made under the supervision of Captain Twining; those at Nos. 2, 3, and 4, east, under the supervision of Lieutenant Greene, and at the rest of the stations under my own supervision, except at the British depot, Sweetgrass Hills, where a semi-daily record of an aneroid barometer was kept during the month of August, 1874, and a transcript of it forwarded to me by the Chief Astronomer of the British Commission.

THE NORTHWEST ANGLE, LAKE OF THE WOODS.

By this title is popularly and generally designated the arm or bay of the Lake of the Woods, at whose northwestern extremity is the point decided, by the Joint Commissioners appointed to carry into effect the 7th Article of the Treaty of Ghent, to be the most northwestern point of the Lake of the Woods. To the locality especial interest attaches, from the fact that the most northwestern point mentioned is the initial point of the boundary-line which it was our work to determine, and because a portion of the American waters of the bay, and of one of the streams emptying into it, form a part of the Dominion Government route of travel and transportation from Lake Superior to Winnipeg, Manitoba.

In order to arrive at a clear understanding of the purpose and methods pursued in the work at the Northwest Angle, I quote the following from the declaration of the Commissioners appointed to establish the boundary-line under the 7th Article of the Treaty of Ghent:—

SECTION 19. *Resolved*, That the following described line (also represented on said maps as before mentioned) is, in the opinion of the Commissioners, so far as the same extends, the true Boundary intended by the before mentioned Treaties:—Namely, * * * * * thence through the middle of the waters of this Bay to the Northwest extremity of the same, being the most Northwestern point of the Lake of the Woods, and from a monument erected in this Bay, on the nearest firm ground to the above Northwest extremity of said Bay, the courses and distances are as follows: viz, 1st, N. 56° W. 1565½ feet. 2d, N. 6° W. 861½ feet. 3d, N. 28° W. 615.4 feet. 4th, N. 27° 10′ W. 495.4 feet. 5th, N. 5° 10′ E. 1322½ feet. 6th. N. 7° 45′ W. 493 feet. The variation being 12° East. The termination of this 6th or last course and distance being the above said most Northwestern Point of the Lake of the Woods, as designated by the 7th Article of the Treaty of Ghent, and being in Latitude Forty-nine degrees, twenty-three minutes, and fifty-five seconds North of the Equator, and in longitude Ninety-five degrees, fourteen minutes, and thirty-eight seconds, west from the observatory at Greenwich.

To discover and re-establish this "most Northwestern point," and to trace, thence, the meridian boundary-line, and to make such surveys at the Northwest Angle as should be necessary, I was directed by Maj. F. U. Farquhar, then Chief Astronomer of the Commission, to accompany him to the Lake of the Woods, with a portion of my topographical party, and such instruments, rations, camp-equipage, &c., as would be needed for a month's work.

We accordingly broke camp on the boundary-line, near the Red River, on the morning of the 1st of October, 1872, marched to Winnipeg, Manitoba, in three and one-half days, distance sixty-eight miles, crossed the Red River, and went into camp at Saint Boniface, opposite Winnipeg, on the evening of October 4. Breaking camp next morning, we marched over the Canadian Government road, known as the "Dawson road," to the Northwest Angle, arriving there upon the evening of October 9, the distance from Saint Boniface being one hundred and ten miles.

We were associated in the work at the Angle with Capt. Samuel Anderson, Royal Engineers, Chief Astronomer of the British Commission, who, with his detachment of English sappers, arrived the same evening. We were also accompanied to the Angle by Capt. W. J. Twining, United States Engineers, and Lieut. W. J. Galwey, Royal Engineers, who, with their astronomical parties, were on their way to determine the 49th parallel on the west shore of the Lake of the Woods.

The country in the vicinity of the Northwest Angle is low and swampy, and covered with a dense growth of coniferous trees, mostly tamaracks; the higher ridges, which however are of slight elevation, are covered with groves of poplars. Vast tracts of the country have been ravaged by forest fires, leaving the burnt portions impassable by reason of the dead-fall. The trees are mostly small; few having a diameter of trunk, at base, of more than six or eight inches, although I secured one dead pine of about twenty-six inches diameter at four feet above the ground, the trunk of which was cut into sections eight feet long, and used for observing-posts. The soil is generally sandy, covered in most places with a considerable depth of vegetable mold.

The point of land included between the northwest arm of the lake and the first considerable stream emptying into it (see accompanying map), on both sides of the meridian boundary-line, is at times occupied by considerable numbers of Ojibway Indians, who come there annually to receive their annuities from the Canadian Government, to fish, to trade at the adjacent Hudson's Bay Company's store, and to adjust, among themselves, the property acquired, by various methods of gambling.

The point marked "Dock" on the map was the terminus of the Dawson road, and the landing-place of the Canadian Government boats at the time of our visit to the Angle in 1872. At the present time, 1875, the terminus of said road, the government buildings, and the Hudson's Bay Company's store are located on British territory, on the north bank of the same creek, and adjacent to the meridian boundary-line.

We found at the Angle the camp of a surveying-party of the British Commission, in charge of Colonel Forrest, who were engaged in making a survey of the entire northwest arm of the lake, which was afterward continued along the west shore of the lake to the 49th parallel. Colonel Forrest, at various times before our arrival, had sought to discover some trace of the reference monument before alluded to, but his search had been in vain. He had sought information as to its location from the Indians in the vicinity, and elicited to the effect that some of them remembered the visit of the party which erected it, in October, 1824, and that but few years had elapsed since its total disappearance. They however refused to point out the locality, which they claimed to know, except upon payment of extravagant rewards to themselves and their tribe. After several pow-wows with them, Colonel Forrest, discrediting their statements, had given up hopes of discovering anything from them, and refused to treat further with them. Colonel Forrest stated to me that some Indians had brought to his camp a portion of an oaken log, charred and much decayed, which they averred was a portion of the center post of the old monument. As before, they refused to say where they had gotten it, unless their preposterous demands were complied with, and carried it away with them when they found they were not to obtain the compensation sought.

It is not necessary to seek far for reasons which would explain the disappearance, in the course of forty-eight years, of a wooden post surrounded by a crib-work of logs.

First, it was in a locality frequently visited by Indians, whose habits of wanton destruction are well known; second, the locality in question has been ravaged by forest fires; third, natural decay, which was hastened by the fact, as will hereafter appear, of its being much in the water. We had as data for our search the map of the Commissioners of 1825, on which were marked the positions of the reference monument, the "most northwestern point," and the place where the astronomical observations were made. We had given, also, the latitude and longitude of the most northwestern point, and the courses and distances connecting this point with the reference monument.

The official map was, however, drawn to so small a scale (two inches to one mile), that details of localities, such as the most northwestern point, &c., were not recognizable; but the points of land marked "monument" and "observatory" were distinguished, and in the vicinity of the former point thorough search was made for some trace of the monument by Major Farquhar, Captain Anderson, and myself, assisted by the men of our respective parties. This proving unsuccessful, it became necessary to await the completion of Colonel Forrest's detailed survey. During this interval I verified this survey by independent observations for azimuth and by rerunning the transit lines upon the northeastern shore of the bay, and resurveying in vicinity of the point of land marked "observatory" on the official map. Separate plats having been made and found in agreement, several points in latitude 49° 23′ 55″ (official latitude of most northwestern point) were platted from latitudes obtained by sextant-observations, and from them were platted the official courses and distances to the reference-monument. Failing to obtain by this means any trace of the exact site of the monument, as was supposed on account of the probable discrepancy which would reasonably exist between the official latitude and the latitude derived from our observations, and as the joint commissioners who were to follow us from the Red River had not yet arrived, Major Farquhar directed me to select a point on the tongue of land on which we supposed should be the most northwest point, to erect there a station, make azimuth-observations, and begin the cutting of the due-south line. The station, pyramidal, with twenty-foot center post, was erected, and the cutting begun, but suddenly abandoned for cause, as will appear.

Mr. James McKay, then member of Parliament of the province of Manitoba, and manager for the Dominion government of the "Dawson route," arrived at the Northwest Angle and became at once interested in the search for the lost monument-site. Mr. McKay is of mixed descent, and speaks with fluency the language of the Ojibways, having spent a large portion of his life among them. On this account, and because of his official position and strong personality, he has much influence with the Indians, and obtained one of the old chiefs, who said he knew the place where the monument had been, to go with him and point it out. Accordingly the Indian, accompanied by Mr. McKay, Major Farquhar, and Captain Anderson, went in a canoe to the point of land which we had searched over so many times, and directed attention to a place, directly off the point, among the rushes which everywhere fringe the shore, and in about two and a half feet of water, which he said he knew to be the place where the monument had been.

By wading, Major Farquhar discovered what were to him and those accompanying him satisfactory evidences that this was indeed the monument-site, and especially as the descriptions heretofore given proved that it must have been in this immediate vicinity. There were depressions where portions of two logs had evidently lain at right angles with each other, and, in the included angle, a cavity such as would have been left by the removal of a log, and whence had probably been taken the log before mentioned as having been brought to Colonel Forrest's camp.

The Indians said that the water-surface was, at the time of our visit to the Angle, eight feet higher than it was at the time the monument was erected, and this statement was partially substantiated by the fact that within the knowledge of the white people living at the Angle, there had been no season in which the water had been so high, in the fall of the year. With the water even four feet lower, this site would have been on "firm ground," as such term would be understood in a country low and swampy, like that in the vicinity of the Angle, and, moreover, in a place very convenient for making the necessary connections with the point marked "observatory," and with the "most northwestern point."

We had been misled by the statement of the commissioners, that it was "A monument erected in this Bay, on the nearest firm ground to the above northwest extremity of said Bay," which induced us to constantly search too far inland, where, to the northeast of the point under discussion, and nearer to the most northwestern point, we had found a ledge of granite, *in place*.

The occupation of this rock, however, would have involved the surveyors in a large amount of heavy timber cutting, which was probably, at that time, not practicable.

To sum up the evidence that the point under consideration is the site of the original reference monument, we find the following:

It is in correct position, according to the official map of the commissioners, as nearly as can be selected on a map whose scale is two inches to one mile.

The same is true for the most northwestern point, when connected with this position by the official bearings and distances.

It was pointed out by an Ojibway chief, and recognized by other Indians, all of whom averred that they remembered the visit, to the Angle, of the party that erected the monument, which they had frequently seen in after years.

The official latitude of the most northwestern point, before quoted, differs from that obtained by Captain Anderson, with the zenith telescope, of the same point (accepting this site as correct) by only 4″.7; a very close agreement, when we consider that the original latitude was determined by sun observations, with a sextant.

It was in a prominent and convenient position for connecting with the point marked "observatory," and with the most northwestern point, involving no timber cutting.

Confirmatory evidence in the shape of a letter from Mr. Barclay, Commissioner of the Commission of 1824, who describes the original monument as having been an oaken center post, surrounded by a crib-work of logs seven feet square.

This coincides with the description, given by the Indians, of the monument, and accounts for the relative positions of the depressions discovered by Major Farquhar. As the evidence that the traces found were those of the remains of the old monument was considered satisfactory, the site was accepted by the Chief Astronomers of the Joint Commission, and a station there erected was connected with the due south line through the Northwest Point, and with the astronomical station, by means of a triangle whose base-line, upon the opposite shore of the bay, was three times carefully

measured. The correction to the measured angles is all applied to the angle at the monument, because that angle was measured with a six-inch Negus theodolite, with verniers, whose least count was thirty seconds, and the angles at the base-stations were measured by careful repetitions, with an eight-inch Würdemann transit, with verniers reading to ten seconds.

It was agreed between the Chief Astronomers of the British and United States Commission, that the due south line should be laid off jointly.

Observations for azimuth of the base-line were made by Captain Anderson, upon Polaris near elongation, and by myself, upon Polaris at greatest eastern and western elongations. My observations at West Base, October 18, on Polaris at eastern elongation, gave for azimuth of base-line 119° 03′ 14″.1, and at East Base, October 19, at western elongation of Polaris, 119° 03′ 19″.2. The azimuth adopted by the Chief Astronomers of the Joint Commission, after a comparison of results, was 119° 03′ 10″.0. I then planted a post upon the base-line, at a measured distance from West Base of 138′.4, being the point of intersection of the due south line through Northwest Point with the base-line (obtained as in the following pages), and measured, by careful repetitions, with the eight-inch Würdemann transit, the angle between the base-line and the due south line. At a distance south from this post of about a half mile, another post similar to it was planted; the two giving the direction of the meridian boundary-line. As it was now late in the season, and we were not prepared for winter work, I left the Angle on the 31st of October, by Major Farquhar's order, and arrived at Fort Pembina on the 7th of November.

The work of cutting through the timbered swamps, on the due south line, to the shore line of the Lake of the Woods, was intrusted to the supervision of the British parties, and was accomplished in 1872. The permanent iron pillars marking this line, were placed in the fall of 1874.

In the autumn of 1875, being then engaged in placing the permanent iron pillars on the 49th parallel, I, by direction of the Chief Astronomer, visited the Northwest Angle, and verified, by observation, the correctness of the positions of the three iron pillars nearest the Northwest Point, and the direction of the cutting to the south. I found portions of the various wooden posts located at the Angle in 1872, still standing; but they will soon have disappeared, as the squaws chop their kindling-wood from them.

The Dominion Government has erected several buildings, warehouses, stage-station, &c., on British territory, immediately adjoining the boundary-line. The present steamboat-dock, and the terminus of the Dawson road are near the buildings.

The government boats are, however, still obliged to pass through nearly a mile of American waters, to reach their dock at the terminus of the Dawson road.

Appended, are the computations of the surveys, connecting the reference-monument with the due south line through the Northwest Point, and the Northwest Point with the astronomical station. Also, a map of the Northwest Angle, upon which are marked all of the points hereinbefore discussed.

Computations of surveys.

Stations.	Measured angles.			Corrections.	Corrected angles.			Azimuth and length of base-line.
	°	′	″	″	°	′	″	
West-base	96	53	12.3	0.0	96	53	12.3	119° 03′ 10″
East-base	46	08	33.6	0.0	46	08	33.6	2,191.0 feet.
Monument	36	58	20.0	—5.9	36	58	14.1	

log 2191.0	3.3406424		3.3406424
log sin, west-base	9.9968552	log sin, east-base	9.8579758
A. C. log sin, mon't	0.2208290	A. C. log sin, mon't	0.2208290
	3.5583266		3.4194472
M. — E. B.	3,616.8	W. B. — M.	2,626.9

West-base — east-base, S 60° 56′ 50″; E. 2,191.0 feet.

log dist.	3.3406424		3.3406424
log cos az.	9.6862922	log sin az.	9.9415973
	3.0269346		3.2822397
	S. 1,064.0		E. 1,915.3

Monument — west-base, S. 22° 09′ 57″.7; W. 2,626.9 feet.

log dist.	3.4194472		3.4194472
log cos az.	9.9666553	log sin az.	9.5766773
	3.3861025		2.9961245
	S. 2,432.8		W. 990.8

The courses and distances from the reference-monument to the "most Northwestern point," as established by the Commissioners, under the seventh article of the treaty of Ghent, are as follows:—

1st, N. 56° W.......1,565¼ feet.
2d, N. 6° W.......861⅓ feet.
3d, N. 28° W.......615.4 feet
4th, N. 27° 10′ W.......495.4 feet
5th, N. 5° 10′ E.......1,322⅓ feet.
6th, N. 7° 45′ W.......493 feet.

The variation being 12° east.

These courses and distances give, with true bearings, the following results for latitude and departure:—

Northing.					Easting.	Westing.
	3.1946531	1st course.	log dist.	3.1946531		
	9.8569341	log cos.	44°, log sin	9.8417713		
1126.1	3.0515872			3.0364244		1087.5
	2.9352553	2d course.	log dist.	2.9352553		
	9.9976143	log cos.	6°, log sin.	9.0192346		
856.8	2.9328696			1.9544899	90.1	
	2.7891575	3d course.	log dist.	2.7891575		
	9.9828416	log cos.	16°, log sin	9.4403381		
591.6	2.7719991			2.2294956		169.6
	2.6949560	4th course.	log dist.	2.6949560		
	9.9846033	log cos.	15° 10′, log sin	9.4176837		
478.1	2.6795593			2.1126397		129.6
	3.1213957	5th course.	log dist.	3.1213957		
	9.9802081	log cos.	17° 10′, log sin	9.4700461		
1263.6	3.1016038			2.5914418	390.3	
	2.6928469	6th course.	log dist.	2.6928469		
	9.9988041	log cos.	4° 15′, log sin	8.8698680		
491.6	2.6916510			1.5627149	36.5	
4807.8 total northing.					516.9	1386.7
						516.9
			Total westing,			869.8
			West-base, west of ref. mon't,			990.8
			Northwest Point, east of west-base,			121.0

Referring to the accompanying map, in the right angled triangle west-base A P, there is given the distance west-base A, and by subtracting the azimuth of the base-line (119° 03′ 10″) from 180°, is obtained the angle opposite and equal to the angle at P; hence

log 121.0	= 2.0827854
A. C. log sin 60° 56′ 50″	= 0.0584027
138.4 feet	= 2.1411881

which is the distance laid off on the base-line, from west-base to the meridian line through the Northwest Point.

The astronomical latitude post was connected with the post at east-base, as follows—bearing being true:

Transit post to stake "A" N. 25° 25′ 30″; E. 325.1 feet.

Northing.					Easting.
	log dist.	2.2510170	log dist.	2.5120170	
	log cos az.	9.9557589	log sin az.	9.6327905	
293.6		2.4677759		2.1448075	139.6

Stake "A"—east-base, N. 41° 35′ 30″; E. 847.0 feet.

	log dist.	2.9278834	log dist.	2.9278834	
	log cos az.	9.8738404	log sin az.	9.8220487	
633.5		2.8017238		2.7499321	562.3
927.1 total northing.				Total easting,	701.9

	Northing.	Easting.	Westing.
Zenith telescope post to transit post,	6.0		28.0
Transit post to east-base,	927.1	701.9	
East-base to reference monument,	3496.8		924.2
Reference monument to Northwest Point,	4807.8		869.8
Zenith telescope post to Northwest Point,	9237.7		1822.0
			701.9
			1120.1

Latitude of zenith telescope post (Anderson),	49° 22′ 19″.137
9237.7 feet =	1′ 31″.146
Latitude of Northwest Point,	49° 23′ 50″.28
Longitude of Northwest Point (by survey of British party from Astronomical Station Lake of Woods),	95° 08′ 56″.7

CHIEF MOUNTAIN LAKE.

Chief Mountain Lake lies at the eastern base of the main divide of the Rocky Mountains, and across our northern boundary-line, in longitude about 113° 53′ west from Greenwich. To the east of it is an outlying range of mountains, which, breaking from the main range some miles south of the head of the lake, trends along its eastern shore, and terminates abruptly near its foot.

The lake consists of two quite distinct basins, connected by a narrow and deep strait. Of these the most southerly is seven miles long, and varies from a half mile to nearly a mile in width. It is by far the larger, constituting, in fact, the body of the lake, and will be understood when in the following narrative the term lake is used.

Hemmed in on all sides by ranges of towering, precipitous mountains, whose peaks rise from two thousand to six thousand four hundred feet

above it, the lake is unapproachable by any route save by the valley of its outlet, the Waterton River.

By turning northward, therefore, from a point on the boundary-line about twenty miles east of the lake, we headed off the outlying mountain-range described, and following up the valley of the Waterton River, reached the foot of the lake, with our wagons, on the 18th of August. Camp was pitched the same evening on a fine shingle-beach at the foot of the lake, a position which, besides the practical desideratum of proximity to an abundant supply of pure, cold water, afforded us also a comprehensive view of lake and mountain scenery, which, for picturesque beauty and grandeur, is probably not excelled, if equaled, by any on the continent.

The lake and neighboring mountain-streams abound with delicious fish, and the vicinity of our camp with dusky-grouse. One fish, said to be a salmon-trout, weighing over twenty-one pounds, was caught from the lake by a soldier, with a hook fashioned from the rim-wire of some tin utensil; and many red-speckled trout were caught from the mountain-streams that weighed in the vicinity of three pounds.

The water of the lake is, of course, clear and cold, and of great depth. I regret that I had at hand no means of taking soundings. A piece of twine over three hundred feet long, with a heavy weight attached, did not reach bottom when let out at a point about two hundred yards from the shore, near Station No. 20. There is no current perceptible except near the outlet of the northern basin before mentioned.

The purpose of my visit was to establish on the shore of the lake the last astronomical station of the survey, and to make a geodetic and topographical survey of the lake and neighboring mountain-region.

Having found by observations with the sextant for latitude that our camp was three and a half miles north of the 49th parallel, I was obliged to cast about for means of water-transportation to the boundary-line, as a very cursory examination was sufficient to demonstrate the unfeasibility of a journey there by land, on account of the precipitous nature of the mountain-sides.

After some experiments with improvised boats composed of wagon-boxes with covers of tent-canvas, which failed on account of the permeability to water of the thin canvas, I finally achieved success in two boats which were modifications of the above. One of these was a wagon-box with the ends and all cracks covered with pieces of raw-hide closely tacked on, and the whole covered with canvas. The other, as the supply of hide was exhausted, was a wagon-box fastened on top of a raft composed of seven logs, to which additional buoyancy was given by securing empty water-casks between the outside logs on each side of the raft. Paddles were used for propulsion, the paddlers being squatted in the bottom, as the crankiness of the boats would not permit the use of elevated seats such as are necessary for oarsmen.

We were ready for the trip up the lake on the evening of the 20th, but a severe storm came up that night which lasted for two days, causing delay and some damage to our boats, which, however, was soon repaired.

On the evening of the 22d, the night, though dark, was still, and I determined to take advantage of the lull to make, at least, part of the distance to the boundary-line before daylight. Leaving the main portion of my party in charge of Dr. Elliott Coues, United States Army, I embarked, about 8 p. m., with my assistants, Mr. Boss and Mr. Edgerton, and five men, the necessary instruments, seven days' rations, and as much camp-equipage as was absolutely necessary. Once fairly out upon the lake the darkness appeared thicker than before, and land-positions were totally unrecognizable. The labor of forcing the unwieldy and heavily-loaded crafts through the water, and our constrained positions in the bottoms of the boats, which we were unable to relieve by change, as the slightest motion produced unpleasant tips, suggestive of capsize and the certain loss of all our instruments, made us all very tired, and we were glad to find a convenient little beach where we landed about 11 p. m., and bivouacked for the night. We had made, in the three hours of toilsome paddling, about one and a half miles.

In the early morning we were again under way, and arrived about 9 a. m. at a good landing-place on the western shore, which was opposite a point on the eastern shore previously determined, by triangulation from the sextant position before mentioned, to be, approximately, in latitude 49°. There we landed our effects, and near by, on a convenient bottom-land, set up the observatory, where astronomical work was begun the same evening.

On the 24th I made an exploration up the ravine of a creek which tumbles down between the mountains, west of Station No. 20, with the hope of finding some accessible points, by means of which a trigonometrical connection could be effected between my station and the Akamina station—the last station established by the Northwestern Boundary Survey in 1861. The latter is on the main divide of the mountains, and, as I knew, only about seven miles west of Station No. 20. After several hours of toilsome climbing, I became persuaded that the project was impracticable, and reluctantly abandoned it.

The latitude-work was completed, and the stone mound which marks the boundary-line erected, on the 26th.

The instruments, &c., were repacked in the boats the same afternoon, and although the wind was blowing almost a gale from the south, making the lake very rough, it was a fair wind for us, and all hands preferred taking the chances of disaster in the day-time, to risking the possibilities of another night-trip. We therefore started about 3 p. m., and by means of square sails extemporized from tent-flies, sped along in quite gallant style. Our unceasing efforts were, however, required to keep the crafts before the wind, and tolerably free from water. The surf was running very high upon the beach near camp, and I greatly feared the danger of capsize in the attempt to land there, for which there was no alternative; but this calamity was averted by several of my men, who from the shore were anxiously watching our progress. They appreciated the situation, and making into the breakers, at exactly the proper moment, seized each boat, as she arrived in shoal water, and bore her upon the wave-crests, high and dry upon the beach.

Immediate preparations were made for the march eastward, which was begun next morning, August 27.

The geodetic and topographical work, I gave into the hands of my assistant, Mr. Lewis Boss, who, laboring under many difficulties, rapidly and accurately performed it. As soon as boat No. 1 was completed, he used it to transport himself, men, and instruments, from point to point on the lake, until we were ready for our trip to Station No. 20. He accompanied me there, and finished his work by the same means, during the time that I was busy at the station.

Though the boat was more manageable when not loaded down with freight, it was yet very unwieldy, and could be propelled but slowly with great expenditure of power, and as the lake was subject to sudden flaws and squalls, crossing it in such a craft, was not only difficult but a matter of considerable concern as to safety.

The geodetic work consisted of a base-line, 1,199.2 feet long, several times carefully measured with a chain, and twenty-four triangles dependent upon it, whose angles were measured, by repetitions, with a six-inch Negus theodolite, reading by verniers to thirty seconds.

The azimuth of the base-line was determined, by observations of Polaris near eastern elongation, on the nights of August 18 and 19, to be 0° 51′ 36″.

There were taken at each of the twenty-one trigonometrical stations occupied, numerous horizontal and vertical angles to prominent mountain-peaks, by means of which twenty such peaks have been platted, and their elevations above the lake determined.

The topography is laid down from continuous shore-line sketches, and numerous profile sketches made at the various stations.

The accompanying sketch shows, on a scale of $\frac{1}{50,000}$, the scheme of triangulation accomplished, and, incidentally, the heights above the lake of the mountain-peaks located. The height of the lake-surface was determined, barometrically, to be four thousand two hundred and thirteen feet above the sea.

From the mean of numerous differences between the true bearings of triangulation-lines and the compass-bearings of the same, the magnetic variation was ascertained to be east 23° 19′.

CHRONOMETER PERFORMANCES.

In connection with my work during the seasons of 1873 and 1874, observations with the sextant, for local time, were made at nineteen points on the boundary-line where longitudes were afterward determined. The chronometers used were subject to conditions similar to those which gene-

rally pertain to those expeditions of exploration or survey which, from the nature of the country traversed, can use wagons as their means of transportation. Therefore, if the longitudes of these points were accurately known, we should have data for estimating, with considerable accuracy, within what probable limit of error chronometric differences of longitude are reliable, when obtained with similar instruments used under similar circumstances. Unfortunately, the longitude of any station is possibly in error to an amount sufficient to largely increase such estimate, but as it does not probably exceed, at any station, five or six seconds of time ($1^s =$ 999.75 feet in latitude 49°), there are still data affording some interesting comparisons with chronometer-longitudes.

We may also satisfactorily ascertain how the chronometers were performing at various stages during the progress of the work, inasmuch as only the difference of the errors of the accepted longitude of consecutive stations enters to affect the determination of the traveling rates between those stations, and this is inappreciable, in comparison with the possible errors of rates derived from observations with the sextant, made at short intervals of time.

The great and frequent changes of temperature to which the chronometers were subject, and the incomplete record of the same, the necessarily rough method of transportation, and the method employed to obtain rates, all combine to preclude refinement in the discussion of results; but I know of no expedition which covers so great an extent of time and travel, where the checks are as good, and this has induced me to elaborate the accompanying tables.

The chronometers used are enumerated in the tables. Nos. 1481 and 1513, Negus, were new instruments, purchased by the commission in 1873. They were swung in gimbals. 1319, Negus, was the property of the Navy Department, and was not a new instrument. 235, Bond, was an old instrument, formerly used on the survey of the northwestern boundary-line. The last two were in ordinary leather cases. All were habitually transported from station to station in a four-spring wagon, generally, in 1873, incased in a cotton-padded box, but in 1874, under the care of an assistant, on the cushioned seat of the wagon. In camp, they were kept in the

observatory tent, where they were free from disturbance, but subjected to greater ranges of temperature than obtained in the open air; the minimum temperatures in the tent and outside being about the same, while, on hot days, the maximum in the tent exceeded, by several degrees, that of the open air.

It was usual to compare the chronometers daily at noon, for which time the corrections were deduced when sun-observations for time were made east and west at corresponding hour-angles. When the observations were made at night, or only east or west, they were compared at the time of observation.

The longitude of Station No. 1 was determined telegraphically by an officer of the British Commission working at that station, in connection with an observer at the Chicago Observatory. From this is deduced that of the succeeding stations, including No. 19, by means of the chained distances along the line between stations. The longitude of Station No. 20, and our determination of the longitude of Akamina Station, depend upon traverse-lines connecting them with the British Station, marked on the joint maps No. 38. The longitude of Akamina Station, so determined, differs from the result obtained by the astronomers of the Northwestern Boundary Survey, by the method of lunar culminations, by 2.1 seconds of time, the latter being the greater.

The longitude of the meridian-line traced by Lieutenant Greene from the boundary-line to Fort Shaw, Montana, is less than the longitude of the same derived from the land-survey determination of their principal meridian near Fort Shaw by 8.5 seconds of time.

Transportation of chronometers from Fort Shaw to Bozeman, Mont., of which the longitude is known by telegraph, gave a longitude for our meridian-line 4.1 seconds of time greater than the boundary-determination of the same.

Taking into consideration all of the circumstances attending the various determinations (for details of these longitudes see Lieutenant Greene's report), I think we may safely say that the error in the accepted longitude of any station does not, in all probability, exceed the amount stated.

Table I gives the errors of the chronometers on Washington time for the dates and stations recorded in columns 1 and 2. There are also given the maximum and minimum open-air temperatures for various dates during the seasons. These were recorded from thermometers hung near the tent in which the chronometers were kept, except for dates September 7, 8, and 12, which are from the records of Wood End Depot.

Table II shows the rates of the chronometers derived from observations on dates given in column 1, which are so selected as to show rates when the chronometers were stationary and traveling alternately.

The sources of error in these rate-determinations are the difference of the errors in longitude of consecutive stations, which enters directly into the traveling rates, but is probably very small, and the algebraic sum of the errors of the chronometer-corrections for the two dates from which the rates are derived, which is diminished proportionately to the number of days intervening between the dates of the observations from which the rates were determined.

I do not think that the error of observation, in any case, is as much as two seconds, as the observations were usually made at corresponding hour-angles east and west, or with a sextant whose eccentricity had been carefully determined.

The results do not show any decided changes of rates, from stationary to traveling, and *vice versa*; they are probably small, and are obscured by the error mentioned. The general rates for the seasons were quite well preserved until the time of low mean temperatures. For instance, during the season of 1873, to the last of August, and of 1874, the season-rate of any chronometer does not differ from any rate given for it in the table by more than $0^s.8$ in 1873, and $1^s.2$ in 1874, reaching those limits only in single instances.

In 1873, however, the rates of chronometers 1319, 1481, and 235, for September, differ from their rates of the rest of the season by $2^s.4$, $1^s.6$, and $2^s.6$, respectively, and the rates of the last half of September, from the same, by $3^s.6$, $2^s.8$, and $3^s.5$, respectively. The reason for the very large losing rates during September, 1873, is obvious from an inspection of the temperatures to which they were then subject.

There have been many discussions of the effects upon the rates of wellcompensated chronometers of various degrees of temperature, but none that I know of where they were subjected to so great extremes as were ours.

Chronometers on trial at the Greenwich Observatory are, in the course of several months, subjected to temperatures between the limits of +40° and +95°, during which time their daily rates are weekly summed, in the order of dates and the order of temperatures, for the purpose exhibited in Table III.

In the discussions of the chronometric expeditions between Liverpool and Cambridge, Professor Bond deduces formulæ for temperature-corrections to the rate for limits of temperature 20° either way from the compensation-temperature. But, in our work, we had at times extremes of temperature of over 50° within twenty-four hours' time, and the extremes, during the season of 1873, were 81° apart, so that none of the discussions are applicable in this case. There only remains to be said in reference to this important point, that our results do not show sensible changes in rates for variation of temperature such as usually occur during ordinary summer and fall weather, say for a variation of 25° either way from 65°.* When, however, the minimum was daily below 40° for a continued period, as in September, 1873, the rates became irregular, and when the minimum was continuously 35° and below, entirely unreliable Whether, at ordinary winter-temperatures, we might expect uniform losing rates to be established, there are not sufficient data to decide, but from the record of chronometer 1455 (see Table II), such would appear to be the case. This chronometer was used by Lieutenant Greene during the summer of 1873 and the following winter. The record of temperatures for the months given is from the record of the Medical Department, United States Army, kept at Fort Pembina. (See Circular No. 8, War Department, S. G. O., 1875.)

It also appears from the table that chronometers 1481, 235, and 1319, in 1873, and 1513, 235, and 1319, in 1874, were meritorious in the order named. This decision is confirmed in Table III, in which, following the method adopted at the Greenwich Observatory, in the tabulated results of

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* In other words the changes due to variation of temperature are obscured by errors in rate-determinations and by changes of rate due to jolting, &c., of the chronometers.

the trials of chronometers for purchase, the order of merit is determined by means of the differences between the greatest and least weekly rates, and the greatest differences between the rates of consecutive weeks. The weekly rates in Table III are derived from Table I, by interpolation, and of course are only approximate, but near enough the truth to make the comparisons indicated.

Table IV gives the accepted longitudes of nineteen points on or near the boundary-line, and the longitudes, by chronometers, of seventeen of them. The rates used in calculating the difference of longitude between consecutive stations, are those obtained at the nearest preceding station, and are used in preference to the mean of those at the stations whose difference in longitude is required, because of the long time elapsed, in some instances, and because at the latter stations in 1874, and at the last in 1873, no rates were determined. In some instances, all of the chronometers were not compared and the differences mentioned depend upon two, and, from Station 20 to Sweetgrass Hills, upon one chronometer. The longitude, by chronometers, of any station given in the table, is the sum of the mean of chronometric differences between the preceding stations; the difference, therefore, at any station, between the accepted and chronometer-longitude, is the total difference, by the two methods, from the initial station.

It is usual with expeditions which determine longitude by transportation of chronometers, to return them to the starting-point, or to arrive with them at some point of which the longitude is known, and by means of the differences of chronometer-errors at the starting and terminal points, the difference of longitude between the two points, and the elapsed time, to deduce a daily rate, which is assumed to have been uniform during time of travel, by means of which intermediate points are fixed in longitude.

To make a case nearly similar, I use the data of Table IV, and rates for 1873 deduced from the observations of June 7 and 8, and August 31, and rates for 1874 derived from the dates July 5.3, and August 13.3, as given in Table II. There result the chronometer-longitudes given in Table V, which, as was to be expected, agree generally better with the accepted longitudes than do those of Table IV, excepting of course Stations 10, 11, and 12, where low temperatures prevailed.

The mean of the differences between the accepted longitudes and the longitudes of the stations by either of the mentioned methods, or between the latter, excepting the last three stations of 1873, is less than two seconds of time, and the greatest difference, at any station, only reaches five seconds, the same stations excepted.

If we suppose that the mean error of the accepted longitude increases the mean differences mentioned by two seconds, and that the greatest error at any station increases the greatest difference by six seconds, which is taking the most unfavorable combinations possible, we have, for the mean error of the chronometer-longitudes of stations, four seconds of time, and for the limit of error, eleven seconds, or, in latitude 49°, about four-fifths of a mile and two miles respectively.

TABLE I.

Errors of Chronometers on Washington time.

Station.	Date.	Mean time chr. 1319, Negus & Co. Slow.	Sidereal chr. 1481, Negus & Co. Slow.	Sidereal chr. 235, Bond & Son. Slow.	Date.	Air temperatures. Max.	Air temperatures. Min.	Date.	Air temperatures. Max.	Air temperatures. Min.
	1873.	h. m. s.	h. m. s.	h. m. s.	1873.	°	°	1873.	°	°
Fort Pembina	June 2	1 23 55.5	1 16 38.4	....	June 15	84	68	Aug. 9	89	45
	7	1 24 02.1	....	....	16	85	62	10	91	40
	8	03.4	30.0	0 06 41.7	17	86	74	11	89	48
No. 2	10	06.2	29.3	41.2	18	88	63	12	85	52
3	12.16	10.6	28.7	43.0	19	73	68	19	97	55
3	15	16.9	28.0	45.1	20	78	66	20	75	43
3	17.17	22.6	24.3	40.5	21	68	55	21	79	27
5	26	37.1	13.0	....	22	66	55	22	81	37
5	29	42.9	....	36.9	29	73	66	23	86	55
5	30	41.3	07.1	32.9	30	77	47	24	81	42
5	July 1	42.8	07.6	32.0	July 1	82	35	25	72	55
5	6	50.5	04.0	27.3	2	86	53	26	90	57
5	9	55.5	1 16 03.0	26.5	3	80	48	28	94	49
5	12	1 24 58.0	1 15 59.5	26.2	4	66	44	29	79	38
5	15	1 25 00.2	55.7	22.9	5	70	33	30	86	41
7	30	18.3	36.3	17.6	6	83	32	31	89	43
7	Aug. 1	21.9	34.3	18.4	7	68	45	Sept. 4	73	35
7	2	25.3	34.5	20.3	8	74	33	5	76	25
7	6	28.5	28.0	16.1	9	72	49	6	73	35
7	7	29.8	26.3	14.5	10	77	32	7?	75	23
9	18	54.0	14.8	09.7	11	84	49	8?	80	28
9	19	1 25 57.9	12.7	10.7	12	88	51	12?	62	37
9	29	1 26 22.9	00.8	12.8	13	88	45	15	72	33
9	30	25.1	1 15 00.3	13.6	14	88	34	16	77	26
9	31	26.2	1 14 58.4	14.6	15	83	53	17	73	30
10	Sept. 4.3	41.4	58.4	20.2	16	72	60	20	71	32
10	5	39.2	53.6	....	30	80	49	21	65	30
10	6	45.6	57.6	22.9	31	66	49	22	79	30
10	7.04	1 26 48.2	57.2	23.8	Aug. 1	72	44	23	69	34
11	15.13	1 27 12.1	50.4	36.1	2	86	35	24	50	29
11	17.34	21.2	54.5	47.0	3	87	39	25	51	29
12	21	39.8	1 14 57.8	0 06 55.2	4	95	53	26	47	24
12	22	1 27 44.8	1 15 00.3	0 07 01.6	5	76	62	27	47	19
12	28.04	1 28 20.2	1 15 12.3	0 07 18.6	6	86	50	28	49	14
					7	91	60	29	49	17
					8	94	58			

Station.	Date.	Mean time chr. 1319, Negus & Co. Slow.	Sidereal chr. 1513, Negus & Co. Slow.	Sidereal chr. 235, Bond & Son. Fast.	Date.	Air temperatures. Max.	Air temperatures. Min.	Date.	Air temperatures. Max.	Air temperatures. Min.
	1874.	h. m. s.	h. m. s.	h. m. s.	1874.	°	°	1874.	°	°
No. 13	July 5.3	2 08 00.9	1 47 40.1	9 55 47.9	July 6	98	60	July 25	85	46
13	8.3	08.6	40.8	47.4	7	101	60	30	84	50
14	10.2	12.5	41.0	48.8	8	101	45	31	81	48
14	10.8	12.6	41.5	49.7	11	98	44	Aug. 1	81	49
14	12.4	14.9	41.9	49.8	12	93	51	2	80	48
15	15.4	16.5	39.8	51.8	16	93	50	8	79	54
15	20.35	20.2	37.7	54.4	17	92	57	9	85	49
16	22.2	23.8	39.0	....	18	89	54	10	85	50
16	25.4	26.0	38.8	45.0	19	88	37	14	76	45
17	29.0	29.5	36.5	45.8	22	87	38	15	77	36
17	Aug. 2	35.3	31.3	50.3	23	89	50	16	77	33
Depot Camp	4	36.2	29.3	53.2	24	89	56	Sept. 3	105	55
No. 18	8	37.3	24.1	58.1						
19	13.55	2 08 44.2	21.3	9 55 58.8						
20	18.4	....	16.8	....						
20	25.1	....	11.7	....						
Sweet-grass Hills	Sept. 1.4	....	1 47 05.4	....						

TABLE II.

Daily rates.

Dates.	Mean time chr. 1319, Negus & Co.	Sidereal chr. 1481, Negus & Co.	Sidereal chr. 2 5, Bond & Son.	Traveling or stationary.
1873.	*s.*	*s.*	*s.*	
June 2 to 8..	1.3 losing	1.4 gaining	....	S.
June 8 to 12.16.	1.7 losing	0.3 gaining	0.3 losing.	T.
June 12.16 to 17.17.	2.3 losing	0.9 gaining	0.5 gaining	S.
June 17.17 to 26.	1.6 losing.	1.3 gaining	....	T.
June 17.17 to 29.	....	....	0.3 gaining	T.
June 26 to July 15.	1.2 losing	0.9 gaining	....	S.
June 29 to July 15.	....	....	0.9 gaining	S.
July 15 to 30	1.2 losing	1.3 gaining	0.4 gaining	T.
July 30 to Aug. 7.	1.4 losing.	1.3 gaining	0.4 gaining	S.
Aug. 7 to 18	2.2 losing	1.1 gaining	0.4 gaining	T.
Aug. 18 to 31	2.5 losing	1.3 gaining	0.4 losing	S.
Aug. 31 to Sept. 4.3.	3.5 losing.	0.0 gaining	1.3 losing	T.
Sept. 4.3 to 7.04.	2.5 losing	0.4 gaining	1.3 losing	S.
Sept. 7.04 to 15.13.	3.0 losing.	0.8 gaining	1.5 losing.	T.
Sept. 15.13 to 17.34.	5.5 losing	1.9 losing	4.9 losing	S.
Sept. 17.34 to 21.	4.3 losing	0.8 losing	2.2 losing	T.
Sept. 21 to 28.04.	5.9 losing.	2.1 losing.	2.8 losing	S.
June 2 to Aug. 31.	1.7 losing	1.1 gaining	....	T. and S.
June 8 to Aug. 31.	....	....	0.3 gaining	T. and S.
June 8 to Sept. 28.04.	2.3 losing	0.7 gaining	0.3 losing	T. and S.
Aug. 31 to Sept. 28.04.	4.2 losing	0.5 losing	2.3 losing	T. and S.
Sept. 15.13 to 28.04.	5.3 losing.	1.7 losing.	3.2 losing	T. and S.

Dates.	Mean time chr. 1319, Negus & Co.	Sidereal chr. 1513, Negus & Co	Sidereal chr. 235, Bond & Son.	Traveling or stationary.
1874.	*s.*	*s.*	*s.*	
July 5.3 to 8.3.	2.6 losing	0.2 losing	0.2 losing	S.
July 8.3 to 10.2.	2.0 losing.	0.2 losing	0.7 gaining	T.
July 10.2 to 12.4.	1.1 losing.	0.4 losing	0.5 gaining	S.
July 12.4 to 15.4.	0.5 losing.	0.7 gaining	0.7 gaining	T.
July 15.4 to 20.35.	0.8 losing.	0.4 gaining	0.5 gaining	S.
July 20.35 to 22.2.	1.9 losing.	0.7 losing	....	T.
July 22.2 to 25.4.	0.7 losing.	0.0.......	....	S.
July 25.4 to 29.	1.0 losing.	0.6 gaining	0.0.......	T.
July 29 to Aug. 2.	1.6 losing.	1.3 gaining	1.1 gaining	S.
Aug. 2 to 4..	0.5 losing.	1.0 gaining	1.5 gaining	T.
Aug. 4 to 8..	0.3 losing.	1.3 gaining	1.3 gaining	T.
Aug. 8 to 13.55.	1.2 losing.	0.5 gaining	0.0.......	T.
Aug. 13.55 to 18.4.	....	0.9 gaining	....	T.
Aug. 18.4 to 25.1.	....	0.8 gaining	....	S.
Aug. 25.1 to Sept. 1.4.	....	0.9 gaining	....	T.
July 5.3 to Aug. 13.55.	1.1 losing.	0.5 gaining	0.3 gaining	T. and S.
July 5.3 to Sept. 1.4.	....	0.6 gaining	....	T. and S.

Dates.	Mean time chr. 1455, Negus & Co.	Traveling or stationary.
1873.	*s.*	
June 14 to July 4 ...	0.45 gaining	T. and S.
July 4 to 22.......	1.0 losing..	T. and S.
July 22 to Sept. 1...	3.9 losing..	T. and S.
Sept. 1 to 15........	3.3 losing..	T. and S.
Sept. 15 to 30.......	2.3 losing.	T. and S.
Nov. 6 to Dec. 5 ...	6.0 losing..	T. and S.
Dec. 5 to 9...........	5.3 losing..	T. and S.
Dec. 9 to 12	3.1 losing..	T. and S.
Dec. 12 to 19.........	5.1 losing..	T. and S.
Dec. 19 to 20.........	6.7 losing..	T. and S.
Dec. 20 to Jan. 17....	7.1 losing..	T. and S.

FORT PEMBINA.			
Month.	Temperature.		
	Mean.	Max.	Min.
1873-'74.	°	°	°
November ..	15.65	45	−25
December..	6.76	35	−27
January	− 3.17	37	−44

TABLE III.

Weekly rates, 1873.

No. of chronometer.	June 2 to 9.	June 9 to 16.	June 16 to 23.	June 23 to 30.	June 30 to July 7.	July 7 to 14.	July 28 to August 4.	August 4 to 11.	August 11 to 18.	August 8 to 25.
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1319	−9.3	−14.2	−11.5	−10.7	−11.6	−7.3	−11.0	−11.7	−15.4	−18.9
1481	+8.8	+ 1.9	+11.2	+ 9.4	+ 3.3	+9.4	+ 6.7	+ 9.3	+ 7.5	+ 8.8
235	....	− 2.7	(16−30) +5.9		+ 5.9	+3.0	+ 0.1	+ 5.5	+ 4.3	− 2.3
Temperatures:	°	°	°	°	°	°	°	°	°	°
Maximum	....	....	88	77	86	88	95	95	89	86
Minimum	....	....	55	47	32	32	35	40	48	27

No. of chronometer.	August 25 to September 1.	September 1 to 8.	September 8 to 15.	September 15 to 22.	September 22 to 29.	Least weekly rates.	Greatest weekly rates.	Difference.	Greatest difference between consecutive weeks.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1319	−14.4	−12.5	−31.7	−33.3	−51.0	−51.0	− 7.3	43.7	17.7
1481	+ 7.2	+ 2.0	+ 5.3	− 9.2	−13.9	−13.9	+11.2	25.1	9.3
235	− 3.6	− 9.0	−11.3	−25.7	−31.3	−31.3	+ 5.9	37.2	14.4
Temperatures:	°	°	°	°	°				
Maximum	94	76	73	79	79	....	....	....	....
Minimum	38	25	33	26	14	....	....	....	....

Weekly rates, 1874.

No. of chronometer.	July 5 to 12.	July 12 to 19.	July 19 to 26.	July 26 to August 2.	August 2 to 9.	August 9 to 16.	August 16 to 23.	August 23 to 30.	Least weekly rates.	Greatest weekly rates.	Difference.	Greatest difference between consecutive weeks.
	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1319	−13.8	−4.7	−7.1	−9.2	−2.3	−9.6	....	....	−13.8	−2.3	11.5	9.1
1513	− 1.8	+3.5	+0.8	+6.2	+7.7	+4.6	+5.6	+6.0	− 1.8	+7.7	9.5	3 1
235	+ 1.9	+3.9	−0.4	+7.4	+5.9	+6.4	+8.9	+2.1	− 0.4	+8.9	9.3	7.8
Temperatures:	°	°	°	°	°	°						
Maximum	101	98	89	84	85	85	....	....	....	....	....	....
Minimum	44	50	57	48	48	33	....	....	....	....	....	....

NOTE.—The sign + indicates a gaining, and − a losing rate.

TABLE IV.

Relative Longitudes of Stations, by Chronometers from Fort Pembina, and by Chain from Station No. 1.

Station.	Date.	Correction to local time.			West of preceding station by chronometer.	Longitude west of Washington.	
		Mean time chr. 1319, Negus & Co.	Sidereal chr. 1481, Negus & Co.	Sidereal chr. 235, Bond & Son.		By chronometer from Fort Pembina.	By chain from Stat'n No. 1.
	1873.	m. s.	m. s.				h. m. s.
Fort Pembina (flag-staff)	June 2	+ 3 25.9	− 4 04.39	(Longitude of Station No. 1 by telegraph			1 20 43.04
	8	+ 3 33.8	− 4 12.79	(Longitude of Fort Pembina flag-staff			1 20 42.77
Rate	....	Losing 1.32	Gaining 1.4		m. s.		
U. S Station No. 2	10	+ 1 50.4	− 5 59.95	....	1 46.33		
					1 44.36	h. m. s.	
Rates as at Fort	Pembina.			h. m. s.	M. 1 45.35	1 22 28.12	1 22 29.29
U.S. Station No. 3	June 12	+ 0 34.5	− 7 20.88	....	1 18.75		
	12.16	....	....	− 1 17 06.78	1 18.13		
	17.17	+ 46.5	− 7 26.09	− 1 17 09.34			
Rate	....	Losing 2.32	Gaining 1.01	Gaining 0.51	M. 1 18.44	1 23 46.56	1 23 49.81
U. S. Station No. 5	June 26	− 2 35.7	− 11 14.1	....	3 43.30		
	30	....	....	− 1 20 54.14	3 39.09		
	July 15	− 2 12.6	− 11 31.36	− 1 21 04.21	3 38.26		
Rate	....	Losing 1.22	Gaining 0.91	Gaining 0.67	M. 3 40.22	1 27 26.78	1 27 27.08
U. S. Station No. 7	July 30	− 12 05.5	− 22 03.48	− 1 31 22.24	10 12.88		
	Aug. 7	− 11 54.0	− 22 13.58	− 1 31 25.30	10 18.47		
					10 07.98		
Rate	....	Losing 1.41	Gaining 1.26	Gaining 0.38	M. 10 13.11	1 37 39.89	1 37 39.80
U. S Station No. 9	Aug. 18	− 18 21.2	− 29 17.595	− 1 38 22.69	6 41.14		
	30	− 17 50.1	− 29 32.103	− 1 38 18.77	6 50.16		
					6 53.21		
Rate	....	Losing 2.6	Gaining 1.21	Losing 0.33	M. 6 49.17	1 44 29.06	1 44 32.36
U. S. Station No. 10	Sept. 4.3	− 21 10.8	− 33 11.52	− 1 41 49.65	3 35.07		
	7.04	− 21 04.0	− 33 12.67	− 1 41 46.06	3 33.01		
					3 32.63		
Rate	....	Losing 2.48	Gaining 0.42	Losing 1.31	M. 3 33.57	1 48 02.63	1 48 09.88
U. S. Station, No. 11	Sept. 15.13	− 25 06.5	− 37 46.658	− 1 46 00.948	4 23.28		
	17.34	− 24 54.36	− 37 42.5	− 1 45 50.05	4 30.60		
					4 25.49		
Rate	....	Losing 5.49	Losing 1.88	Losing 4.93	M. 4 26.46	1 52 29.09	1 52 37.04
U. S. Station No. 12	Sept. 21	− 28 39.0	− 41 40.084	− 1 49 42.696	4 05.40		
					4 04.47		
			Sid. chr. 1513,		4 10.69		
			Negus & Co.		M. 4 06.85	1 56 35.94	1 56 37.9
U. S. Station No. 13 *	July 5.3	− 6 57.92	− 13 42.70	−11 57 10.7			
	8.3	+ 7 05.69	− 13 42.00	−11 57 10.25			
Rate	....	Losing 2.59	Losing 0.23	Losing 0.15	....	....	2 01 22.82
U. S. Station No. 14	July 10.2	+ 3 52.7	− 16 59.26	−12 00 29.06	3 18.45		
	12.4	+ 3 55.1	− 16 58.37	−12 00 30.05	3 17.70		
					3 19.10		
Rate	....	Losing 1.69	Losing 0.405	Gaining 0.45	M. 3 18.42	2 04 41.24	2 04 40.22
U. S. Station No. 15	July 15.4	− 46.4	− 21 44 28	−12 05 15.9	4 45.55		
	20.35	− 42.67	− 21 46.4	−12 05 18.48	4 47.12		
					4 44.50		
Rate	....	Losing 0.75	Gaining 0.43	Gaining 0.52	M. 4 45.72	2 09 26.96	2 09 24.12
U. S. Station No. 16	July 22.2	− 3 43.4	− 24 49.88	No comparison.	3 02.62		
	25.4	− 3 41.23	− 24 50.16		3 02.69		
Rate	....	Losing 0.68	Gaining 0.09		M. 3 02.65	2 12 29.61	2 12 28.91
U. S. Station No. 17	July 29	− 7 39.9	− 28 55.3	−12 12 17.6	4 01.78		
	Aug. 2	− 7 34.1	− 29 00.5	−12 12 22.11	4 04.82		
Rate	....	Losing 1.45	Gaining 1.3	Gaining 1.13	M. 4 03.30	2 16 32.91	2 16 31.77
Depot Camp Sweet-grass Hills.	Aug. 4	− 8 57.5	− 30 26.9	−12 13 49.4	1 26.54		
					1 23.80		
					1 25.04		
		Rates as at Station No. 17.			M. 1 25.13	2 17 58.04	2 17 56.17
U. S. Station No. 18	Aug. 8	− 10 48.73	− 32 24.78	−12 15 47.02	1 57.35		
					1 52.68		
					1 53.10		
		Rates as at Station No. 17.			1 51.38		
U. S. Station No. 19	Aug. 13.2	− 14 33.4	− 36 19.04	−12 19 39.7	M. 3 52.55		
					3 47.50		
					3 46.82		
					M. 3 48.96	2 23 41.38	2 23 41.28
Camp near Sweet-grass Hills.	Sept. 1.4	....	− 30 49.4	....	....	2 17 56.54	2 17 51.67
U. S. Station No. 20	Aug. 18.4	No comparison.	− 40 01.47	No comparison.	9 24.95		
	25.1		− 40 09.2				
Rate	....	....	Gaining 0.706			2 27 21.49	2 27 20.92

* Initial station for chronometer longitudes 1874.

TABLE V.

1873.		1874.	
	h. m. s.		h. m. s.
Longitude, Fort Pembina	1 20 42.77	Longitude, Station No. 13	2 01 22.82
Chronometer-longitude, Station No. 2	1 22 28.79	Chronometer-longitude, Station No. 14	2 04 39.57
No. 3	1 23 47.91	No. 15	2 09 24.59
No. 5	1 27 26.93	No. 16	2 12 27.51
No. 7	1 37 43.34	No. 17	2 16 30.86
No. 9	1 44 34.35	Depot Camp	2 17 56.86
No. 10	1 48 05.40	Station No. 18	2 19 53.00
No. 11	1 52 23.57	No. 19	2 23 44.23
No. 12	1 56 15.55	Camp, September 14	2 17 55.36
		Station No. 20	2 27 18.66

NOTE.—Results obtained by using uniform rates for the seasons.

JAMES F. GREGORY,
Captain of Engineers.

APPENDIX B

TO

REPORT OF CAPT. W. J. TWINING,

CORPS OF ENGINEERS,

CHIEF ASTRONOMER.

REPORT OF FIRST LIEUT. F. V. GREENE, UNITED STATES ENGINEERS.

UNITED STATES NORTHERN BOUNDARY COMMISSION,
Washington, D. C., June 30, 1876.

SIR: I have the honor to submit herewith the following report of the work done under my charge, upon the survey of the boundary-line of the United States, from the Lake of the Woods to the Rocky Mountains.

I am, sir, very respectfully, your obedient servant,

F. V. GREENE,
First Lieutenant of Engineers.

Capt. WM. J. TWINING,
United States Engineers, Chief Astronomer

PRELIMINARY.

By Special Orders No. 131, War Department, Adjutant-General's Office, June 7, 1872, I was "detailed for duty upon the joint commission for the survey of the boundary-line along the forty-ninth parallel, in accordance with the act of Congress approved March 19, 1872," and was directed to report in person to the Adjutant-General. By letter of July 2, 1872, that officer directed me to report to the Department of State, which I did, by letter, on the 3d of July, and in reply received a letter, dated 6th July, 1872, from Charles Hale, Acting Secretary of State, directing me to report to Maj. F. U. Farquhar, Corps of Engineers, then Chief Astronomer of the Commission. I did so on the same day, and have since been continuously on duty with the Commission, and under the orders of the Chief Astronomer.

The portion of the survey intrusted to me in the field comprised the immediate charge and direction of the parties engaged upon geodetic and topographical operations, and the making of reconnaissance-surveys of all routes passed over by these parties, outside of the belt of more accurate surveys. The geodetic work was that necessary to establish and mark the forty-ninth parallel between adjacent astronomical stations; the topographical work was to survey a belt not less than five miles in width, on the United States side of the boundary. In the office, I have had the immediate charge, under your general supervision, of the preparation of all the maps of the Commission.

Before describing these operations in detail, I deem it proper to give a short narrative of the various seasons' work. This, however, will be limited to the most concise statement of the movements of my parties, and will not include any description of the country, or account of the many details which make up "plains experience," such as means of supply, lack of wood and water, troubles from prairie-fires, hail and snow storms, &c. Although habitually separated from the parties of other officers, and acting under general instructions only, yet, on the whole, I passed over nearly the same ground as yourself and Captain Gregory, whose experiences were also about the same as my own, and whose reports, doubtless, give complete information on these points. I shall, however, subsequently speak more in detail of the monument on the summit of the Rocky Mountains, and of the swamps of the Roseau country, as I was the only officer of the United States Commission who visited those localities.

SEASON OF 1872.

By direction of Maj. F. U. Farquhar, then Chief Astronomer of the Commission, I left Washington on the 1st of August, for Pembina, Dak., charged with the safe transportation of all the instruments for the survey, contained in thirty-two boxes. Mr. Lewis Boss, assistant astronomer, accompanied me. Our route was via New York and Buffalo, by steamer through the lakes to Duluth, and thence to Pembina by rail and boat. We arrived at Fort Pembina on the 17th of August, with the instruments in good order, and began observations with the sextant and chronometers to establish an approximate latitude and longitude for the initial point of the survey. The rest of the commission arrived overland on the 5th of September, and the regular work of the season was then begun. While encamped on the Red River, I made a topographical survey with theodolite and chain of the Red River, from the boundary-line to a point five and a half miles south of it. This was done under Captain Gregory's direction, between the 10th and 20th of September. On the departure of the commissioner and other officers of the commission for the Lake of the Woods, October 2, I was left at Pembina with a party of twenty-five men, with instructions from Major Farquhar to trace a tangent line eastward until I met a British party coming west. By the 6th of November I had reached the Roseau River, thirty-three miles from Pembina, without seeing any signs of a British party, and on the 9th I received an order from Major Farquhar to return at once to Pembina. There I reported to Captain Gregory, and returned to the States with him. In the office at Detroit, during the winter of 1872–'73, the topographical work of the summer was plotted and drawn.

SEASON OF 1873.

The organization for this year comprised a tangent party and two topographical parties, under Mr. F. Von Schrader (succeeded in September by Mr. C. L. Doolittle) and Mr. A. Downing, in all about fifty men. Mr. L. Chauvenet acted as recorder and computer for azimuth observations, and, owing to the pressure of topographical work, a stadia party was organized for him. From September 1 to October 13 I was accompanied by an escort of twenty-five cavalry-men under command of Lieut. R. H. L. Alexander, Seventh Cavalry. We began work at Pembina on the 8th of June, and continued it without interruption until the 3d of October: over two weeks (9th to 25th August) having been devoted to cutting a sight-line in Turtle Mountain. On the 3d of October we were at the British astronomical station, three hundred and eighty-four miles from Pembina, with the geodetic and topographical work completed up to that point. The lateness of the season and scantiness of supplies on hand precluded the idea of finishing the topography of the twenty-four miles intervening between us and Captain Gregory's most westerly station, and on the 4th of October I turned eastward. At the supply depot on the Mouse River I found, October 13, your letter directing me to follow on to Fort Totten. I took a route along the Mouse River on its southern bend, in order to make a reconnaissance of its course. Leaving this river after it had turned to the north, I struck eastwardly, across the burnt prairies and salt lakes, for Fort Totten, reaching that post October 22. On the 24th, yourself and the astronomical parties left for Fort Seward and the States, and on the 25th I left for Fort Pembina, under your instructions, to complete the survey of the boundary between the Lake of the Woods and Red River. During the winter, Mr. O. S. Wilson was assigned to me as recorder and computer, in place of Mr. Chauvenet. A full account of this winter's work will be given in another place.

We reached Fort Pembina on the 29th of October, and returned there, on the completion of the survey, on the 5th of February, 1874. About half of the men were discharged here, and with the balance I marched to Breckenridge, and there took the cars to Saint Paul, where the parties were disbanded on the 16th February. On the 20th of February I reported to you in the office at Detroit, with my assistants and records.

Before leaving Pembina I sent Foreman Kennedy, with three men and two dog-sleds, to Turtle Mountain, to construct the mounds which we had been obliged to leave unbuilt during the summer, the British cutting not being completed until October 5. They performed this service, and reached Saint Paul March 5.

The office-work, at Detroit, was continued from March 1 to June 1, 1874. Mr. Doolittle and Mr. Wilson were engaged in adjusting the stadia-lines; Mr. E. Mahlo and Mr. V. T. McGillycuddy in plotting and draughting. Mr. Downing was obliged by private business to leave the survey from March to November, 1874. During our absence in the field the following summer Mr. Mahlo was left in the office engaged in draughting.

SEASON OF 1874.

The organization for this year comprised a tangent-party, three topographical parties, under Messrs. Doolittle, McGillycuddy, and Wilson (in addition to the latter's duties as recorder), and a party of mound-builders—in all, counting scouts and teamsters, about seventy men. Mr. B. Vitzthum was attached to my party as draughtsman. The escort, under command of Capt. E. R. Ames, consisted of Companies E and I, Sixth Infantry, and twelve Indian scouts. The greater part of E Company was detached August 1. The various working-parties and their escorts left Fort Buford on the 21st of July, following the Benton trail up the Missouri. On the 26th my parties and escort left the main column near the mouth of Poplar River and struck northward along that stream. At the principal forks I detached Messrs. Doolittle and McGillycuddy, with their parties and a small escort, to follow and reconnoiter the west fork, myself, with the other parties, following the east fork. The east fork brought us, June 29, to Lieutenant Galwey's station, where we had concluded work in 1873, and the next day I moved on to Captain Gregory's station on the west fork, where Mr. Doolittle arrived the day after.

On the 1st of July the regular work of the season was begun at four hundred and eight miles from Pembina (the topography at three hundred and eighty-four miles) and it was carried on without interruption until August 18, when I arrived at your camp on Chief Mountain Lake in the Rocky Mountains, seven hundred and fifty-eight miles from Pembina; the geodetic work was completed to that point, and the topographical and mound parties were a short distance behind.

The country beyond being impracticable for wagons, you directed me to fit out a pack-train, in order to reach the monument placed on the summit of the Rocky Mountains by the Northwest Boundary Commission in 1860. We left Chief Mountain Lake on the 20th, and reached Akamina Station, near the summit, on the 23d, the distance being over forty miles by the trail, although only seven in a direct line. Mr. Wilson carried a stadia-line from Chief Mountain Lake over the divide, by the Kootenay Pass, and connected it on known points of the British traverse carried along the Kishenehn Valley to Akamina Station, in 1860. This connected the summit-monument with that on Chief Mountain Lake. After completing the triangulation about the summit I returned to Chief Mountain Lake, August 28, and devoted the following day to locating the peaks in the neighborhood. August 30 we began the return march, and reached the supply-depot at the Sweetgrass Hills September 2. Here my escort was relieved. On the 31st of August, at the British Astronomical Station near Chief Mountain, I met Mr. Doolittle, and joining to his party that of the mound-builders, making their total strength about twenty men, I directed him to follow and reconnoiter the "Riplinger Road," skirting the base of the mountains, to the Blackfoot agency on the Teton River; thence to march to Benton, *via* Fort Shaw. He reached Fort Benton, without accident, on the 9th of September. I picked up Mr. McGillycuddy's party at the Sweetgrass Hills, and with it and the tangent-party, about thirty men in all, I started, September 4, due south, through the Piegan and Blackfoot country, for Fort Shaw, arriving there September 8. The object of taking this route was to reconnoiter the country, and, principally, to run a meridian-line to Fort Shaw for longitude purposes. This line was traced partly by Mr. Wilson and partly by myself. From Fort Shaw we marched to Fort Benton, where I reported to you September 11. The next day the whole Commission began the boat-journey down the Missouri. During this journey I had charge of the survey of the river, making the astronomical observations myself. Messrs. Doolittle and McGillycuddy relieved each other in taking compass-bearings and sketches. We reached Bismarck, Dak., on October 1. The office-work was resumed on the 1st of November, at Washington, and has been carried on, uninterruptedly, to this date. Messrs. Doolittle and Wilson reduced the stadia-readings and adjusted the co-ordinates of the topographical-surveys between November 1, 1874, and April 1, 1875. The series of preliminary maps was finished October 1, 1875; photo-lithographic copies were made of each sheet as soon as it was finished. The series of final maps was commenced August 1, 1875, and finished April 15, 1876. The series of reconnaissance maps was begun November 1, 1874, and finished February 1, 1876. Special tracings of various sheets have been made from time to time. The office-force has usually comprised eight draughtsmen.

SEASON OF 1875.

You directed me to proceed to Fort Shaw and make certain observations there. I left Washington June 30, and, proceeding by way of Salt Lake, reached Fort Shaw July 11. I remained there ten days, and made an extended series of azimuth-observations on the meridian-line of 1874, of latitude-observations with the sextant at Fort Shaw, and a triangulation to connect the meridian, and consequently the boundary-surveys, with Fort Shaw and the land-surveys. I arrived in Washington, on my return, on September 3.

Summary of field-work.

	Summer of 1873.	Winter of 1873–'74.	Summer of 1874.	Summer of 1875.	Total.
Number of azimuth stations	15	8	15	1	39
Number of latitude observations (sextant)	14	10	58	17	99
Number of time observations (sextant)	104	34	90	12	240
Miles of tangent lines	223.3	56.5	176.5	......	456.3
Miles of timber cutting	10.3	42	....	......	52.3
Number of mounds built	98	56	44	......	198
Miles of topographical lines (stadia)	380	365	542	......	1,287
Miles of reconnaissance lines (compass)	250	98	550	......	898
Miles of Missouri River travel and reconnaissance	....	....	807	......	807
Miles of march between camps	951	542	1,010	......	2,503

This seems to be an appropriate place to acknowledge my indebtedness to the assistants who have been associated with me, and to the officers who have commanded my escorts.

Messrs. C. L Doolittle,* O. S. Wilson, and A. Downing, have been with me in the office and field for more than two years, including the winter campaign in the swamps around the Lake of the Woods. To them I owe my most cordial thanks for their unremitting labors, the excellent character of their work, and their cheerful and ready compliance with all instructions, involving no matter what hardship. Mr. F. von Schrader† was the principal topographical assistant in 1872 and part of 1873, and rendered excellent service; as did also Dr. V. T. McGillycuddy‡ in 1874. Mr. L. Chauvenet

* Now Professor of Mathematics and Astronomy at Lehigh University, Pennsylvania.

† Now Second Lieutenant Twelfth Infantry, United States Army.

‡ Since Topographer of the Black Hills Expedition, 1875.

was recorder in 1873, and showed great aptitude for his work, although somewhat embarrassed by lack of experience and by ill health.

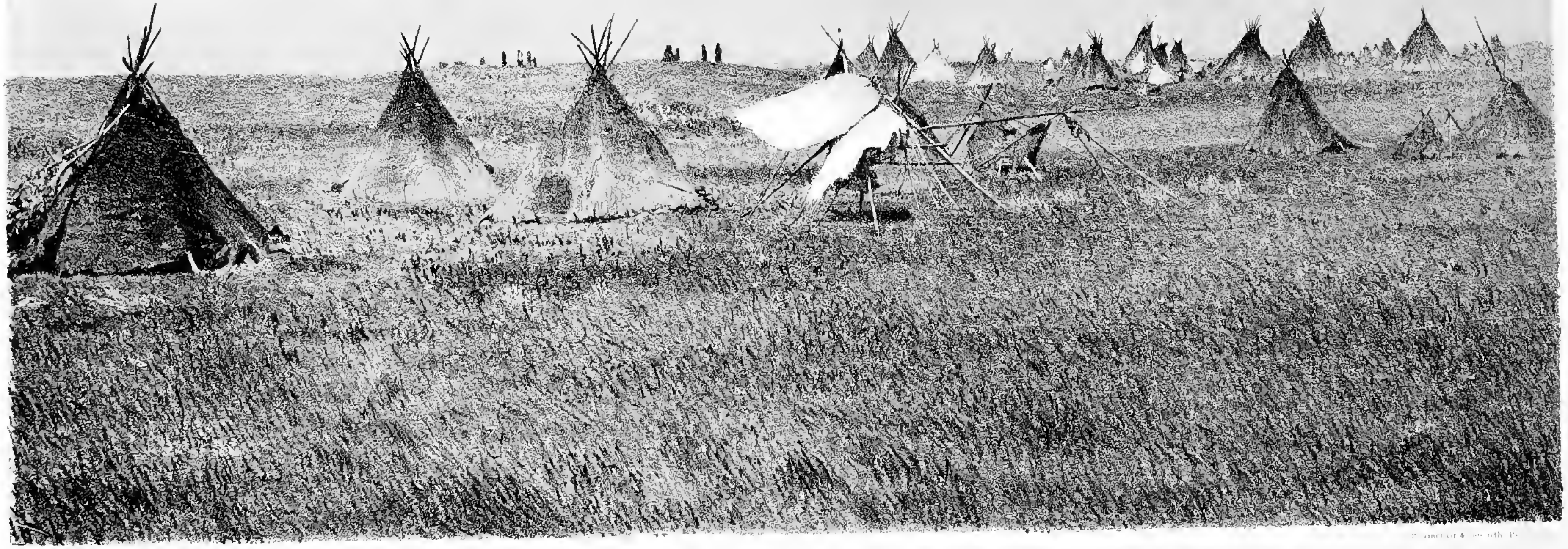
In the office, in addition to Messrs. McGillicuddy and Downing, the draughtsmen have been Messrs. E. Mahlo, A. A. Aguirré, A. von Haake, A. Pohlers, and H. S. Hebard, all of whom rendered good service. Messrs. B. Vitzthum and —— Penny were also employed for short periods.

With the officers of the escorts my relations were always of the most cordial nature, and although usually superior to me in rank, they never failed to accede to my requests in distributing their commands, if they could do so without violating the positive instructions of their own superiors.

In 1872, Capt. A. A. Harbach's company of the Twentieth Infantry remained with me when the rest of the commission went to the Northwest Angle. We met no Indians in the short distance which we penetrated eastward, but when we came to an impassable swamp, and had to make a quarter of a mile of corduroy-road, Captain Harbach at once ordered out his whole company to assist in it.

From June, 1873, to March, 1874, I was accompanied by an escort only during September and a part of October. This cavalry detachment was commanded by Lieut. R. H. L. Alexander, since deceased, who used every effort to assist us.

In 1874 my escort was considerably larger, consisting nominally of two companies of infantry and twelve Indian scouts, under the command of Capt. E. R. Ames, Sixth Infantry. I say nominally, because an officer and fifteen men of one of these companies were left at Fort Buford to escort the Commissioner, and did not rejoin their company, and at the Sweet-grass Hills, August 1, the remainder of that company was detached. Captain Ames, however, did everything in his power to facilitate the work of the survey, and I feel the more grateful to him as his interests were entirely opposite to mine. It was essential to the performance of my work that the topographical and mounding parties, three and sometimes four in number, should carry on their operations in rear of my own tangent party, and independently of each other; and as we were in the proximity of Indians, whose peaceful and honest intentions were at least open to doubt, it was also essential that these parties should each have a small escort. On the



ASSINIBOINE CAMP

other hand, Captain Ames naturally desired to keep his companies together for discipline, supply, and defense. He, however, yielded to my requests, and sent a detachment, with a non-commissioned officer and a scout, with each party, until he soon found his force reduced to fifteen men, and the main body of the escort was over one hundred miles away, and its exact whereabouts unknown. We were in this condition on the 18th of July, my parties being spread out over a distance of about seventy-five miles, when, on informing Captain Ames of my intention of moving ahead the next day, he replied that his original instructions from Major Reno were very positive, not to separate himself from his detachments by more than forty miles. These instructions were entirely unknown to me, and, although completely binding on Captain Ames, placed me in a very disagreeable position. A large band of Assiniboines had been encamped, only a few days previous, in the very locality where we then were (Astronomical Station No. 28), and the mail-rider had been chased almost into camp, only the day before, by a party of Yankton Sioux; so that I was taking considerable risk in going ahead with my party containing only fifteen carbines, and attempting to work on a tangent twenty miles long, without any escort in camp. On the other hand, it was only by the utmost exertions—often working for twenty-two consecutive hours—that I could keep the tangents up with the astronomy, and if I waited a week for the detachments to close up, there would be another one hundred miles between Captain Gregory and myself. I therefore determined to push on alone, and after bidding good-bye to Captain Ames the next morning, saw no more of him for ten days.

I can only repeat that Captain Ames sacrificed his personal inclinations, and did everything in his power to assist the progress of the survey, but that his force was inadequate and his instructions too circumscribed to have allowed him to materially aid us in case the Indians, who hovered about our trail, had at any time proved troublesome. The question of the relations between an officer in charge of a surveying-party and the officer in command of his escort, is at best a vexed one, and particularly so when the surveying-officer, who must necessarily direct the movements, is the junior, and I am glad to be able to record my appreciation of the forbearance and kindness exhibited by all the officers who were detailed with me.

On my journey from the Sweet-grass Hills to Benton via Fort Shaw, I was also without an escort, my party numbering twenty-five men and fifteen carbines. We passed through the country of the Blackfeet and Piegans, and within a few miles of the spot where the latter were so terribly punished by Major Baker, in 1870. These Indians followed us, and once accosted the men at the rear target, but they did not molest us in any way.

In closing these acknowledgments, I wish to record my thanks to Capt. L. Wheaton and Maj. J. E. Yard, successively in command, and Lieut. Paul Harwood, Twentieth Infantry, post quartermaster at Fort Pembina, who during the summer of 1872, and the winter of 1873 and '74, constantly extended favors to us. And I particularly wish to express my gratitude to Gen. John Gibbon, commanding, and Lieut. J. W. Jacobs, Seventh Infantry, quartermaster at Fort Shaw. In 1874, I was a day and a half, and in 1875 ten days, at their post; during which I was constantly the recipient of their private hospitality as well as their official courtesy. Being alone in 1875, I was entirely dependent on them for men and transportation to assist in the work I had to do, and these were furnished most kindly and cheerfully.

To the officers at Fort Buford I am also indebted for many favors, but as I was only there at the same time as yourself, your acknowledgments naturally supersede mine.

CHAPTER I.

GEODETIC CONNECTIONS.

The geodetic operations were those necessary to establish and mark the 49th parallel of north latitude, in the intervals between astronomical stations, which were about twenty miles apart.

There are two methods of tracing a curved line—one by means of chords, and the other by tangents and offsets The latter method was exclusively employed on this survey. A tangent-line (tangent to prime vertical great circle at initial point) was prolonged on the surface of the earth from the meridian of one astronomical station to the meridian of the next, and on each meridian was measured the distance from the tangent to the astronomical determination of the parallel. By the use of proper geodetic formulæ the relative positions of the two stations were determined, and the difference between the geodetic and astronomical determinations, including the errors of both, was taken as the "Station-error." The astronomical determinations were regarded as an absolute standard, and the station-error was distributed between the stations in direct ratio to the distance. To fix intermediate points of the parallel, meridional offsets were measured from the tangent, and the proportional part of the station-error was included in these offsets.

The successive steps in these operations were:

1. Azimuth-observations at initial point.
2. Tracing the tangent-line on the ground.
3. Azimuth-observations at terminal point.
4. Deducing the station-error and computing the offsets for mounds on forty-ninth parallel.
5. Construction of the mounds.

The results of these observations are given in full in the details of the tangents.

1. *Azimuth-observations.*—The instrument used was a transit-theodolite, made by William Würdemann, of Washington. The horizontal limb, eight inches in diameter, was divided to 10′, and read to 10″ by two verniers; vertical limb (used principally as a finder) was four inches diameter, divided to 20′, and read to 1′ by single vernier. The spindles of the instrument were of steel, all the other parts of brass. There were three foot-screws, a circular level between the standards, and striding-level for the axis of telescope. All tangent-screws worked against springs, which was, I think, a serious defect. The telescope was of one and one-half inches aperture, and sixteen inches focal length, eye-piece magnifying twenty-five times. A 45° prism, fitting in a slot in front of the eye-piece, answered the purpose of a diagonal eye-piece. The tripod consisted of three double legs supporting a solid block of wood two inches thick. This instrument was mounted in the meridian of the astronomical station, and as near as convenient to the mound marking the forty-ninth parallel. An approximate azimuth of 90° was then turned off, from any data available, and on this direction was placed a bull's-eye lantern, firmly fixed to a small post. It was at first customary to inclose the lantern in a box, but this was found unnecessary, for the lantern was generally at a distance of two miles from the instrument, and at that distance the image of the light was about the same as that of a second magnitude star. The true astronomical azimuth of the direction of this lamp was then observed. The chronometer-error was derived from time-observations with the sextant, taken in the intervals between azimuth-stars. An observing-list of these latter stars was prepared for each month, giving the magnitude, azimuth, altitude, and chronometer time of elongation for each star. The methods of observing culminations above and below the pole, and Polaris at any hour-angle, were both tried, but did not give such good results as a series of observations near the time of greatest elongation. The stars most convenient, in July and August, were δ and γ, Cephei, and Polaris, eastern elongation, and δ and ε, Ursæ Minoris, western elongation. Δ and λ, Ursæ Minoris, and 51 Cephei, although much nearer to the pole, were not used, because the telescope did not define stars below the fourth magnitude with sufficient accuracy. The method used was to take five pointings on the mark, then five on the star, the time being noted for each; then

revolve the instrument 180° in azimuth, and take five more readings on the star, followed by five on the mark. To each reading on the star was applied a differential azimuth-correction, due to the interval of time from elongation. The mean of the corrected results, with the mean reading on the mark, gave the result for that star. Five stars observed in this manner, and in different parts of the divided arc, constituted a good determination, although three were considered sufficient. The azimuth resulting from each individual reading was also computed, and these were treated in the usual manner (after applying a collimation correction) to obtain the probable error of the mean. This varied from $\pm 0''.8$ to $\pm 4''.0$ at a station, with a mean of $\pm 1''.8$. The average range of forty individual observations was $57''.3$. With tangent-screws working in ball-and-socket joints, this range can probably be reduced one-half. Level-corrections were at one time applied, but were soon given up, in the belief that they only introduced additional error. The length of the striding-level was only six inches, and the value of one division over $4''$. A slight inaccuracy in the grinding of the glass would introduce large errors, and the behavior of the level showed such inaccuracies. Hence the instrument was carefully leveled before each set, and examined afterward, in both positions of the axis. If it had been disturbed in level during the observations, they were rejected.

The following formulæ were employed:

A_e = Azimuth of star at elongation.

Φ = Latitude of station.

α = Right ascension of star.

δ = Declination of star.

T_e = Chronometer time of elongation.

τ = Difference between observed time and T_e.

ρ = Reduction to elongation.

E = Chronometer-error $\left\{ \begin{matrix} + \text{fast.} \\ - \text{slow.} \end{matrix} \right.$

t_e = Hour angle at elongation $\left\{ \begin{matrix} - \text{east.} \\ + \text{west.} \end{matrix} \right.$

$$\cos t_e = \frac{\tan \Phi}{\tan \delta} \qquad T_e = \alpha \pm t_e \pm E \qquad \sin A_e = \frac{\cos \delta}{\cos \Phi}.$$

$$\rho = \frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''} \tan A_e.$$

The value of

$$\frac{2 \sin^2 \frac{1}{2} \tau}{\sin 1''}$$

is given in the usual tables for "reduction to the meridian." I deem it only proper to add that this method was derived from the Coast Survey Manual by Mr. C. A. Schott, published in Appendix 11 to the Report for 1866. This is the only publication I know of in the English language where the subject of azimuths is treated at any length.

2. *Tracing the tangent-line.*—After finding the true azimuth of the mark, it was a simple matter to find a point of the prime vertical near it; the required meridional distance being the tangent of the angle equal to 270° or 90° minus the observed azimuth, for a radius equal to the distance from instrument to mark. A stout picket was driven and the point of the tangent was marked upon it with a pencil point; with this and the point of observation, the direction was established, and the line was prolonged to the next station. In 1872, with the idea of avoiding errors due to error of collimation, the method employed was that of two front-sights, *i. e.* the two targets were always in front of the instrument, the more distant being aligned with the one nearer. This method was found to work very badly in practice. A little reflection will show that in passing over even a small hill it was necessary to take very short sights, sometimes as short as fifty feet. At fifty feet an error of three-hundredths of an inch subtends an arc of 2′, and this, at a mile, gives an error of three feet. From these causes the tangent of 1872, which was thirty-three miles in length, was found to have an azimuth error at its extremity of 7′ 44″. It was therefore entirely rejected, and retraced. After 1872 a different method was pursued, viz, the method of back and fore sights, collimation-errors being cut out by taking the mean of two pointings in reversed positions of the axis. With this method the average azimuth error at the terminal points was 28″.7. Into this determination enter the local errors due to deflection of plumb, and actual errors of observation at both ends of the line. If we take the whole line to have been in error by 14″.3, the deviation of the tangent, at the end of twenty miles, will average nine and a half feet. This shows at once the superiority of the method by back and fore sights. The same

TARGETS

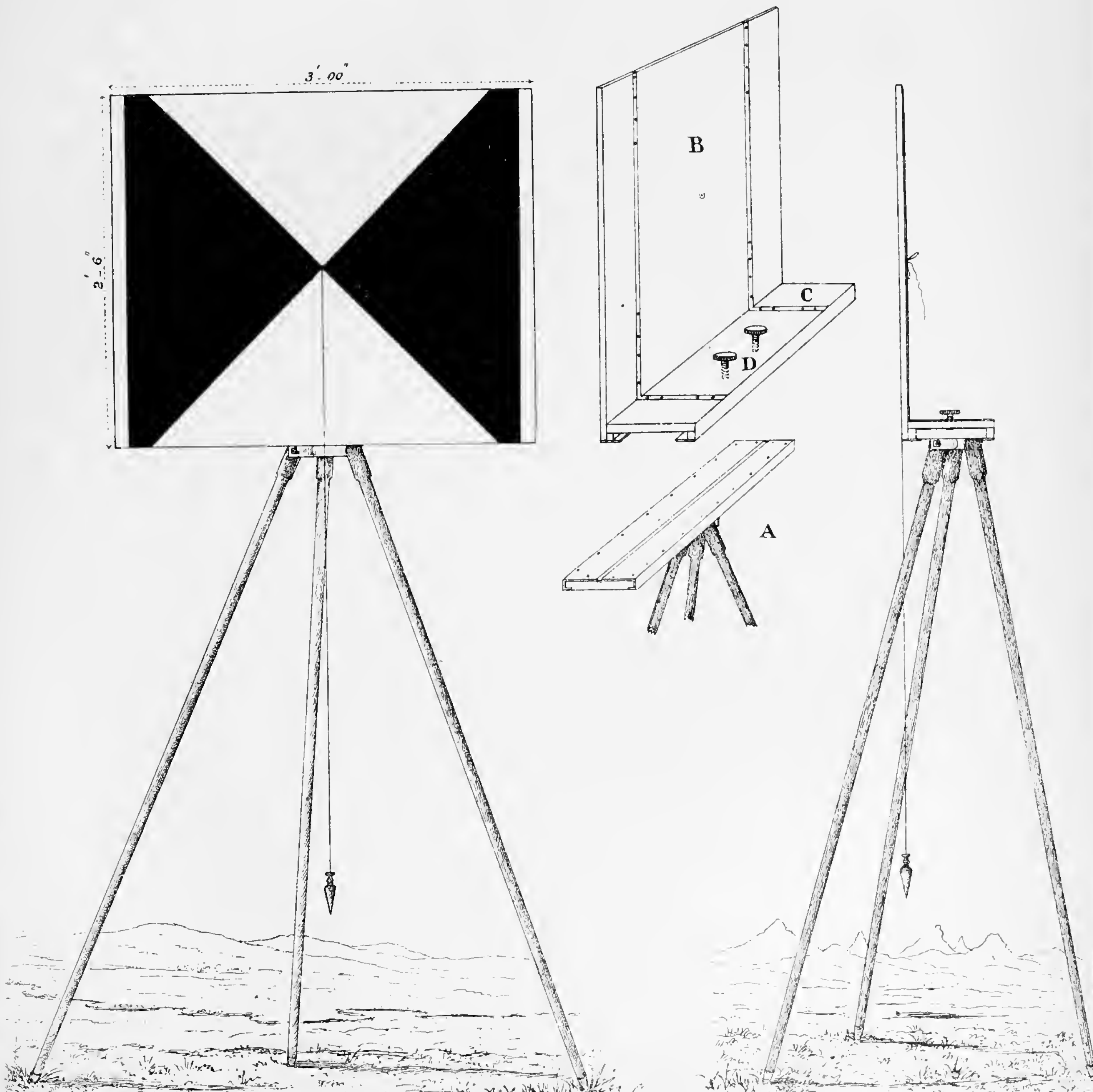
USED IN

TRACING TANGENTS

devised by

LIEUT. F. V. GREENE, U.S. ENGRS

SCALE 1 INCH = 1 FOOT



FRONT VIEW

SIDE VIEW

instrument was used for tracing the tangent as for azimuth observations, and the objects sighted on were two targets, one in front and one in rear. Their shape is shown in these drawings. The legs of the tripod were fastened to a triangular brass casting, similar to that used on theodolites, and this casting was firmly attached to the under side of the stand A. This stand was made of oak, 24″ long, 6″ wide, and 1″ thick, and was covered, on the upper side and edges, with a thin piece of brass. The target B was of three-eighths of an inch pine, strengthened with light iron braces, and was fastened to a slide, C, of oak, tipped with brass. This slide embraced the stand A, and moved freely along it, thus giving a slight motion to the target; and it could be clamped in any position by the binding-screws D. Through a small hole in the center of the target, passed a cord, from which was suspended a plumb-bob, which could thus be lowered to the stake marking the line.

With favorable conditions of the atmosphere, these targets have been distinctly seen and aligned at a distance of over six miles.

The rear target was set up over the point where the instrument stood in the azimuth observations. The instrument was set up over the point determined near the mark, and the front target sent ahead with three men provided with a telescope—the length of sight depended on the nature of the ground, but was usually about three miles. The telescope was pointed on the rear target, turned on its axis, and the front target ranged approximately into line. Then the target was set up, and slight lateral motion given by the slide until it was bisected by the cross-hair. A point was then marked by the plumb-bob on a cross-piece fixed to a firm stake. The axis of the telescope was then reversed by turning the instrument in azimuth (owing to the presence of dust, the telescope was never taken from the Y's). The same operation was repeated and another point determined. As it was found impossible to collimate inside of 3″, the two points were about ten inches apart for a sight of three miles. The point midway between them was taken as the point of the tangent. The instrument and targets were then moved forward one station and the same operations repeated, and so on to the terminus of the line. Much time was saved by using the United States Army code, supplemented by a few special signals. The men quickly learned the system, and to prevent any liability to mistakes, each one was provided with a printed card containing the alphabet. The flags used were of red cloth, six feet square, and containing a white square in the center. These were easily read, with a field-glass or small telescope, at a distance of six miles in ordinary weather. The weight of the instrument precluded the idea of carrying it by hand, and a light, two-wheeled spring-cart was used for this purpose, and to carry the signal-flags, men's lunches, &c. Occasionally, also, the men at the front target were carried in a two-horse wagon, thus saving a great deal of time. With these favorable circumstances as much as eighteen miles of tangent has been traced in a single day. The most favorable state of the weather for this work was a cloudy day, or failing that, the hour just before and after sunrise, and the three hours before sunset. Between 10 a. m. and 3 p. m., on bright days, the radiation and reflection of heated air from the surface of the ground caused such a dancing of the images in the telescope as often to necessitate an entire stoppage of the work until later in the afternoon. A slight breeze diminished this disturbance, and a strong wind removed it altogether; but this latter introduced other sources of error by deflecting the telescope. The only large azimuth-error in all the tangents (viz, 1′ 49″, on tangent No. 8), was due to attempting to work in a high wind—being very much pressed for time. This disturbance does not extend more than thirty or forty feet from the ground, and hence gave but little trouble in sighting over valleys. In a mountainous country it is hardly noticeable. The chaining was carried along at the same time as the tangent, the alignment being corrected at every instrument-station, and once or twice between them. The tallies were recorded in a book by one of the chainmen, and a small stake was driven at every second tally and marked with its distance from the initial point of the tangent. The instrument-pickets were also marked with their distance. As I rode along the tangent I examined the tally-pickets to avoid the chance of any error. In 1872 and 1873 I had several distances, of over ten miles in length, chained twice. The results differed by only six inches in a mile at the most, and it was, therefore, not considered necessary to chain twice on level ground. What little broken country we met was always chained a second time. The standard of length

was a box-wood rod, tipped with brass, ten feet long and two inches square in cross-section, made by Negus & Co., of New York. The chain was compared with this for each tangent. We also had one of Stackpole's fifty-feet tape-lines, with level, thermometer, and spring-balance adjustments. This instrument measures to within 1 in 100,000, but it was found to require too much time for our purposes, and was only used occasionally as a standard of comparison. Its length always agreed with the wooden rod. Our longitudes are all deduced from the record of the chaining.

3. *Azimuth-observations at the terminal point.*—There were 22 tangent-lines in all traced by myself. On twelve of these, independent azimuth-observations were taken at the terminal points, similar in every respect to those described above for the initial points. On five of the remainder the azimuth was tested by a series of angles connecting the tangent with some line whose azimuth was carefully determined—either a British tangent or astronomical meridian. Two tangents (Pembina and Turtle Mountains) were only a few miles in length. This, then, leaves three tangents whose azimuth was never tested beyond the initial point, viz, Nos. 11 and 12, of 1873, and No. 18, of 1874. At Nos. 11 and 12 the season was very late (October), and we were in the midst of a series of snow-storms and cloudy nights. At No. 18 the azimuth-observations gave such unsatisfactory results that they were rejected. A summary of the errors in the tangent, deduced from these observations, has been given above.

4. *Deducing the station-error and computing the offsets for the mounds.*—The formulæ employed to find the geodetic latitudes, longitudes, and azimuths at points on a line perpendicular to first meridian, are:—

$$H - H' = K^2 \frac{\tan H\,(1 + e^2 \cos^2 H)}{2\,N^2 \sin 1''} = K^2\, C$$

$$P' - P = K \frac{1}{N \sin 1'' \cos H} = K\, C'$$

$$Z' = 90^\circ - K \frac{\tan H}{N \sin 1''} = 90^\circ - K\, C''$$

These formulæ are discussed on pp. 256, and from them is derived, pp. 257, the table of offsets and azimuths of the tangent. Entering this table with the argument K, equal to the length of tangent in English feet, the computed offset to 49° is found. If E_s represent the station-error, O_c the computed offset, E_i the error of the initial point, north or south of 49°, E_a the error due to azimuth-deviation, and O_m the measured distance from the tangent to the second astronomical determination of 49°, then $E_s = O_c \pm E_i \pm E_a - O_m$. To compute the offset for any intermediate mound let $O_{c'}$ represent the computed offset for the given distance, $E_{r'}$ the proportional part of the station-error, $E_{a'}$ the proportional part of the azimuth-error, and $O_{m'}$ the required offset, then $O_{m'} = O_{c'} \pm E_{r'} \pm E_i \pm E_{a'}$.

5. *Construction of the mounds marking the boundary.*—While tracing the tangent at each station where it was thought a mound should be built, the true meridian was turned off, by the aid of the table of azimuths of the tangent, and a picket driven to mark its direction. After finishing the tangent the offsets were computed by the formulæ given above, and a list containing the position of each mound and its offset was sent to the chief of the mound-builders' party, who built the mounds, and kept a complete record of all distances measured, and all the facts relating to his work. Along the Red River Valley, and up to the astronomical station at Long River, mounds were built at intervals of one mile; these were subsequently replaced by the iron pillars planted by Captain Gregory in 1875. Beyond Long River they were built at an average distance of three miles, and placed on the crests of the rolling prairie, the conditions being that each mound should be plainly visible with the naked eye from the two adjacent ones. Wherever a sufficient amount of stone could be found within a radius of five miles the mounds were built of the small prairie bowlders, weighing from ten to eighty pounds each, and in the form of a cone twelve feet in diameter at the base, and six feet high. Where stone was not available they were built of earth and well rammed, and in the same shape and size as the others. If there was any timber available a large post was sunk two feet in the ground in the center of the mound, and marked on the southern face "XLIX PAR." In all cases a picket was driven one foot under ground, with a cross cut on its head marking the exact position of the parallel.

In the Great Roseau Swamp there was no earth to be found within several miles, and, if there had been, it would not have withstood the action of the water. The mounds here consisted of a pine post, about eighteen feet long, squared to ten inches, and pointed on its lower end. This was sunk, by its own weight, to various distances, from two to ten feet. Around it, from two hundred to two hundred and fifty tamarack poles, four inches in diameter, were driven into the mud, as far as possible, with heavy malls. Their tops were then cut off to give the shape of a rude cylinder with conical top. The center post was marked on its southern face "XLIX PAR."

The computation of the offset and the nature of each mound will be found in the details of tangent-lines.

LONGITUDES AND STATION-ERRORS.

As previously remarked, the longitudes adopted are those derived from the chaining along United States and British Tangent Lines. The origin of longitudes is the joint astronomical station near Pembina. This was observed, in the winter of 1872–'73, by the British Commission, in telegraphic communication with Mr. T. H. Safford, at the Observatory in Chicago. The result as communicated by Capt. S. Anderson, Royal Engineers, is 97° 13′ 51″.5; which was adopted as the basis of all our longitudes. In order to convert the chained distances into arc, I made an examination of the various authorities on the elements of the earth's figure, with the following results:—

L = Length of 1° of longitude on equator.

L' = Length of 1° of longitude at Φ.

a = Equatorial radius of the earth. $\qquad L' = L \dfrac{\cos \varphi}{(1 - e^2 \sin^2 \Phi)^{\frac{1}{2}}}.$

b = Polar radius of the earth.

e = Eccentricity $= \left(\dfrac{a^2 - b^2}{a^2}\right)^{\frac{1}{2}} \qquad e^2 = 2E$

E = Ellipticity $= \dfrac{a - b}{a}$

Kater's value of the meter, $39^{in}.370790$.

Clarke's value of the meter, $39^{in}.370432$.

	a	b	E	L	$L', (\Phi = 49°)$.
Bessel's spheroid, Kater's value of meter,	20923644	20853703	$\frac{1}{299.66}$	365186	240040

Bessel's spheroid, Clarke's value of meter,	20923404	20853464	$\frac{1}{299.66}$	365182	240038
Ordnance survey, 1858, Sir Henry James,	20926330	20855240	$\frac{1}{294.36}$	365233	240079
*Ordnance survey, 1866, Capt. A. R. Clarke, Spheroid of revolution,	20926062	20855121	$\frac{1}{294.98}$	365229	240076
"Figure of the earth", 1871, John H. Pratt,	20926184	20855304	$\frac{1}{295.2}$	365231	240077

The above results are in English feet, and Clarke's value of the meter is used in deducing all except the first. Clarke's results are obtained by applying Bessel's method to the results of the measurement of the following arcs of meridian, viz, the Anglo-French, 22° 10′; the Indian, 21° 21′; the Russian, 25° 20′; the Cape, 4° 37′; and the Peruvian, 3° 7′. In Pratt's discussion the last two are rejected, on account of their small length. Bessel's elements have generally been adopted up to the present time, in this country; but Clarke's results were thought to have the most weight, and were adopted for our purposes, with the concurrence of Capt. S. Anderson, Royal Engineers.

The accuracy of the chaining is a matter about which nothing certain can be stated. From the trials given above, it was believed to be within a foot per mile, on level ground and twenty-five per mile over a broken country. In order to test its accuracy, I ran, by your direction, a meridian-line, over level country, from a point near the Sweetgrass Hills to the neighborhood of Fort Shaw, in September, 1874. It was intended to observe the longitude of Fort Shaw by telegraphic communication with Lieutenant Wheeler's Observatory at Ogden, Utah, whose

* Ordnance Survey—Comparison of Standards of Length. London, 1871. On p. 285 are given the following elements:—

Major semiaxis $= a_{,,}$ of equator, longitude 15° 34′ E.		20,926,350 feet.
Minor semiaxis $= b_{,,}$ of equator, longitude 105° 34′ E.		20,919,972 feet.
Polar axis,	$= c_{,,}$	20,853,429 feet.

$$\frac{a-c}{c} = \frac{1}{285.97}; \quad \frac{b-c}{c} = \frac{1}{313.38}; \quad \frac{a-b}{c} = \frac{1}{3269.5}.$$

The elements given above are found on p. 287, and pertain to the "Spheroid of Revolution best representing the geodetic measurements."

longitude has been determined, telegraphically, with great care. This scheme fell to the ground, in consequence of the fact that the telegraph line between Helena and Fort Shaw was down, for several miles, in 1875; and to have prolonged the meridian, over the mountains, to the telegraph at Helena, would have involved great expense, and given very doubtful results. The opportunity for determining this valuable and interesting check on our chaining was therefore lost, but it may be accomplished by other parties, at some future day. It was impossible to get azimuth-observations at Fort Shaw in 1874, owing to cloudy nights; but the terminal points of the meridian were securely marked, and in 1875 its azimuth was carefully determined, and a connection was made with Fort Shaw, and with the principal meridian of the United States Land Surveys. The observations on this meridian are given herewith.

Fort Shaw Meridian.

Azimuth-observations at initial point.

[Error of Chronometer: by α Andromedæ (fast), 13m 41s.4; by Arcturus (fast), 13m. 39s.4; mean (fast), 13m 40s.4.—Observer, O. S. Wilson, C. E.]

Date.	Position of instrument.	Position of mark.	No. of readings.	Stars.	Azimuth.
1874.					° ′ ″
Sept. 2	Picket at 660m 1ch.30 from Pembina; longitude, 111° 45′ 04.9.	7406.5 feet south of instrument.	10	γ Cephei........E.	179 51 10.2
			10	Polaris........E..	54 12.9
			5	β Ursæ Minoris..W..	53 50.8
			10	γ² Ursæ Minoris..W..	54 39.5
Mean					179 54 13.6

Mark was moved 12′.1 west, to establish direction of tangent point.

Azimuth-observations at terminal point.

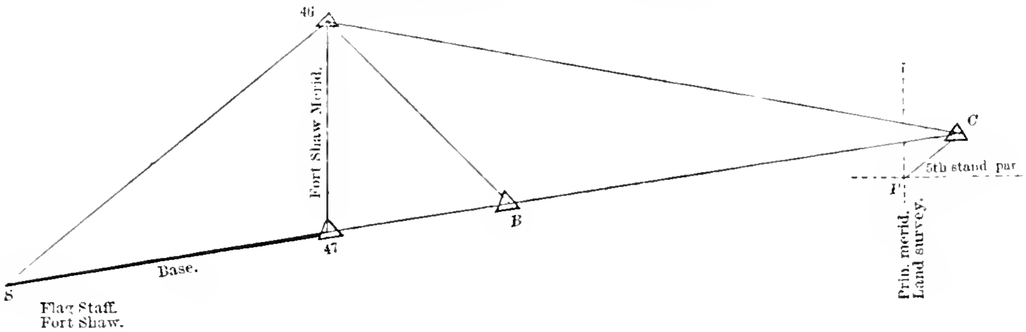
[Observer, Lieut. F. V. Greene.]

Date.	Position of instrument.	Position of mark.	No. of readings.	Star.	Azimuth.
1875.					° ′ ″
July 16	Terminal point of meridian south of Sun River.	Station 46 of meridian, north of Sun River.	5	γ Cephei........ E..	359 53 01.1
			10	λ Draconis.......W..	*54 55.6
			10	β Cephei.........E..	53 04.2
			10	4 Draconis.......W..	51 04.3
			10	Polaris.........E..	53 07.4
July 19	....	....	10	Polaris.........E..	53 26.3
			10	γ Cephei.........E..	53 45.2
			10	β Ursæ Minoris..W..	53 19.2
			10	γ² Ursæ Minoris..W..	52 45.4
Mean					359 53 19.1 ± 2′.4

* Rejected.

This error was larger than was anticipated, but the notes showing no reason for assigning it to any one place, it was distributed over the whole length, 102.5 miles, of the line, by assigning 1′ to each fifteen miles. The successive increments in deviation were then computed; giving a total of five hundred and ninety-eight feet at the terminal point, equal to 8″.8 of longitude.

Triangulation at Fort Shaw.



	Angle.		Length in feet.	Azimuth.	Lat.	Dep.		Coordinates from △ 47, in feet.	
	° ′ ″			° ′ ″					
47–*S*–46	32 17 25.4								
S–47–46	97 17 51.2	*S*–47	13420	82 35 27.9	1730.5	13308	△ 46	N. 9302.7	W. 18.0
S–46–47	50 24 43.4	*S*–46	17273	50 18 02.5	11033	13290			
46–47–*B*	79 02 31.0	47–46	9302.7	359 53 19.1	9302.7	18.1	*S*	S. 1730.5	W. 13308.0
46–*B*–47	55 27 54.5	47–*B*	8053.6	78 55 50	1546.3	7903.8			
47–46–*B*	45 29 34.5	46–*B*	11086.8	134 23 44.6	7756.4	7921.7	*B*	N. 1546.3	E. 7903.8
46–*C*–*B*	19 59 10.4	46–*C*	26932.8	98 15 04.6	3865.3	26654	*C*	N. 5437.4	E. 26636.0
46–*B*–*C*	123 52 09.6	*B*–*C*	19132	78 15 54.2	3891.1	18732.2			
C–46–*B*	36 08 40.0	*C*–*P*	2550	223 15 54.6	1856.9	1747.8	*P*	N. 3580.5	E. 24888.2

In order to obtain the longitude of the Principal Meridian, I consulted the plats of the land-office in Helena, and found that, in latitude 45° 41′, it was thirty and one-fourth miles west of Lieutenant Wheeler's Observatory in Bozeman, Mont., whose longitude, established by telegraph, is 111° 03′ 31″.9. By this means, we are enabled to compare our own longitude with those of the Land-Surveys, as follows:—

Longitude of Bozeman, Mont., ...	111° 03′ 31″.9
Thirty and one-fourth miles of longitude in latitude 45° 41′,	37′ 29″.8
Longitude of Principal Meridian, ...	111° 41′ 01″.7

Westing from Principal Meridian to Fort Shaw Meridian, 24,888 feet in latitude 47° 31′, ...	6′ 02″.5
Longitude of △ 47, Fort Shaw Meridian, as determined by land-surveys, ...	111° 47′ 04″.2
Longitude of Pembina	97° 13′ 51″.5
Westing to Initial Point, Fort Shaw Meridian, 660^{m} 18^{ch}.30 in latitude 49°	14° 31′ 13″.4
Longitude Initial Point, Fort Shaw Meridian, ...	111° 45′ 04″.9
Deviation in Azimuth to east, ...	8″.8
Longitude of △ 47, Fort Shaw Meridian, as determined by Boundary Survey, ...	111° 44′ 56″.1
I also made a chronometer expedition from Fort Shaw to Bozeman, from which the longitude of △ 47 was .	111° 45′ 57″.6

It will be seen that the chronometric determination is nearly the mean of the other two, but to this no particular importance is attributed. The difference between the land-survey longitude and our own is 2′ 08″, equal to 8,795 feet, or 1.67 miles; but the method in which the Principal Meridian was run makes the Land-Office determination of no greater value than our own. The Principal Meridian was one hundred and twenty-six miles in length from the latitude of Bozeman to that of Fort Shaw. Of this length forty-eight miles was traced over the broken country west of the Gallatin River. Here an offset was made of eighteen miles to the west in order to avoid the almost impassable mountains east of the Missouri River. From the end of this offset a meridian was traced north, over the spurs of the Rocky Mountains to Sun River Valley, where an offset was measured eastward again, and a stone post planted to indicate the intersection of the Principal Meridian and Fifth Standard Parallel. The lines were traced by a solar compass. Our own surveys embraced lines aggregating a length of seven hundred and sixty-three miles from Pembina to Fort Shaw, against one hundred and ninety-two miles of the land-surveys from Bozeman to Fort Shaw; but their methods were not considered sufficiently accurate to warrant a change in our determination. At the monument on the summit of the Rocky Mountains we connected with the surveys of the Northwest Boundary Commission. The longitude of this monument, as determined in 1861 by the method of lunar culminations, is 114° 03′ 28″.4. Our own determination of the same point, by chaining, is 114° 02′ 56″.5. The difference, 31″.9, is equal to 2,124 feet.

It is difficult to say how much importance should be attributed to this result; but, at all events, the results of the land-survey near Fort Shaw were not sufficiently reliable to warrant any change in our chaining, which was adopted for the determination of longitudes.

The following table contains the longitudes of the astronomical stations, and their station-errors, with reference to the Lake of the Woods Station:

Longitudes and Station-errors of Astronomical Stations.

No.	By whom observed.	Name of astronomical station.	Longitude.	Distance from Lake of the Woods Station.	Station-error N. or S. of Lake of the Woods Station.
			° ′ ″	*M. Ch.*	*Feet.*
1	British and United States	Lake of the Woods (joint station)	95 16 55.3	....	....
2	British	Pine River	95 59 01.0	31 72.05	388.0 N.
3	....do	West Roseau	96 46 51.9	68 12.83	470.2 N.
4	British and United States	Red River (joint station)	97 13 51.5	88 43.36	556.1 N.
5	....do	Michel (joint station)	97 40 25.2	108 59.62	588.4 N.
6	....do	Pembina Mountain (joint station)	98 00 33.0	124 00.02	533.3 N.
7	United States	Pembina River	98 16 06.3	135 63.07	459.5 N.
8	....do	Long River	98 51 52.0	165 13.05	376.7 N.
9	British	Sleepy Hollow	99 19 03.0	183 39.11	213.4 N.
10	....do	Turtle Mountain east	99 46 04.3	203 77.29	54.2 N.
11	United States	Turtle Mountain west	100 31 13.8	238 15.10	154.9 N.
12	British	1st Mouse River	100 57 29.8	258 07.44	240.2 N.
13	United States	South Antler Creek	101 28 02.9	281 19.73	203.3 N.
14	British	2d Mouse River	101 57 56.0	303 71.50	40.0 N.
15	United States	United States, No. 8	102 26 25.2	325 38.46	7.8 N.
16	British	Short Creek	102 50 00.9	343 28.92	183.4 N.
17	United States	3d Mouse River	103 11 11.3	359 32.54	203.2 N.
18	British	Grand Coteau	103 34 53.7	377 29.77	138.8 N.
19	United States	Mid Coteau	104 05 34.0	400 49.25	414.1 N.
20	British	Big Muddy River	104 39 53.6	426 50.35	40.4 N.
21	United States	Bully Spring	105 12 21.4	451 18.41	151.8 N.
22	British	Poplar River	105 41 39.2	473 34.54	333.5 N.
23	United States	West Poplar River	106 12 34.4	496 69.06	156.7 N.
24	British	Little Rocky Creek	106 46 31.5	522 47.42	390.7 N.
25	United States	Frenchman's Creek	107 23 48.2	550 67.40	436.9 N.
26	British	Cottonwood Coulé	107 45 45.9	567 38.81	593.6 N.
27	United States	Pool on Prairie	108 13 09.2	588 19.31	540.9 N.
28	British	Near Goose Lake	108 48 59.5	615 32.02	397.1 N.
29	United States	East Fork	109 24 07.7	642 02.18	836.0 N.
30	British	West Fork	109 41 38.2	655 23.57	669.3 N.
31	United States	Milk River Lake	110 10 19.5	677 02.81	416.0 N.
32	British	Milk River	110 43 46.0	702 30.23	166.6 N.
33	United States	East Butte	111 11 02.5	723 03.83	304.3 S.
34	British	West Butte	111 33 02.6	739 57.70	571.2 S.
35	United States	Red Creek	112 00 19.5	760 31.60	166.5 N.
36	British	South Branch Milk River	112 32 50.3	785 02.79	181.5 N.
37	United States	North Branch Milk River	112 58 25.2	804 33.61	115.5 N.
38	British	Rocky Mountains	113 26 35.3	825 61.33	112.5 S.
39	....do	Belly River	113 40 39.0	836 33.85	383.5 S.
40	United States	Chief Mountain Lake	113 53 19.6	846 02.40	10.6 S.
41	British and United States (1861).	Summit of the Rocky Mountains	114 02 56.5	853 25.29	133.4 N.

CHAPTER II.

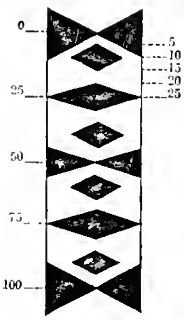
TOPOGRAPHY.

The sources from which our topographical information was obtained were as follows:

1. The tangent-lines.
2. Meander-lines, with the theodolite and stadia-rods.
3. Minor compass-surveys.
4. Triangulation and intersection in the Rocky Mountains.
5. Reconnaissances.

Tangent-lines.—The topographical information obtained by these was altogether secondary to the main object of making a geodetic connection of the astronomical stations. It consisted of noting the crossings of streams and valleys intersecting distant hills, and sketching the immediate vicinity. The stakes of these lines, however, were the basis of the stadia-lines both for distance and azimuth.

Stadia-lines.—The theodolites employed in this method of survey were made by Würdemann, and were similar in construction to the large eight-inch transits used for azimuth work. The horizontal limb was six inches in diameter, divided to 10′, and reading, by two verniers, to 10″; vertical limb, four inches in diameter, divided to 20′, and reading, by vernier, to 1′; telescope of 10″ focal length, magnifying 17 times, and having in the reticle three horizontal and one vertical line, which were fixed. The rods were made of pine, $3'' \times 0''.\frac{5}{8}$, in cross-section, were about twelve feet long, and folded on a hinge at the middle. The inner side was painted white, and marked with figures,



as shown in this sketch. Each rod was adjusted for a particular theodolite, as follows: A distance of 1,000 feet was measured on the ground with great care, and the rod placed at one end, the theodolite at the other. The space covered by the constant visual angle was noted on the rod, and this space (representing 1,000 feet) was subdivided into equal parts, the smallest of which represented five feet, from which one foot could be read by estimation.

Habitually two, but sometimes three, rods were used with each theodolite, and all measurements were made twice—*i. e.*, the distance and elevation of a course were recorded once as a foresight and once as a backsight.

The azimuth was taken from the tangent, and was kept throughout the line—*i. e.*, each recorded angle was the angle between the course and the true meridian.

An average day's work for a single party was a line of five miles in length, but as much as twelve miles of line have been run by one party in a day.

The notes of the stadia-surveys were reduced in the office—first, each reading for distance (being the hypothenuse of a vertical right-angled triangle) was reduced to horizontal distance and difference of level, then each bearing was corrected by its proportional part of the total error in azimuth: the horizontal distance was then resolved into rectangular co-ordinates, with reference to the first meridian; these co-ordinates were algebraically summed, and compared with the co-ordinates of the terminal point as given by the tangent; the error of the last point, in latitude and longitude, was then distributed in the co-ordinates of each course in proportion to its length; the adjusted co-ordinates were then plotted on the map. For reducing the readings to horizontal and vertical distances, the formulæ used were those deduced by Prof. S. W. Robinson, C. E., formerly of the Lake Survey. They were originally published in the Journal of the Franklin Institute for February, 1865.

$$d=\frac{R'}{R}(B-c-f)\cos^2 V+(c+f)\cos V$$

$$h=\frac{R'}{2R}(B-c-f)\sin 2V+(c+f)\sin V$$

in which—

V = angle of elevation or depression.

B = length of a measured base.

R = reading of stadia on that base.

f = principal focal distance of object-glass of telescope.

c = distance from axis of telescope to object-glass.

R' = any reading for which the horizontal distance and difference of level are required.

d = horizontal distance corresponding to R'.

h = difference of level corresponding to R'.

With these formulæ, tables have been constructed by Alfred Noble and William T. Casgrain, assistants in the United States engineer's office at Milwaukee. They assumed B and R each equal to 1,000 feet, and $(c+f)$ equal to 1.4 feet. These assumptions correspond to our own instruments and rods. The tables are of the same form as traverse tables, the arguments being the stadia-reading and angle of elevation or depression.

The total number of stadia-traverse lines is one hundred and thirty, aggregating a length of one thousand two hundred and eighty-seven miles. The notes were all reduced in the manner above described. Of these, sixty-nine lines (seven hundred and thirty-eight miles) were closed on known points, and their results are brought together in the following table in order to show the degree of accuracy of this kind of surveying:

Stadia-lines.

Number.	Assistants.	Date.	Length in miles.	Number of courses.	Average length of course.	Total errors of closure. Azimuth.	Latitude.	Departure.	Height.	Proportional errors. Azimuth per course.	Latitude per 1,000 feet.	Departure per 1,000 feet.
					Feet.	′ ″	*Feet.*	*Feet.*	*Feet.*	″	*Feet.*	*Feet.*
15	A. D	Nov., 1873	1.48	6	1307	+ 8 00	25.4 N.	35.7 E.	......	80.0	3.2	4.6
28	L. C	Aug., 1873	1.50	7	1186	....	277.8 S.	32.3 E.	......	......	33.4	3.9
41	..do.........	Oct., 1873	1.71	7	1297	....	14.9 N.	17.4 W.	......	......	1.6	1.9
25	A. D	July, 1873	1.79	10	948	....	16.8 N.	4.0 W.	......	361.4	1.7	0.4
29	..do.........	Sept., 1873	2.61	11	1336	....	15.8 S.	131.1 E.	......	......	1.0	8.9
63	C. L. D	Aug., 1874	2.65	13	1070	+12 51	103.8 S.	30.3 W.	+27.5	58.5	7.5	2.2
58	V. T. McG....	Aug., 1874	2.66	7	2012	−11 00	127.5 S.	23.1 E.	......	120.0	9.0	1.6
53	O. S. W	July, 1874	3.11	9	1827	....	19.8 S.	1.9 W.	......	......	1.2	0.1
20	L. C ...... / F. v. S	June, 1873	3.17	24	698	....	85.9 S.	275.7 E.	......	......	5.1	16.5
24	A. D	June, 1873	3.24	20	851	+19 40	31.5 N.	217.2 E.	......	59.0	1.8	12.7
17	..do.........	Dec., 1873	3.35	12	1475	+ 6 50	53.0 S.	77.0 W.	......	34.2	3.0	4.4
27	F. v. S	Aug., 1873	3.44	14	1297	+ 8 30	30.2 S.	175.6 W.	......	36.4	1.6	8.6
36*	L. C	Sept., 1873	3.85	13	1556	....	....	165.5 E.	......	......	......	9.1
38†	A. D	Sept., 1873	3.89	14	1412	....	....	1.0 W.	......	......	......	0.0
57	V. T. McG....	Aug., 1874	3.91	10	2065	....	2.1 S.	90.9 W.	......	......	0.1	4.4
33	A. D	Sept., 1873	3.93	16	1297	− 8 00	63.6 S.	57.9 E.	......	3.0	3.2	2.8
21	..do.........	June, 1873	4.43	20	1172	− 2 45	29.3 N.	33.3 E.	......	8.2	1.2	1.4
65	V. T. McG....	Aug., 1874	4.48	17	1390	− 6 31	59.1 S.	85.2 W.	+38.1	23.0	4.5	3.6
47	..do.........	July, 1874	5.17	20	1365	....	26.2 N.	5.7 W.	+14.0	......	0.9	0.2
8	C. L. D	Nov., 1873	5.24	21	1253	−11 20	235.5 N.	126.2 E.	......	35.8	7.7	4.0
6	..do.........	Nov., 1873	5.41	20	1429	+ 2 45	325.3 N.	361.0 E.	......	8.2	11.4	12.7
2	O. S. W	Nov., 1873	5.71	19	1588	....	116.8 N.	39.8 E.	......	......	3.8	1.3
61	C. L. D	Aug., 1874	6.52	25	1378	+ 2 34	55.3 S.	142.2 W.	......	6.1	1.6	3.5
16	O. S. W	Dec., 1873	6.56	34	1004	+ 3 15	182.2 N.	96.2 E.	......	5.7	5.3	2.8
12	C. L. D	Dec., 1873	6.63	17	2060	− 5 40	16.0 S.	6.0 W.	......	20.0	0.5	0.2
46	V. T. McG....	July, 1874	6.65	28	1254	....	208.2 S.	249.5 W.	......	......	5.9	7.1
30	C. L. D	Sept., 1873	6.76	33	1038	−16 30	207.7 S.	259.7 E.	......	30.0	6.0	7.6
19	L. C ...... / F. v. S	June, 1873	6.79	43	834	+18 00	28.8 N.	333.5 W.	......	25.1	0.8	9.6
32	C. L. D	Sept., 1873	7.24	31	1125	....	64.8 N.	143.1 W.	− 4.2	1.7	1.7	3.7
7	..do.........	Nov., 1873	7.54	37	919	− 6 50	60.4 N.	34.0 W.	......	11.0	1.8	1.0
4	..do.........	Nov., 1873	7.57	33	1212	....	455.7 N.	8.6 W.	......	......	11.4	0.2
52	O. S. W	July, 1874	8.24	26	1673	− 4 20	41.1 N.	17.9 W.	......	10.0	0.9	0.4
56	C. L. D	July, 1874	8.43	27	1647	+ 9 00	78.2 S.	377.0 E.	......	20.0	1.7	8.5
48	V. T. McG....	July, 1874	8.75	35	1321	− 1 00	63.0 N.	47.0 E.	−36.0	1.7	1.3	1.0
42	A. D	Sept., 1873	8.76	33	1401	....	204.5 S.	18.3 E.	......	......	4.4	0.4
49	V. T. McG....	July, 1874	9.36	36	1372	....	291.0 N.	155.3 W.	......	......	4.9	2.6
31	F. v. S	Aug., 1873	9.38	36	1377	....	99.1 N.	131.7 E.	......	......	2.0	2.7
55	C. L. D	July, 1874	9.46	43	1138	− 1 15	39.3 S.	22.5 W.	......	1.7	0.8	0.4
45	..do.........	July, 1874	9.54	33	1526	− 2 12	3.2 S.	13.3 W.	......	4.0	0.06	0.2
62	..do.........	Aug., 1874	9.76	44	1165	+17 08	71.7 S.	26.3 W.	......	23.4	1.4	0.5
43	A. D	Sept., 1873	9.95	35	1501	+22 25	203.0 N.	469.8 E.	......	38.4	3.8	8.1
51	C. L. D	July, 1874	10.75	37	1535	+ 8 38	120.4 S.	203.9 W.	......	11.0	2.1	3.6
26	A. D	Aug., 1873	11.56	58	1052	+28 40	193.7 S.	47.9 E.	−44.1	29.6	3.1	0.3
35	C. L. D	Oct., 1873	12.14	43	1725	−29 35	165.0 S.	203.5 W.	......	41.3	2.5	3.1
1	..do.........	Jan., 1874	12.21	40	1610	....	87.5 N.	53.5 E.	......	......	1.3	0.8
66	V. T. McG....	Aug., 1874	12.28	32	2025	+ 6 05	49.2 N.	8.7 W.	......	11.4	0.7	0.1
54	O. S. W	July, 1874	13.11	34	2040	+13 40	177.5 S.	191.5 W.	......	24.1	2.5	2.7
37‡	C. L. D	Sept., 1873	13.16	71	970	....	....	561.8 E.	......	......	......	8.4
3	..do.........	Nov., 1873	13.19	53	1315	....	91.3 N.	46.0 E.	......	......	1.3	0.7
59	..do.........	Aug., 1874	13.92	47	1561	+ 1 20	211.3 S.	122.4 W.	......	1.5	3.3	1.7

* Along Coteau-tangent. † Tangent west of Coteau. ‡ Coteau-tangent.

Stadia-lines—Continued.

Number.	Assistants.	Date.	Length in miles.	Number of courses.	Average length of course.	Total errors of closure.				Proportional errors.		
						Azimuth.	Latitude.	Departure.	Height.	Azimuth per course.	Latitude per 1,000 feet.	Departure per 1,000 feet.
					Feet.	″	*Feet.*	*Feet.*	*Feet.*	″	*Feet.*	*Feet.*
67	V. T. McG....	Aug., 1874	14.31	37	2043	— 9 25	288.1 N.	20.4 E.	......	15.3	3.8	0.2
69	.do..........	Aug., 1874	14.71	39	1991	— 3 15	337.2 S.	280.4 E.	......	5.0	4.3	3.6
9	C. L. D	Nov., 1873	14.91	85	927	— 7 00	125.8 N.	268.8 W	......	4.9	1.6	3.4
13	..do..........	Dec., 1873	15.91	105	801	+ 4 00	21.5 N.	36.5 E.	......	2.3	0.2	0.4
64	V. T. McG....	Aug., 1874	16.63	52	1687	— 0 50	6.7 S.	112.3 W.	+89.8	0.9	0.1	1.2
68	..do..........	Aug., 1874	16.96	45	1990	— 4 15	5.6 S.	802.3 E.	......	5.7	0.1	9.0
11	C. L. D	Dec., 1873	17.26	106	860	—46 00	283.9 N.	30.3 W.	......	26.0	3.1	0.3
50	C. L. D .... } V. T. McG.. }	July, 1874	17.73	82	1112	....	95.4 S.	136.9 W.	.....	......	1.1	1.4
60	C. L. D	Aug., 1874	17.81	51	1844	....	69.5 S.	175.0 W.	—33.1	......	0.7	0.8
44	..do..........	July, 1874	18.36	63	1539	+ 4 05	420.0 S.	158.3 E.	......	3.9	4.3	1.6
39	..do	Sept., 1873	19.35	102	1001	—59 40	148.2 S.	27.6 E.	+16.0	34.9	1.4	0.3
34	..do..........	Oct., 1873	20.40	75	1435	—18 05	96.7 N.	47.6 E.	......	14.4	0.9	0.4
40	..do..........	Sept., 1873	20.40	104	1036	— 3 12	54.4 S.	6.0 W.	+44.3	1.8	0.5	0.1
5	..do....	Nov., 1873	21.36	99	1138	....	791.2 N.	193.7 E.	......	......	6.8	1.7
18	F. v. S	June, 1873	22.00	108	1085	—13 45	304.8 N.	569.9 W.	......	7.6	2.6	4.8
10	C. L. D	Dec., 1873	25.91	111	1232	—10 16	521.9 N.	130.4 E.	......	5.5	3.8	0.9
22	L. C....... } A. D....... }	June, 1873	26.37	181	769	+26 40	50.8 S.	532.7 W.	......	8.8	0.4	3.8
23	F. v. S	July, 1873	27.86	178	799	—26 00	1700.0 S.	496.5 W.	+92.0	8.7	11.9	3.5
14*	C. L. D	Jan., 1874	46.34	112	2186	+14 20	112.9 N.	....	......	7.7	0.5	......

* Along Lake of the Woods; closed on sextant-station.

MEANS.

	Lengths.	Number of stations.	Lengths of courses.	Total errors.			Proportional errors.		
				Az.	Lat.	Dep.	Az.	Lat.	Dep.
				′ ″	*Feet.*	*Feet.*	″	*Feet.*	*Feet.*
The 69 lines	10.69	45	1361	12 14.6	160.5	146.4	27.2	3.40	3.31
Season of 1873	9.83	50	1154	20 05.9	177.7	188.8	......	4.03	4.72
Season of 1873–74	12.74	54	1313	10 46.3	206.3	96.7	......	3.92	2.46
Season of 1874	10.20	34	1600	6 26.6	115.4	134.6	.....	2.49	2.42
Assistant O. S. W................	7.35	24	1626	7 05	105.5	69.5	.....	2.74	1.46
Assistant V. T. McG	9.66	30	1710	5 40.1	122.0	156.7	.....	2.96	2.88
Assistant C. L. D	13.67	57	1310	12 55.5	172.1	131.8	......	2.97	2.49
Assistant A. D	4.50	20	1225	12 19.2	70.4	59.3	......	2.51	3.59
Assistant F. v. S	15.67	84	1139	16 05	533.5	338.4	......	4.52	4.90
Assistant L. C	7.62	44	1120	22 21.7	110.2	231.0	......	7.52	7.56
According to length:									
From 9.48^{m} to 5.71^{m}	3.49	14	1356	9 28.4	83.0	89.6	69.2	5.14	4.79
From 6.52^{m} to 12.28^{m}	8.87	35	1363	10 46.3	124.5	126.6	16.4	2.75	2.85
From 13.14^{m} to 46.34^{m}	19.48	84	1365	14 46.0	270.3	224.9	10.0	2.51	2.35

The mean of sixty-nine lines shows that the average error of our topographical surveys, by this method, was about one foot in three hundred. The means for the various seasons show a constant increase in the accuracy. The mean error of 1873 is larger than the others, and arises from the want of experience on the part of one or two assistants. Most of the work of that summer was done under fair circumstances, including several days of high winds which cannot be avoided on the plains. The work during the winter of 1873–'74 was done under very unfavorable circumstances. The thermometer was near zero every day, and most of the lines were run over swamps and ice, where it was almost impossible to keep the instrument in level. The two lines, Nos. 10 and 11, were run on the ice of the Roseau River, and up through the swamp, to the forty-ninth parallel. One, over seventeen miles in length, closed within about three hundred feet ($\frac{1}{600}$), and the other, nearly twenty-six miles long, closed within about five hundred feet ($\frac{1}{400}$).

Line No. 14 was run on the ice of the Lake of the Woods, and meandered the shore from the forty-ninth parallel to Rainy River. It was closed on a sextant latitude station, and a carefully observed azimuth. Although more than forty-six miles in length, its error in azimuth was only 14′ 20″, or 7″.7 for each course, and in latitude only one hundred and thirteen feet, or $\frac{1}{2000}$. These lines were run by Mr. C. L. Doolittle, and reflect great credit on his carefulness and precision.

The work in 1874 was all done by experienced assistants, and under the ordinary circumstances to be met on the plains, that is, a high wind and "boiling" of the air on three days out of five. The error is seen to be about $\frac{1}{400}$. This I take to be the greatest accuracy that can be expected for a whole season's work, when the party is so pressed for time that it cannot lie over on windy days. Several individual lines are much more accurate. The smallest error is in Line No. 45 by Mr. Doolittle, length about ten miles and error $\frac{1}{25000}$. This of course is accidental; but there are eleven lines whose error is less than $\frac{1}{1500}$. The last three means are obtained by dividing the lines into three equal sets, according to length. For the first set, with a mean length of about three miles, the error was $\frac{1}{200}$; for the second, with a length of about nine miles, $\frac{1}{300}$; and for the third, with a length of about eighteen miles, $\frac{1}{400}$; that is, the longer lines were the more accurate, in proportion to their length. This probably shows a considerable error on one or two courses of the short lines, which, divided by a small distance, gives a large proportional error. The same error distributed over a long line would, of course, be much smaller proportionally. It is also probable that the accidental errors tend more nearly to counterbalance each other in long lines.

As the proportional errors are smaller for the long lines than the short, it would seem probable that there are no cumulative errors, such as lost motion in tangent-screws, &c.

An error once made, however, is carried through to the end of the line, and as it is impossible to discover where the error is, the only feasible method of adjustment is that which we have adopted; namely, to distribute the azimuth-error, proportionally, in each course, and the position-errors in each course proportionally to its length.

As the result of our own experience, then, the average accuracy of surveys with the stadia is $\frac{1}{300}$, under good circumstances we may expect $\frac{1}{450}$, and on selected days, with great care, $\frac{1}{1500}$ can be obtained.

This shows that this method is available for surveys for maps of a scale of $\frac{1}{10000}$, or about six inches to the mile.

The plane-table is, of course, superior for minute topography in certain localities, in populated countries, &c.; but for meandering streams on the plains, I think the stadia-method is the best. If there are ravines to be crossed, its measurements are more accurate than those made with the chain; and it has advantages at all times in its great celerity in giving heights, as well as distances, and in the fact that all the measurements are under the control of the engineer. The plane-table would be useless on the plains, on account of high winds, dust, and sudden storms.

General Comstock, in charge of the Lake Survey, states that he considers $\frac{1}{1000}$ on ordinary ground to be the precision of good chaining and $\frac{1}{700}$ that of good stadia-work. On rough and broken ground, the stadia was equal to the chain in precision, and on bad ground was superior. He adds, "In topographical work our main lines are chained, or derived from chained bases which have an accuracy of $\frac{1}{2000}$ to $\frac{1}{5000}$; the side lines diverging from these, and checked by returning to them, are all stadia-lines, whose average accuracy (probable error) I estimate at $\frac{1}{300}$ to $\frac{1}{400}$ for distances of 1,000 feet."

Prof. S. W. Robinson states that the error of stadia-measurement has been found to be about $\frac{1}{800}$ to $\frac{1}{1000}$, and that lines "have been run from one to six miles, and over heights of one hundred and fifty to two hundred feet, in which the final error in height ranged from 0 to 1.5 feet, with no more than ordinary care." We have no precise data for determining the errors in height. Some of the lines were closed on points whose approximate height was determined by the barometer, or by trigonometric leveling. The errors ranged from four to one hundred feet; the greater part of this was probably in the barometric result. The superiority of this method of survey over that with the chain, in very rough country, is clearly shown by lines 36, 37, and 38. All of these lines were along the tangent. Nos. 36 and 37 were in the Coteau—a series of irregular hills in close proximity—and both of them gave measurements less than the chain, by nearly the same amount, about $\frac{1}{115}$. No. 38 was also along the same tangent, but on level ground. It differed from the chained measurement by only one foot in nearly four miles; the intermediate errors—never larger than a few feet—having balanced.

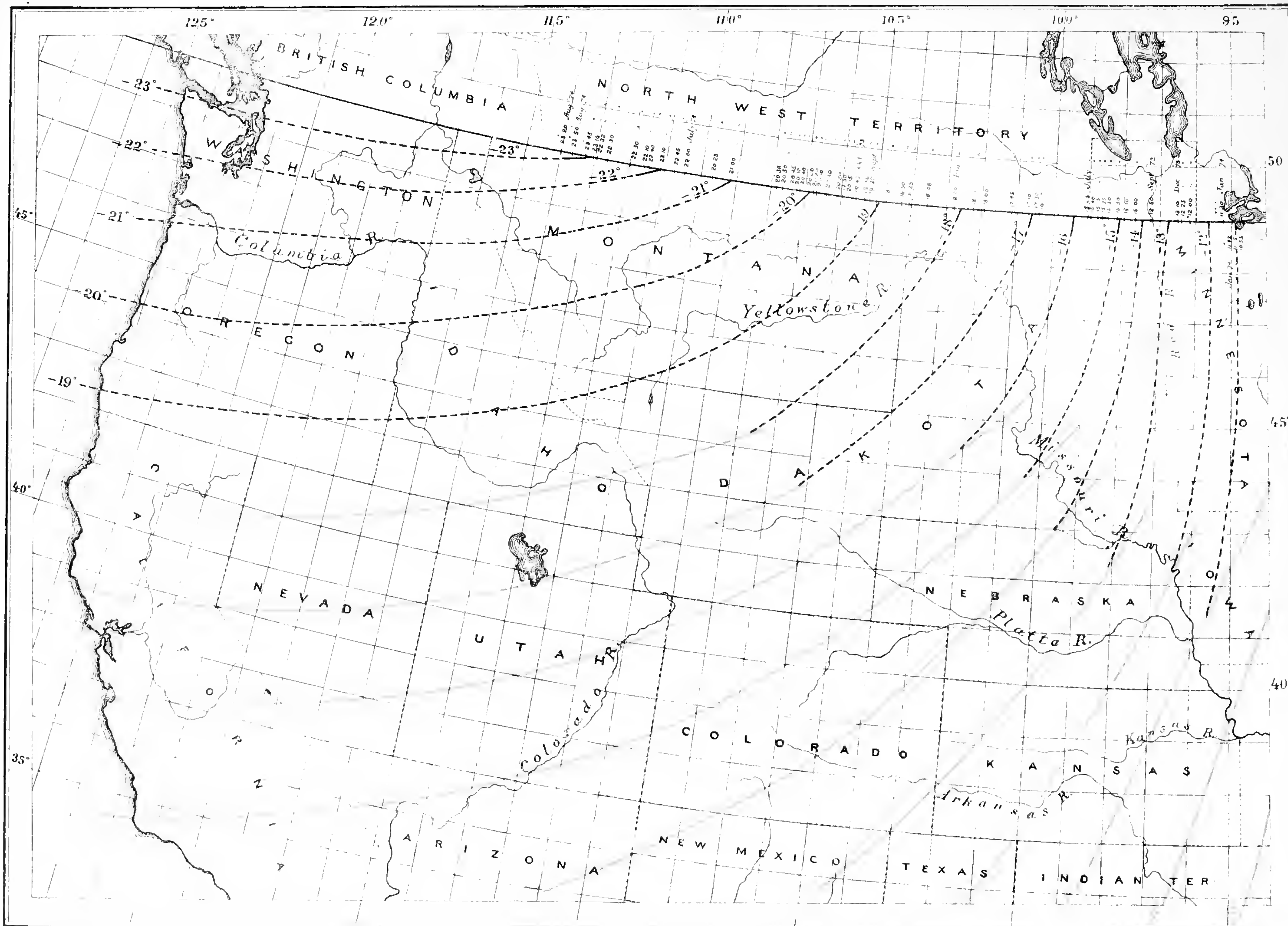
Minor compass-surveys.—In connection with these stadia-lines, surveys of small extent along minor features, such as branch-ravines, &c., were made with a six-inch compass, the distances being estimated from pacing.

The variation of the compass was obtained from the true azimuth of the stadia-line, and these compass-surveys started and closed on points of the stadia-line. They were of small extent, seldom a mile in length, although aggregating about two hundred miles. Their average accuracy is about $\frac{1}{75}$. They were adjusted in the same manner as the stadia-lines.

The Rocky Mountains.—The portion of the Rocky Mountains crossed by the 49th parallel, between the summit and the eastern slope, is about twenty-six miles. In this inaccessible region the method of stadia-surveys was not feasible, and we had not the time for a comprehensive triangulation. Hence this portion of our map is not as accurate in detail as the others. We have, however, considerable data for constructing it. These data consist of a stadia-line, by Mr. Doolittle, along the eastern slope, and

UNITED STATES NORTHERN BOUNDARY COMMISSION.

MAGNETIC CHART



General Authority U.S. Coast Survey chart for 1875

Declinations along 49 Parallel from records of Theodolite surveys by Northern Boundary Commission

extending into the valley of Belly River to connect with the British Astronomical Station; of a careful triangulation of Chief Mountain Lake, under Captain Gregory's direction, including intersections on neighboring peaks; of a stadia-line by Mr. Wilson, from Chief Mountain Lake, through the South Kootenay Pass, over the water-shed and connecting with a traverse made in 1861, to the Akamina Station; and, lastly, of a triangulation, by myself, of certain peaks in the neighborhood of the summit-monument, from which intersections were taken on all the principal peaks within the five-mile belt. I also obtained cross-intersections on these points from a peak at the head of Chief Mountain Lake, located accurately by Captain Gregory's triangulation.

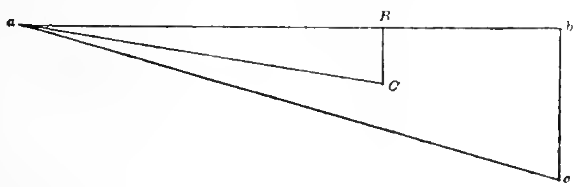
The principal peaks were approximately located in position and altitude by these means, and the topography was supplemented by numerous profile sketches. To accomplish the triangulation near the summit I followed the old and very blind trail along Akamina Creek to the base of the water-shed, where I identified the astronomical station of 1860–'61 by the observing-logs, old boxes, &c. Here I observed for azimuth, and measured a base-line. The length of this was one thousand seven hundred and forty-nine feet, being the mean of four measurements with the Stackpole tape, differing from each other by less than one inch, or $\frac{1}{21000}$. From this base the triangles were expanded to the peaks near the summit-monument, and from them intersections were taken. I had intended to extend the triangles to a point about two miles south of the monument, where, from an altitude of nearly nine thousand feet above the sea, and five thousand feet above Chief Mountain Lake, the whole country can be seen, but I found it impossible to transport the heavy eight-inch theodolite beyond the monument. This monument is finely placed, upon the very water-shed of the Rocky Mountains, at an altitude of six thousand seven hundred feet above the sea. It is in the center of a flat saddle, about five hundred by one hundred and fifty feet, and is overlooked, on the north and south, by sandstone knobs, from eight hundred to a thousand feet higher than itself. On the east is a sheer precipice of nearly two thousand feet, terminating in a lake which discharges, through the Saskatchewan River, into Hudson's Bay. On the west the slope is steep, but still accessible with care, and terminates in a lake discharging through the Columbia River into the Pacific. The monument is a rude pyramid of undressed-sandstone blocks, about ten feet at the base, and eight feet high. It is in as perfect order as when built in 1861. Within a few rods of the cairn the divide is reduced to a mere knife-edge of ragged rock, which must be passed, if at all, *à cheval*. It was at this point that I found it impossible to transport the transit any further. In company with one of the men, named Macey, I passed over this, and, taking an aneroid barometer with me, followed the crest of the divide to a prominent sandstone peak, about two miles south of the line. The climbing was difficult, for the sedimentary sandstone was weathered in vertical cracks. Some of these, not more than eight or ten feet across and one hundred feet or more deep, we easily jumped; but at the larger ones we had to let ourselves down, from ledge to ledge, for two hundred feet on one side, and ascend, similarly, on the other—a tiresome operation, after the novelty of the first two or three trials had worn off.

The view from the peak was, however, very fine. On the east we could see over the tops of the range beyond Chief Mountain Lake on to the brown plains extending indefinitely eastward. To the west we recognized the broad valley of the Flathead River, and beyond that another mass of mountains. In our immediate vicinity was a most tumultuous mass of mountains. From the main divide the ridges curved off in circles, on either side, forming vast amphitheaters. The effect was heightened by the immense masses of snow—some of them more than a mile in extent—covering the northern slopes of these ridges, and frequently terminating in lakes whose intense blue revealed great depths.

The barometer gave the altitude of this peak eight thousand six hundred feet. This ought to be about the timber-line for this latitude and distance from the sea, but this line is not at all distinctly marked. The heavy pine timber of the valleys did not seem to extend much beyond the altitude of seven thousand feet, and terminated gradually. Beyond this were irregular bunches of dwarfed spruce; but the greater part of the curved ridges was destitute of any timber, and this, together with the reddish-brown color of the bare rock, and the curious shapes it has assumed under the effects of

the weather, combined to give an exceedingly wild and rugged appearance to the whole landscape.

Reconnaissances.—Trails passed over, outside the belt of accurate survey, were approximately surveyed. The basis of the survey was the astronomical position of the various camps, where observations were taken, on north and south stars for latitude, and east and west stars for time. The trail generally began and ended at points accurately known, and thus we had the means of determining the traveling rate of the chronometers. Between the camps the courses were kept by a six-inch vernier compass, mounted on a jackstaff. Two light spring-carts were employed, one carrying a man to set up flags on prominent points, and the other the assistant with the compass, who sighted on the flags and sketched the topography. The distance was derived from odometer measurements. The courses and distances were plotted, and then adjusted to agree with the astronomical work. The trails thus reconnoitered were, in 1873, from the Mouse River to Fort Totten; in 1874, from the Missouri to the Boundary along the two branches of Poplar River, the Meridian trail to Fort Shaw, the Riplinger road from the Boundary to Fort Shaw, and the stage road from Fort Shaw to Fort Benton. In addition to this, a reconnaissance of the course of the Missouri River was made while descending that stream in boats, in September, 1874. The astronomical camps, as before, were considered as fixed points; the courses between them were kept by compass-readings, and the distance was obtained from a record of the time combined with estimates of the velocity of the current, based upon some rough measurements by floats. To adjust the compass-work to conform to the astronomical positions, the co-ordinates were first computed and summed algebraically between camps.



Let us suppose that the result is $a\ b$ and $b\ c$, and that the astronomical co-ordinates are $a\ B$ and $B\ C$; each course is then corrected in azimuth by the angle $c\ a\ C$, and multiplied by a "factor of distance" representing the ratio of $a\ c$ to $a\ C$; the co-ordinates are then recomputed, and their sum is found equal to $a\ B$ and $B\ C$.

The "factor of distance" varied from 0.85 at Fort Benton to 0.57 near Bismarck, showing that the velocity of the current was always overestimated, and more at the lower part of the stream than the upper; the mean was 0.66. Our estimated distance, from Fort Benton to Bismarck, was one thousand two hundred and eighteen miles, agreeing closely with that of the steamboat men; but the adjusted survey reduces this to 805.4 miles.

It is believed that this reconnaissance is more accurate than any other of its predecessors, particularly in the matter of longitudes I got good observations at fifteen of the seventeen intermediate camps, and had six chronometers to get the longitudes. The longitude of Fort Benton was fixed by an accurate reconnaissance from the Boundary-line. That of Bismarck had been determined by telegraph From observations at these points I deduced the traveling-rates. The most important change from previous maps is in the longitude of the mouth of the Muscle Shell River, near which we camped. We move the mouth to longitude 107° 53′ 18″ from 108° 08′ 52″, as given on the engineer map of the Department of Dakota.

The information gained from these various reconnaissances, and those made by other parties of the survey, has been combined to make the reconnaissance maps. The land-office plats of the Canadian Dominion and the United States have been utilized to fill up the blanks near Red River and the headwaters of Sun River. Your reconnaissances in 1869, in Dakota, have also been used. The rest of the map is our own.

In the appendix is a summary of the astronomical work.

Construction of maps.—In the field, the topographical note-books were forwarded to me by the assistants in charge of small parties. The lines were then platted on a scale of $\frac{1}{30000}$, upon protractor sheets, and the topography filled up. It was not always possible to keep these field-plats up to the work in the field, but they were completed at once on returning to the office. After the stadia-notes had been reduced and adjusted, they were plotted by co-ordinates upon forty-five sheets of super-royal paper, on a scale of 1 mile = 1 inch, or $\frac{1}{63360}$. The topography was filled in by reducing from the field-plats. This formed the preliminary series of maps, and represented a belt of country five miles in width, on the United States side of the line, and extending from Rainy River to the summit of the Rocky Mountains. Photolithographic copies of these were made as soon as they were finished, and these copies were furnished to the British Commission. They, in turn, furnished us with tracings of a similar set of maps, showing their surveys on the northern side of the Boundary. From these two sets of preliminary maps the final joint series has been constructed, on a scale of 1 inch = 2 miles, or $\frac{1}{126720}$, the reduction being made by squares. There are twenty-four sheets in this series. In both series the projection used was the polyconic. The forty-ninth parallel at Lake of the Woods being taken as the central parallel, each sheet was projected with reference to its own central meridian, and the parallel shown on the map was the parallel actually marked, including station-errors.

The reconnaissance notes were reduced and adjusted in a similar manner, and then plotted on protractor sheets, on a scale of 1 inch = 4 miles, or $\frac{1}{253440}$. From these, a reduction was made by squares, to a scale of 1 inch = 8 miles, or $\frac{1}{506880}$. The projection was polyconic; the central parallel being 48° 15′, and each sheet being projected with reference to its own central meridian; the borders being rectangular, the sheets join on the parallel of 47° 30′, and overlap on the parallel of 49°.

Each sheet is 20.54 by 15 inches. Six of these sheets show the general outlines of the topography from the Rocky Mountains to the Lake of the Woods, and between the parallels of 47° 30′ and 49° 10′. The seventh sheet is a profile along the boundary. The data for this are the barometric heights at the United States astronomical stations, the trigonometric altitudes on the United States tangents, and accurate leveling for forty-five miles west of the Lake of the Woods. The horizontal scale of this sheet is 1 inch = 8 miles, to agree with the others, and the vertical scale 1 inch = 2,000 feet.

CHAPTER III.

OPERATIONS DURING THE WINTER OF 1873–'74.

The experience gained in carrying on a survey in the depths of winter, in a locality where the temperature reached a point 50° below zero, was of such a novel character that I think a somewhat detailed account of it will not be out of place.

As previously stated, on the conclusion of the summer's work at Fort Totten, you directed me, October 24, 1873, to proceed to Fort Pembina with my parties, and complete the geodetic and topographical work between the Red River and the Lake of the Woods; and to adopt, without examination, the intermediate astronomical stations observed by the British parties during the preceding winter. These two stations were at West Roseau and Pine Ridge, about twenty and fifty-six miles respectively from Pembina; and, together with the joint stations at Pembina and Lake of the Woods, made four stations in eighty-nine miles. The British parties had also made topographical surveys of the six-mile belt on their side of the line, had cut sight-lines for their tangents, and had marked the parallel for thirty-one miles from the Lake of the Woods.

We left Fort Totten on the 25th and arrived at Fort Pembina on the 29th of October. The greater part of this journey was over an open prairie from which the grass had been burned, and was made in the face of a northerly snow-storm. As we were insufficiently clad, having only the ragged remains of the summer's outfit, we suffered considerably—more perhaps than during the rest of the winter.

On arriving at Pembina I immediately began to reorganize the parties and provide their outfit for the winter. I hired enough additional men to carry the total strength up to forty-seven; of these, eight were teamsters and seven dog-drivers, the rest being divided into a tangent-party and two stadia-parties.

The outfit to be provided included transportation, clothing, snow-shoes, forage, rations, tent-stoves, and iron tent-pins. It was also necessary to overhaul the tents, tools, and instruments, which had been in constant use throughout the summer, and were all in need of repairs

The best form of transportation was a subject upon which I asked the opinion of the settlers in the Red River Valley and the officers of the British Commission. I found that what was commonly used in freighting along the Red River country in winter, on hard roads, was either wagon-beds mounted on runners or single ox-sleds; farther north, around Lake Winnipeg where there are no roads, dog-sleds are in universal use. The English officers advised me strongly to procure dog-sleds at once, giving it as their opinion, based upon their experience of the previous winter, that large animals could not make their way through the swamps. I thought it best, however, to give the mules a trial. I had four government wagons (six mules each), an ambulance (four mules), and three hired teams, two of which were drawn by two mules each, and the other by a pair of oxen. After some difficulty I succeeded in procuring about Pembina a sufficient number of second-hand sleigh-runners, known by the freighters as "Maineite bobs," for all the wagons. These were repaired and fitted with new tongues for long teams, and they answered the purpose very well. On hard roads the wagons were loaded as high as six thousand pounds, and the mules found no trouble in drawing them. Even in soft snow there was no trouble in hauling as much as could be loaded in the wagons, provided the animals could find a hard footing under the snow. In following the winding roads through the woods great care was required in driving the long teams (six mules), and even this was not always sufficient to keep clear of the trees. At the end of every trip one or more bobs would be broken; fortunately there was plenty of oak and ash available for repairs, for during the winter the wood-work of every set of bobs had to be replaced. The mules withstood the extreme cold very well. They were occasionally allowed to run loose during the day, but at night were always tied up in the shelter of the thickest brush at hand, but without any covering. Their forage allowance, as was to be expected, had to be largely increased. Of hay, each mule consumed about forty pounds per day as food and bedding, an ample supply having been cut and stacked for our use during the summer. There was no corn to be had in the country, and their grain was oats, wheat, and barley. Of this they consumed daily about twelve and one-quarter pounds each; an allowance greater by one-third than the Army ration, and more than twice as large as we had been feeding during the summer. I could detect no sickness or signs of weakness among the mules, and at the close of the season they were in nearly as good condition as at the beginning. Their superiority over oxen was clearly proved, as I had an ox-team with Mr. Doolittle's party. Their greatest daily travel was eighteen miles, against forty-four for the mules. At the close of the season they could only make eight miles a day, and were abandoned by their owner, whereas the mules carried us from Pembina to Georgetown, one hundred and forty miles, over a heavy road, in five days. With these heavy teams I was enabled to get all the supplies for the winter transported to a depot at Point d'Orme, on the Roseau River, thirty-three miles from Pembina. I also used them for camp transportation until we came to the edge of the Great Roseau Swamp, about midway between Red River and the Lake of the Woods. I tried an empty sleigh on this swamp, and, in so doing, mired the mules to their bellies, and lamed one quite badly. To my great surprise it was found that the swamp was not frozen at all, in spite of the fact that we had already had the thermometer down to 35° below zero. The explanation of it was soon discovered. The swamp is covered with a tall and strong grass. Before the cold weather had come there had been a heavy fall of snow, which had bent down the tops of the grass, but not into the water; the swamp was then covered, as with a blanket, with a foot or more of snow, separated from the water by a stratum of air. It formed a perfect protection for the water, whose temperature was slightly above the freezing-point.

The swamp being thus impassable for the teams, I took them back to Point d'Orme, and thence followed up the Roseau River on the ice, which was about eighteen inches thick, to Roseau Lake, and thence up to the Pine Ridge Station. But as it was essential that the tangent should be carried across the swamp, it was necessary to provide some sort of transportation for Mr. Wilson and a small party. To this end I had the carpenters make in camp three "tobogans" or flat trains, each to be driven by a single animal. These tobogans were made of two pine boards, fastened side by side with transverse cleats, and sprung up in front by hot water. This made, in fact, a rude sledge, twelve by two feet. Its load was packed after the fashion of a dog-sled. Before taking an animal on the swamp it was necessary to prepare a road. To do this a party of men were sent ahead on snow-shoes, and by passing and repassing over the same ground the snow was packed and pressed into the water; it instantly froze, and in a few minutes was hard enough to hold several tons, and there was no danger of its thawing for the next five months. Mr. Wilson crossed his outfit in this way, and as the route was much shorter than by the river, I had the road widened by the same process of packing, and it was used by the large teams to bring supplies up to Pine Ridge Station. It was not a very safe road, however, for the drifting snow soon filled it up to the level of the surrounding country. It was not distinguishable by the eye, and had to be followed by feeling, the road being hard, and the rest very soft snow. If, by any carelessness, a sleigh got a runner off the road and in the soft snow, the whole was instantly upset, and it required several hours to right it again. This mishap occurred two or three times.

Beyond Pine Ridge the dense windfall along the line rendered the use of large sleighs quite impossible. By following the ice on the streams, however, I managed to carry forward enough supplies to form a depot on the main East Roseau River, about ten miles north of the line, and about thirty miles from the Lake of the Woods station.

Beyond this depot dog-sleds were absolutely necessary, and I procured six of them from Pembina, at a cost of about \$80 for each train complete, including dogs. The dog-sled used in the Saskatchewan and Hudson's Bay country, consists of a straight piece of hickory, or ash board, about half an inch thick, ten feet long and ten inches wide. The front end is bent up, in the form of a curl, by steam. There are five transverse cleats which prevent the sled from splitting, and afford points to which are attached the loops of buffalo thong used in lashing. To pack the sled, a wrapper made of moose-skin is laid out flat across the sled and the load is placed on it, as compactly as possible; the wrapper is then folded over and the lash-rope is passed through the loops on either side in succession, from front to rear, and tightly fastened. The team generally consists of four, or sometimes five dogs, which are driven tandem. The pure Esquimaux dog is the best. His fur resembles that of a grizzly bear in length and color, and he weighs from seventy to one hundred and twenty-five pounds, and is short and thick set. I had only three of these in the whole number, the rest being a motley collection of large curs of all kinds—the only requisite being strength. They averaged about eighty pounds in weight, were soon broken to harness, and worked very well. The most important dog in the team is, of course, the leader. If he is intelligent and willing, all goes well; if not, there is always trouble and often disaster. The harness consists of a light collar of moose-leather, padded with hair around a piece of one-fourth-inch iron, a pair of traces, and back and belly bands. Decorations in the shape of bells, fancily worked cloth covering the back, flags, &c., are added, according to the taste and means of the owner. The drivers which I had were all half-breeds from Pembina. They were lazy and unreliable, and apparently very cruel to the dogs; but they got a great deal of work out of them, and were themselves capable of great endurance in running, and possessed of enormous gastronomic powers. The art of driving dogs consists in the adroit use of a whip, with a short stock, but stout lash about six feet long, and in an unbroken volley of oaths in bad French. When traveling on a well-beaten road, the leader keeps the road, and the driver follows at a half trot, in rear of the sled, cracking his whip and shouting to the dogs. Occasionally he thinks they are lagging, and he runs out, alongside the team, and gives each dog a sound welting and cursing, beginning with the leader; the howling of the dogs and the shouting of the driver makes a very lively scene, for the time, but everything soon quiets down again. The cruelty of the drivers is more apparent than real, for the dogs begin to howl as soon as they see the whip, and as their fur is nearly six inches long, it takes a good stroke to make any impression. Occasionally, however, their cruelty is outrageous, and they beat their dogs for several minutes in succession. I saw one driver—not in my employ—cut off a dog's ear with his whip, and as several of the dogs were minus an ear when they came to me, I suppose the practice is not uncommon. Some, also, had lost the sight of one eye, which was said to be due to the same cause. On good roads such as ice, hard crust, or well-packed snow, the dogs will travel along at about four miles an hour for ten or twelve hours without showing fatigue, and carry a load of about four hundred pounds per sled. In soft snow where there is no road the difficulties of this mode of travel are alternately ludicrous and vexatious beyond all patience. Every one has then to put on snow-shoes, and one man goes ahead to break the road; the dogs tug along after him for a few hundred yards when the sled is brought to a stand-still by some twig which has caught fast in the lashing; the dogs lie down to rest with perfect unconcern, and the driver has to maneuver round the sled (no easy matter with snow-shoes) and disengage the lashing, give the sled a start and a few cuts to the dogs. After a few of these mishaps the lashing becomes loose and the pack begins to oscillate: if passing over windfall (sometimes as high as the shoulder) one dog slips between two logs, the sled oscillates for a second on top of a log, and then falls bottom side up, and to crown all, the driver slips astride of a log, and tripping on his snow-shoe, is precipitated, head first, into the snow. Then it is necessary for the whole train to stop, first extricate the driver, then right the sled, take off the load and entirely repack it—an operation requiring a half hour, at the least. On such roads the speed is reduced to about two miles an hour, and the load to about two hundred pounds. The dogs require but little care. Arrived in camp, they are unharnessed and chained to the nearest bush: here they curl up and burrow in the snow, and sleep comfortably until required for work again. Often, in the morning, after a heavy fall of snow, nothing is visible but their noses. Their food is a pound of pemmican per day. This is chopped off with a hatchet, and thrown to them in one lump about sundown, or at the close of the journey. If pemmican cannot be had, they are fed on fish (about three pounds), or meat, or, in fact, anything available. They are great thieves, and should never be allowed to run loose about camp. Occasionally one will manage to slip his collar, and make way with ten pounds of meat during the night. They are never fed before starting on a journey, as it makes them lazy. They eat snow for water, and on the regular daily meal of a pound of pemmican keep in good condition. Those that I had gained about ten per cent. in weight during the winter.

On account of the extremely cold weather the men were all supplied with a suit of outside clothing, at a cost of $24 each. It consisted of—

Head-gear—a close-fitting skull-cap, made of two thicknesses of blanket, and lined with flannel. Sewed to this was a havelock, also of blanket, reaching to the shoulders, and fastening under the nose. This left only the eyes and nose exposed. In addition to this the men generally wrapped around the face and ears a heavy scarf of some kind, as it was found that in a wind, on the open swamps, the ears were frozen through the blanket-cap.

Sack-coat—of buffalo-leather, made loose, and fastened around the waist by a scarf.

Trowsers—of buffalo-leather, made "barn-door fashion" to keep out the wind. The coat and trowsers for myself and assistants were made of moose-leather, which is closer and keeps out the wind better. Its cost is about double that of buffalo-leather.

Mittens—of moose-leather, lined with blanket, with gauntlets reaching to the elbow. These were made large so that a pair of gloves might be worn inside of them, but this was not found desirable. The mittens were suspended from the neck by a string.

Foot-covering—early in the season, while the snow was wet, I tried the Fort Garry "beef-packs," but when the thermometer began to get down in the twenties below zero, these were useless, as the leather froze as stiff as iron. I then procured moccasins for the whole party. They were made after the Sioux pattern, and several sizes too large. The ordinary covering for the foot, throughout the rest of the winter, consisted of one or two pairs of woolen socks, then a pair of "neeps" (slippers made of blanket), then a square piece of blanket wrapped several times around the foot from heel to toe; finally the moccasin was put on, more to keep the blanket and slipper in place than for any other purpose. This method of covering proved to be a perfect protection to the foot, provided care was taken to always have a dry pair of moccasins and stockings on hand. The feet often got wet in moving about a fire, and to start out on a journey with wet stockings was to insure the freezing of the feet.

The trowsers were always tied tightly around the ankle to keep out the snow, and, in addition, we sometimes wore leggins made of moose-leather or of blanket—the latter being preferable, as the snow did not soak into it as into leather.

The leather clothing was worn over a suit of woolen clothes and two or three suits of woolen underclothes. In the woods where the wind could have no force, it formed a perfect protection, and the men worked cheerfully and lustily in temperatures of 20° and 25° below zero. But on the open swamp, a temperature of —5° accompanied by a wind was sufficient to put a stop to all stationary work, such as mounding, &c. The building of the mounds across the Great Roseau Swamp occupied about ten days, whereas there was not more than three days' real work in it; but the men could not work more than an hour or two at a time, and on some days could not work at all.

We traveled across open places, however, in all sorts of weather, but it was accompanied with considerable suffering, with frozen ears, noses, and fingers, with icicles hanging from the beard, and the eyelashes closed from time to time with ice. Our snow-shoes were kindly procured for us, from Montreal, by the British Commissioner. They were well made, but rather small and light for our work among brush and windfall. They generally broke at the point where the sides meet, near the rear end, and at the close of the season not one in fifteen pairs was fit for use. They measured forty inches in length, and sixteen inches in width at the widest part, and weighed one and one-half pounds each. Those made and used by the Indians about the Lake of the Woods measured sixty to seventy inches in length, fifteen inches in width, and weighed three and three-quarter pounds. The sticks of which they are made are an inch in cross-section, and will easily bear the weight of a man without breaking when caught on a stump.

In regard to supplies of rations and forage, I had expected to purchase them from the commissary and quartermaster at Fort Pembina, but he could only spare me ten thousand pounds of grain, and no rations. It therefore was necessary to procure everything from the Hudson's Bay and other stores about Pembina. The supplies were of excellent quality, but the rations cost 15 per cent. and the forage 60 per cent. more than the government price. The camp-equipage was thoroughly overhauled and repaired as soon as we arrived at Pembina. For heating the tents I had with me six Sibley stoves. In addition to these I had the blacksmith make eight box-stoves of light sheet-iron, 14 × 10 × 12 inches, and the necessary pipe. This gave one stove to nearly every tent, and some of the men's tents were joined together, end to end, so as to make one stove heat both. These box-stoves, although more difficult to transport, were in every other way superior to the Sibley. Water and dishes could be heated on them, which was a very important consideration when everything metallic was so cold in the morning that it could not be held with the naked hand. Moreover, we were often dependent on snow for water, and required some place to melt it, and, worst of all, we sometimes encamped on a frozen swamp where the fire in a Sibley stove would melt the ice, which, in turn, would extinguish the fire. Great care was required in guarding against fire with so many stoves. In spite of our caution, during the winter two tents were entirely destroyed, with a considerable amount of clothing and bedding, and every tent we had was more or less punctured with spark-holes.

Wooden tent-pins were useless in the hard-frozen ground. The iron pins were very good, but many of them were lost in the snow, the men being rather careless about them, since we always camped in thickets where the ropes could be secured to a bush or tree.

The tents, thus arranged, and banked with three feet of snow on the outside, were very comfortable—that is, the temperature, during the day, was 35° or 40° against —20° outside, and this, with our thick clothing, was sufficient. I do not remember hearing a single complaint all winter of loss of sleep from cold, even when the nights were as cold as 45° below zero. With the large Hudson Bay blankets the men used to make a bed stretching across the tent, about eight thicknesses of blanket under them, and four thicknesses of blanket and a buffalo-robe over them, the whole well tucked in on the sides and ends. In this four men slept. Myself and assistants slept separately, and each had a bag of buffalo-leather, eight feet long, and about the same in circumference. This was surrounded, above and below, by several thicknesses of blanket, and the whole was strapped up in the canvass bed-cover. On first getting into it it was very cold, and it required half an hour for the heat of the body to warm it. After that we slept without interruption till daylight.

While the preparations for the winter were being made at Pembina the parties were not idle. The third day after our arrival enough leather suits were finished to clothe Mr. Doolittle's party, and a few nights before the thermometer had suddenly gone several degrees below zero, freezing the river to a depth of more than a foot, and rendering a crossing very simple; consequently I started him out, November 4, to begin topographical work at the twelve-mile ridge. From there he worked on to the east, and arrived at the Roseau River, where I visited him on the 23d, and directed him to survey the course of that river on the ice, and close his line on the Pine Ridge Station. We all met there on the 15th December.

About the 5th November I moved the other parties from Fort Pembina to the east bank of the Red River, near the Hudson's Bay post; here I observed for azimuth, and began to trace the tangent eastward, and Mr. Wilson and Mr. Downing made topographical surveys in the neighborhood. At the same time I sent out about twenty thousand pounds of supplies to form a depot near Point d'Orme, on the Roseau River. About the 20th November I finished the first tangent, and moved the parties to Lieutenant Galwey's Station at Roseau Ridge. The thermometer had already been down in the minus twenties, and the winter was fairly begun. Nearly everything in the commissariat line was frozen hard. The beef had to be sawed off in slabs like limestone; vinegar, if left in an open vessel, had to be chopped out with a hatchet; several novices attempted to drink out of metallic cups without first warming them in water, and, as a result, left the skin of their lips on the cups; the dark mules were white and glistening with frost in the morning; and various other novel and amusing effects of a minimum temperature were witnessed. At this station I observed for azimuth on three nights when the thermometer was 20° or more below zero. In anticipation of the cohesion of the parts from the congealing of the oil, I had previously taken each instrument apart and carefully wiped off every particle of lubricant with warm cotton in a hot room. I have since been told that black lead makes an excellent lubricant in extremely cold weather, but I did not know of this at the time, and it was hoped that, with perfectly

T. Sinclair & Son, lith. Phila.

CAMP AT PINE RIDGE
DEC. 22D 1873

clean surfaces, the plates would not adhere to each other. The first night's work was very unsatisfactory. Out of six sets of observations three had to be rejected, and the remaining three had a range of over 1′. In those rejected the readings of the arc, for lamp east and lamp west, differed by several degrees from each other; this showed—as the lower clamp was fast and the upper one perfectly loose—that, in turning the instrument 180° in azimuth, the plates had held fast together while the spindles had moved one within the other. Besides this, it was found, on examining the clamp and tangent-motion, that when the tangent-screw was turned away from the spring, the latter did not follow the screw, the spindles being so frozen together that the spring was not sufficient to move them. After fixing the cross-hairs upon any object, as a slow-moving star, the tangent-screw could be moved away from the spring until nearly out of its socket, and still the cross-hair would be on the star, when, suddenly, with a jump, the star would leave the field altogether. The weakness of this spring was partially remedied by strengthening it with rubber bands, but the adhesion of the spindles could not be prevented. The only method to pursue was to place the azimuth mark as nearly as possible in the meridian so that the instrument would have to be turned only slightly in azimuth during the observations; then make a set of observations with lamp east—make a fresh setting—and observe with lamp west.

The meridian mark and tangent had then to be connected by a long series of repetitions, which gave very discouraging results, the only resource being to take a great number of readings, and reject all which differed very largely from the mean.

The usual number of sets of observations for azimuth, in the summer, was four, and the range of them averaged 34″ in 1873, and 22″ in 1874. During the winter it was found necessary to take from eight to fifteen sets, to get even a tolerable result, and the average range was 1′ 53″. These poor results were all the more discouraging from the fact that they involved so much labor, and such great personal discomfort. If a tangent screw was touched with the bare fingers the instantaneous result was a "burn," and not a temporary sensation, but one like that from a hot iron, lasting several minutes. If the fingers were wet the metal clung to them so tightly that it could only be removed with the skin. The lamps burned about fifteen minutes before the oil congealed and extinguished them, hence it was necessary to have duplicate sets at the mark and about the instrument, one set being constantly by the fire. For the comfort of the recorder, and as a refuge for the observer, it was found necessary to pitch a tent within a few feet of the instrument, and to keep a bright fire in it. If the wind blew the smoke in the direction of the instrument the observations had to cease, for the fire was essential to thaw out the lamps, keep the observer's fingers flexible, and occasionally unfasten his eyelashes stuck together with frost. The pain in the eyes, from the proximity of the cold eye-piece, was at times very severe, and occasionally brought tears, which congealed in little icicles depending from the eyelashes, and gave the face a comical look, somewhat like that in the children's pictures of Jack Frost.

The chronometers were packed in straw to protect them as much as possible from sudden changes of temperatures. As the winter went on the oil gradually thickened and the rates changed from about -2^s to about -10^s, but on the whole they did good service, the change being gradual.

After returning to the East I took them to the makers, Messrs. Negus & Co., of New York, who said that these sudden changes (say from $-35°$ outside to $+40°$ inside a tent) had injured the metal of some of the more delicate parts so much that they had to be replaced.

The topographical parties had less trouble with their instruments, as their work was done in the day-time, when the thermometer was from 20° to 30° higher than during the night. The accuracy of their work (1 in 300) was nearly equal to that of the summer.

Our experience, then, proves that fair topographical work can be done in a semi-arctic climate, and that astronomical work of a certain sort can also be done, but that refinements are out of the question. While at Roseau Ridge I carried the tangent eastward thirteen miles, to Point d'Orme, on the Roseau River, Messrs. Wilson and Downing completing the topography, and keeping the field-plots up with the surveys. On the 27th of November we moved over to Point d'Orme, and I left Mr. Wilson here to make the necessary azimuth observations and to carry the tangent on to the next junction, at the forty-mile point, while I returned to Pembina to complete the purchase of supplies for the winter. I returned to camp on the 7th December, and we immediately moved on to the forty-mile point, and made a snug camp in a thick grove of spruces. Here the necessary azimuth observations and horizontal angles were taken, and then Mr. Wilson was left, as previously described, with a small party and two "tobogans," to carry the tangent across the Great Roseau Swamp, while I took the other parties and sleigh-train around the swamp by the ice of Roseau River, and reached Pine Ridge Station December 15. All the parties came together at this point the next day. Mr. Doolittle was then provided with fresh supplies and some "tobogans," and directed to follow the ice on the branches of East Roseau River, and survey their courses until he came to the crossing of the boundary, when I would furnish him with dogs, and he could complete the topography to the Lake of the Woods, and survey its shore-line to Rainy River.

As the British Commission had marked the boundary-line between Pine Ridge and the Lake of the Woods, it was unnecessary for me to retrace their tangents. It only remained to examine their azimuths at one or two points. Consequently, I left the greater number of the men, animals, and heavy sleighs with Mr. Wilson, at Pine Ridge, and directed him to complete the topographical work in that neighborhood, and then begin building the mounds westward. Mr. Downing remained at the same point, to finish the field-plats. The dog-trains arrived, about this time, from Pembina, and I loaded them and a few tobogans with enough supplies to last a month for the few men I took with me, and for Mr. Doolittle's party. With these I went eastward, about twenty-five miles, and found a good location for a small depot on the East Roseau River, about twenty miles from the Lake of the Woods, and accessible for heavy teams from Pine Ridge by the ice of the stream. I then traveled up a branch of this river to the boundary-line, where, at East Roseau azimuth station, the two parts of the British tangent joined. Here I was delayed, by stormy weather, from December 23 to 30, during which I got azimuths on two nights which were partly clear. A more dismal holiday-week I have never passed. There were six of us in all, but I had no assistant for company. Our camp, of two little tents, was pitched in an opening of windfall, close to the post marking the junction of the tangents. Under the intricate lacing of fallen logs, and the three feet of snow in which they were imbedded, was a frozen swamp. My own tent-floor was composed of ice, and in order that the stove might not melt through this and disappear, it was supported on a scaffolding of logs run out under the tent. In the morning the tent-floor was hard, but, during the day, the heat of the stove melted a pool under it, with a radius of about two feet, but there was never sufficient heat to soften the ice in the opposite corner, where my bedding lay. It snowed fiercely during the greater part of the week, and our efforts at cooking (the regular cook being left behind), over an open fire, were not the most successful. The appearance of the camp, with a smoldering fire, the dogs curled up in the snow, and the whole shut in by cold-looking pines, was lonely and desolate in the extreme; and to add to its weirdness, at intervals a wolf would approach camp and utter a low moan, which would be taken up by all the dogs. Beginning gently with a soft sigh, it swelled with a full crescendo, in which every cur joined, and then gradually subsided, only to begin again. Finally, some driver's impatience would overcome his antipathy to leaving his warm bed, and he would get up, whip in hand, and go through the pack. Then the would-be musical howl would change into the sharp "ki-yis" of pain and fear, supplemented by a choice selection of French imprecations, in which all the other drivers joined from their tent. Then we would have quiet, but only for a few hours. I finally obtained enough azimuth observations to satisfy myself that the English tangent was correct, within the uncertainty of my observations, and then packed up to move over to the Lake of the Woods. The breast-high windfall in the intervening space being absolutely impassable for large animals, I had given Mr. Doolittle four dog-sleds, keeping two for myself; so that I had to reduce my party to myself and two others, McKenney, a Scotch dog-driver, and King, an observatory attendant. Even then, I had to borrow some of Mr. Doolittle's sleds when I reached his camp, for I had been five hours in making four miles. The loads were top-heavy and upset every hundred yards. With the extra sleds we still made slow progress, and, at the close of the short day, had only traveled twelve miles. We stopped for supper, and then pushed on along the British cutting, on a cold but beautifully clear and moonlit night. We reached the Lake of the Woods Station a little before midnight. We had been sixteen hours in passing over seventeen miles, and were rather disgusted with snow-shoes and dog-sleds, but we were satisfied that no other animal but a dog could have drawn a load through the thickets, windfall, and swamps over which we had passed.

The next night, December 31, was clear, and I got good azimuth observations, and, on the 1st of January, I started out to cross the Lake of the Woods to Rainy River. McKenney and King were with me, and we had only the instruments, tent, blankets, and enough provisions for two weeks. The surface of the lake was in fine condition for traveling. A frozen crust of snow, a few inches thick, covered the ice, and gave a good footing, and left no necessity for snow-shoes. The thermometer was a few degrees above zero. The sun was shining brightly near the horizon, and the air was quiet and very bracing. We went along, at a jog-trot, behind the dogs, in high spirits—a marked contrast to our return. We arrived at the mouth of Rainy River early on the second day, and pitched our tent on the narrow point of land between the river and the lake.

The object of coming to Rainy River—which is several miles south of the forty-ninth parallel—was to get an accurate survey of all that portion of the lake within our territory. The British had carefully surveyed the shore line from the Northwest Point to the forty-ninth Parallel; Mr. Doolittle carried on the survey from the forty-ninth Parallel to Rainy River, and, at the latter point, I checked his work by a careful series of sextant latitudes and by azimuth observations. I remained there ten days. The Indians did not receive me very cordially, and there were several pow-wows and a good deal of "bluff" and threats on either side. They did not succeed, however, either in inducing me to go away, nor in getting any rations (I had barely enough for myself), nor did they molest me. One Indian, indeed, was good enough to invite me to go with him on a moose-hunt, and I had the satisfaction of living on tea and bad bread for four days, and of trudging after him through the snow all day long for the same period. We were much exhilarated by the sight of several warm elk-trails, but we saw no game.

I had finished my observations, and was only waiting for a storm to clear up before I ventured on the open lake to return westward, when, on the night of January 11, about one o'clock, I was awakened by a scuffling of the other men, and beheld our only tent in flames over my head. All our efforts to extinguish it were unavailing, and we were glad to save our bedding and clothes from more than partial destruction, and to have pulled three pound-cans of powder from the edge of a burning mass of leggins. The bright fire lit up the woods and made the dogs blink in an inquiring manner, and revealed the spirit-thermometer fixed to a neighboring tree. It stood at 18° below zero, and plainly told us that, storm or no storm, we could not remain where we were. So we heaped up a big blaze, and while one man repaired the scorched dog-harness the others prepared a breakfast of indigestible "flippers," strong tea, and rich, fat pork. We dispatched this, packed up our remaining traps, and with light loads, at four in the morning, started out in the black darkness of the cloudy night. With this accident to our tent began a week of misfortunes. The day broke about seven in the morning (we had been traveling by compass), and revealed dark, threatening clouds, and an indistinct line of shore a mile to our left, showing that we were not much out of our course. It was still very cold, but as yet only a few flakes of snow were flying in our faces. One of the lead-dogs had a swelling on his shoulder, which pained him a good deal, and caused him to keep circling off out of the course. We put the other sled in front, when its leader slipped his collar and broke loose. He kept along with us, but about a hundred yards to one side, and eluded all our efforts to catch him for more than an hour. We kept on our course, however, only deviating from it to cross the large cracks and piled-up snow, which in the dim light we approached in bad places, and, about ten o'clock, passed Mr. Doolittle's party moving south. It was now snowing quite fast, with a good breeze against us, and still very cold. About noon we reached a point of land where our course turned to the west, and here we found a tent and one of Mr. Doolittle's men. We had run twenty-five miles, and now took a good rest, and ate an enormous lunch of strong tea and pork. Meanwhile the storm had increased, and was blowing a fierce gale from the north, with such masses of snow that it was impossible to see clearly for a hundred yards. At two o'clock I wanted to start out to reach the Astronomical Station, about fifteen miles distant, but I found great difficulty in inducing the driver, McKenney, to venture out in the storm. We finally started, however, and in a few minutes were out of sight of every thing but blinding masses of snow. We kept our course by compass, and relieved each other in taking the lead, as it was found that, after half an hour's peering into the whirling whiteness, it was impossible for one to keep a straight course. Just at dark (about half past four o'clock) we came in sight of a dark point of timber, and were sheltered from the storm. We felt our way along the shore until about seven o'clock, when I thought I recognized the appearance of a point of land near the station. After several minutes of yelling we brought forth a response from a man named Macey, whom I had left there with one tent. We got to bed about ten o'clock, thoroughly exhausted with forty miles of travel, and twenty-one hours without sleep We were up the next morning at five, and soon ready to continue our journey. McKenney told me he knew a much better trail to return by than the horrible windfall along the boundary cutting, and, as he said it was not much longer, I determined to follow it.

We went south across a bay of the lake, for about eight miles, to an Indian village at the mouth of War Road River. Here we turned westward, through the woods and across open "muskeages," and kept traveling until nearly dark, when we stopped to rest. McKenney assured me now that it was only about eight miles to the depot on East Roseau River, and which I knew was on the trail. As I was anxious to get on as fast as possible, and had only enough provisions to make two half meals, I decided not to camp, but to consume all our provisions in a hearty supper, and then travel on during the night. If it was only eight miles we could surely make it before midnight, for the storm had broken and left a clear sky. By eight o'clock we had finished our supper, put on dry socks and moccasins, packed up, and started. Midnight did not find us safely at the depot, but only three or four miles from our resting-place. The sky had clouded again; we had lost the road, and had broken through some shell-ice in a little brook of whose existence McKenney did not know. One man had floundered in up to his shoulders, and the water had permeated through his socks and "neeps" to his foot. The rest of us had gotten out so quickly that only our leggins were wet; but as the temperature was somewhere about 20° below, our legs were instantly incased in a garment of ice which rendered locomotion impossible, and the dog-sleds had added about two hundred pounds to their loads in the shape of ice. The dogs lay down with perfect unconcern, glad of a rest, and we cut sticks and began a vigorous beating, first of our leggins and then of the sleds, to detach the ice. We got our legs pretty well limbered, but could not clear the sleds, which were so heavy and so rough on the bottom that we had to abandon about half the loads—everything in fact but our blankets, instruments, and records. Then we went on again, McKenney and King with one sled, in front, and Macey and myself with the other. McKenney was a better driver than myself, and got more work out of his jaded dogs, and so was soon out of sight. We followed on the trail, however, occasionally losing it in the darkness, until, about ten o'clock, I discovered a fire ahead of us on the trail, and coming up found that King's foot was very badly frozen, and he was in great pain. We thawed his foot with snow, and bound it in pieces of dry blanket, and then I particularly warned McKenney not to get out of hearing of us, as the trail was very blind. A few minutes after we had started, however, I broke the cord of my snow-shoe, and had to stop to repair it. We saw no more of McKenney, our guide, till noon the next day. Macey and I were now on an open muskeage, where we had never been before, and as we had nothing to eat, and had abandoned our stoves, there was no use of camping, so we kept on. Presently the lead-dog turned sharp to the right and got the sled stuck in a soft snow-bank. We tried to move it along, but could get no work out of the dogs, and so threw off all the load except the records and chronometers. With an empty sled we managed to make the dogs move on slowly, in a westward direction, while we took turns in feeling with our hands for the hard snow of the "road." But we could not find it, and could not retrace our steps, for our tracks were almost instantly covered up by the drifting snow. In a few minutes the dogs stopped short, and each scratched a little hole in the snow and lay down as if he intended to stay. We were so exhausted that we could hardly use the whip, but we plied it to the utmost of our strength, and accompanied with shouts, to urge them on. The only result was a low moan as each dog curled closer and buried himself deeper in the snow. They were utterly exhausted. Then we yelled in hopes of finding McKenney, but without success. The only thing left for Macey and myself was to get ourselves out of the scrape as best we could. By the aid of some matches I wound the chronometers (2.15 a. m.), and covered them and the records with the sleigh-wrapper. Then twisting the whip in the lead-dog's collar, to suggest what was in store for him when he woke up, we bade them good-bye, and started out to the westward, across the muskeage. I had a good compass with me, and the moving clouds occasionally revealed the stars, so that there was no difficulty in keeping our course. I knew, also, that the supply-depot was on a river flowing north, and not more than fifteen miles off at the utmost, and that there was a sleigh-trail to the depot, but not beyond it, so that if we reached the river I would know which way to turn. Hence there was no fear of being lost, but what I did seriously fear was that before we could reach the river we should succumb to sleep and that terrible languor which is the premonition of freezing, and which we already felt.

During the last forty-eight hours we had run between sixty and seventy miles, and for twenty hours we had had but one meal. The longing for sleep was so great that whenever I stopped to rest for an instant, I lost consciousness, and was awakened by the thud of having fallen into the snow. I was strongly possessed with the temptation to quietly lie there, it was so comfortable. But I had just enough sense left to know that if I did lie there it would be three or four days before I would be found, for the wind covered up our tracks at once; and in three days I would, undoubtedly, be frozen to death. So we trudged on through the snow, knee-deep, on our broken snow-shoes, tripping, and falling, and making perhaps a mile an hour, through the long hours of the night, into the dim day-break and the early hours of the morning. Still going west, we had crossed the muskeage and come into some timber, but, as yet, had found no tracks, although I knew we must be nearing the stream. Finally, near noon, we came to a small stream, and there, nearly covered by fresh snow, but still unmistakable, were snow-shoe tracks. Macey and I leaned up against a tree, and getting a good ready we yelled—all the breath there was in us. No answer. We rested awhile and tried it again, and still no answer! The tracks led to the northwest, and as they would not take us much out of our course, we followed them. In about half an hour we came upon a track, not three hours old (for the snow had fallen then), and crossing the other at right angles. We sat down on the bank, and gathered breath, and yelled again. We almost jumped as an instantaneous reply came, seemingly not one hundred feet off. It was, in fact, not very much farther, and, moving in its direction, we soon beheld the river, the depot, and two men quietly unloading some hay. Our first question, somewhat enraged, was, "How long has McKenney been here?" McKenney? They did not know anything about McKenney—"had not seen him for a month." So it seemed that he had been lost as well as ourselves. I immediately started a man out with a sled to find them, and to pick up my dogs and various articles which had been abandoned, and then we ate a mighty breakfast, after our thirty-hours' tramp. We were just finishing when we heard the jingle of bells and the "marche! marche!" of a driver, and McKenney appeared with his sled, and King riding on it. It seems that when he discovered that he had left us behind, he waited awhile, and shouted to attract attention. Failing in this he started to go on for a distance, but his dogs refused to move. King's foot now began to pain him so much that he could not walk. In this dilemma there was nothing to do but burrow in the snow, and wait till the dogs were enough rested to go on. So McKenney had unhitched his dogs and dragged his sled to the nearest point of timber. It was at this place that my leader had turned off and we had lost the trail, for McKenney found my dogs there in the morning. Once in the woods they shoveled out the snow and got the materials for a fire, but discovered, to their dismay, that all the matches had been in King's pocket, and had been wet in his bath. There was a strong probability of freezing if they could not get a fire, so they searched every particle of their bedding and clothes for a stray match. At last, in the corner of the inside pocket of McKenney's overcoat, they did find an old stump, about half an inch long, but with the "sulphur end". They took great precautions against its going out, and collected enough dry shavings for a first-class attempt at arson. Their efforts were successful, and with the fire once going they were all right. They slept till morning and then came on. As soon as they had arrived I turned in and slept for eighteen hours. During this time my dogs had been brought in, very hungry, but looking as bright and cheerful as possible, except the leader, whose shoulder was fearfully swollen. I had to leave him behind; but, with the others and an empty sled, I started out the next day, January 15, for Pine Ridge, and made the journey of twenty-five miles in six hours. There I found Mr. Downing with the field-plots well advanced, and the next day I rode along in a "carriole" (light sleigh for one horse) to where Mr. Wilson was at work on the mounds across the Great Roseau Swamp. I then sent a telegram to you asking for instructions about cutting the parallel, and received answer to clear it a width of ten feet, from the end of the British cutting, near Pine Ridge, to Red River. This was intrusted to Mr. Wilson. He also built the mounds along this interval. Leaving Mr. Wilson engaged upon this work, I sent word to the East Roseau depot to *cache* enough supplies for Mr. Doolittle and bring the rest to Pine Ridge, where I collected the sleighs, and moved them to Point d'Orme, January 20. I remained here a week waiting for the other parties and completing my computations. During this week we had the coldest weather of the winter. On every night the thermometer went down to 40° below zero or lower, and during the day it seldom reached as high as 15° below. One night, just before going to bed, I looked at the two spirit-thermometers fastened to a tree, and they read 46° and 47° below. In the morning they recorded the astounding temperature of 50° and 51° below zero. Every one had slept soundly, however, inside of skin and blanket bags.

The parties all arrived at Point d'Orme on the 26th of January, and I sent Mr. Doolittle on to resurvey the Red River, on the ice, and left Mr. Wilson to finish his cutting and mounds. Taking my dogs and an empty sled, I drove in to Fort Pembina, forty miles, in the nine hours of sunlight, on January 27, and began to settle up accounts and get ready to turn toward the States.

On the 6th of February Mr. Wilson's party arrived at Pembina, and the winter's work was over. I had previously turned over the dogs and sleds to the British Commission to be sold or disposed of in any way they could, and on the evening of the 6th discharged about half the men. The next morning, with the balance of the men and the six heavy sleighs, I started south for the railroads of Minnesota. We made the journey to Fort Abercrombie, one hundred and eighty miles, in five and a half days, during which we suffered greatly on the open prairie from the cold and the driving snow. At Fort Abercrombie I sent the train of sleighs, under Wagon-master Estes, across country to Saint Cloud to report there to Lieutenant Ladley. With the rest of the men I took the cars at Breckinridge for Saint Paul, where we arrived February 16. The parties were disbanded and paid off the same day.

GENERAL DESCRIPTION OF THE COUNTRY.

The flat, treeless valley of the Red River extends on the east for twelve miles; here a gentle ridge is encountered about thirty feet high and running in a northwest and southeast direction. For the next twenty miles to the Roseau River the country is slightly broken. The knolls are covered with small poplars, and the intervening hollows are marshy and full of large granite bowlders. Beyond the Roseau River the country entirely changes. The woods are dense—at first of oak, elm, and ash, gradually giving place to spruce and pine and then to tamarack. The last forty-five miles to the Lake of the Woods may be characterized as one vast tamarack swamp, with large openings of "muskeage." This is not only true along the Forty-ninth Parallel, but wherever I penetrated back from the shore of the Lake of the Woods the same character of country was found. Some of the Norway pine grows to a large size—three feet and more in diameter—but nearly all of it has been taken out by lumbermen and rafted down to Fort Garry, so that now there is no considerable amount of valuable timber along the line. Except the Red River Valley, the whole country is at present not only worthless for agricultural purposes, but is quite impassable in summer, even to Indians, except along the streams, in canoes. All of these swamps, west of about ten miles from the Lake of the Woods, are partially drained into the Red River by the Roseau River system. This river rises in two branches—one north and the other south of the line, which, united, are known as the East Roseau River, and flows into a small lake of the same name, which also receives a small affluent from the north, known as Pine River. This lake discharges into the Roseau River, which flows south of, and really parallel to, the boundary for about thirty miles, crossing it at Point d'Orme, and continues, in a northwesterly course, till it meets the Red River, about twelve miles north of the line. This Roseau River is about two hundred feet broad throughout its length, and has a rapid current of about three miles. The depth was about ten feet wherever we sounded it. It would be navigable for small boats but for the presence of of a few rapids. The principal one of these I did not visit. It is about twenty-five miles below Point d'Orme, and from the description of the half-breeds is quite violent, and must have a fall of fully twenty feet in a quarter of a mile. Logs cannot be rafted over it later than the 1st of May.

If land ever becomes so valuable in this region that it is desirable to drain this country, it could be done by cutting through these rapids. The bed of the river is, generally, a soft clay, through which the stream would lower its bed, and thus drain the swamps. At present the large swamps are on a level with, or a little lower than, the water of the stream, from which they are separated only by a natural dike of clay and grass, a few feet in height.

The Lake of the Woods contains an area of between six hundred and seven hundred miles. It is very irregular in shape, and its eastern shore has never been carefully surveyed. There are a large number of islands dotting its surface. Some soundings were, I believe, taken by the English parties, and the greatest depth obtained was eighteen feet. As the surrounding country is very low and flat, it is possible that it has no great depth, but we have no positive knowledge of this. As the ice was from two to three feet thick, I had no opportunity to make soundings. Various small streams drain into it from the surrounding swamps, but the principal affluent is the Rainy River, which empties at its most southern point. This stream comes from Rainy Lake, is about sixty miles long, and a quarter of a mile broad at its mouth. It forms part of the international boundary.

The Lake of the Woods discharges, by Winnipeg River, into Winnipeg Lake, and forms part of the great northern chain of lakes, whose waters eventually reach Hudson's Bay.

The Indians residing in this neighborhood are small tribes of the formerly great Ojibway nation. There are about twenty families around Lake

Roseau, as many more at the mouth of War Road River, and about fifty families at the mouth of Rainy River.

Several families also pass the winter on the islands in the lake. They are generally peaceable, but extremely indolent. Those about Rainy River live on lands which have never been ceded, and they are the only ones that show any spirit. They have several log houses, and make feeble attempts at agriculture, but many of them live in birch "tepees," and their principal sustenance is fish. Several varieties of whitefish, pike, and pickerel are caught, through the ice, by the squaws in winter. The men occasionally hunt the moose, elk, deer, and feathered game, using the Hudson's Bay shot-guns, with an ounce-ball, or with shot. They also do a good deal of trapping; beaver, marten, mink, otter, and fisher being quite plentiful. Those who survive the age of ten years seem to be a healthy race of people, but many children perish from lung diseases and exposure to the cold. The winter climate of this country is exceedingly severe: the thermometer going below 40° every year. And in spite of the fact that the maximum is, every year, nearly 100°, the annual mean is lower than at any other point in the United States and Territories, and lower than any inhabited point in Europe.

I insert here the record of the Medical Department, at Fort Pembina, for two years. My own record, during the winter of 1873, is a little lower than this, but it was not taken with so much care.

Meteorological report—Fort Pembina.

Month.	1872–'73.				1873–'74.			
	Mean.	Max.	Min.	Rain-fall.	Mean.	Max.	Min.	Rain-fall.
	°	°	°	*Inches.*	°	°	°	*Inches.*
July	67.66	97	36	3.09	67.10	89	34	1.30
August	65.41	91	34	82	66.43	91	24	2.38
September	53.78	85	25	1.67	47.78	80	23	2.05
October	43.91	77	15	1.16	36.37	82	3	56
November	18.28	48	— 28	53	15.67	45	— 25	66
December	— 5.72	34	— 51	2.95	6.76	35	— 27	18
January	— 4.49	31	— 40	41	— 3.17	37	— 41	26
February	4.43	33	— 31	75	2.49	32	— 32	25
March	12.05	43	— 40	35	12.11	47	— 29	35
April	34.64	64	16	39	30.32	76	— 4	20
May	53.76	81	29	2.11	57.04	98	27	1.55
June	67.20	93	38	2.91	66.29	94	33	3.41
For the year	34.21	97	— 51	17.14	33.81	98	— 44	13.15

For purposes of comparison, I add the annual mean temperatures at the coldest posts in the United States, and at a few other points, from data kindly furnished by the Chief Signal Officer of the Army.

Mean temperatures.

Forts.	Territory.	Latitude.	Years.	Annual mean temp.	Authority.
		° ′		°	
Pembina	Dakota	48 57	1870–'74	31.0	Circular No. 8, Surgeon-General's Office, U. S. Army.
Seward	....do	46 52	'74	37.0	
Brady	Michigan	46 30	1872–'74	37.6	
Buford	Dakota	48 00	1870–'74	38.0	
Stevenson	....do	47 34	1870–'74	38.5	
Baker	Montana	46 40	1872–'74	38.8	
Abercrombie	Dakota	46 27	1870–'74	39.3	
Ellis	Montana	45 45	1871–'73 1872–'74	40.1	
Rice	Dakota	46 40	1870–'74	41.3	
Lincoln	....do	46 47	1870–'74	41.9	
Snelling	Minnesota	44 53	1870–'74	42.9	
Sitka	Alaska	57 03	1870–'74	43.6	
Plattsburg	New York	44 41	1870–'74	43.9	
Benton	Montana	47 45	1870–'74	44.4	
Shaw	....do	47 30	1870–'74	44.7	
Winnipeg	Manitoba	49 50	....	32.6	Dawson.
	Iceland	61	1845–'71	37.0	Thorlacius.
St. Petersburg	Russia	60	1867–'70	38.0	Wild.
Do	....do	60	90 years.	38.5	v. Käntz.
Stockholm	Sweden	59 20	1859–'71	41.8	Edland.

ASTRONOMICAL POSITIONS ON RECONNAISSANCES.

LONGITUDES.

On reconnaissance from second crossing of Mouse River to Fort Pembina via Fort Totten, by Lieut. F. V. Greene, 1873.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	*h. m. s.*	*h. m. s.*		*Chr.* | *Rates.*
1455 953	Slow 1 19 52.26 Fast 4 50 21.74	Fast 34 41.6 Fast 6 44 55.6	1 54 33.86	Lieut. Galwey's station, on Poplar River, Oct. 30, 1873.	1455 | Losing... 4s.34 953 | Losing... 4s.08
1455 953	Slow 1 21 55.66 Fast 4 48 25.84	Slow 1 13.3 Fast 6 09 08.2	1 20 42.36	Fort Pembina, Oct. 31.4.	*Latitudes.*
1455 953	Slow 1 20 46.1 Fast 4 49 31.1	Fast 17 55.3 Fast 6 28 17.1	1 38 41.4 46.0	Mouse River, Oct. 15.4.	Polaris... 48° 39′ 40″.7 ε Pegasi ... 38 13.5
			Mean 1 38 43.7	101° 44′ 01″.3	Mean.. 48 38 57.1
1455 953	Slow 1 20 50.4 Fast 4 49 27.0	Fast 17 13.8 Fast 6 27 35.9	1 38 04.2 08.9	Mouse River, Oct. 16.4.	Polaris .. 48 23 23.2 ε Pegasi ... 16.3
			Mean 1 38 06.5	101° 34′ 44″.1	Mean.. 48 23 19.7
1455 953	Slow 1 21 01.3 Fast 4 49 15.8	Fast 14 22.3 Fast 6 24 45.9	1 35 23.6 30.1	Oct. 18.9.	
			Mean 1 35 26.8	100° 54′ 48″.6	
1455 953	Slow 1 21 03.0 Fast 4 49 15.2	Fast 11 54.1 Fast 6 22 16.9	1 32 57.1 61.7	Oct. 19.3.	
			Mean 1 32 59.4	100° 17′ 56″.8	α Aquilæ .. 48 02 46.3
1455 953	Slow 1 21 07.8 Fast 4 49 10.7	Fast 10 20.6 Fast 6 20 42.5	1 31 28.4 31.8	Oct. 20.4.	Polaris... 48 00 58.1 ε Pegasi ... 25.3
			Mean 1 31 30.1	99° 55′ 37″.3	Mean.. 48 00 41.7
1455 953	Slow 1 21 12.1 Fast 4 49 06.6	Fast 8 03.8 Fast 6 18 25.3	1 29 15.9 18.7	Oct. 21.4.	Polaris... 47 58 24.0 ε Pegasi ... 25.9
			Mean 1 29 17.3	99° 22′ 25″.3	Mean.. 47 58 25.0
1455 953	Slow 1 21 23.4 Fast 4 48 56.0	Fast 6 26.3 Fast 6 16 47.2	1 27 49.7 51.2	Camp near Fort Totten. Oct. 24.0. 99° 00′ 42″.6	
			Mean 1 27 50.4		

ASTRONOMICAL POSITIONS.

Station.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Initial point, stone mound	49 00 00	101 54 50.9
Camp, October 15, 16, Mouse River	48 38 57.1	101 44 01.3
October 16, 17, Mouse River	48 23 20	101 34 44.1
October 18, 19, Mouse River	....	100 54 48.6
October 19, 20, Alkali Lakes	48 03 08.3	100 17 56.8
October 20, 21, Girand Lake	48 00 42	99 55 37.3
October 21, 22, Stony Lake	47 58 25	99 22 25.3
October 23, 25, near Totten	47 58 40.5	99 00 42.6
Fort Totten flag-staff	....	99 01 38.1

ASTRONOMICAL POSITION OF CAMPS.

Reconnaissance from Fort Buford to Forty-ninth Parallel, June, 1874, by Lieut. F. V. Greene.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	*m. s.*	*h. m. s.*		*Chr.* | *Rates*
1455	Slow 2 01 28.7	Slow 13 47.7	1 47 41.0	Fort Buford, June 20.	1455 | Losing... 3s.61
953	Slow 2 07 34.3	Slow 19 53.3	41.0		953 | Gaining.. 0s.495
			Mean 1 47 41.0	103° 58′ 20″	
1455	Slow 2 02 06.0	Slow 5 28.1	1 56 37.9	U. S. Ast. Station No. 12, near West Poplar River, June 30.33.	
953	Slow 2 07 29.2	Slow 10 51.3	37.9		*Latitudes.*
			Mean 1 56 37.9	106° 12′ 35″	49° 00′ 00″
1455	Slow 2 01 40.9	Slow 11 33.3	1 50 07.6	Crossing of Big Muddy, June 23.4.	Sun 48 08 45.5
953	Slow 2 07 32.6	Slow 17 26.2	06.4		Polaris .. 39.6
			Mean 1 50 07	104° 34′ 50″	Mean.. 48 08 42.6
1455	Slow 2 01 46.6	Slow 10 23.8	1 51 23.8	Frenchman's Point, on Missouri River, June 24.94.	Polaris .. 48 08 46.4
953	Slow 2 07 31.8	Slow 16 11.4	20.4		Sun 12.0
			Mean 1 51 22.1	104° 53′ 40″	Mean.. 48 08 29.2
1455	Slow 2 01 51.7	Slow 9 48.0	1 52 03.7	Camp on Poplar River, June 26.4.	Polaris .. 48 16 43.1
953	Slow 2 07 31.1	Slow 15 22.3	08.8		Sun 18.3
			Mean 1 52 06.2	105° 04′ 40″	Mean.. 48 16 30.7
1455	Slow 2 01 59.0	Slow 8 32.8	1 53 26.2	Camp on Poplar River, June 28.4.	Polaris .. 48 44 32.2
953	Slow 2 07 30.2	Slow 14 09.4	20.8		Sun 02.5
			Mean 1 53 23.5	105° 24′ 00″	Mean.. 48 44 17.3

Reconnaissance from Little Rocky Creek to United States Astronomical Station No. 13, via Fort Turnay, by Lieut. F. V. Greene, 1874.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	m. s.	h. m. s.		Chr. / Rates.
1455	Slow 2 02 19.9	Slow 3 26.2	1 58 53.7	Little Rocky Creek, July 4.3.	1455 / Losing... 2s.74
953	Slow 2 07 26.7	Slow 8 33.0	53.7		953 / Gaining.. 0s.568
					Latitudes.
					° ′ ″
			Mean 1 58 53.7	106° 46′ 31″.5	49 00 00
1455	2 02 31.0	Slow 1 08.2	2 01 22.8	U. S. Ast. Station No. 13, July 8.35.	
953	2 07 24.4	Slow 6 01.6	22.8		
			Mean 2 01 22.8	107° 23′ 48″.2	49 00 00
1455	2 02 25.8	2 13.7	2 00 12.1	July 6.4.	Polaris.. 48 45 20.5
953	2 07 25.5	7 14.5	11.0		α Ophiuchi 44 39.5
			Mean 2 00 11.5	107° 06′ 00″	Mean.. 48 45 00
1455	2 02 28.2	1 08.8	2 01 19.4	July 7.34.	Polaris.. 48 54 11.7
953	2 07 25.0	6 06.5	18.5		α Ophiuchi 05.5
			Mean 2 01 19.0	107° 22′ 50″	Mean.. 48 54 08.6

Reconnaissance of Riplinger Road, by Assistant C. L. Doolittle, 1874.

Date.	Latitude.	Longitude.	Remarks.
	° ′ ″		
September 2	Polaris 48 39 32.1		
	α Aquilæ 07.7		
	Mean 48 39 19.9	....	Cut Bank River.
September 3	Polaris 48 20 50		
	α Aquilæ 19 58		
	Mean 48 20 24	....	Birch Creek.
September 4	Polaris 47 59 46.5		
	α Aquilæ 58 44.7		
	Mean 47 59 15.6	....	Muddy Fork.
September 5	Polaris 47 47 25.3		
	α Aquilæ 46 35.2		
	Mean 47 47 00.2	....	Teton River.

Sextant latitudes on Shaw meridian, by Lieut. F. V. Greene.

Date.	Latitude.	Longitude.	Remarks.
	° ′ ″	° ′ ″	
September 4	Polaris .... 48 45 49.6 α Aquilæ 12.0		
	Mean 48 45 30.8	111 46	On small lake.
September 2	49 00 00	111 45 05.1	Initial point of Shaw meridian.
September 8	Polaris 47 31 03.3	111 48	About 1,500 feet east of flag-staff at Fort Shaw.

Sextant latitude on trail near spring, about half-way between Fort Shaw and Fort Benton, by Lieut. F. V. Greene.

Date.	Latitude.	Longitude.	Remarks.
	° ′ ″		
September 10	Polaris .... 47 43 22.7 α Aquilæ 10.2		
	Mean 47 43 16.5		

MISSOURI RIVER.

Longitudes and latitudes.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	h. m. s.	h. m. s.		
1319	Slow 2 09 32.4				
1514	Slow 1 15 13.2	Fast 59 13.6	2 14 26.8	Fort Benton, Sept. 10.4.	*Chr.* — *Rates.*
235	Fast 9 56 12.0				1319 Losing... $2^s.70$
1513	Slow 1 47 02.6	Fast 27 24.2			1514 Gaining.. $0^s.93$
1481	Slow 6 00 56.4				235 Losing... $1^s.03$
188	Fast 45.3			110° 39′ 48″	1513 Losing... $0^s.57$ 1481 Gaining.. $0^s.43$
1319	Slow 2 10 28.2				188 Losing... $0^s.42$
1514	Slow 1 14 54.0	Fast 20 12	1 35.06	Bismarck, Oct. 1.0.	
235	Fast 9 55 50.9				
1513	Slow 1 47 14.4				
1481	Slow 6 00 47.5				
188	Fast 36.6			100° 49′ 36″.6	*Latitudes.*
1319	Slow 2 09 39.4	Fast 2 12.9	2 11 52.3	Sept. 13.	° ′ ″ Polaris .. 47 48 58.9
1514	Slow 1 15 10.8	Fast 56 39.1	49.9		α Aquilæ .. 49 06.6
235	Fast 9 56 09.3				Mean.. 47 49 02.7
1513	Slow 1 47 04.1				
1481	Slow 6 00 55.3				
188	Fast 44.2	Fast 2 12 40.5	56.3		
			Mean.. 2 11 52.8	110° 01′ 17″.8	

Longitudes and latitudes—Continued.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	*h. m. s.*	*h. m. s.*		
1319	Slow 2 09 42.1	Slow 1 19.2	2 08 22.9	Sept. 14.	Polaris .. 47 46 53.2
1514	Slow 1 15 10.0	Fast 53 12.8	22.4		*a* Aquilæ .. 53.9
235	Fast 9 56 08.3	Fast 12 04 34.6	26.3		
1513	Slow 1 47 04.7	Fast 21 20.7	25.4		Mean.. 47 46 53.5
1481	Slow 6 00 54.9	Slow 3 52 29.5	25.4		
188	Fast 43.8	Fast 2 09 11.9	28.1		
			Mean.. 2 08 25.1	109° 09′ 22″.3	
1319	Slow 2 09 47.5	Slow 6 23.9	2 03 23.6	Sept. 16.	Polaris .. 47 27 50.7
1514	Slow 1 15 08.1	Fast 48 16.0	24.1		*a* Aquilæ .. 28 01.6
235	Fast 9 56 06.2	Fast 11 59 31.3	25.1		
1513	Slow 1 47 05.8	Fast 16 20.4	26.2		Mean.. 47 27 56.1
1481	Slow 6 00 54.0	Slow 3 57 26.8	27.2		
188	Fast 43.0	Fast 2 04 11.4	28.4		
			Mean.. 2 03 25.8	107° 54′ 32″.8	
1319	Slow 2 09 52.9	Slow 11 31.0	1 58 21.9	Sept. 18.	Polaris .. 47 47 07.0
1514	Slow 1 15 06.2	•Fast 43 16.4	22.6		*a* Aquilæ .. 46 56.5
235	Fast 9 56 04.2	Fast 11 54 25.1	20.9		
1513	Slow 1 47 06.9	Fast 11 16.9	23.8		Mean.. 47 47 01.7
1481	Slow 6 00 53.2	Slow 4 02 28.9	24.3		
188	Fast 42.1	Fast 1 59 09.4	27.3		
			Mean.. 1 58 23.4	106° 38′ 56″.8	
1319	Slow 2 09 55.4	Slow 13 13.9	1 56 41.5	Sept. 19.	Polaris .. 48 01 37.5
1514	Slow 1 15 05.3	Fast 41 37.2	42.5		*a* Aquilæ .. 36.2
235	Fast 9 56 03.2	Fast 11 52 43	39.8		
1513	Slow 1 47 07.5	Fast 9 35.7	43.2		Mean.. 48 01 36.8
1481	Slow 6 00 52.8	Slow 4 04 09.5	43.3		
188	Fast 41.7	Fast 1 57 28.3	46.6		
			Mean.. 1 56 42.8	106° 13′ 47″.8	
1319	Slow 2 09 58.1	Slow 16 01.7	1 53 56.4	Sept. 20.	Polaris .. 48 04 10.0
1514	Slow 1 15 04.1	Fast 38 53.8	58.2		*a* Aquilæ .. 13.7
235	Fast 9 56 02.2	Fast 11 49 56.9	54.7		
1513	Slow 1 47 08.1	Fast 6 49.7	57.8		Mean.. 48 04 11.8
1481	Slow 6 00 52.3				
188	Fast 41.3	Fast 1 51 43.4	62.1		
			Mean.. 1 53 57.8	105° 32′ 32″.8	
1319	Slow 2 10 00.8	Slow 18 30.6	1 51 30.2	Sept. 21.	Polaris .. 48 06 09
1514	Slow 1 15 03.5	Fast 36 27.7	31.2		*a* Aquilæ .. 05 55
235	Fast 9 56 01.1	Fast 11 47 29.7	28.6		
1513	Slow 1 47 08.6	Fast 4 21.6	30.2		Mean.. 48 06 02
1481	Slow 6 00 51.9				
188	Fast 40.8	Fast 1 52 14.0	33.2		
			Mean.. 1 51 30.7	104° 55′ 46″.3	
1319	Slow 2 10 03.6	Slow 21 33.2	1 48 30.4	Sept. 22.	Polaris .. 48 02 52.5
1514	Slow 1 15 02.5	Fast 33 29.6	32.4		*a* Aquilæ .. 03 11.5
235	Fast 9 56 00.1	Fast 11 44 29.6	29.5		
1513	Slow 1 47 09.2	Fast 1 21.9	31.1		Mean.. 48 03 02.5
1481	Slow 6 00 51.5	Slow 4 12 1[illegible].8	32.7		
188	Fast 40.4	Fast 1 49 14.0	33.6		
			Mean.. 1 48 31.6	101° 10′ 59″.8	

Longitudes and latitudes—Continued.

Chr.	Error on Washington time.	Error on local time.	Longitude from Washington.	Station and date.	Remarks.
	h. m. s.	h. m. s.	h. m. s.		
1319	Slow 2 10 06.3	Slow 22 26.8			
1514	Slow 1 15 01.5	Fast 32 34.6	1 47 36.1	Near Fort Buford, Sept. 23.	Polaris .. 47 58 58.8
235					α Aquilæ .. 59 20.8
1513					
1481					Mean.. 47 59 09.8
188					
			1 47 36.1		
1319	Slow 2 10 09.1	Slow 24 35.1	1 45 34.0	Sept. 24.	Polaris .. 48 02 09.8
1514	Slow 1 15 00.6	Fast 30 34.9	35.5		α Aquilæ .. 01 12.8
235	Fast 9 55 58.1	Fast 11 41 31.8	33.7		
1513	Slow 1 47 10.4	Slow 1 33.3	37.1		Mean.. 48 01 41.3
1481	Slow 6 00 50.6	Slow 4 15 13.8	36.8		
188	Fast 39.6	Fast 1 46 17.2	37.6		
			Mean.. 1 45 35.8	103° 27′ 02″.8	
1319	Slow 2 10 11.8	Slow 27 27.5	1 42 44.3	Sept. 25.	Polaris .. 48 06 56.7
1514	Slow 1 14 59.6	Fast 27 48.2	47.8		
235	Fast 9 55 57.1	Fast 11 38 42.6	45.5		
1513	Slow 1 47 11.0	Slow 4 21.2	49.8		
1481	Slow 6 00 50.1	Slow 4 18 01.2	48.9		
188	Fast 39.1	Fast 1 43 27.3	48.2		
			Mean.. 1 42 47.4	102° 44′ 56″.8	
1319	Slow 2 10 14.5	Slow 29 26	1 40 48.6	Sept. 26.	Polaris .. 47 46 21
1514	Slow 1 14 58.7	Fast 25 48.6	47.3		α Aquilæ .. 45 53.9
235	Fast 9 55 56.1	Fast 11 36 45.9	49.8		
1513	Slow 1 47 11.5	Slow 6 19.1	52.4		Mean.. 47 46 07.5
1481	Slow 6 00 49.7	Slow 4 19 56.9	52.8		
188	Fast 38.7	Fast 1 41 31.8	53.1		
			Mean.. 1 40 50.7	102° 15′ 46″.3	
1514	Slow 1 14 57.8	Fast 23 53.0	1 38 50.8	Sept. 27.	Polaris .. 47 31 33.3
					α Aquilæ .. 21.6
			1 38 50.8		Mean.. 47 31 27.5
1319	Slow 2 10 20.1	Slow 33 09.9	1 37 10.2	Sept. 28.	Polaris .. 47 20 58.8
1514	Slow 1 14 56.8	Fast 22 16.2	13.0		α Aquilæ .. 21 16.8
235	Fast 9 55 54.1	Fast 11 33 05.2	11.1		
1513	Slow 1 47 12.7	Slow 10 01.0	11.7		Meau.. 47 21 07.8
1481	Slow 6 00 48.8	Slow 4 23 36.5	12.3		
188	Fast 37.8	Fast 1 37 51.3	13.5		
			Mean.. 1 37 12.0	101° 21′ 05″.8	
1319	Slow 2 10 22.8	Slow 34 52.7	1 35 30.1	Sept. 29.	Polaris .. 47 07 11.8
1514	Slow 1 14 55.9	Fast 20 35.2	31.1		α Aquilæ .. 05.6
235	Fast 9 55 53.1	Fast 11 31 23.6	30.5		
1513	Slow 1 47 13.3	Slow 11 42.6	30.7		Mean.. 47 07 08.7
1481	Slow 6 00 48.4	Slow 4 25 17.2	31.2		
188	Fast 37.4	Fast 1 36 09.5	32.1		
			Mean.. 1 35 31.0	100° 55′ 50″.8	
1319	Slow 2 10 06.3	Slow 22 26.8	1 47 39.5	Fort Buford.	By zenith telescope, Capt. Gregory:
					47° 59′ 22″.19
			1 47 39.5		

STATION-ERRORS ON THE 49TH PARALLEL OF LATITUDE,

BETWEEN THE LAKE OF THE WOODS AND THE ROCKY MOUNTAINS.

Stations.	*D.* Station errors, mean parallel = 0.	*A.* Computed deflections 1 to 10 miles.	*B.* Computed deflections 10 to 40 miles.	*D*−(*A*+*B*) Unexplained deflections.
1	− 2.31		− .007	− 2.30
2	+ 1.52		0	+ 1.52
3	+ 2.33		0	+ 2.33
4	+ 3.28		− .15	+ 3.43
5	+ 3.50		− .23	+ 3.73
6	+ 2.95	− .42	− .27	+ 3.64
7	+ 2.22	− .09	− .46	+ 2.77
8	+ 1.40		− .36	+ 1.76
9	− .21		− .54	+ .33
10	− 1.78	− .09	− 1.16	− .53
11	− .78	− .15	− .74	+ .11
12	+ .06		− .65	+ .71
13	− .30		− .46	+ .16
14	− 1.91		− .68	− 1.23
15	− 2.23		− .83	− 1.40
16	− .50		− .92	+ .42
17	− .31		− 1.07	+ .76
18	− .94		− .99	+ .05
19	+ 1.77		− .38	+ 2.15
20	− 1.91		+ .10	− 2.01
21	− .81		+ .80	− 1.60
22	+ .98		+ 1.50	− .52
23	− .76		+ 1.90	− 2.66
24	+ 1.54		+ 3.29	− 1.75
25	+ 2.00		+ 2.16	− .16
26	+ 3.55		+ 2.85	+ .70
27	+ 3.03		+ 2.80	+ .23
28	+ 1.61		+ 2.03	− .42
29	+ 5.94		+ 1.38	+ 4.56
30	+ 4.30		+ .99	+ 3.31
31	+ 2.09		+ .95	+ 1.14
32	− .67		− 1.43	+ .76
33	− 5.32	− 2.31	− 1.77	− 1.24
34	− 7.95	− 7.25	− 1.37	+ .67
35	− .67		− 1.04	+ .37
36	− .52		− 1.00	+ .48
37	− 1.17	?	?	
38	− 3.42	?	?	
39	− 6.09	?	?	
40	− 2.42	?	?	
41	− 1.00	?	?	
σ	43″.97 43″.98			36″.09 15″.82
Means...	2″.146			1″.442

In the preceeding table, the column *D* contains the "Station-errors", or the discrepancies between each astronomical determination of the parallel and the mean parallel. The mean parallel is that with reference to which the sum of the discrepancies north is equal to the sum of those south; its position is determined by referring all the discrepancies to one station and dividing their algebraic sum by 41.

It will be noticed that the first and last stations (Nos. 1 and 40) observed by this commission differ from each other by only 0″.11 in latitude, although 346 miles apart. The least discrepancy between adjacent stations is between Nos. 35 and 36, where at a distance of 24.6 miles from each other, the astronomical latitudes differ only 0″.15; the largest discrepancy is near the Sweet Grass Hills between Nos. 34 and 35, where the latitudes differ by 738 feet, or 7″.28. The most northerly (No. 29) is nearly 14″ north of the most southerly (No. 34). The mean deflection is 2″.146.

These results are shown more clearly on the accompanying diagram. The upper figure represents a profile of the country constructed from observations with the mercurial barometer at the astronomical stations and from trigonometric leveling in the intermediate points; the lower figure shows the main features of the topography for a distance of forty miles on each side of the line. The middle figure is a representation (exaggerated more than 200 times) of the relative positions of the astronomical and mean parallels. The scales are given for each figure (pp. 267).

Having given the actual deflections, it now becomes interesting to see how far these can be accounted for by the attraction of masses above the surface, and how many of them must be referred to some attracting force under ground, where, as Pratt says, "we seem to have an unlimited resource upon which to draw, to explain any anomalies of local attraction we may perceive on the surface."

The formulæ which I have used for calculating the deflections are those deduced by Lieut. Col. A. R. Clarke, R. E., of the British Ordnance Survey. The whole discussion is found at length in his "Account of the Principal Triangulation", pp. 576–630, but I shall merely give an outline of the manner in which the deduction is made.

"The plumb-line is acted upon by gravity G in a vertical direction, and by the disturbing force A acting in a horizontal direction; the resultant of these forces $=\sqrt{A^2+G^2}$ acts in a direction which makes the angle $\tan^{-1}\frac{A}{G}$ with the direction of gravity. When A is very small in comparison with G, this angle is identical with its tangent." Using Airy's expression for gravity, Clarke shows that

$$\psi = 12''.447 \frac{A}{\delta} \qquad (1)$$

in which ψ is the deflection caused by an attraction A, and δ is the mean density of the earth.

In order to find the value of A the ground in the vicinity of the station is divided into compartments by a series of radii and circles; and the attraction of one of these compartments is found to be:—

$$A = \rho \, (r' - r_,) \, (\sin a' - \sin a_,) \frac{h}{r} \qquad (2)$$

in which: ρ is the mean density of the compartment.
h the mean height of the compartment.
r' and $r_,$ the bounding radii.
a' and $a_,$ the azimuths of bounding radii.
$r = \frac{r' + r_,}{2}$

It would be extremely inconvenient to compute the attraction of each compartment separately, and the form of (2) immediately suggests a law of division of the lengths and direction of the radii, which will avoid this, and make the second member of the form, constant $\times$ h. This law evidently is to make the lengths of the radii in arithmetical progression, and their directions such that their sines shall be in arithmetical progression.

Denoting then by (r) and (s) the common difference respectively of the lengths of the radii and the sines of their azimuths, and by H_n the sum of the mean heights of all the compartments between the nth and $n + 1$th circles on the north, and by H'_n the same on the south, we have:—

$$\Sigma A = \rho \, (s) \, \Sigma \frac{H_n - H'_n}{n + \frac{1}{2}} \qquad (3)$$

and consequently:

$$\psi = 24''.894 \frac{\rho}{\delta} (s) \Sigma \frac{H_n - H'_n}{2n + 1} \qquad (4)$$

$\frac{\rho}{\delta}$ may be taken at $\frac{1}{2}$ since the average specific gravity of rocks varies from 2.5 to 3.0, and the mean density of the earth is about 5.5. If the radii are so drawn that their azimuths are $\sin^{-1}\left(\frac{1}{10}\right) \sin^{-1}\left(\frac{2}{10}\right)$, etc., ($s$) becomes $\frac{1}{10}$; and if H_n, etc., be expressed in feet the formula becomes, for $n+1$ circles:

$$\psi = 0''.00023574 \left(\frac{H_1 - H'_1}{3} + \frac{H_2 - H'_2}{5} + \ldots\ldots \frac{H_n - H'_n}{2n+1}\right) \quad (5)$$

In order to use this formula contoured maps are necessary for finding the mean heights; our stadia surveys supplied these maps in the immediate vicinity of the station, and for distant attractions I have used 200 feet contours on the diagram to which I have before referred.

In the preceding table the system of deflections A was calculated with radii whose common difference was 1 mile, and which extended from 1 to 10 miles, except at station 34, where the common difference of the radii was 2,000 feet. The system of deflections B was calculated with radii, whose common difference was 10 miles, and which extended from 10 to 60 miles Deflections A have been calculated at only six stations—those, namely, in the vicinity of the Pembina and Turtle Mountains, and the Sweet Grass Hills. All the other stations from 1 to 36 are surrounded, in their immediate vicinity, by level plains, only broken here and there by the gorge of a stream; the maximum deficiency of attraction of any one of these ravines is 0''.3, and this is less than the estimated uncertainty of the numbers in column D.

Beyond station 36, and in the Missouri Coteau, we have not sufficient data for contours.

It may seem strange at first that the distant attractions should be so much larger than those nearer the station; but this must always be so in a country like the plains east of the Rocky Mountains, where there are few abrupt irregularities, but where large tracts of country have a gradual tilt in the direction of the drainage. For instance, let us suppose a tract of country with a radius of sixty miles, which has everywhere a uniform slope to the north of only 2 feet in a mile; the plumb-line at the center of this tract will be deflected less than 0''.04 by the attraction within the 10-mile circle, but 0''.36 by that between the 10 and 60 mile circles.

By inspecting the table given above, we see that some of the observed deflections are accounted for by the irregularities of the surface and some are not.

The column $D-(A+B)$ contains the unexplained deflections, the mean of which is $1''.442$, or about two-thirds the mean of the observed deflections. Only one-third of these deflections is then accounted for by the irregularities of the surface. If we correct the latitudes by the deflections $A+B$, the mean parallel will be $0''.39$ north of its present position. * * * *

The results of this investigation may then be summarized as follows: On the 49th parallel, between the 95th and 114th meridians, the average meridional deflection of the plumb-line is $2''.146$. At 29 stations the deflections calculated from the irregularities of the surface are in the same directions as those observed, and at 12 stations they are in the opposite direction. The residual deflections, unexplained by the irregularities of the surface, have an average value of $1''.442$, or about two-thirds of the whole deflection.

It is possible that these results might be modified by more extended and detailed topographical surveys than it was possible for us to make consistently with our prime duty of marking the parallel beyond the possibility of dispute and without unnecessary expense.

F. V. GREENE,
First Lieutenant of Engineers.

APPENDIX H

TO

REPORT OF CAPT. W. J. TWINING,

CORPS OF ENGINEERS,

CHIEF ASTRONOMER.

REPORT

ON

THE DECLINATIONS OF THE STARS EMPLOYED IN LATITUDE WORK WITH THE ZENITH TELESCOPE, EMBRACING SYSTEMATIC CORRECTIONS IN DECLINATION DEDUCED FOR VARIOUS AUTHORITIES, AND A CATALOGUE OF FIVE HUNDRED STARS FOR THE MEAN EPOCH 1875,

BY

ASSISTANT LEWIS BOSS,

NOW DIRECTOR OF DUDLEY OBSERVATORY.

DUDLEY OBSERVATORY,
Albany, N. Y., February 21, 1877.

DEAR SIR: After unexpected delay I have the honor to transmit, herewith, my report on the accuracy of the declinations adopted by the United States Commission in the latitude work of the Northern Boundary Survey. In doing this, permit me to thank you most cordially for the kind interest and generous support which you have throughout accorded to this undertaking. The sense of obligation is the more keenly felt, when I reflect upon the many imperfections and deficiencies of the work; but your intercourse with me has been uniformly such as to cause me to forget the debt, and leaves only the most pleasant recollections.

I have the honor to be, very respectfully, your obedient servant,

LEWIS BOSS,
Director of Dudley Observatory, and late Assistant Astronomer of the United States Northern Boundary Commission.

Capt. WILLIAM J. TWINING,
United States Engineers, Chief Astronomer and Surveyor of the United States Northern Boundary Commission.

INTRODUCTORY.

The method of obtaining latitudes with the zenith telescope, which was adopted by the United States Northern Boundary Commission, rendered it necessary, in 1872, to calculate the declinations of a large number of stars. The short time allowed for preparation rendered a critical discussion of these star-places quite impracticable. The declinations adopted in the work of 1872 were, therefore, derived from a limited number of authorities; but were subsequently revised whenever additional material could be secured. Thus the catalogue for 1874 was compiled from nearly all the authorities which could be obtained from the library of the United States Naval Observatory.

The method of reduction was substantially that employed by Argelander in the seventh volume of Bonn observations.* The principal deviations from this plan consisted in the smaller weights given to declinations from the older authorities, and in applying no systematic corrections to those of a mean date later than 1860.

Upon the accuracy of the adopted declinations depend the latitudes of twenty-two stations in the vicinity of the forty-ninth parallel. There is every reason to believe that for the majority of the stations the error in location due to instrumental causes is practically insignificant, and that if any considerable correction is needed it may safely be ascribed to systematic error in the values of declination assigned to the determining stars.

To ascertain the numerical limits between which the value of such a correction is likely to exist, and, as far as practicable, to compute its actual amount, was the original purpose of this discussion.

When the work was about half completed, it appeared that the systematic corrections and the declinations of the principal stars, adopted as standard in this paper, might prove acceptable to others engaged in certain classes of astronomical reductions. This circumstance led to a considerable enlargement of the original scope of the work. Only stars of the northern hemisphere, with a few in the first ten degrees of south declination, had hitherto been considered. The list was now extended so as to include all the stars of the American Ephemeris.

Quite recently, upon my appointment to the astronomical direction of Dudley Observatory, the work received an additional impulse from my determination, in reducing observations made with the transit circle, to use a standard catalogue in declination as well as right ascension. This course was adopted for the reason that, whenever the places of the principal fixed stars can be predicted from observations already made, with greater accuracy than they can be determined at any one observatory by a single series of a few years duration, a desire for the greatest economy of labor and accuracy in results should dictate one of two courses: either a special and rigorous research, having in view the independent determination of the places of a small number of the brighter stars; or, the use of a standard catalogue, compiled from the best available sources, to which the observations of all other objects should be essentially referred.

It is much to be regretted that owing to unavoidable circumstances this change in plan was made too late for the most advantageous disposition of materials available for the purpose in view. On the other hand, the corrections and the resulting declinations are probably very near those which would have resulted from a more systematic and elaborate discussion, adopting the same general principles.

This considerable extension of the original plan was determined upon at a time when it was out of the question that the computations should be completed during the existence of the boundary commission; so that in the performance of the work it has been necessary for me to incur many obligations. For material assistance I am especially indebted to Prof. Simon Newcomb, of the United States Naval Observatory.

* *Bonn Beob., Band* VII., *Abth.* I., "Untersuchungen über die Eigenbewegungen von 250 Sternen."

Without his generous intervention it would have been impossible for me to have completed the work in its present extent, within the prescribed limits of time. For further aid, I am under the greatest obligations to the office of the American Ephemeris and Nautical Almanac; and to the Dudley Observatory, where the later computations have been carried on partly for the purpose of constructing a standard catalogue of declinations, for use with the transit circle, as already explained.

The services of several computers have been engaged from time to time, generally for short periods. For such services, I am chiefly indebted to Assistant C. L. Doolittle, since Professor of Mathematics and Astronomy in the Lehigh University, Pennsylvania, and to Assistant O. S. Wilson, who have labored on the work in a most disinterested and competent manner. My thanks are also due to Thomas R. Featherstonhaugh, A. M., formerly assistant at the Dudley Observatory.

The facilities of the Observatory at Washington were most kindly extended to me by Admiral B. F. Sands, Superintendent, and by his successor in office, Admiral C. H. Davis. To the various members of the astronomical corps at that institution I desire to express my acknowledgments; particularly to Professors Eastman, Harkness, and Nourse, for special courtesies.

PRELIMINARY STATEMENT AND GENERAL PLAN OF THE WORK.

It is well known that troublesome systematic discordances exist even among independent declination determinations of the highest rank, while the differences which were found between the earlier results of Bessel, Brinkley, and Pond, and even between different results by the same astronomer, were such as to provoke an acrimonious controversy and to lead to most erroneous theories. The science of exact measurement of zenith distances was no doubt very much stimulated by the latter circumstances, for in the period extending from 1820 to 1850 we have more than one-half the entire material now available for researches upon the absolute declinations of the fundamental stars.

For the purpose here proposed, it will not be necessary to make any extensive enumeration of the attempts which have been made from time to time to ascertain and reconcile these differences. Since the appearance of Bessel's reduction of Bradley's observations,* the uniform practice has been to consider these places for 1755 as absolute, and to compare them with the results of a single modern series, or with the mean of two or more. With the declinations and proper motions thus formed, the corrections necessary to reduce any given series to the standard could be ascertained. Mädler compared a number of modern catalogues with Pond's Catalogue of 1,112 stars, the proper motions being derived from the *Fundamenta*.† Dr. Gould reduced the star-places now adopted in the American Ephemeris in a similar manner, using for the modern catalogue the Abo Catalogue of the late Dr. Argelander.‡ Dr. Wolfers corrected the declinations of Bessel's *Tabulæ Regiomontanæ*, using for that purpose eleven modern catalogues. Many series of observations were adapted to the system thus formed through the labors of Dr. Argelander and Dr. Auwers.§ The latter has con-

* *Fundamenta Astronomiæ pro anno* 1755, *ex observationibus* J. Bradley, *Auctore* F. W. Bessel. *Regiomonti*, 1818.

† Dorpat observations, vol. xiv. J. H. Mädler.

‡ Dr. B. A. Gould's *Standard Places of Fundamental Stars, United States Coast Survey*, 1866.

§ *Tabulæ Reductionum, Auctore* J. Ph. Wolfers. *Berolini*, 1858. Dr. Auwers in *Astronomische Nachrichten*. Dr. Argelander, *Astronomische Nachrichten*, *Bonn Beob.* Bd. vii, etc.

tributed an exhaustive independent investigation of declination corrections in *Astronomische Nachrichten*, Band 64 (pp. 305 to 382). Taking the Abo Catalogue, referred to the *Fundamenta*, as the medium of comparison, the corrections necessary to reduce the principal modern series of observed declinations to the system of the Abo are first ascertained and afterward corrected by the mean of fourteen catalogues judged most suitable for the purpose, in such a way that, for the epoch 1755, the system is that of the *Fundamenta* as at first; but for the mean modern date (about 1837) that of the mean of the fourteen catalogues. Shortly afterward (A. N., Bd. 64, p. 193) Dr. Auwers used these corrections in discussing the declinations of thirty-four fundamental and nine circumpolar stars. Similar discussions and compilations relating to star declinations have also been made by Baily,* Laugier,† Safford,‡ Bruhns,§ and others.

It is evident in the cases cited that, if we denote by ΔN the correction required by a normal system for the epoch T, which corresponds to the mean of the modern catalogues employed in its formation, and by ΔB the correction required for the same system—or what is the same thing, Bessel's *Fundamenta*—at the epoch 1755, the correction of the system for any other epoch T' will be,

$$(\Delta B - \Delta N)\frac{T - T'}{T - 1755} + \Delta N.$$

If we put $\Delta N = O$ and $T = 1835$, we shall have as the correction of the normal system, when $T' = 1875$,

$$-\tfrac{1}{2}\,\Delta B.$$

Thus, if declinations are required for the epoch 1875, a single determination at that date having weight 5, when the unit of weight is the corresponding determination by Bradley, is worthy of more confidence than that which is derived from a discussion which assumes the *Fundamenta* as absolute at the epoch 1755, even though modern determinations be absolutely without error for the epoch 1835.

After the time of Bradley we meet with no important independent determination of declination until that of Piazzi for the mean epoch 1800. But the instrument used in this series was entirely inadequate for the purpose, and although all the elements of reduction—precession, nutation, and aberration excepted—were derived from the observations themselves, the execution of the work is not such as to command our entire confidence. Passing over the circumpolar catalogue of Groombridge (epoch 1810), the first which appears to answer our requirements results from observations made with the Reichenbach circle, in 1820 and 1821, by Bessel (*Königsberg Beob.*, vol. vii). This may be regarded as the first example in the new era of declination determinations with meridian instruments. The form of discussion there employed has, with slight modifications, served as a model for similar independent researches of the highest order ever since that time; and since this epoch there is no lack of material for the formation of standard catalogues of declination.

* Catalogue of the Royal Astronomical Society for 1830. British Association Catalogue of 8,377 stars for the epoch 1850, etc.

† *Mémoire sur la Détermination des Distances Polaires des Etoiles Fondamentales par E. Laugier. Deuxième section*, p. 75.

‡ Annals of Harvard College Observatory; Memoirs American Academy, New Series, vol. iii; Mean declinations of 981 stars for 1875. Washington, 1873, etc.

§ *Generalbericht der Europäischen Gradmessung*, 1871.

It will be shown that the interval of time between the group of early determinations by Bessel (1821), Struve (1824), and Argelander (1829), and the later ones at Leiden, Melbourne, Greenwich, and Washington observatories (not to mention intermediate catalogues), is quite sufficient for an independent judgment as to the approximate accuracy and consequent weight of Bradley's results, and that a reliable system of corrections to the various catalogues may be founded on a discussion of recent catalogues alone, taking as the earliest that of Bessel for the mean epoch 1821.

Having premised this much, for the purpose of a more exact understanding of the scope and contents of the succeeding pages, the successive steps and objective points will be indicated in brief. These are:—

1. The selection of stars to form the catalogue, and particularly of a list of stars most frequently observed, which shall serve as the basis of the normal system and as a medium of comparison between the various series of observations.

2. The formation of approximate positions and proper motions for the fictitious epoch 1875.0. These will be necessary for the computation of precession coefficients. Furthermore, the values of the assumed δ and μ' should be fair approximations, for reasons which will appear in the proper place.

3. The computation of precession coefficients, and with the aid of these (and in the case of close circumpolar stars by the rigorous formulæ) the reduction of the individual declinations to the required epochs, in order that the assumed declinations may be corrected by comparison with the observed values.

4. The selection of catalogues and series of observations, which shall serve in various stages of the work to correct the assumed declinations. These will be divided into three classes.

5. The application to the declinations given by these catalogues of certain corrections deemed advisable from an inspection of the constants and methods of reduction, and numerous compilations of the results of several successive years at the same observatory into single catalogues embracing convenient intervals of time. These corrections are such as can be determined without recourse to comparisons of the determinations of one instrument with those of another. The compilations are for the purpose of rendering available a large mass of material that would otherwise be inconvenient or unsuitable for the purpose here proposed. Generally, published catalogues, which combine in one determination the results of several years, have been used without change.

6. The collection of results and formation of the approximate normal system from a discussion of the declinations of the fundamental and principal circumpolar stars, using for this purpose only those series of observations which are supposed to give determinations of sufficient independence and weight.

7. By the aid of the approximate corrections to the selected list of authorities to enlarge the number of standard declinations, and, in turn, with these to derive the systematic correction required by Bradley's observations as reduced by Bessel in the *Fundamenta Astronomiæ*.

8. With this correction together with those previously found, and with an increased list of stars, to ascertain corrections to the assumed declination and proper motion of each star; and taking them as a basis, to compute definitive corrections and weights for all the catalogues except those of the third class; with which final weights and

corrections, the definitive declinations are computed (as they appear in the catalogue at the end of this paper), a few excepted which depend on a small number of authorities.

9. The computation of a few systematic corrections to catalogues of the third class; and the formation of all remaining declinations for the final catalogue.

10. A few deductions relative to the accuracy of the declinations formerly adopted in obtaining latitudes on the Northern Boundary.

SECTION I.

SELECTION OF STARS.

The preliminary catalogue necessarily embraces all the stars used in zenith telescope work of the United States Northern Boundary Commission, 1872–1875.

All of the stars of the American Ephemeris for which apparent places are given in that publication are added to this list, Sirius and Procyon excepted. The great majority of these stars are required for the purpose of constructing the normal system. These were supplemented by a considerable number of the Poulkova *Hauptsterne*, preference being given to those most frequently observed at Poulkova and elsewhere.

At the suggestion of others a few stars were added which might serve for latitude determinations with zenith telescope on or near the parallel of 39° north latitude.

Effectively, the selection may be regarded, for convenience, as embracing at least five different classes of stars:

a. The fundamental and principal circumpolar stars which have been by common consent quite universally observed.

b. A class of stars less frequently observed, but with the observations so distributed in time, that reliable determinations of declination and proper motion can be had without recourse to Bradley's observations; and which, together with the fundamental stars, may serve to construct an approximate normal system for the epoch 1755.

c. A class of stars similar to the last, but lacking in satisfactory authorities for the epochs included between 1820 and 1840. After the systematic corrections of the older authorities are ascertained, these will serve equally with the preceding in determining the systematic corrections required by the principal authorities.

d. A considerable number of stars, which do not furnish proper material for ascertaining systematic corrections to the principal authorities, but which will be found valuable for the purposes of perfecting the system of corrections adopted for a few catalogues of small weight, and for extending the system to catalogues deficient in observations of the first three classes of stars.

e. The remaining declinations are such as depend on few authorities, and are practically of no service in ascertaining systematic corrections. They belong to the class of stars selected and used for observation with the zenith telescope; and it is desirable to calculate their declinations with whatever precision can be attained by the use of all authorities that are conveniently accessible.

SECTION II.

APPROXIMATE POSITIONS FOR 1875.0.

Our plan contemplates the assumption at a given epoch of approximate values of the right ascension and declination, and of proper motion in both co-ordinates. These will serve for the accurate computation of the precession coefficients. For this purpose it is simply necessary to avoid errors which are large enough to introduce appreciable errors in those terms of precession in declination that depend on the higher powers of the time, and in the geometrical part of the annual variation. It is, however, desirable in order to facilitate subsequent computations that the declination and its proper motion should be so determined that the corrections they may require will not be inconveniently large; and that the difference between the assumed and concluded proper motions will not be so large, that the neglect of the small difference between the adopted mean epoch of observation for each catalogue and the particular mean for a given star will seriously affect the final result for declination and proper motion.

The epoch of reduction selected for the catalogue is the fictitious or Besselian epoch 1875.0.

Right ascension.

For the fundamental stars this is copied from Professor Newcomb's paper, Appendix III., Washington Observations for 1870. The proper motions are from the same source.

Except for stars south of declination -30°, the remaining right ascensions are taken from the American Ephemeris for 1875, as far as possible. The following inconsiderable corrections are, however, applied in most cases. They are intended to reduce these right ascensions to the standard of Professor Newcomb's paper, above cited.

Hour.	Correction.	Hour.	Correction.	Hour.	Correction.
	s.		s.		s.
0	+ .03	8	— .02	16	+ .01
1	+ .02	9	— .02	17	+ .02
2	+ .01	10	— .02	18	+ .03
3	+ .01	11	— .02	19	+ .03
4	00	12	— .01	20	+ .03
5	— .01	13	— .01	21	+ .03
6	— .01	14	— .00	22	+ .03
7	— .02	15	+ .01	23	+ .03
8	— .02	16	+ .01	24	+ .03

The proper motions, in A. R., of these stars were taken from the Star Tables of American Ephemeris (Wn., 1869). They are mostly those of Dr. B. A. Gould's Standard Places of Fundamental Stars, United States Coast Survey, second edition (Wn., 1866). For other stars the A. R. and μ were computed, if possible, from at least two good modern authorities compared with either Bradley, Piazzi, or Groombridge, and occasionally with all three. The authorities were first corrected by the tables of Professor Newcomb's paper just mentioned. In a few cases where older authorities were wanting the assumed A. R. and μ were computed with greater care.

Declinations.

In computing assumed declination and proper motion in declination, the preference was given: first, to the Northern Boundary catalogue of latitude stars for the epoch 1874.0; second, to the declinations for 1870.0 reduced by Bruhns for the *Gradmessung*, and contained in *Generalbericht der Europäischen Gradmessung für* 1871;* third, excluding stars south of $-30°$ declination, to the declinations for 1875.0 of the American Ephemeris; and fourth, in the failure of these three sources of supply, declinations were computed in a manner entirely analogous to that adopted with right ascensions, except that no systematic corrections were applied. Nearly all the declinations of stars south of $-30°$ declination were formed from the mean of Mr. Stone's recent catalogue of Maclear's observations at the Cape for 1860, and the First Melbourne Catalogue for 1870, the assumed proper motions being copied from the latter. In "Details of Corrections to Assumed Places" the preliminary α and δ with their assumed variations are given at the head of the table for each star.

SECTION III.

COMPUTATION OF PRECESSION TERMS.

The constants of Peters and Struve have been adopted. They are†:—

$$m = 46''.0623 + 0''.0002849\ (t - 1800)$$
$$n = 20''.0607 - 0''.0000863\ (t - 1800),$$

where t is expressed in years. These are now in very general use, and probably are not far from the correct values.‡

At any rate, since our object is not so much to ascertain the exact amount of proper motion as to know the total change produced by the annual movement, great accuracy is required only in terms of precession involving higher powers of the time. The effect of proper motion has been considered in every case, and for this purpose the formulæ given by Professor Hill in Star Tables of the American Ephemeris (p. xix) have been adopted. The coefficient of t^3 has received a slight modification due to the neglect of small terms. So that, if the first and second differential coefficients in both

* "*Die Declinationen der bei der Gradmessung zu Breitenbestimmungen benutzten Fixsterne,*" C. Bruhns. The declination and μ' of α Cephei there given appear to be in error. Taking the geometrical precession as computed on p. 11, the seconds of δ for Bradley's observations reduced to 1870, should be 04''.23 instead of 05''.26 as printed in the last column of p. 7. The corrected proper motion will be + ''.024 instead of + ''.006, and the seconds of δ for 1870, 7''.13 instead of 7''.03.

† *Numerus Constans Nutationis*, pp. 66, 71. Dr. C. A. F. Peters.

‡ Dr. C. Bruhns in "*Die Declinationen der bei der Gradmessung,*" u. s. n., takes the same course, * * * "*da dieselbe* [precession of Struve] *zwischen dem Werthe der Bessel'schen und der Leverrier'schen Præcession liegt und nach den neueren Beobachtungen die Variatio sæcularis von Struve und Leverrier, die fast identisch ist, entschieden genauer als die Bessel'sche Variatio sæcularis sich findet,*" pp. 2 and 3

co-ordinates are known, the computation of $\frac{d^3\delta}{dt^3}$ will be sufficiently rigorous, simple, and expeditious. In computing

$$-\frac{n}{R}\left(\frac{d^2\alpha}{dt^2}+\frac{d\mu}{dt}\right)\sin\alpha,$$

$\frac{d\mu}{dt}$ is usually without sensible influence on the result. Let

α and δ = respectively the right ascension and declination of a star,
μ and μ' = the corresponding proper motions,
n and m = coefficients of precession,
$\frac{dn}{dt}$ and $\frac{dm}{dt}$ = their respective annual variations.

We shall have:—

$$\frac{d\alpha}{dt} = m + n \sin\alpha \tan\delta + \mu$$

$$\frac{d\delta}{dt} = n\cos\alpha + \mu'$$

$$\frac{d\mu}{dt} = n\,\mu\cos\alpha\tan\delta + n\,\mu'\sin\alpha\sec^2\delta + 2\,\mu\,\mu'\tan\delta$$

$$\frac{d\mu'}{dt} = -\,n\,\mu\sin\alpha - \tfrac{1}{2}\,\mu^2\sin 2\delta$$

$$\frac{d^2\alpha}{dt^2} = -\frac{m}{n}\frac{dn}{dt} + \frac{dm}{dt} + \frac{dn}{dt}\frac{1}{n}\left(\frac{d\alpha}{dt}-\mu\right) + n\left(\frac{d\alpha}{dt}+\mu\right)\cos\alpha\tan\delta$$
$$+\,n\left(\frac{d\delta}{dt}+\mu'\right)\sin\alpha\sec^2\delta + 2\,\mu\,\mu'\tan\delta.$$

$$\frac{d^2\delta}{dt^2} = +\frac{dn}{dt}\frac{1}{n}\left(\frac{d\delta}{dt}-\mu'\right) - n\left(\frac{d\alpha}{dt}+\mu\right)\sin\alpha - \tfrac{1}{2}\,\mu^2\sin 2\delta$$

$$\frac{d^3\delta}{dt^3} = -\,2\,\frac{dn}{dt}\left(\frac{d\alpha}{dt}+\frac{\mu}{2}\right)\sin\alpha - n\left(\frac{d^2\alpha}{dt^2}+\frac{d\mu}{dt}\right)\sin\alpha - n\left(\frac{d\alpha}{dt}+\mu\right)\left(\frac{d\alpha}{dt}\right)\cos\alpha.$$

If α, μ, m, and $\frac{dm}{dt}$ are expressed in time, and the factor $\frac{1}{R}$ supplied, when necessary, we have the following tables of logarithmic values for the coefficients, the arguments being the year, and quantities depending on the place of the star, except for the first table, which simply gives the values of m and n for various epochs:—

Year.	m	n.	log n	log $\frac{n}{15}$
	s.	″		
1750	3.06987	20.0650	1.3024395	0.126348
1775	3.07035	20.0629	1.3023928	0.126302
1800	3.07082	20.0607	1.3023461	0.126255
1825	3.07129	20.0585	1.3022994	0.126208
1850	3.07177	20.0564	1.3022527	0.126162
1875	3.07225	20.0542	1.3022059	0.126115
1900	3.07272	20.0521	1.3021592	0.126068

$$\frac{d^2a}{dt^2}$$

Year.	Constant.	Log. coefficients of—			
		$\frac{da}{dt}-\mu$	$\left(\frac{da}{dt}+\mu\right)\cos a \tan \delta$	$\left(\frac{d\delta}{dt}+\mu'\right)\sin a \sec^2 \delta$	$\mu\,\mu' \tan \delta$
		(−10)	(−10)	(−10)	(−10)
1750	+ .0000 3220	4.63357 *n*	5.98801	4.81192	4.9866
1775	3220	4.63362 *n*	5.98797	4.81188	"
1800	3220	4.63366 *n*	5.98792	4.81183	"
1825	3221	4.63371 *n*	5.98787	4.81178	"
1850	3221	4.63376 *n*	5.98783	4.81174	"
1875	3221	4.63380 *n*	5.98778	4.81169	"
1900	+ .0000 3222	4.63385 *n*	5.98773	4.81164	"

$$\frac{d^2\delta}{dt^2}$$

Year.	Log. coefficients of—		
	$\mu^2 \sin 2\delta$	$\left(\frac{d\delta}{dt}-\mu'\right)$	$\left(\frac{da}{dt}+\mu\right)\sin a$
	(−10)	(−10)	(−10)
1750	6.73673 *n*	4.63357 *n*	7.164105 *n*
1775	"	4.63362 *n*	7.164059 *n*
1800	"	4.63366 *n*	7.164012 *n*
1825	"	4.63371 *n*	7.163965 *n*
1850	"	4.63376 *n*	7.163918 *n*
1875	"	4.63380 *n*	7.163872 *n*
1900	"	4.63385 *n*	7.163825 *n*

$$\frac{d^3\delta}{dt^3}$$

Year.	Log. coefficients of—		
	$\left(\frac{da}{dt}+\frac{\mu}{2}\right)\sin a$	$\left(\frac{d^2a}{dt^2}+\frac{d\mu}{dt}\right)\sin a$	$\left(\frac{da}{dt}+\mu\right)\left(\frac{da}{dt}\right)\cos a$
	(−10)	(−10)	(−10)
1750	2.09871	7.16411 *n*	3.02577 *n*
1775	"	7.16406 *n*	3.02573 *n*
1800	"	7.16401 *n*	3.02568 *n*
1825	"	7.16396 *n*	3.02563 *n*
1850	"	7.16392 *n*	3.02558 *n*
1875	"	7.16387 *n*	3.02554 *n*
1900	"	7.16383 *n*	3.02549 *n*

With these tables, and with the assumed values of α, δ, μ, and μ', $\frac{d\alpha}{dt}$, $\frac{d^2\alpha}{dt^2}$, $\frac{d\delta}{dt}$, $\frac{d^2\delta}{dt^2}$, and $\frac{d^3\delta}{dt^3}$ were computed for the epoch 1875 for every star. The values of all these will be found in the definitive catalogue (end of this Appendix), except that of $\frac{d\delta}{dt}$, for which the catalogue gives the corrected value. The assumed value of $\frac{d\delta}{dt}$ and $\frac{d\alpha}{dt}$ will be found with assumed values of α and δ at the head of the table for each star in "Details of Corrections to Assumed Places."

Having now assumed declinations and variations in precession for 1875.0, the position for any other date, T will be:—

$$\delta + \frac{d\delta}{dt}(T-1875) + \tfrac{1}{2}\frac{d^2\delta}{dt^2}(T-1875)^2 + \tfrac{1}{6}\frac{d^3\delta}{dt^3}(T-1875)^3.$$

By this formula the declinations of all the Nautical Almanac stars, with others most frequently observed, were computed for the dates 1755, 1800, 1810, 1820, and for each succeeding year until 1875. Stars less frequently observed were computed only to those dates actually required. The computation in every part was carefully scrutinized, and either checked by differences or duplicated.

For stars within 5° of the pole, and for one or two others at particular dates, the above proceeding will not answer. These were rigorously reduced by the trigonometrical formulæ to the required dates before and to every five years after 1820 from places and proper motions assumed for the epoch 1855. The following formulæ, taken from Chauvenet's Spherical and Practical Astronomy (vol. i, p. 615), were used:—

$$p = \sin\theta\,(\tan\delta + \tan\tfrac{1}{2}\theta\cos A)$$

$$\tan(A' - A) = \frac{p\sin A}{1 - p\cos A}$$

$$\tan\tfrac{1}{2}(\delta' - \delta) = \tan\tfrac{1}{2}\theta\left(\frac{\cos\tfrac{1}{2}(A' + A)}{\cos\tfrac{1}{2}(A' - A)}\right)$$

in which

$$A = \alpha + z + \vartheta, \text{ and } A' = \alpha' - z' + \vartheta',$$

α and α' being respectively the assumed and required right ascensions, ϑ the planetary precession, and z, z', and θ are found from the formulæ:—

$$\tan\tfrac{1}{2}(z' + z) = \tan\tfrac{1}{2}(\psi' - \psi)\cos\tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)$$

$$\tfrac{1}{2}(z' - z) = \frac{\tfrac{1}{2}(\varepsilon_1' - \varepsilon)}{\tan\tfrac{1}{2}(\psi' - \psi)\sin\tfrac{1}{2}(\varepsilon_1' + \varepsilon_1)}$$

$$\sin\tfrac{1}{2}\theta = \sin\tfrac{1}{2}(\psi' - \psi)\sin\tfrac{1}{2}(\varepsilon_1' + \varepsilon_1),$$

where the symbols used have the same signification as in the place from which the formulæ are cited. Reckoning from 1800, we have $\vartheta = +7''.584$. For the other quantities I have computed the following table:—

Table giving values of ϑ', z, z', $\frac{1}{2}\,\theta$, log. tan $\frac{1}{2}\,\theta$, and log. sin θ, in the formulæ for reducing star places, from 1855, to other dates.

Date.	ϑ'	z	z'	$\frac{1}{2}\,\theta$	log. tan $\frac{1}{2}\,\theta$	log sin θ
	″	′ ″	′ ″	′ ″	(−10)	(−10)
1755	− 7.293	− 38 31.402	− 38 29.890	− 16 42.994	7.6868766 *n*	7.9878963 *n*
1790	− 1.536	− 25 05.201	− 24 58.399	− 10 51.904	7.4997603 *n*	7.8007864 *n*
1800	000	− 21 14.881	− 21 06.567	− 9 11.601	7.4272008 *n*	7.7282277 *n*
1805	+ 0.750	− 19 19.726	− 19 10.656	− 8 21.450	7.3858037 *n*	7.6868312 *n*
1810	+ 1.488	− 17 24.574	− 17 14.748	− 7 31.301	7.3400421 *n*	7.6410700 *n*
1815	+ 2.213	− 15 29.423	− 15 18.841	− 6 41.152	7.2888849 *n*	7.5899133 *n*
1820	+ 2.927	− 13 34.274	− 13 22.936	− 5 51.005	7.2308885 *n*	7.5319172 *n*
1825	+ 3.629	− 11 39.131	− 11 27.037	− 5 00.858	7.1639373 *n*	7.4649665 *n*
1830	+ 4.318	− 9 43.989	− 9 31.139	− 4 10.713	7.0847517 *n*	7.3857811 *n*
1835	+ 4.995	− 7 48.849	− 7 35.243	− 3 20.568	6.9878370 *n*	7.2888666 *n*
1840	+ 5.661	− 5 53.712	− 5 39.350	− 2 30.424	6.8628935 *n*	7.1639233 *n*
1845	+ 6.314	− 3 58.577	− 3 43.459	− 1 40.282	6.6867983 *n*	6.9878282 *n*
1850	+ 6.955	− 2 03.448	− 1 47.568	− 0 50.140	6.3857631 *n*	6.6867930 *n*
1855						
1860	+ 8.201	+ 1 46.812	+ 2 04.198	+ 0 50.139	6.3857545	6.6867844
1865	+ 8.805	+ 3 41.937	+ 4 00.079	+ 1 40.278	6.6867791	6.9878093
1870	+ 9.398	+ 5 37.061	+ 5 55.957	+ 2 30.415	6.8628659	7.1638957
1875	+ 9.979	+ 7 32.179	+ 7 51.833	+ 3 20.551	6.9877997	7.2888293

SECTION IV.

SELECTION OF AUTHORITIES.

Nearly all authorities for declination which were conveniently accessible have been selected for use. The scattered observations in astronomical journals, and zone observations, with a few others of small weight, have generally been neglected. For convenience I have divided them into three classes, for reasons which will subsequently appear.

CLASS I.

Embraces catalogues and series of observations which have been adopted in construction of the normal system. The designation of each catalogue is first given, the principle of nomenclature being that the letters usually indicate the first and final letters in the name of the observatory according to the English spelling, and the figures the mean year of observation, roughly estimated. In designating the various annual catalogues (as well as compilations) in such series as those of Greenwich and Washington, this system is found to be very convenient.

Kg 21. Bessel's observations in 1820 and 1821 with the Reichenbach Circle, published in *Kön. Beob.* Bd. vii. Döllen's discussion has been adopted, however. This is found in "*Recueil de Mémoires des Astronomes de l'Observatoire Central de Russie*," vol. ii, p. 203 to 232. The seconds of declination are adopted from column headed "B_2" in tables iii and iv. These differ from Bessel's own reduction (*Kön. Beob.* Bd. vii) by the quantity

$$+\,''.30 + 0''.56 \sin Z + ''.023 \tan Z$$

which must be applied as a correction to Bessel's declinations. The declinations so reduced adopt for the horizontal flexure $+\,0''.56$, which is the mean between that found by Bessel in 1820–'21, from reflection observations, and afterward by horizontal collimators. The reduction of the observations in this manner is found to correspond closely with Bessel's observations of the sun.*

Gh 22. Olufsen's reduction of Pond's observations at Greenwich for the year 1822, printed in *Ast. Nach.* 422.

Dt 24. Struve's declinations in "*Catalogus Primarius, p. xxxxviii, Introductio,*" "*Stellarum Fixarum imprimis Duplicium et Multiplicium Positiones Mediæ pro Epocha* 1830.0."

Ao 29. The Åbo Catalogue of Argelander, "DLX *Stellarum Fixarum Positiones Mediæ, ineunte Anno* 1830."

S. H. 31. Johnston's St. Helena catalogue. "A Catalogue of 606 Principal Fixed Stars in the Southern Hemisphere, deduced from observations made at the observatory, St. Helena, from November, 1829, to April, 1833." The epoch of reduction is 1830.

C. G. H. 33. Henderson's declinations derived from observations made at the Cape of Good Hope. The series extends from May 16, 1832, to May 24, 1833, and is reduced to the mean epoch 1833. It is found in Memoirs of the Royal Astronomical Society, vol. x, p. 80.

Ce 34. Airy's observations at Cambridge, England, taken in the years 1833, '34, and '35, and printed in the annual volumes of the observatory for those years.

Eh 37. Henderson's observations made at the Royal Observatory in Edinburgh, in the years 1834–'39, and printed in the annual volumes for those years.

Kg 38. Bessel's declinations observed with the Reichenbach circle in 1836–'40. These are reduced by Busch, and the results are found in *Ast. Nach.*, 422.

Gh 39. Greenwich observations, which form the first part of the Greenwich Twelve-year Catalogue. They are reduced to the epoch 1840, and embrace the results from two mural circles, for the period 1836–1841.

Ce 40. These are the first observations made under the directorship of Rev. J. E. Challis. They extend from the year 1836 to 1844, both inclusive, and are taken from the annual catalogues of the Cambridge observatory.

Eh 43. Henderson's Edinburgh results found in annual catalogues 1841–'44. They are reduced by Professor Smyth.

Kg 43. There are three reductions of this series. I have used that found in *Ast. Nach.*, 1076, made by Luther. The observations were made in years 1842–'44, by Bessel, at the Königsberg observatory, with Repsold circle.

Gh 45. Second part of the Greenwich Twelve-year Catalogue, embracing Greenwich observations 1842–1847, reduced to the epoch 1845.

Pa 45. The catalogue of declinations given for the epoch 1845.0 in the fourth volume of "*Observations de Poulkova*" (p. 50). The observations were made with the vertical circle by Dr. Peters, in 1842–1849, and the reductions are partly made by him and partly by Dr. Gylden.

Re 45. First "Radcliffe Catalogue of 6317 Stars chiefly circumpolar, reduced to the Epoch 1845 0," Johnson.

Wn 47. The annual catalogues of the Washington observatory for the years 1845–1848 inclusive. The observations are made with the mural circle, by various observers. (The results of the four succeeding years occasionally exhibit enormous discrep-

* *Vide* Döllen's Memoir, p. 221.

ancies both among themselves and when compared with the approximate places above mentioned. No use is made of these four catalogues, 1849–1852.)

Ce 48. Cambridge (Eng.) annual catalogues, 1845–1851.

Gh 51. Greenwich Six-year Catalogue, epoch 1850.

Ps 53. Laugier's declinations with the Gambey circle at Paris observatory, principally made in the years 1852 and 1853, and reduced to the epoch 1852. They are taken from pp. 72 to 74 of "*Mémoire sur la Détermination des Distances Polaires des Etoiles Fondamentales*, par E. Laugier," tome xxvii, 2e partie des *Mémoires de l'Académie des Sciences*.

So 55. Moesta's declinations with the Pistor and Martin's circle at Santiago in the years 1853–1855, reduced to the epoch 1855, and printed in "*Observationes Astrónomicas hechas en el Observatorio Nacional de Santiago*, en los años de 1853, 1854, y 1855, por el Dr. Cárlos Guillermo Mösta, director del observatorio." Tomo I. Santiago de Chile 1859.

Wn 56. This series embraces observations with the Washington mural circle in the years 1853–1858. They are reduced and the results printed in Appendix II., Washington observations for 1870. Prof. A. Hall has formed the declinations of the fundamental stars into a single catalogue, printed in *Ast. Nach.* 1947. I have taken the declinations from the original source.

Gh 57. The Greenwich Seven-year Catalogue of 2022 Stars reduced to the epoch 1860.0. The observations embrace the years 1854–1860 inclusive.

C. G. H. 58. Observations made with the Cape circle in the years 1856–'61 by Sir Thomas McClear, reduced to the epoch 1860 by E. J. Stone, astronomer royal at the Cape of Good Hope, and printed in "The Cape Catalogue of 1159 Stars," etc., Cape Town, 1873.

Wn 64. Results of observations with Washington mural circle for the years 1861–1865, printed in the annual catalogues of the respective years.

Gh 64. The new Seven-year Catalogue of Greenwich, embracing the results of observations with the Greenwich transit circle, for the years 1861–1867, both inclusive.

Ln 67. This series is taken from "*Mittlere Declinationen von 57 Fundamentalsternen, abgeleitet aus Leidener Meridiankreisbeobachtungen in den Jahren* 1864–1868," W. Valentine (*Ast. Nach.* N. 902 Bd. 80, s. 93); and from "*Annalen der Sternwarte in Leiden, herausgegeben von Dr. F. Kaiser.*"

Me 68. "The First Melbourne General Catalogue of 1227 Stars, for the Epoch 1870. Deduced from Observations extending from 1863 to 1870, made at the Melbourne Observatory," etc. R. L. J. Ellery, Melbourne, 1874.

Wn 68. Results of observations made with the Washington transit circle in the years 1866–1869, taken from the annual volumes.

Re 68. Results of observations made with the Carrington circle at the Radcliffe observatory in the years 1862–1873. These are taken from the annual catalogues of the Radcliffe observatory. They are finally divided into two series—Re 66, including years 1862–1869; Re 72, including years 1870–1873.

Gh 70. Results of observations made with the Greenwich transit circle and printed in the annual catalogues of the Greenwich observatory, 1868–1872.

Wn 72. Results of observations with the Washington transit circle 1870–1874, printed in annual volumes. The results of 1874 in manuscript were generously placed at my disposal by Prof. J. R. Eastman.

CLASS II.

This embraces catalogues supposed to be unsuitable for use in founding the normal system; but excludes a few catalogues of small extent, or weight, which are used only with stars of class *c*. Many of these are the results of observations, which in turn depend on the places of a standard list of stars; others are independent, but of small weight; or their use for other reasons may be regarded as of doubtful propriety.

Gh 1752 or Gh 1755. "*Fundamenta Astronomiæ pro Anno MDCCLV. deducta ex Observationibus Viri Incomparabilis James Bradley in Specula Astronomica Grenovicensi per Annos* 1750–1762 *institutis, Auctore Frederico Wilhelmo Bessel.*" *Regiomonti* 1818. This is in effect the result of two series of observations—the one of northern stars (stars north of Greenwich zenith), mean epoch about 1752; the other of southern stars, mean epoch 1755 or 1756.

Po 1800. "*Preeipuarum Stellarum Inerrantium Positiones Mediæ inuente sæculo XIX. Ex observationibus habitis in Specula Panormitana ab anno* 1792 *ad annum* 1813," Panormi 1814, by Joseph Piazzi.

Bh 10. "A Catalogue of Circumpolar Stars, deduced from the Observations of Stephen Groombridge, Esq.", &c., at Blackheath observatory. Reduced to January 1, 1810, and edited by Sir G. B. Airy. Lond. 1838.

Va 29. Professor Littrow's declinations of fundamental stars, from observations made at the Vienna observatory in the years 1827–'8–'9. They are reduced to 1830, and printed in Mem. Royal Ast. Soc. IV., p. 328.

Dt 30. Struve's *Positiones Mediæ*, above cited, *Catalogus Generalis.* These places are quite numerous and appear to be when *correctiones ultimæ* are applied, systematically the same as the results of *Catalogus Primarius.* The observations from which the catalogue is constructed extend over the period 1822–1843, however, and there were consequently doubts whether Dt 24 and Dt 30 should be classed together.

Gh 30. Pond's catalogue of 1112 stars reduced to 1830. These are the results of observations made with two mural circles from January 1, 1825, to January 1, 1833.

C. G. H. 31. Results obtained by Fallows, in 1830 and 1831, at the Cape of Good Hope; reduced to 1830, and printed in Mem. R. A. S. vol. XIX. The catalogue contains but few declinations, and has only been used with a few stars south of $-30°$.

Mh 34. The results of Lamont's observations at Munich in the years 1829–1840. Most of the observations were made in 1833 and 1834, and are found in "*Observationes Astromicæ in Specula Regia Monachiensi,*" etc., for those years. I have for convenience taken all from "*Annalen der Königlichen Sternwarte bei München,*" Bd. XX., München, 1874; and from the detailed positions, commencing p. 264.

Ah 41 and Ah 52. Robinson's Armagh catalogue of 5345 stars. Owing to the great period of time embraced in the observations of this catalogue, I have divided them into two series—the first, for the years 1835–1846; the second, 1847–1854. This I have done by a method which will be explained (p. 39).

So 51. The observations of Captain Gillis made at the observatory of Santiago, in Chili, in the years 1850–1852. The catalogue reduced to 1850 is printed in Appendix I., Washington Astronomical Observations for 1868.

Bs 56, Bs 60, Bs 65. These are to be found in "*Annales de l'Observatoire Royal de Bruxelles*", for years 1855–1867. The groups are: 1855–1856; 1857–1862; 1863–1867.

Ps 56 and Ps 60. These are found in "*Annales de l'Observatoire Imperial de Paris.*"

The first group covers the years 1851–1857, the second 1858–1862; and both are the results of observations of the Gambey mural circle.

Ps 64 and Ps 66. These are in continuation of the series just mentioned, but the observations are principally made with the great meridian circle of Eichens and Secretan. The groups are 1863–1864, and 1865–1867.

Ce 56. This series embraces the annual catalogues in the volumes of the Cambridge (Eng.) observatory for the years 1852–1860.

Re 58. "Second Radcliffe Catalogue containing 2386 stars; deduced from observations, extending from 1854 to 1861, at the Radcliffe observatory, Oxford; and reduced to the epoch 1860."

Me 62. "Astronomical Observations made at the Williamstown Observatory in the years 1861, 1862 and 1863, under the direction of Robert L. J. Ellery," etc. Reduced to 1860. Melbourne, 1869.

Bn 66. Argelander's observations with the transit circle at Bonn observatory. These are found partly in *Ast. Nach.* No. 1719, and partly in *Bonn Beob.* Bd. VI.

Le 67. "*Resultata aus Beobachtungen auf der Leipziger Sternwarte,*" Dr. Engelmann, 1870; also "*Die Declinationen der bei Gradmessung,*" etc., Dr. C. Bruhns.

Class III.

When an authority is of small weight, and especially when it has few declinations in common with the standard stars of Section VIII, there is danger that the error in adopted systematic correction for computing the definitive declinations may work a disadvantage, which will more than counterbalance any benefit to be derived from supposed additional weight. This objection will be, in a measure, removed by the computation of a large number of definitive places, giving more and better standards for comparison.

In making up this list a few series of observations have been omitted, either because they were not at my disposal, or because it was believed that the labor of collating them and ascertaining the proper reductions and corrections would not be repaid by the weight of new material thus acquired. Zone observations for the most part are neglected on account of their small weight in a discussion of this kind. A very few of Lalande's and D'Agelet's observations were, however, used in extreme cases.

Ms 35. "General Catalogue of the Principal Fixed Stars, from Observations made at Madras, by T. G. Taylor." Madras, 1845. The declinations are reduced to the epoch 1845.

Ms 50. Astronomical observations made at Madras for the years 1848–1852. Madras, 1856.

Wn 48. Declinations from the prime vertical transit at Washington, principally in the years 1847 and 1848.

Eh 58, Eh 63, and Eh 67. Edinburgh astronomical observations. The groups are respectively 1851–1860; 1861–1864; and 1865–1869. The declinations are taken from the annual catalogues.

Pa 62. "*Observations faites à l'Instrument des Passages établi dans le premier Vertical,*" volume iii, "*Observations de Poulkova,*" pp. 224 to 237. The declinations are determined by Mr. F. A. Oöm.

Wn 70. Declinations by Prof. M. Yarnall with the mural circle of the Washington observatory, 1866–1873, taken from the detailed results in annual volumes of Washington Astronomical Observations.

Pa 71. In the ninth volume of "*Vierteljahrsschrift der Astronomischen Gesellschaft* (pp. 83 to 88), is given a catalogue of the "*Zusatzsterne*" from observations of the Poulkova observatory. The declinations are undoubtedly of a high order of accuracy; but feeling some uncertainty about the proper manner of deducing systematic correction from them, I have placed them in Class III.; and in consequence use but one of the declinations for definitive purposes.

SECTION V.

EXPLANATION OF PRELIMINARY CORRECTIONS AND COMPILATION OF RESULTS.

Before procceding to actual discussion of normal declinations, it will be necessary to examine each catalogue for the purpose of applying such corrections as shall appear advisable from inspection. These corrections may be regarded as of three classes :

First. Those required on account of the reduction of the observations from apparent place to the true epoch of the catalogue. These are principally for nutation and proper motion actually employed. In a few cases small corrections have been applied to reduce from epoch "Jan. 1" (Greenwich), or $\odot = 281^\circ$ to the fictitious epoch $\odot = 280^\circ$; and rarely, a correction for precession which is always practically insignificant.

Modern researches appear to show that no considerable correction to Peters's nutation is needed; and that value is now universally used. This value for 1800 is (*Numerus Constans Nutationis* p. 37):

$$9''.223 \cos \Omega \sin a - 6''.865 \sin \Omega \cos a.$$

Among other values of nutation that have been used in reducing observations are these:—

Value employed by Bessel in *Fund. Ast.*	9″.648
Bradley's (original value)	9″.00
Maskelyne's	9″.55
Groombridge's	9″.63
Lindenau's	8″.977
Baily's (A. S. C. and B. A. C.)	9″.25.

The individual corrections applied to each catalogue are for the principal terms, and are of the form

$$\eta \sin a + \eta' \cos a,$$

which appears to require no explanation.

In most cases requiring it the correction for proper motion has been applied. If t denotes the epoch of reduction of the catalogue and t' the mean epoch of the observations of a particular star in the same, μ', the assumed proper motion (Section III.), and μ'' the proper motion which was applied in the reductions of the catalogue, we shall have corrections for proper motion, where $(t - t')$ is expressed in years:—

$$(\mu' - \mu'')(t - t').$$

Where the correction is practically insignificant, where the epoch of observation is not conveniently ascertained, where reductions are inaccurate, or not carried beyond first decimal place of seconds, and, especially, in a few of the cases where proper motions have been determined by comparison with Bradley, this correction is commonly neglected.

The correction, for epoch, *i. e.*, from sun's longitude 281° or from "Jan. 1" to ⊙ = 280°, is applied to most of the English catalogues whose epoch is previous to 1857, and to Wn 47.

The correction for precession is generally insignificant, and is often included in the form, An. Var. assumed — An. Var. of Catalogue. In case of catalogues which had been reduced by help of the Astronomical Society's Catalogue (Baily 1830) it was convenient to include a correction for precession with that for epoch and nutation.

Second. In many catalogues, corrections which have been derived by special examination of the instrument, or discussions of the observations, are indicated in the introductions, but not applied to the results. Similar corrections sometimes occur through the neglect of certain precautions, and which, discovered too late for correction of the printed results, are in the nature of *errata*, to be applied by the reader. *Correctiones Ultimæ*, in Struve's *Pos. Med.*, are of the former class; certain corrections in the introductions to the two Radcliffe catalogues are of the latter class. Finally, under this head come *errata* wherever found.

Third. In a limited number of cases it has been thought advisable to examine certain series of annual catalogues in order to reduce the discordances in the results of separate years, and, if possible, to ascertain corrections which seem to be required by preliminary inspection. This is analogous to the work already done by the authors in many cases, where catalogues have been formed from those of several separate years.

Under the designation of each catalogue will be enumerated all the corrections above specified which have actually been applied in this discussion. Some of the peculiarities in methods of observation or reduction which appear to invite special attention will be noticed in the same connection. The reasons for grouping, and the methods of combining the results of partial catalogues, will be explained.

The corrected catalogue declinations are then compared with the assumed declinations of this paper (Sections II. and III.), and the residuals, in the sense Observed—Assumed Declinations are exhibited in column "C," in "Details of Corrections to Assumed Declinations". To facilitate comparisons of separate years in the case of compilation, the subtraction, Observed—Assumed Declination is made at the outset, by which means the various catalogues are effectively referred to a common mean epoch, with the assumed annual variations (Section II.). These residuals are then combined with or without correction, as the case may require.

Gh 1752–1755. The coefficient of nutation adopted by Bessel in the reductions is $9''.648$. Taking the mean epoch of observation for northern stars to be 1752, and for southern 1755, the corrections to the declinations will be:—

$$\text{Northern stars} - ''.34 \sin(\alpha - 53^\circ.9)$$
$$\text{Southern stars} - ''.425 \sin(\alpha - 2^\circ.7)$$

Before discussing the systematic correction, the corrections applied by Bessel to Bradley's declinations between the parallels $+14^\circ$ and -14° are subtracted from the catalogue places. No attempt was made to ascertain proper motion corrections on account of the difficulty of finding the mean epochs of observation, and also from the fact that Bessel has applied the correction, approximately, by comparison with Po 1800.

In Dr. *Bruhns'* reduction of *Gradmessung* stars is found a list of declinations which have been computed by Dr. Auwers from the observations of Bradley. But these are not definitive, nor are they at this stage of their reduction independent, because Bessel's (Königsberg) refractions have been employed. It will be seen that the weight of testimony is in favor of refractions, on the average, at least as small as those which Bessel deduced from Bradley's observations. Professor Newcomb kindly placed at my disposal similar results for a limited list of stars which he was reducing. But both the lists combined embrace less than half the stars required in this discussion, so that the old results were used.

Po 1800. I have applied correction to this catalogue only for proper motion in a few cases where the latter is large. The effect of the nutation correction is included in the A. R. term of the declination correction subsequently ascertained.

Bh 10. The mean epochs of observation are secured from the first Radcliffe catalogue, and the proper motion correction applied in every case. As the catalogue was not included in Class I., the application of nutation correction was not made, but it is included in the A. R. term subsequently found.

In the use of this catalogue I have encountered a difficulty which introduces some uncertainty in the results. For many of the stars most frequently observed two results for declination are given in the catalogue. In the introduction this is explained by saying that the first of the two results was originally reduced to 1807, and the second to 1812. I have assumed that the observations are distinct, and that the epoch given for these stars in Re 45 is the epoch of the first set. In all these cases the mean of the two results has been taken, without correction for proper motion, as the mean epoch is probably very near 1810.

The history of the reductions, for reasons partly unavoidable, is an unfortunate one, and this is the more to be regretted, for the editor says (p. ix, Int.), "There can be no doubt, I conceive, that this instrument at the time of its erection, and for several years afterward, was the finest in the world." It appears to have been well handled, and was reversed ten times at least during the active period of the observations making up this catalogue. The materials were probably suited to the formation of an independent catalogue, which would have been no mean contribution to the solution of the problem of absolute declinations.

Kg 21. To the results as given by Döllen has been applied the correction $-{}''.24 \sin(\alpha + 7^\circ.5)$, due to the use of Lindenau's nutation.

Gh 22. The correction $-{}''.22 \sin(\alpha + 32^\circ.1)$ is applied for nutation.

Dt 24. No correction is applied to this catalogue.

Ao 29. Correction for Lindenau's nutation $+{}''.24 \sin(\alpha - 9^\circ.3)$, is adopted.

Va 29. The same nutation correction as for Ao 29 is used.

The observations are reduced with Bessel's Königsberg refractions, but no details are given whereby an independent judgment may be formed of the character and accuracy of the declinations.

Dt 30. To all the results have been applied "*Correctiones Ultimæ*" (*Pos. Med.*, pp. 351 to 371), which is considered as bringing them systematically in accordance with those of Dt 24. It may be doubted whether this is completely accomplished for the entire series, and so this catalogue has not been used in formation of Normal System. Wherever the proper motions have not been ascertained by comparison with *Fund. Ast.* this correction has been applied, using for the purpose the mean date of observation, always supplied in such cases in the *Catalogus Generalis.*

S. H. 31. The observations were reduced with Young's refractions. This table is given in the introduction, p. 22, for "adapting the St. Helena declinations to Bessel's refractions."

δ	Correction.	δ	Correction.
°	″	°	″
− 85	0.0	+ 5	+ 1.4
− 75	+ .4	+ 15	+ 1.5
− 65	+ .6	+ 25	+ 1.6
− 55	+ .8	+ 35	+ 1.8
− 45	+ .9	+ 45	+ 2.0
− 35	+ 1.0	+ 50	+ 2.2
− 25	+ 1.1	+ 55	+ 2.4
− 15	+ 1.2	+ 60	+ 2.6
− 5	+ 1.3	+ 65	+ 2.2
+ 5	+ 1.4		

These corrections are applied at the outset to all the declinations. The position of the observatory ($\varphi = -15° 55'$) does not admit of a determination of the refraction by observations of circumpolar stars. A considerable number of catalogues of northern observatories, which are based upon Bessel's refractions, have been admitted into Class I. (see p. 14), and it is likely that errors arising from that course will be counteracted to some extent by the adoption of the same refractions for the observations of the southern hemisphere. The results are reduced to the nearest tenth of seconds, and when these are corrected for refraction the declinations may be in error, from neglect of hundredths, nearly a tenth of a second. I have, therefore, neglected the small nutation correction, and, except in a few extreme cases, that for proper motion. The effect of nutation correction is, however, included in the A. R. term found in the discussion of systematic correction.

Gb 30. The employment of Bradley's refractions, the variety of practice in reduction of declinations from apparent to mean place, and the difficulty in searching out the mean epoch of observation for each star, have led me to neglect all corrections and to use the catalogue places unchanged. Dr. Auwers* has briefly and conclusively shown that a new reduction of this beautiful series of observations is desirable.

C. G. H. 31. The nutation correction is $+ ''.23 \sin (\alpha + 20°.3)$. The observations are reduced with the latitude subsequently found by Henderson. The results are few and of small weight, but their important bearing on the declinations of stars in the southern hemisphere has led to their use.

C. G. H. 33. The constant of nutation used in this series is that of the A. S. C., 9″.25. The observations were reduced to 1833, ⊙ = 281°. The total correction for both causes is $- ''.07 \sin (\alpha + 81°.5)$. The observations are very carefully reduced and discussed; and, as far as possible, with a non-reversible instrument, the methods of Bessel (*Kön. Beob. Bd.* vii, and *Ast. Nach.* 73) were followed by Henderson. Strictly

* Publications of the *Astronomische Gesellschaft* (11.). Dr. Auwers's paper on the proper motion of Sirius.

speaking, however, this series does not give independent determinations; for the corrections for flexure from reflection observations, and for refraction from observations of circumpolar stars, are rejected on the authority of comparisons made with the results obtained by Bessel, Struve, and Airy, at northern observatories. A defect in the instrument by which the readings of separate microscopes are made to differ very greatly, is exhaustively discussed by Sir George B. Airy and others (vol. viii, Mem. R. A. S., etc.), and assurance is given that the mean of six microscopes is free from serious error. This appears to be confirmed by the small probable error $\pm$ ″.23 for mean of an infinite number of observations found by Henderson. The precision of the individual observations, all made by Henderson in person, has seldom been excelled in work of this kind.

Mh 34. The nutation correction is $+$ ″.18 sin (α + 82°). The declinations as given in vol. xx, Munich Obs., are combined into single results according to the number of observations in each year from 1829 to 1840. In deducing systematic corrections, the numbers in column "$B - L$" in the tables preceding the observations for 1833 and 1834 (in *Obs. Astr. in Spec. Reg. Mon.*) are used. These are corrections to Bessel's declinations (*Tab. Reg.*) given by Lamont's observations of fundamental stars; but I have not used them in discussing the places of the fundamental stars.

CAMBRIDGE ANNUAL CATALOGUES.

Ce 34. The annual catalogues at Cambridge for many years were constructed by the aid of the proper motions and constants of the Ast. Soc. Catalogue (Baily 1830), with the day numbers of Nautical Almanac. By use of Nautical Almanacs previous to 1857, stars are reduced with nutation 9″.25, to "Jan. 1," instead of ⊙ = 280°. Both corrections, with the small correction for precession of A. S. C., can be combined in one formula. The following list of corrections will serve for this and other series shortly to be mentioned.

Year.	Correction for nutation, epoch, and precession.	Year.	Correction for nutation, epoch, and precession.
	″ °		″ °
1833	+ .08 sin (α + 265)	1841	+ .05 sin (α + 288)
1834	+ .07 sin (α + 272)	1842	+ .04 sin (α + 284)
1835	+ .06 sin (α + 276)	1843	+ .02 sin (α + 270)
1836	+ .04 sin (α + 293)	1844	+ .01 sin (α + 227)
1837	+ .08 sin (α + 287)	1845	+ .05 sin (α + 254)
1838	+ .06 sin (α + 291)	1846	+ .05 sin (α + 245)
1839	+ .04 sin (α + 305)	1847	+ .05 sin (α + 237)
1840	+ .03 sin (α + 322)		

These corrections are entirely unimportant, and the neglect of them would have produced no serious consequences. The correction for proper motion is, however, often considerable. But few proper motions are given in A. S. C., and some of these few are very far from the truth. The approximate mean epochs of observation for all stars for which the latter correction is more than ″.02 or ″.03 were examined and the corrections carefully applied. The barometer used in 1833–1835 gave readings .1 in. too small. This error was disregarded in 1833 and 1834. Among the *errata* in the volume for 1835 a table is given, which serves to correct north polar distances to the values they would have had if the barometer had given the correct readings. The table with changed signs, to make it applicable to declinations, is here given:—

δ	Correction.	δ	Correction.	δ	Correction.
°	"	°	"	°	"
50 S. P.	— .73	+ 80	— .05	+ 30	— .23
60 S. P.	— .32	70	— .09	+ 20	— .27
70 S. P.	— .16	60	— .13	+ 10	— .33
80 S. P.	— .06	50	— .16	— 00	— .40
+ 90	00	+ 40	— .19	— 10	— .52
				— 20	— .75
				— 30	— 1.50

These corrections were applied to all declinations of 1833 and 1834.

The peculiar feature of the entire Cambridge series is the frequency of reflection observations. Within the limits of zenith distance where they are practicable, their number is generally equal to those taken directly, the practice being to observe both at the same transit. The discordance, which is large, is divided equally between the two classes of observations. The position of the telescope was frequently changed on the circle—two or three times each year in the first three years, afterward at the beginning of each year with considerable regularity until 1852, and less frequently after that.

At this observatory the experiment was tried of measuring flexure in different zenith distances with the help of movable collimators. An abstract of the results is printed in Gould's Astronomical Journal, vol. v, p. 28. The correction for flexure determined in this way is much smaller than one-half the discordance between direct and reflected observations, and its form bears little resemblance to the latter. There can be little doubt that a portion of the discordance is due to the unequally heated air of the observing-room; a consideration which serves to modify the weight which this series might otherwise have had in forming the normal system.

In the annual catalogues the results for declination are given separately for direct, reflected, above and below pole. In combining, I have given equal weight to the two classes of observations, direct and reflected, and have used no observations of stars beyond 70° zenith distance below the pole. To 60° zenith distance equal weights are assigned; provided in each case eight or more observations were given. In the few cases where the number of observations is smaller and quite unequal, weights nearly in proportion to the square root of the number of observations are given. At 65° zenith distance determinations below the pole receive weight $\frac{3}{4}$, and at 70°, $\frac{2}{3}$. This practice is adhered to throughout the series.

For the years 1833, '34, '35, in order to avoid errors which would arise from systematic differences, the results of separate years are combined with equal weights, unless the discrepancy in the number of observations was great and the smaller number less than 5, when arbitrary weights are assigned.

These observations have been combined in a single catalogue* by Sir George B.

* "A catalogue of 726 stars, deduced from the observations made at the Cambridge observatory, from 1828 to 1835; reduced to 'Jan. 1,' 1830, by Geo. Biddell Airy," etc.

Airy, in Mem. R. A. S., vol. ii. The proper motions of A. S. C. were used by him, and the determinations of different years combined with weights proportioned to the number of observations. The possible error from these sources may be considerable; and the labor of constructing anew the particular places desired, though much greater than would have arisen from the correction of the catalogue for proper motion, is probably worth the while.

Ce 40. The corrections for nutation, epoch, and precession are given above under Ce 34. No proper motions were used in reduction except those of the Nautical Almanac. In volume for 1838 a new co-latitude is given derived from observations of 1837 and 1838. The correction to that used in previous years is $+''.09$; therefore to the declinations above pole of 1836 and 1837 the constant correction $-''.09$ has been added, after which no correction is required. In order to form a judgment as to the individual accuracy of the declinations, the probable error is computed from a few of the stars most frequently observed within 40° zenith distance.

In 1837	284 residuals (dir.) gave	$\pm ''.59$
	283 residuals (ref.) gave	$\pm ''.60$
In 1840-'43	511 (dir.)	$\pm ''.52$
	509 (ref.)	$\pm ''.55$

The mean $\pm$ .56 is considered as the probable error of a single pointing. A comparison of observations made in different years gives for the minimum error of a single position $\pm$ .20. The minimum for a single year for stars observed, both directly and by reflection, would be $\pm$ .14. These results are apparently too small. The argument for using the accompanying table of weights is one-half the total number of observations in any one year; and it supposes that the probable error of any star, circumpolars excepted, cannot be less than $\pm$ .14. It can only be considered a rough approximation to the true weights.

Wt.	Number of observations.	Wt.	Number of observations.	Wt.	Number of observations.
1	1	6	8 and 9	11	26 to 34
2	2	7	10 to 12	12	35 to 44
3	3 and 4	8	13 to 15	13	45 to 61
4	5	9	16 to 20	14	62, or more.
5	6 and 7	10	21 to 25		

The probable error of the unit is thus supposed to be about $\pm$ .45, in the average of cases. With these weights, the residuals formed by subtracting the assumed declination from the corrected value for each year, are formed into a single correction to assumed place.

The numerous *errata* in these and subsequent years are carefully applied.

Ce 48. In 1844 a few nadir observations had been taken for practice; and the method was adopted for obtaining zenith points in 1845 and subsequent years. It was, however, controlled by the results of direct and reflected observations. In 1846 began the use of the a', b', c', and d' of the B. A. C. In other respects the observations are not different from those of previous years. The long period of time, however, rendered these somewhat arbitrary divisions necessary.

These corrections for nutation, etc., are applied in respective years:—

1845	$+''.05 \sin(\alpha + 254^\circ)$	1849	$+''.07 \sin(\alpha + 251^\circ)$
1846	$+''.05 \sin(\alpha + 245^\circ)$	1850	$+''.06 \sin(\alpha + 253^\circ)$
1847	$+''.05 \sin(\alpha + 237^\circ)$	1851	$+''.05 \sin(\alpha + 256^\circ)$
1848	$+''.03 \sin(\alpha + 214^\circ)$		

Inspection of the observations of circumpolar stars indicate that a considerable correction for latitude is needed. Observations of α and δ Ursæ Minoris are alone available for ascertaining this correction. The table of weights given under Ce 40 is used, and reflected as well as direct observations included. Following is the summary:—

	Corrections to assumed latitude.	Weight.		Corrections to assumed latitude.	Weight.
	''			''	
1845	—.26	5	1851	—.32	6
1846	—.32	8			
1847	—.30	11	(Dir.) ...	—.52	21
1848	—.76	4	(Ref.) ...	—.34	20
1849	—.94	1			
1850	—.73	6	Mean..	—.43 ±.04	

Probable error of unit of weight $\pm''.56$.

The correction $-''.43$ is applied to all the declinations of this group. This steady diminution in values of latitude obtained since 1833 with the same instrument, used substantially in the same method, is suggestive of an actual change in that element when it is taken in connection with the apparent existence of the like phenomenon at Greenwich, Washington, Poulkova, and elsewhere.*

Ce 56. During this period there is a marked falling off both in the number and character of the observations. These corrections for nutation and epoch have been employed:—

1852	$+''.04 \sin(\alpha + 265^\circ)$
1853	$+''.08 \sin(\alpha + 274^\circ)$
1854	$+''.06 \sin(\alpha + 282^\circ)$
1855	$+''.05 \sin(\alpha + 294^\circ)$
1856	$+''.04 \sin(\alpha + 313^\circ)$

As in preceding years, only the proper motions of the Nautical Almanac were used in the annual catalogues. The position of the telescope on the circle was changed at irregular intervals, but the same relative weights and system of combining, as in Ce 40 and Ce 48, are here employed. As this series is not used in forming the Normal System, no correction for error of assumed latitude is applied, nor do the observations themselves afford adequate means for deducing such a correction independently. The *erratum* to reflected observations of 1854 is important.

Ms 35. The results from this catalogue are used without charge. The proper

* "Die Polhöhe von Pulkowa. Von Dr. Magnus Nyrén." St. Petersburg, 1873. See also pp. 36 and 60 of this paper.

motion correction is often large, but it is not always easy to find out whether it ought to be applied, and the mean date of observation will often be very inexact. The weight of these observations is so small that I have not thought it worth while to construct places anew from the special catalogues by the help of division corrections on pp. ccxix and ccxx, vol. v.

Ms 50. The declinations require the full amount of the correction for proper motion, but this is usually small, owing to the small difference between epoch of observation and that of reduction.

EDINBURGH ANNUAL CATALOGUES.

Eh 37. The methods of reduction to apparent place are, with few exceptions, those employed at Cambridge in the corresponding years, so that the same corrections have been applied. The position of the telescope on the circle was moved at the beginning of 1839, and yearly, afterward, during the directorship of Henderson. Strictly speaking, only the observations of 1834–5, in volume I., are independent, and the succeeding catalogues as reduced by Henderson depend upon this first one. Ivory's refractions are employed throughout the catalogues composing Eh 37, so that in this respect the series is not independent. The discordance in 1834–'35, between direct and reflected observations, is quite large, and the latter are rejected by Henderson in making up the declinations. The corrections derived from sun observations in the different years are in the mean small, and furnish tolerable assurance that the declinations will be found quite free from systematic error. All determinations of the same star, up to 1839, I have combined with weights proportional to the number of observations. This result is then combined with that for 1839, on the supposition that the minimum error in each case is equal, and one-half the error of a single pointing. This was an oversight, for previous to 1837, in most observations, six microscopes were used; after that only two, so that for the first series the minimum error might have been taken about one-fourth the error of pointing. However, no serious error has arisen from this cause.

Henderson estimates (1839) the probable error of pointing at ± .5, and probable division error, when mean of two microscopes is taken, ± .3. For the former quantity I have found, from a rough trial, ± ″.6. It will be seen in the latitude discussion of Eh 43 that, if error of pointing is assumed to be twice the minimum error, we have for the former ± ″.59, and for the latter ± ″.29, in close agreement with above estimates. It is difficult to believe that the minimum error, under the circumstances, can be so small, and doubtless a more rigorous determination of probable error of pointing would show that to be slightly smaller, and the minimum error would then result in a larger quantity.

The catalogue for 1840 cannot properly be classed either with those preceding or following it, and no use is made of its declinations.

Eh 43. The observations of this series were reduced by Professor Smyth. During the entire period the zenith points were derived from nadir observations, a practice begun in 1841. The observations in 1841–'2–'3 were reduced with Bessel's refractions, and the help of Nautical Almanac and A. S. C. In 1844 the Nautical Almanac was used with the constants and proper motions of British Association Catalogue. The corrections to first three years for nut., etc., are taken from the corresponding formulæ for Cambridge. For 1844 the correction is insignificant.

In reducing from the mean of two microscopes to the mean of six, Professor Smyth continued to use the results of the investigation made by Henderson (vol. I., p. vii, *et seq.*). As the telescope was clamped to a different part of the circle in each year, it is evident that any considerable error in the formulæ of correction would show itself in the difference between the declinations of the same star in different years, and also in the latitudes deduced from observations of circumpolar stars. Fortunately, in each of the years there are a considerable number of the latter well suited to the examination of this question. In *Ast. Nach.* Bd. 65, s. 195, by Dr. Auwers, and in *Bonn. Beob.* Bd. VII., Theil II., s. 251, by Dr. Argelander, we have the results of such an examination. They are exhibited in the following table:—

Year.	Correction to assumed latitude given by observations of each year.	
	Auwers.	Argelander.
	"	"
1841	— .20	— .20
1842	— .95	— .96
1843	+ 1.44	+ 1.41
1844	— .17	— .15

Both Auwers and Argelander use these as constant corrections to the declinations of respective years. The latter says, "Wie diese grossen Vershiedenheiten zu erklären sind, weiss ich nicht zu deuten. Theilungsfehler an dem Orte des Sterns können es unmöglich sein.; dagegen streitet die nahe Uebereinstimmung bei allen vershiedenen Sternen, und besonders auch der Umstand, dass die Untershiede auch bei dem Polarsterne sich zeigen, bei dem die Puncte des Kreises für die OC. und UC. nur 3° auseinander liegen. Man erhält aber 1842 aus resp. 76 und 64 Beobachtungen UC.—OC. — 2″.5, im Jahre 1843 aus 48 und 42 Beobachtungen + 3″.1. Man muss also den Fehler wohl in der Bestimmung des Nadirpunctes suchen, aber auch hier kann man ihn durch Theilungsfehler allein schwerlich erklären. Es hiesse dies voraussetzen, dass bei einem 6füssigen Kreise von Troughton und Simms der Theilungsfehler des Kreises an zwei Puncten desselben um 2″.4 verschieden wäre, was wohl Niemand, der die ausgezeichneten Leistungen dieser Künstler kennt, für möglich halten wird * * * * so kann man die grossen Unterschiede nur dem unglücklichen Zusammentreffen mehrerer Ursachen zuschreiben."

An examination of the declinations near the equator shows that to apply these constant differences will, for this region, in some cases, produce greater systematic discordance than existed before. In view of all the arguments so strongly put by Argelander, there appeared to be but one available hypothesis by the adoption of which the difficulty could be satisfactorily solved. The reduction for division error actually used is supposed to be inapplicable, and an attempt is made to deduce a new one from a comparison of the observations of the same stars in different years. Granting the correctness of the reduction from two microscopes to six, as found by Henderson (vol. i), we may easily conceive such changes to have taken place in the instrument that these, combined with small errors in zenithal divisions and the possible error of the mean reading of six microscopes, may have caused the discrepancies actually found. The arrangement of the observations is tolerably favorable to this undertaking. The circle readings increase from the pole toward the equator, and for the zenith were:—

1841	59° 58′
1842	34° 08′
1843	79° 05′
1844	139° 05′

The effect of the corrections actually applied to nadirs and zenith distances of stars is first subtracted from the declinations. For that purpose the table of division corrections in the introduction to each volume is used. We now have the declinations as they would have resulted had no correction for division been applied. It is possible that an important part of the discrepancies may have been caused by flexure of the circle, but not likely. If such is the case, it cannot well be determined from the data furnished by the observations. It is therefore assumed that the difficulty is due to division error. The mean of two microscopes may be affected by errors requiring corrections of the form:—

$$x \sin 2R + x' \cos 2R + x'' \sin 4R + x''' \cos 4R + \&c.$$

The coefficients x and x', only, have been determined; which is perhaps to be regretted. The effect of accidental errors of the nadir divisions has also been included. The following notation is adopted:—

δ = Declination as printed in annual catalogues, but referred to 1843, and corrected by the requisite amounts for nutation and proper motion.
R = Circle reading for a given declination.
R' = Nadir reading for the same.
k and k' = Division corrections actually applied to R and R'.
x and x' = Coefficients of division correction as explained above.
$v_1, v_2, v_3, v_4,$ = Correction to nadir divisions respectively of 1841, 1842, 1843, and 1844, for accidental error, or deviation from the law expressed by $x \sin 2R + x' \cos 2R$.
$\Delta \varphi$ = Correction to assumed latitude, φ.

The application of any of the above quantities is restricted to a given year by the use of subscript figures, 1, 2, 3 and 4, respectively for 1841, 1842, 1843, and 1844. The declinations are referred to the common epoch 1843.0 by means of the reduction of assumed places (Section III). The corrected declination will then be:—

$$(1)\quad R' + k' + 180^\circ + \varphi - R - k + x(\sin 2R' - \sin 2R) + x'(\cos 2R' - \cos 2R) + v + \Delta\varphi$$

We shall then have:—

$$(2)\quad 0 = (\delta_1 - k'_1 + k_1) - (\delta_2 - k'_2 + k_2) + x(\sin 2R'_1 - \sin 2R'_2) + x'(\cos 2R'_1 - \cos 2R'_2) + v_1 - v_2 + x(\sin 2R_2 - \sin 2R_1) + x'(\cos 2R_2 - \cos 2R_1).$$

The comparison for any other years may be derived from this by the substitution of the required figures in subscript. For convenience, the comparison was confined to stars of the provisional catalogue and to those north of 10° south declination.

It is evident that v_1, v_2, v_3, and v_4, cannot be absolutely determined with the data proposed. It will be necessary to assume:—

$$v_1 + v_2 + v_3 + v_4 = 0;$$

and to express v_4 in terms of the other three quantities. This will not affect the declinations; but will produce an error in the latitude of one-fourth the sum of the quantities in question.

Every combination of differences that could be made was used. Thus, a declination observed in three years furnished three differences; and four years, six. There were very few of the latter. The weights are assigned on the supposition that a declination is subject to a constant probable error which is equal to one-half the error of pointing.

Where a star has been observed in three years there are but two independent comparisons; and for four determinations we have three independent comparisons. In the former case, each of the three equations received two-thirds the weight it otherwise would have had, and in the latter, each of the six one-half. The unit of weight is that due to five observations in each of two years where there is but one comparison for a given star. It was found that the computation could be much simplified, without appreciable error, by assuming the simple scale of weights, 1.0, .6, and .3.

The coefficients were computed to the nearest tenth only; but the equations were not grouped in the solution. There were in all 307 equations of the total weight 188. Every part of the work was either rigorously checked or duplicated. The resulting normal equations are these:—

$$\begin{array}{rrrrrrl}
+257.4\,v_1 & +\ 90.5\,v_2 & +\ 74.9\,v_3 & +152.2\,x & -\ 10.7\,x' & +\overset{\prime\prime}{107.2} & =0 \\
+\ 90.5\,v_1 & +236.4\,v_2 & +103.5\,v_3 & +134.3\,x & +\ 62.5\,x' & +138.2 & =0 \\
+\ 74.9\,v_1 & +103.5\,v_2 & +187.6\,v_3 & +\ 81.4\,x & -\ 57.7\,x' & +\ 36.5 & =0 \\
+152.2\,v_1 & +134.3\,v_2 & +\ 81.4\,v_3 & +257.1\,x & +\ 46.2\,x' & +205.6 & =0 \\
-\ 10.7\,v_1 & +\ 62.5\,v_2 & -\ 57.7\,v_3 & +\ 46.2\,x & +260.2\,x' & +224.4 & =0
\end{array}$$

The solution gives, with $v_4 = -v_1 - v_2 - v_3$

		Henderson.
$v_1 = -''.11$	$x = -''.664$	$(-''.100)$
$v_2 = -''.21$	$x' = -''.598$	$(-''.388)$
$v_3 = +''.46$		
$v_4 = -''.14$		

The differences are well represented, the error seldom rising as high as $''.3$ in the mean of a zone 10° wide. The probable error cannot be estimated from the residuals. If taken from them, it would be much too small. Assuming the probable error found from latitude discussion, that of the unit of weight would be $\pm\,''.56$; and the probable errors of x and x' would be $\pm\,''.01$ each; and of v_1, v_2, etc., $\pm\,''.06$ each. But in reference to the latter, it must be borne in mind that this probable error is that of the relative values, and that their common probable error can be taken roughly at $\pm\,''.15$; so that the actual probable error of the quantities in the absolute sense is about $\pm\,''.16$.

Thus the values of the zenithal division errors are reduced to quantities of not improbable magnitude. The difference between the coefficients of x and x' as here determined, and as determined by Henderson, is important.

The further correction $\Delta\,\varphi$ is required before the declinations can be regarded as definitive. The discussion of $\Delta\,\varphi$ for the different years will also afford a good test of the corrections already deduced.

The systematic corrections of the zenithal divisions are respectively $-\,''.19$, $-\,''.80$, $+\,''.39$ and $+\,''.50$ for 1841–2–3 and 4. These added to the respective corrections for accidental error, and k' for each year, give the following corrections to the declinations:—

$$(A)\quad \begin{array}{ll} (1841) & -\,''.38 + ''.894 \sin (2\,R + 48^\circ) + k_1 \\ (1842) & -\,''.96 + ''.894 \sin (2\,R + 48^\circ) + k_2 \\ (1843) & +\,''.72 + ''.894 \sin (2\,R + 48^\circ) + k_3 \\ (1844) & +\,''.18 + ''.894 \sin (2\,R + 48^\circ) + k_4 \end{array}$$

Where k_1 etc., is to be taken for each star from the table p. 186, volume for 1841, or from the succeeding volumes. These corrections are, of course, to be applied with opposite signs to results from observations of lower culmination.

Each year furnishes a considerable number of observations suited to determination of latitude. Except for α and δ Ursæ Minoris, with a few others, three observations of the same star were generally made in each culmination. The computation is thus practically unaffected by the question of relative weights, and is greatly facilitated. Taking three observations in each culmination as the standard unit for $2\,\Delta\,\varphi$, weights were computed for the few that required it on the same assumption as in the preceding portion of the discussion. The latitude observations are all on stars of declination greater than 74°, so that the refraction cannot be examined, and the observations may be assumed to be of equal accuracy in the small range of zenith distance. The results are these :—

Year.	$\Delta\,\phi$	Number of stars.	Weight.
	''		
1841	— .49 [± .12]	18	50
1842	— .15 [± .11]	32	72
1843	+ .15 [± .11]	31	69
1844	+ .04 [± .12]	27	56
Mean...	— .09 [± .06]	108	247

The differences are not much greater than the probable errors should lead us to expect. The probable error of the unit of weight calculated from the 108 residuals is $\pm\,''.64$. This gives for probable error of pointing $\pm\,''.59$, and for minimum probable error $\pm\,''.29$; the latter is in close agreement with the value $\pm\,''.3$ assumed by Henderson in 1839. The probable errors of $\Delta\,\varphi$, as given above, take into account the probable error of the formulæ derived for division correction. The probable error of the mean value of $\Delta\,\varphi$ computed from the residuals is $\pm\,''.04$. All the values, however, are subject to a common probable error of about $\pm\,''.15$, besides the error in adopted refraction; so that, absolutely considered, the correction to the assumed latitude has a probable error not far from $\pm\,''.2$. Except for the uncertainty of refraction this increase of probable error is without influence on the declinations. The quantity $-\,''.09$ is therefore added to each of the corrections marked (A), and, since $R =$

$R' + \varphi - \delta$, we have by the proper substitutions, the following corrections to the declinations of Eh 43, as printed in the annual catalogues:—

$$(B)\quad \begin{array}{l} (1841)\ -\ \ ''.47 + ''.894\ (280^\circ - 2\,\delta) + k_1 \\ (1842)\ -\ 1''.05 + ''.894\ (228^\circ - 2\,\delta) + k_2 \\ (1843)\ +\ \ ''.63 + ''.894\ (218^\circ - 2\,\delta) + k_3 \\ (1844)\ +\ \ ''.09 + ''.894\ (\ 78^\circ - 2\,\delta) + k_4 \end{array}$$

where k_1, etc., are to be taken, as before, from the tables of division correction in the annual volumes.

The following table exhibits in column I. the values of this expression, computed for every five degrees of declination (and includes k). Column II. is the sum of column I. and the definitive correction found for Eh 43 in Table IX. at the end of this paper. To this is still to be added a small correction depending on right ascension.

Table of corrections to Edinburgh, 1841–1844.

δ	1841.		1842.		1843.		1844.	
	I.	II.	I.	II.	I.	II.	I.	II.
S. P. °	"	"	"	"	"	"	"	'
75	+ .13	+ .13	+ 1.24	+ 1.24	− 1.37	− 1.37	+ .34	+ .34
80	+ .01	+ .01	+ 1.16	+ 1.16	− 1.39	− 1.39	+ .37	+ .37
85	− .17	− .17	+ 1.06	+ 1.06	− 1.36	− 1.36	+ .37	+ .37
90	− .23	− .23	+ .94	+ .94	− 1.29	− 1.29	+ .36	+ .36
Above pole. + 90	+ .23	+ .23	− .94	− .94	+ 1.29	+ 1.29	− .36	− .36
+ 85	+ .28	+ .28	− .80	− .80	+ 1.18	+ 1.18	− .34	− .34
+ 80	+ .28	+ .28	− .67	− .67	+ 1.04	+ 1.04	− .31	− .31
+ 75	+ .25	+ .25	− .56	− .56	+ .90	+ .90	− .28	− .28
+ 70	+ .16	+ .16	− .44	− .44	+ .75	+ .75	− .26	− .26
+ 65	+ .05	+ .03	− .36	− .38	+ .59	+ .57	− .24	− .26
+ 60	− .08	− .13	− .31	− .36	+ .46	+ .41	− .23	− .28
+ 55	− .23	− .31	− .30	− .38	+ .35	+ .27	− .23	− .31
+ 50	− .39	− .47	− .33	− .41	+ .26	+ .18	− .23	− .31
+ 45	− .54	− .60	− .40	− .46	+ .20	+ .14	− .21	− .27
+ 40	− .67	− .70	− .51	− .54	+ .17	+ .14	− .20	− ,23
+ 35	− .78	− .78	− .65	− .65	+ .18	+ .18	− .16	− .16
+ 30	− .86	− .81	− .78	− .73	+ .18	+ .23	− .10	− .05
+ 25	− .91	− .79	− .94	− .82	+ .20	+ .32	− .02	+ .10
+ 20	− .93	− .74	− 1.09	− .90	+ .23	+ .42	+ .09	+ .28
+ 15	− .93	− .66	− 1.23	− .96	+ .27	+ .54	+ .21	+ .48
+ 10	− .92	− .58	− 1.34	− 1.00	+ .28	+ .62	+ .34	+ .68
+ 5	− .89	− .53	− 1.43	− 1.07	+ .30	+ .66	+ .47	+ .83
0	− .87	− .53	− 1.48	− 1.14	+ .31	+ .65	+ .59	+ .93
− 5	− .84	− .59	− 1.51	− 1.26	+ .31	+ .56	+ .71	+ .96
− 10	− .82	− .69	− 1.51	− 1.38	+ .32	+ .45	+ .79	+ .92
− 15	− .80	− .78	− 1.50	− 1.48	+ .33	+ .35	+ .83	+ .85
− 20	− .80	− .88	− 1.48	− 1.56	+ .35	+ .27	+ .83	+ .75
− 25	− .80	− .95	− 1.46	− 1.61	+ .38	+ .23	+ .81	+ .66
− 30	− .79	−1.00	− 1.44	− 1.65	+ .45	+ .24	+ .74	+ .53

With the corrections of column I. added to those for nutation and proper motion all the results for a given star were formed into a single mean, with the following table of weights:—

Weights.	Observations.
1	1
2	2 and 3
2.5	4
3	5 to 9
4	10 to 35
5	36, or more.

Eh 58, Eh 63 and Eb 67. There are few observations in this series; but many of them relate to stars for which few observations are found elsewhere. The unimportant corrections for nutation applied to Cambridge annual catalogues of corresponding years previous to 1857 are used. The proper motion correction is generally neglected; the difference between those assumed in this paper and those of B. A. C. used in reduction of Edinburgh observations being usually small, for the short interval of time intervening between the mean epoch of observation and the beginning of the year. The grouping is determined by constancy of zenith circle readings, which, however, were often changed during the period embraced in Eh 58.

Kg 43. The reduction by Luther, in *Ast. Nach.* 1076, employs Bessel's refractions (1821) and derives the latitude from *α* Urs. Min., *α* Aurigæ and *α* Cygni. I have followed the lead of Dr. Auwers (*Ast. Nach.* 1549), taking the latitude from *α* Urs. Min. alone and applying the correction $-''.17$ to the declinations of all stars, except *α* Aurigæ and *α* Cygni, whose declinations are taken from upper culmination alone, and the catalogue places corrected respectively by $-''.44$ and $-''.41$. The observations were originally reduced with Peters's nutation.

GREENWICH CATALOGUES, 1836-1872.

This long and valuable series of observations is remarkable for the uniformity of its plan and methods, the thoroughness and accuracy of its numerical reductions, and the vast amount of material it contains, chiefly relating to places of sun, moon, planets, and stars of the sixth magnitude, or brighter. The observations are made with non-reversible instruments, and the problem of absolute declinations is rendered altogether subordinate to the requirements of routine work on a large number of objects.* This robs the series of an interest it might otherwise possess; but when systematic corrections to its various catalogues are once ascertained, it becomes the richest mine of information on the declinations of the brighter stars.

Two mural circles were used until March, 1839, then a single mural circle† until 1851, when the great transit circle was mounted, and has been used until the present time. The position of the telescope on each of the mural circles was changed at the beginning of each year. The relation of the telescope and circle of the transit circle is invariable.

* In a critical examination of Greenwich polar distances for 1851-1854 Mr. A. Marth has pointed out very conclusively the defects of the Greenwich transit circle, as applied to the problem of absolute declinations. (*Ast. Nach.*, 1260.)

† In 1848, for a short time, the Jones Cape circle was used.

The observations were reduced with Bessel's refractions (*Tab. Reg.*) until 1868, when the refractions of the *Fundamenta* multiplied by 0.99797 were adopted on the authority of a discussion by Mr. E. J. Stone (Month. Not., vol. 28, p. 27), who uses for the purpose observations made with the transit circle of Greenwich 1857–1865.

Gh 39 and Gh 45. The observations of separate years are usually reduced to the beginning of the year with no proper motion, or with values of that element taken from A. S. C. Wherever the error from this is considerable, it has been carefully attended to in the *errata* of later catalogues. I have not investigated any cases independently of these. The proper motions of the B. A. C. were used in compiling the general from the special catalogues. Where the difference between these and those assumed in this paper is worth regarding the proper correction has been applied, using for the purpose the mean epochs of the Twelve-year catalogue, which are only given to the nearest year. For reduction to apparent place the special catalogues depend upon the Nautical Almanac. The following mean corrections for nutation and epoch have been applied :—

Gh 39. $+ ''.04 \sin(\alpha + 305^\circ)$
Gh 45. $- ''.02 \sin(\alpha + 61^\circ)$

Gh 50. The nutation correction is :—

$$- ''.05 \sin(\alpha + 76^\circ)$$

The remarks under the preceding catalogues are generally applicable. A portion of the time the mural circle was used in a temporary observing-room, and the circumstances under which much of the work was done were necessarily unfavorable. Some uncertainty in the systematic correction of this catalogue must arise from the fact that it combines results from two distinct instruments at different times.

Gh 57. This catalogue may be regarded as containing the work of the transit circle in its best estate, when the observers had become accustomed to its peculiarities, and before any appreciable imperfection or wear had resulted from long use. Though the instrument was used in a single position during the entire period, the circle readings were made with six microscopes. Furthermore, the error of division was carefully examined for every degree and for some special divisions, and the high reputation of the makers is a guarantee that the accidental errors of division are probably small. The proper motions of this and succeeding catalogues of Greenwich are generally in fair agreement with the assumed proper motions, so that this correction is seldom applied by me. The special catalogues, until 1857, require small corrections for nutation and epoch; after that year the observations were reduced with Peters's nutation, and to epoch $\odot = 280^\circ$. The resulting small correction was neglected.

Gh 64. The series embraced in this catalogue is essentially a continuation of the preceding. No correction is needed save that for proper motion, which is usually insignificant. During the long period of its use the instrument underwent slow changes from wear, which might be quite sufficient to cause a real difference in the systematic correction required (see Gh 70).

Gh 70. The slight corrections required by the annual variations of the special catalogues were sometimes regarded. The results of separate years were then combined with weights according to number of observations in each year. I became aware of the large error due to wear of the micrometer screws too late to make any use of a special correction on that account. I have taken my information from Mr. Christie's paper in Month. Not. R. A. S., for November, 1876.

The series of reflection observations made during the period 1836–1872, at Greenwich, has attracted wide attention, and has been the subject of some interesting memoirs. A brief consideration of the principal points involved will be of use in judging the value of the declinations in the absolute sense. During most of the period occupied by observations with the mural circles, the correction $\frac{R-D}{2}$ was found to be so small and so irregular that it could not safely be applied.* The corrections of earlier years, and for 1850, were small. It may, therefore, be assumed that the declinations of that period (1836–1850) are practically uninfluenced by the discordance in question. On the introduction of the great transit circle in 1851 this discordance was at once noticeable, and a correction has always been applied to all polar distances deduced from the observations of this instrument—this correction being assumed to be equal for the two classes of observations (direct and reflected), but applied with opposite signs. The division error was discussed for every degree of pointer reading, first in 1851–'2, again in 1856, and lastly in 1871. The results of the three investigations essentially confirm each other. The first table of corrections was used in the years 1851-1856; the second, 1857–1867; the third, which is the mean of the first and second, 1868 and later. The horizontal flexure was several times determined by the opposing horizontal collimators. Until 1866 the telescope was raised from its bearings in order to render the collimators intervisible. In the latter part of 1865 the telescope cube was pierced in such a manner as to dispense with the raising. Owing to construction of the instrument a single circular opening could not be cut, but several radiating apertures in the form of sectors were made. This necessitated the use of very large collimators (aperture 7 inches). The value of the horizontal flexure suddenly changed at this time nearly one second, passing from a decided plus value to a minus value. In the table to be given it will be observed that there is a simultaneous change in the opposite direction of the sign of the coefficient of $\sin Z \cos^2 Z$. As Professor Newcomb suggested to me recently that the entire series of observations with the transit circle could be reconciled to the supposition of a uniform coefficient of flexure, depending on $\sin Z$, I have examined this question, not, however, in any very critical or conclusive manner. It is necessary to remark that the formula of correction was, until 1862, assumed to be

$$(1) \quad a + b \sin Z;$$

subsequently to that time

$$(2) \quad a + b' \sin Z \cos^2 Z.$$

I have reduced b' to make it comparable with b, by supposing that the mean Z, where $D - R$ occurs, is effectively about 25°, and, therefore, that b would have been about .8 b', had the law expressed in (1) been used instead of (2). The groups are partly determined by the periods during which the same coefficient determined from opposing collimators was used. The following table exhibits approximate results. The first column gives the year or period; the second, adopted value of flexure depend-

*Airy says, p. xli, Int. Gh. Obs., 1840, "The values of $R - D$ are so small, and the existence of any law among them so uncertain, that I have thought it best to adopt the circle-results without any correction for $R - D$." This remark is substantially repeated in each volume until 1850.

ing on sin Z, obtained from observation of collimators; the third, the average value of b for the given period—for the first three groups directly derived—for all after 1862 from b' in the manner explained; the fourth, the average value of the constant term a; the fifth, the sum of second and third columns; the sixth, the weight—the result of one year being the unit. The spaces indicate epochs of change in division correction used:—

Period.	Collimator flexure.	b, or. $8b'$	a	Residual flexure.	Weight.
	$''$	$''$	$''$	$''$	
1851	+ .73	− .24	+ .10	+ .49	1
1852	+ .73	[− .24]	[+ .10]		
1853-1856	+ .50	− .31	− .03	+ .19	4
1857-1861	+ .56	− .42	+ .04	+ .14	5
1862-1864	+ .56	− .43	+ .01	+ .13	3
1865	+ .76	− .62	− .04	+ .14	1
1866-1870*	− .37	+ .62	+ .10	+ .25	5
1871 and 1872	− .12	+ .51	− .01	+ .39	2
Mean				+ .21	21

* The actual change in division correction used took place in 1868, and is unimportant.

Thus it appears that, if the uniform value of sine flexure, + $''$.21, had been employed throughout the series, we should have had sufficiently good agreement between direct and reflection observations. This appears to me to throw discredit upon the value of flexure derived from opposing collimators, and forces me to the belief that the change in the collimator flexure between 1865 and 1866, if it has indeed any reality in fact, was much smaller than has been supposed. In this particular case, at least, the foregoing discussion appears to argue strongly for the utility of reflection observations.

If there is a real residual discordance, $R - D$, it would appear from the discussions of Airy (Mem. R. A. S. xxxiii, and Seven-year Catalogue, p. viii); Faye (*Comptes Rendus*, xxi, pp. 401, 635, 757); and Van de Sande Backhuyzen* (*Ast. Nach.* 1720), that it is probably due in some measure to the effect of variations of temperature at different altitudes in the observing room. It is quite likely, that the reflection observations are principally affected—as Henderson and others have supposed.

It may be interesting to note that, if we assume the latitude derived by Bessel from Bradley's observations (*Fund. Astr.*) to be near the truth—and there is good reason for believing it is—and if we suppose the mean latitude for the period 1836–1860 to be that which is affected by the correction $\frac{R - D}{2}$, we shall have:—

$$1755: \varphi = 51^\circ\ 28'\ 39''.6$$
$$1847: \varphi = 51^\circ\ 28'\ 38''.17,$$

* "*Ueber den Einfluss der Strahlenbrechung im Beobachtungesaale, auf die mit dem Meridiankreise bestimmten Declinationen.*" This paper treats, most thoroughly, the observations of Greenwich transit circle, 1851–1864, with reference to discrepancies in polar distance, which are cotemporaneous with difference of readings of outer and inner thermometers. As a practical result, the form of an ideal surface of junction between the outer and inner air is deduced, which appears to explain the discrepancies in a satisfactory manner.

Annual variation of latitude $-''.0155$, or $-''.0139$, if the latitudes are reduced to the same refractions.

Comparing the results found by Airy (p. viii, Seven-year Catalogue), with $\varphi = 51^\circ\ 28'\ 38''.17 - ''.0139\ t$, we have :—

Period.	Latitude observed.	From formula.
	° ′ ″	° ′ ″
1836–1841	51 28 38.23	51 28 38.28
1842–1848	38.17	38.19
1851–1860	38.15	38.04

If, on the other hand, we consider the results for latitude as printed in the Greenwich Annual Catalogues later than 1860, we have seconds of latitude for 1861–67, 38″.25; and (after approximate reduction to the refractions previously used) for 1868–72, 38″.18, results which contradict the theory of diminishing latitudes.

RADCLIFFE CATALOGUES.

Re 45. The nutation correction is neglected, because the period embraced in the observations is so great, that an error greater than the correction would often be introduced. The places were corrected, wherever necessary, for the difference between assumed proper motion and that found in the catalogue. An important correction is found in the Introduction, pp. viii to xi. This has been carefully applied, as well as that for error in reducing three stars specified, p. xii, Int.

The refractions used in this catalogue are those of Bessel (1820) multiplied by .9967. A much smaller refraction was deduced by Johnson (Re Obs. xv, p. xxiv). The instrument was very imperfect, and was used in a single position.

Re 58. This is essentially a continuation of the foregoing catalogue. The important correction p. xviii Introduction to second Radcliffe catalogue was applied before using the results.

Re 66 and Re 72. The trifling correction for proper motion has been applied in a few instances. The telescope was shifted relatively to the circle at the beginning of 1870; so that in the final discussion of declinations the series has been divided into two groups. In making up these groups the observations were given weights proportional to number of observations, the corrections of Table IX. being first applied. The results were then considered as agreeing with the Normal System and were used without further correction. But, for preliminary purposes, owing to the large systematic differences in polar distances of different years, stars were omitted which were not observed in at least four different years. Each year was given equal weight unless the number of observations was less than 4; two or three observations were given weight .7; and 1, weight .4. The following table exhibits corrections to assumed places thus derived :—

Star.	C.	Star.	C.	Star.	C.
	″		″		″
α Andromedæ	— .26	ε Piscium	— .14	51 Andromedæ	— .59
γ Pegasi	+ .39	β Andromedæ	— .12	ο Piscium	— .78
α Cassiopeæ	— .04	α Ursæ Minoris	— .26	ε Cassiopeæ	+ .20
η Cassiopeæ	+ .08	θ¹ Ceti	+ .64	β Arietis	— .12
μ Andromedæ	+ .28	η Piscium	— .60	50 Cassiopeæ	+ .57

Star.	C	Star.	C	Star.	C
	″		″		″
α Arietis	+ .15	κ Draconis	+1.08	θ Cephei	+ .04
ξ^1 Ceti	— .17	α Can. Ven	+ .21	α Delphini	+ .74
ξ^2 Ceti	+ .25	θ Virginis	— .40	α Cygni	— .24
γ^2 Ceti	— .09	α Virginis	+ .26	μ Aquarii	—1.74
α Ceti	+ .31	ζ^1 Ursæ Majoris	— .43	61^1 Cygni	+1.48
β Persei	+1.23	ζ Virginis	—1.02	ζ Cygni	— .04
α Persei	— .23	η Ursæ Majoris	— .12	α Cephei	+ .10
η Tauri	+ .71	η Bootis	— .03	β Aquarii	+ .06
B. A. C. 1235	+ .61	α Draconis	+ .03	β Cephei	— .09
γ Tauri	— .28	α Bootis	— .55	ε Aquarii	—1.04
ε Tauri	+ .06	θ Bootis	— .08	ε Pegasi	+ .11
α Tauri	— .01	ρ Bootis	+ .39	16 Pegasi	+ .21
4 Camelopardalis	+ .12	ε^1 Bootis	+ .46	α Aquarii	+ .04
ι Aurigæ	+ .29	β Ursæ Minoris	+ .17	θ Aquarii	— .62
α Aurigæ	+ .29	β Bootis	— .80	γ Aquarii	+ .59
β Orionis	+ .22	β Libræ	+ .37	δ^2 Cephei	— .15
β Tauri	+ .13	γ^2 Ursæ Minoris	— .79	η Aquarii	— .33
δ Orionis	— .07	ι Draconis	— .80	ζ Pegasi	+ .65
ε Orionis	— .87	α Coronæ Borealis	— .20	μ Pegasi	+ .43
α Orionis	+ .55	α Serpentis	+ .44	ι Cephei	+ .10
β Aurigæ	— .24	ε Serpentis	+ .48	λ Aquarii	—1.27
η Geminorum	+1.23	ζ Ursæ Minoris	— .31	α Pegasi	+ .21
μ Geminorum	+ .01	θ Draconis	+ .27	ο Cephei	+1.57
γ Geminorum	+ .02	δ Ophiuchi	— .04	ι Piscium	+ .02
B. A. C. 2157	+ .11	γ^2 Herculis	+ .68	γ Cephei	+ .16
ζ Geminorum	+ .93	η Draconis	— .45	ω Piscium	— .62
δ Geminorum	+ .06	15 Draconis	+ .03		
β Can. Minoris	+ .49	ζ Ophiuchi	—1.07		
β Geminorum	— .54	ζ Herculis	+ .07		
β Cancri	+ .21	η Herculis	—1.53		
ο Ursæ Majoris	+ .14	κ Ophiuchi	+1.11		
ε Hydræ	— .25	ε Herculis	+ .76		
σ^2 Ursæ Majoris	+1.32	ε Ursæ Minoris	— .38		
κ Cancri	+ .09	α^1 Herculis	+1.10		
α Hydræ	— .10	β Draconis	+ .13	*Stars south of — 10°.*	
ο Leonis	+ .21	α Ophiuchi	+ .26	β Ceti	— .08
ε Leonis	+ .27	μ Herculis	+ .51	γ^1 Eridani	— .11
ν Ursæ Majoris	+ .19	ψ^1 Draconis	— .34	α Leporis	+ .19
μ Leonis	+ .08	89 Herculis	+ .47	ε Can. Majoris	+ .39
α Leonis	+ .57	γ Draconis	— .02	15 Argus	— .07
γ^1 Leonis	— .54	δ Ursæ Minoris	— .03	δ Crateris	— .68
ρ Leonis	+ .08	η Serpentis	+ .74	β Corvi	+ .34
53 Leonis	— .62	χ Draconis	+ .03	α^2 Libræ	+ .06
β Ursæ Majoris	— .69	α Lyræ	— .07	β^1 Scorpii	+1.40
α Ursæ Majoris	+ .31	β Lyræ	+ .50	α Scorpii	+ .96
δ Leonis	+ .16	ε Aquilæ	+ .78	44 Ophiuchi	— .48
τ Leonis	+ .04	ζ Aquilæ	+ .58	μ^1 Sagittarii	+ .02
λ Draconis	+1.28	δ Aquilæ	+ .95	43 Sagittarii	—3.26
υ Leonis	— .05	θ Cygni	+ .20	α^2 Capricorni	+ .03
ψ Ursæ Majoris	+ .37	γ Aquilæ	+ .62	α Pis. Aust	— .77
β Leonis	+ .16	α Aquilæ	+ .52		
β Virginis	— .21	β Aquilæ	+ .27		
γ Ursæ Majoris	+ .11	λ Ursæ Minoris	+ .33		
δ Ursæ Majoris	— .54	κ Cephei	+ .74		
η Virginis	- .51	ε Delphini	+ .63		

NOTE.—The catalogue for 1873 was not received in time to be used in forming the above corrections, but is used later in making up $C_{\prime\prime}$ for R_t 72.

In forming the corrections, a few polar distances marked in the catalogues as doubtful, or to be rejected, with a few which result solely from observations below the pole at great zenith distances, were not used. The weights of a few others were reduced in forming the means, on account of unusual discordance, or because the catalogue p. d. is made up partly of *sub polo* determinations at zenith distances over 70°.

In general, the results are far less exact than we should have expected from the circumstances. Though the instrument is of the non-reversible pattern, the relation of the telescope to the divided circle can be altered at pleasure; yet this precaution was exercised but once, at the beginning of 1870. It would be impossible to detail the various systematic corrections which have been applied in the reductions from time to time. The division error was determined on the assumption that the mean of 8 microscopes is free from error, and a correction applied after 1862. The values of horizontal flexure as adopted in reductions have varied from $+1''.13$ to $+2''.82$. The dependence on the time is not marked, the adopted value in 1862–'63 being $+2''.5$; and in 1871–'73, $+2''.8$. In 1862–'63–'64 and '67, corrections were applied for $\frac{R-D}{2}$. Various corrections were applied for discordance of zenith points, determined by nadirs and by reflection observations, etc. The refractions are those deduced by Johnson, and used in the Radcliffe general catalogues. To show the variety of practice in reducing the observations, we have the following table of latitudes adopted in reductions:—

Year.	Adopted latitude.			Year.	Adopted latitude.		
	°	′	″		°	′	″
1862	51	45	35.85	1869	51	45	35.42
1863			35.73				
1864			35.50	1870			36.20
1865			35.28	1871			35.81
1866			36.55	1872			36.06
1867			35.96	1873			36.33
1868			36.16				

The groups indicate periods for which the zenithal circle readings were the same.

Pa 45. The catalogue results are used without change. The instrument used in these observations is of peculiar construction, and in many respects superior to any yet employed in meridian observations for the purpose of deducing standard declinations. The results like those of Kg 21, Dt 24, and Ao 29 are independent in every essential respect, and are such as to inspire the highest confidence.

Ah 41 and Ah 52. It was decided to use the Armagh places for 1840 as two catalogues. The first includes the observations 1835–1846; the second, 1847–1854. Where a star had been observed in both periods, the separation was accomplished in this manner. In the section entitled "Observed Places of Stars," pp. 1 to 646, the means, for each period, of corrections to the assumed polar distance (that of A. S. C., B. A. C., etc.), were taken. The mean of all the results was then subtracted from the separate means; the results are corrections to the catalogue polar distances for the respective periods. In the majority of instances all the observations of a given star are embraced in one or the other of the two periods. No correction for nutation was applied. The catalogue places are reduced without proper motion except in a few cases specified by Dr. Robinson in *Ast. Nach.* lx, 75. The proper correction has been carefully applied.

WASHINGTON MURAL CIRCLE, 1845–1873.

The most of this series, together with observations of meridian circle, meridian transit, and prime vertical transit, have been compiled in a general catalogue* for the epoch 1860, by Professor Yarnall. For the present purpose it is desirable to separate the work of the various instruments, and to combine the work of the mural circle into such convenient groups as appear to be advisable. The error of division of this instrument though not investigated is undoubtedly small, and to provide against error from this and other causes the position of the telescope on the circle was frequently changed.

Wn 47. The declinations are reduced in 1845 with Lindenau's nutation; in the three following years with that of the B. A. C., and to epoch, $\odot = 281^\circ$. The corrections are:—

$$\begin{array}{ll} 1845 & +\ ''.21 \sin (\alpha + 315^\circ.2) \\ 1846 & +\ ''.05 \sin (\alpha + 244^\circ\ ) \\ 1847 & +\ ''.06 \sin (\alpha + 244^\circ\ ) \\ 1848 & +\ ''.06 \sin (\alpha + 247^\circ\ ) \end{array}$$

The proper motions employed in the reductions are those of N. A., 1848, and B. A. C. After 1845 the declinations are reduced to 1850, so that the correction is often considerable.

The latitude which results from the observations of circumpolar stars in 1845, and which is adopted in subsequent years, is smaller by ''.25 than that actually employed in the reductions of 1845. Accordingly, the correction — ''.25 has been applied to the catalogue declinations of that year, reversing the sign where the declination results from observations below the pole.

The circle was used in thirty different positions, relative to the zenith, in 1845; in 1846 and 1847 the zenith reading remained the same, and was again changed at the beginning of 1848. The process of combination is as follows: The declinations of 1846 and 1847 are combined with weights proportional to the number of observations; to the resulting declinations for 1845, 1846–'47 and 1848 weights are assigned according to this table:

Weight.	Number observations.	Weight.	Number observations.
1	1	5	8 to 11.
2	2	6	12 to 16.
2.5	3	7	17 to 26.
3	4	8	27 to 50.
4	5 to 7	9	51 and upward.

Wn 56. The simple mean of the separate results in all the years is taken without correction. Professor Hall (*Ast. Nach.*, 1947) finds the correction + ''.19 to the lati-

* "Catalogue of stars observed at the United States Naval Observatory during the years 1845 to 1871." Appendix III., Washington Astronomical Observations for 1871.

tude actually used in reductions (38° 53′ 39″.25). The resulting correction to declinations, I have not used.

Wn 64. All the declinations must be corrected for the full amount of proper motion—that of α Lyra in 1862 excepted. The latitude assumed in the reductions should be corrected by − ″.47, according to the discussion by Professor Newcomb.* I have applied to all declinations above the pole the correction − ″.47; and to all below, + ″.47. To all the declinations by direct observations in 1861 and 1862, I have applied the correction, − ″.21 for discordance of direct and reflected observations, on the authority of the discussion, p. xxx, Wash. Ast. Obs. 1863. In combination, the weights were taken from the table given in Wash. Obs., 1864, p. xli, which is here copied for reference:

Weight.	Number of observations in different years.		
	1861–'62.	1863.	1864.
1.......	1 or 2	1 or 2	1.
2.......	Above 2 ..	3 to 5	2 or 3.
3.......	....	Above 5..	4 to 7.
4.......	....	....	8 to 20.
5.......	....	....	Above 20.

Wn 70. All declinations are corrected for full amount of proper motion. In 1872 and 1873 the assumed latitude is 38° 53′ 38″.8, and this is ″.45 smaller than that of previous years. + ″.45 is applied as a correction to the catalogue declinations of 1872–'73.

So 51. The declinations of the catalogue are used without alteration.

So 55. Proper motions were employed by Mösta in a few cases only. These are specified on p. xli, Int. The nutation correction is that of Ce 55.

Ps 53. The declinations of the catalogue are used without change. The position of the telescope on the circle was twice changed during the observations of this series. There is every reason to believe that the observations are exceptionally free from errors due to the instrument (Gambey circle). The error of division appears to have been small (vide Laugier's catalogue, p. 55, and *Compt. Rend.*, *tome*, xxvii, p. 633).

No sensible flexure is indicated by the few reflection observations which were taken. Caillet's refrac ions† were adopted in the reductions, and the numerous observations of circumpolar stars do not indicate any considerable correction to them.

PARIS ANNUAL CATALOGUES, 1854–'67.

The declinations of the annual catalogues require no sensible correction. Until 1862 the Gambey mural circle was used alone. After that time the declinations depend principally upon observations made with the great meridian circle. The position of the telescope on the circle was changed in September, 1857. A comparison between results obtained before and after this time shows that there is a constant difference, amounting, approximately, to ″.25. In 1863 and 1864 the transit circle was used without any correction for flexure; afterward the correction − ″.77 sin Z was applied in the reductions.

* Appendix to Washington Astronomical Observations for 1864.
† Additions à la Conn. des temps, 1851.

Comparison of the results obtained by the two circles, when used in common, shows no appreciable systematic difference between them.

The declinations are not independent—the polar points being derived from observations of the stars of a standard catalogue, the places of which are revised from time to time on the authority of the observations themselves. The process is analogous to that commonly adopted in the determination of right ascensions.

The separate results making up each of the four groups—1854-'57, 1858-'62, 1863-'64, and 1865-'67, are combined with weights proportional to the number of observations.

The observed declinations of stars, not included in the Paris standard catalogue, are not conveniently accessible, and the apparent places for the days of observation only are given. Consequently they have been used only in a few special cases.

BRUSSELS ANNUAL CATALOGUES.

The declinations of these catalogues are unaffected by the reduction for proper motion, except for stars of the British Nautical Almanac. I have applied the proper correction. The nutation correction for 1855 and 1856 is identical with that of Cambridge for corresponding years.

The correction for division was not applied until 1857. Though there is no appreciable alteration in methods during the period 1857 to 1867, the observations were divided into two nearly equal groups—1857-'62, 1863-'67—by which means greater accuracy is secured in the solution of conditional equations according to the adopted method. This is the more to be desired because the Brussels series contains numerous observations of stars generally neglected, elsewhere, in recent times.

The combination of the separate years in each of the three groups was effected by means of weights strictly proportional to the number of observations.

C G H 58. The proper motions employed in this catalogue are usually very near those assumed in this paper. Where this correction becomes sensible it has been applied. The instrument is a duplicate of the Greenwich transit circle, and is of course subject to the same theoretical objections. Mr. Stone suspects that the zenith distances given by this instrument require a considerable correction*, which is proportional to cos *Z*. This will tend to throw suspicion upon the results of the discussion of refraction correction in introduction to the Cape catalogue (p. x). This discussion indicates that Bessel's refractions should be multiplied by .9953 in order to correspond to the observations of circumpolar stars, but no use is made of this result by Mr. Stone in forming the catalogue.

Me 62. The small corrections for difference between assumed and catalogue (Main's) proper motions have been applied, also the table of corrections for flexure, etc., given in the catalogue (p. xxi. int.). The instrument used in these, and subsequent meridian observations at Melbourne, is similar in most respects to the Greenwich transit circle. It is much smaller, however, and there are only four circle microscopes.

During the period embraced in Me 62 the instrument was used at Williamstown, a short distance from its present site. The instrumental reductions are very uncertain,

* Month. Not. R. A. S., vol. 33, p. 69.

and the circumstances were unfavorable for accurate work. The declinations are probably much inferior to those obtained with the same instrument at Melbourne.

Me 68. The catalogue polar distances are reduced to 1870, with proper motions, which seldom differ much from those of Section II. However, the resulting small corrections have been carefully applied. Following the discussion by Mr. E. J. Stone (Month. Not., vol. 28, p. 27), the declinations are reduced by Mr. Ellery on the assumption that for stars culminating north of Melbourne zenith, Bessel's refractions should be multiplied by .9909, and for stars south by .9963. The latter number results from observations of circumpolar stars at Melbourne, the former from comparison with Greenwich declinations, 1857–'65. From circumpolar stars Dr. Gylden has found .99718 (V. J. S. Bd., iv, 102), and arguments derived from a consideration of Cape of Good Hope and St. Helena declinations, compared with those of northern observations, incline him to the belief that there may be a real difference in the refractions for the two sides of the zenith at Melbourne, though the question is much obscured by the uncertainty as to division error and flexure of the instrument. The instrument being non-reversible we must remain in ignorance as to the amount of cosine flexure, and while this uncertainty remains it will be difficult to draw decided conclusions about refraction, especially when we consider the necessarily large probable error of refraction determinations at the latitude of Melbourne. The comparison of Washington and Melbourne (p. 66) throws some further light on the matter.

Bn 66. The declinations taken from *Ast. Nach.*, 1719, are used without change; those from the sixth volume of Bonn observations are corrected for the full amount of proper motion, and for the quantities (applicable to declinations, clamp east) in the following table, which is extracted from the introduction to the volume in question (p. xiv):—

δ	Correction.	δ	Correction.
°	"	°	"
− 25	− .51	35	+ .47
− 15	− .47	45	+ .52
− 5	− .38	55	+ .50
+ 5	− .20	65	+ .43
+ 15	+ .06	75	+ .32
+ 25	+ .31	85	+ .13

When the clamp is west the sign of the correction must be reversed. The declinations depend essentially upon those of the Berlin *Jahrbuch* (Wolfer's).

Lc 66. The declinations must be corrected for the full amount of proper motion, none having been employed in the reductions. The declinations are founded systematically upon the standard catalogue of the German Astronomical Society (V. J. S., iv, 324).

Ln 67. A few small corrections for proper motion have been applied. In transcribing the declinations from this series, the order of preference has been—first, *Ast. Nach.*, 1992; second, circumpolar stars, p. [141], second volume Leiden Obs.; third, from the catalogue of *Gradmessung* stars, p. [125] *ibid.*

The stars of the *Gradmessung* catalogue depend upon readings of circle *B* alone; for the others both circles were used. Exceptional care appears to have been exercised both in the observations and their reductions. The instrument is of the reversible pattern, and, where practicable, equal numbers of observations have been taken in each of the four positions—clamp east (dir. and ref.), clamp west (dir. and ref.). The error of division for every 5′ mark on both circles has been ascertained. The corrections for flexure, and to assumed latitude and refraction constant, are thoroughly discussed according to the methods of Bessel. The *Gradmessung* stars were each observed sixteen times—the others much more frequently.

RESULTS OF OBSERVATIONS FOR DECLINATION MADE WITH THE WASHINGTON TRANSIT CIRCLE FOR YEARS 1866–1874.

These are printed in the annual volumes of the United States Naval Observatory for the respective years, and have been taken from the sections entitled "Corrections to the star positions of the American Ephemeris," etc., and "Positions of Miscellaneous Stars," etc. I have not used the results obtained by Professor Newcomb, from the observations of 1866 and 1867, and published in Appendix III. of the Washington volume for 1867, nor the annual catalogues in the later volumes.

Notwithstanding the large probable error of its single determinations, this series appears to be worthy of particular attention, both on account of the great variety of circumstances under which the observations were taken, and because the instrument under consideration is in latitude nearly 13° farther south than any other in the northern hemisphere which has been used for important independent determinations of declination in recent times.

The instrument, one of the largest of its class, is easily reversed. It has two finely divided circles, denominated respectively A and B. Circle A was read in 1866 and B in subsequent years. In the Washington volume for 1865 will be found an elaborate and exhaustive treatise by Professor Newcomb relating to the theory of errors of the transit circle, and in the same connection a practical application of the principles derived, to the particular case of the Washington transit circle. The division correction of each circle is ascertained with great care at intervals of single degrees; the corrections for flexure of circles and telescope are examined, so far as the same was practicable without recourse to celestial observation. The reductions of subsequent years assume the accuracy of these investigations. The instrument is usually reversed at the beginning of each calendar year, and at various times the circle is shifted relatively to the telescope, so that a given polar distance will depend upon different divisions in different years. The only exception is in the years 1871 and 1872, which, for practical purposes, may be regarded as the work of a single year. The zenith points until June, 1867, were mainly derived from observations of leveled collimators; after that period from observations of the nadir. A few observations by reflection were taken, but after the first three years the number of these is so scanty that no reliable discussion of instrumental peculiarities can be based upon their testimony. Besides the corrections for division and flexure in each year, certain corrections derived from the observations for polar distance are applied for discordance of direct and reflected observations and for error of assumed latitude, so that, in effect, the results of separate years are essentially independent and in a certain sense absolute.

Perhaps the most remarkable feature in the method of reduction pursued throughout this series is the assumption of a comparatively sudden change near the zenith in the correction for discordance of direct and reflected observations. This correction is assumed to be constant from 90° to 5° northern zenith distance, and from 5° to 90° southern zenith distance, different values of the correction being applied according as the object observed is north or south. Between the point 5° north and that which is 5° south the value of the correction is interpolated. If we denote by—

ΔZ the corrections actually applied to polar distances between 5° and 90° zenith distance south,

$\Delta Z'$ the corresponding correction for polar distances between the limits 5° and 90° zenith distance north,

we have for separate years the following values of $\Delta Z - \Delta Z'$.

1866	$-''.47$	1870	$+''.31$
1867	$-''.60$	1871–2	[$''.00$]
1868	$-''.68$	1873	$-''.42$
1869	$-''.18$	1874	$-''.82$

The difference for 1871–2 was actually found to be $-1''.45$, but its improbable magnitude led to its rejection. Consideration of the values of latitude derived from the observations of separate years, as well from reflected as direct observations,* strengthens the belief that too much reliance has been placed upon the results of the former. In view of the precautions which were taken, the adoption of a sudden variation in the correction applicable to polar distances near the zenith is at least open to grave objections, while the persistence in the sign of $\Delta Z - \Delta Z'$ during the entire history of the circle thus far, renders it highly probable that the discordance in question has been produced mainly by causes which are independent of the instrument itself, and which affect, perhaps chiefly, if not entirely, observations by reflection. Moreover, the final results of separate years, as printed, exhibit considerable systematic discordances.

I therefore resolved to investigate the relative accuracy of the results for separate years, and, with certain preliminary assumptions, to derive if possible from the observations themselves systematic corrections, which should appear theoretically admissible, and which might at the same time produce a tolerable degree of harmony. It appeared to me that this would be practicable only in the case of the earlier years, there being after 1868 few observations of stars at lower transit or by reflection.

In 1869 the instrument was dismounted and placed in a new room especially designed for its use. In 1870 the object-glass was reground and other important changes accomplished. These and other considerations have led to a division of the entire series into two distinct portions, viz:

Wn 68, embracing the years 1866–1869.
Wn 72, years 1870–1874.

Wn 68.

The following notation is adopted:

Z = Zenith distance, reckoned from 0° to 360° in usual direction.

ΔZ = Required constant correction for a given year to direct zenith distances, as adopted and corrected for division error.

D = Correction for division error, taken from tables § 72 of description of transit circle, Wn. Ast. Obs., 1865.

* See p. lxxviii, Introduction to Washington Astronomical Observations for 1873.

P' = Polar distance of American Ephemeris. For direct observations counted from 0° to 360°.

Δp = Correction given to P' by a single observation of polar distance as printed in the column entitled "Miscellaneous Corrections," in the sections entitled "Observations with the Transit Circle;" but this designation is also applied to the same quantity when corrected for *errata* and certain corrections required by some of the zenith points of 1867 and 1868.

$\Delta P_{,}$ = Mean of n values of Δp. Does not include division correction.

$\Delta P = \Delta P_{,} + D$.

P and $P_{,}$ for stars not in Am. Eph, correspond to $P' + \Delta P$ and $P' + \Delta P_{,}$.

F = Horizontal, or sine flexure.

F' = Zenithal, or cosine flexure.

$\Delta\varphi$ = Correction to assumed latitude, — 38° 53′ 38″.80.

ρ and ρ' = Computed refractions, respectively for the upper and lower culminations of a given star.

$(1 - k)$ = Factor by which these must be multiplied to bring them in accordance with observation of circumpolar stars.

The true probable error of any final result for a given star in a single position of the circle, is supposed to be of the usual form $\sqrt{\varepsilon_{,}^2 + \frac{\varepsilon^2}{n}}$; where—

ε = Probable error of a single pointing, or that part of the error which diminishes according to the value of $\frac{1}{\sqrt{n}}$; and

$\varepsilon_{,}$ = Probable error for a single position of the instrument when n is infinite. ε is supposed to increase with the zenith distance according to the law $\varepsilon^2 = \varepsilon_{,,}^2 + \varepsilon_{,,,}^2 \tan^2 Z$; where

$\varepsilon_{,,}$ = value of ε when $Z = 0$; and—

$\varepsilon_{,,,}$ = arbitrary constant.

π' = Weight, the probable error of whose unit is E.

Whenever it is necessary to limit the application of the above quantities to a particular year or mode of observation it is effected by adding to the expression for the quantity the designations 66, 67, 68, 69, or (Dir), (Ref), etc. These designations are omitted in many cases where no ambiguity can arise from that course.

The change in method of obtaining zenith point, which took place in 1867, requires an examination of the determinations of north polar distance in that year, for the purpose of ascertaining whether there is any constant difference between the results obtained before and after June 1, when the change took place. To settle this point, the direct observations of 70 stars most frequently observed (and at least three times in each period) were selected. The observations previous to June 1 were grouped in a single mean, $\Delta P_{,}$; and those subsequent, in another, $\Delta P_{,,}$. Weights were assigned according to the usual formula: *i. e.*, $n_{,}$ being the number of observations making up $\Delta P_{,}$ and $n_{,,}$ the number of observations making up $\Delta P_{,,}$, we have $\pi = \frac{n_{,} n_{,,}}{n_{,} + n_{,,}}$. These weights were taken roughly to the nearest unit. The resulting value of the correction is

$$\Delta P_{,} - \Delta P_{,,} = -''.34 \pm ''.032; \text{ weight } 294.$$

$$\varepsilon_{67} = \pm ''.55.$$

All the polar distances subsequent to June 1 were consequently corrected by $-''.34$, to bring them into systematic accordance with those values of Δp obtained previous to that date. Where the number of determinations for a given star is small, particular examination of observations made in May was instituted, and such observations in that month as appeared to depend on Nadirs were corrected. ΔP_{67} was then formed anew, respect being had for the list of *errata* (end of this Appendix).

Even a superficial examination of the results for 1868 is sufficient to show that the probable error, ε_{68}, is much larger than the corresponding quantity for any other year, and while it was found to be impracticable if not impossible to assign all the reasons for this, an examination leaves no doubt that it is partly due to constant errors in the determination of *zenith point* correction. Some of these errors are quite large, and though extreme caution should be exercised, I have not hesitated to apply the more important corrections which seemed to be required. I have followed a method precisely like that adopted by Professor Newcomb in similar cases occurring in 1866.* The suspected periods were quite numerous, but only those in the subjoined table were adopted for treatment. $\Delta P_{,,}$ for each star common to any one or more of these nights, was formed from all the remaining observations of the year; and then each compared with the questionable values of its corresponding Δp. Thus a series of values $\Delta P_{,} - \Delta p$ were obtained for each date, and the mean of each set adopted as the correction to the results as printed. The column headed "No." shows the total number of values of $\Delta P_{,} - \Delta p$, which are used to form the corresponding correction. The corrections with reversed signs are applicable to the results of reflection observations.

Date.	Observer.	Correction.	No.	Remarks.
		″		
March 18.....	H	+ 1.5	10	Polaris to κ Cancri.
September 7..	F	— 1.5	19	
October 1.....	T	— 2.0	16	
October 13....	F	— 2.0	19	
October 16....	F	— 1.7	16	
November 6...	E	— 0.9	22	ζ Cygni to Polaris.
November 6...	E	— 2.3	11	δ Canis Majoris to α Hydræ.
December 8...	F	— 1.2	14*	

* The result from α Aquilæ is excluded.

The corrections on November 6, taken in connection with the corresponding "zenith point corrections," which for the first group was 13″.0, and for the second 14″.3, show that the Nadir determinations may indicate a considerable change in the zenith point without any real alteration. The "zenith point corrections" on November 6, according to the above table, should have been 12″.1 and 12″.0 respectively, for the first and second groups; while they were found to be from Nadir observations on

* Washington Astronomical Observations, 1866, p. xvii. Introduction.

November 5, 11″.9, on November 7, 13″.2, and on November 9, 10″.6, each depending on two separate observations,—those on November 7 being respectively 14″.58 and 11″.97.

The only remaining corrections adopted to aid in forming ΔP in this and in other years are for *errata*, which are to be found at the end of this Appendix. Twenty seven observations in 1868 which differed more than 3″.5 from the concluded means, were rejected.

In 1866 the values of ΔP resulting from zenith points as corrected are adopted.

Probable Error.

Before combining the results of separate years, it is important to know their relative weights; especially as an examination, merely preliminary, shows that the accuracy of a single determination varies greatly in different years. In getting probable error, the corrected results were used in 1866; and the results as printed and corrected for *errata*, in subsequent years; except that the rejected observations of 1868 were not included. Each Δp was compared with its ΔP, and the residuals arranged in groups according to zenith distance. The probable error ε was supposed to follow the well-known law*

$$\varepsilon^2 = \varepsilon^2_{\prime\prime} + \varepsilon^2_{\prime\prime\prime} \operatorname{tang}^2 Z$$

Whatever the theoretical objections to this formula, they are nothing in comparison with the uncertainty of the determination; because in this particular case there are few observations at great zenith distances. No distinction is made between observations north or south of the zenith, owing to the considerable number of bisections taken at each pointing; and these, for northern stars frequently observed, are more numerous on the average than for the southern; so that the greater accuracy in a single bisection of an equatorial star is in this way assumed to give no marked advantage. In 1866 and 1867, stars observed twenty times or more were used, except at zenith distances greater than 55°, where the minimum was reduced to 7 observations of the same star. In the two succeeding years the minimum for zenith distances less than 60° is 10. The results follow:—

1866.

Group.	Mean Z	No. residuals.	Observed ε	ε from formula.
	°		″	″
1	6	210	± .54	± .57
2	20	202	± .52	± .57
3	28	194	± .58	± .58
4	43	212	± .63	± .60
5	51	251	± .71	± .63
6	58	201	± .65	± .67
1867.				
1	10	226	± .51	± .51
2	25	232	± .55	± .52
3	49	205	± .53	± .55
4	53	127	± .60	± .57
5	59	85	± .54	± .59
6	69	31	± .74	± .71

* *Vide* Langier's Memoir; Kaiser, Second Volume Leiden Observations, etc.

1868.

Group.	Mean Z	No. residuals.	Observed ε	ε from formula.
	°		″	″
1	8	199	± .86	± .76
2	21	229	± .71	± .76
3	32	295	± .76	± .77
4	50	343	± .77	± .79
5	56	79	± .72	± .81
6	65	83	± .60	± .86
7	72	45	±1.00	± .96

Two hundred and eighty-seven residuals of stars most frequently observed in 1869 give $\varepsilon = \pm .67$.

One hundred and sixty-five residuals of stars most frequently observed by reflection in 1867 give $\varepsilon = \pm ''.50$.

The following formulæ were adopted for the respective years:

$$
\begin{array}{ll}
1866 & \varepsilon^2 = ''.323 + ''.0450 \ \text{tang}^2 Z \\
1867 & \varepsilon^2 = ''.261 + ''.0333 \ \text{tang}^2 Z \\
1868 & \varepsilon^2 = ''.578 + (''.0333) \ \text{tang}^2 Z \\
1869 & \varepsilon^2 = (''.455) + (''.0415) \ \text{tang}^2 Z
\end{array}
$$

For 1868 the factor multiplied by $\text{tang}^2 Z$ was assumed equal to that found by experiment in 1867; the result for 1868 being of extremely small weight.

For 1869 the formula found from the observations of Wn 1870–1873 was adopted as being a close approximation.

With the arguments Z and year, we have the following table of—

Values of ε

$Z =$	0°	20°	30°	40°	50°	55°	60°	65°	70°	75°
	″	″	″	″	″	″	″	″	″	″
1866	.57	.57	.58	.60	.62	.64	.68	.73	.81	.97
1867*	.51	.52	.52	.53	.55	.57	.60	.64	.72	.85
1868	.76	.76	.77	.78	.79	.80	.82	.86	.91	1.02
1869	.68	.68	.68	.70	.72	.74	.76	.80	.88	1.02

The value of ε, must be determined from a comparison of observations in different positions of the circle.

It will now be assumed that the systematic corrections required by the adopted values of $\varDelta P$, are: *a*, a correction D for division error. This has been taken from tables in § 72 of the description of the transit circle, Washington Observations for 1865.

b, a constant correction, $- \varDelta Z$, to all of the zenith points of a given year. The correction to $\varDelta P$ will be $+ \varDelta Z$.

* The value of ε_{67} at 50°Z agrees precisely with that found in another way (see p. 47). The value there found corresponds to a zenith distance of about 40°.

c, a correction for flexure, arbitrarily assumed to be of the form $F \sin Z + F' \cos Z$.

d, a correction, $-\Delta\varphi$, to ΔP (1866–1869) for error in the assumed latitude, 38° 53′ 38″.80.

These corrections are of the forms usually adopted, and seem to require no explanation on theoretical grounds.

Accepting these, the final polar distance by direct observation will be—

$$\left.\begin{matrix} P' + \Delta P, \\ P, \end{matrix}\right\} + D + \Delta Z + F \sin Z + F' \cos Z - \Delta\varphi$$

Of these corrections ΔZ will vary with the year; $\Delta\varphi$ will be constant; and D, F and F' will depend upon the reading of the circle used.

Values of ΔZ, F and F'.

During the years 1867 and 1868 circle B was used. It was reversed at the beginning of 1868, but was not shifted relatively to the telescope. In each year there is a considerable number of reflection observations, both north and south. The necessary conditions are thus established for ascertaining the quantities $\Delta Z\,67$, $\Delta Z\,68$, F and F'. F and F' have been already investigated as stated above* (p. 44); but that portion of F' which depends upon the flexure of the telescope could only be roughly inferred, and was taken as .00. So far as this assumption is supported by the present investigation, it will be found to be substantially correct. However the discordance between the direct and reflected observations of these and other years may originate, if one of the possible causes of error is known, and if the form of the differences can be reconciled, within a fair degree of probability, to represent the effect of that cause, we are bound to accept the latter, provisionally, as the most probable, or at least as an important source of the difficulty. If other means of measuring the effect of the known disturbing agency exist and have been employed, the question then relates to the weight of each determination or method, and, except for considerations of expediency, neither should be adopted to the exclusion of others, unless there is great disparity of weights.

It is *a priori* possible that the whole or a part of the discordance in question may be produced by flexure. The horizontal flexure (F) has been measured by opposing collimators and also by the aid of leveled collimators, in the manner detailed in the Washington volume for 1865.† The definitive result was taken from the former method. The values given by leveled collimators, for reasons stated, are justly regarded as of little weight, though it will be seen that their mean is very near the mean finally adopted in this discussion. Professor Newcomb considers the flexure of the circles and of the telescope separately. The former was ascertained by a method of comparing simultaneous readings of the two circles, combined with a systematic rotation in their relative positions. The flexure of the telescope in the horizontal position was determined by subtracting from the value of F, found by opposing collimators, that previously found for the circle read in the observation. A rough check on the zenithal flexure of telescope was obtained in an analogous manner by the aid of nadir observations combined with readings on leveled collimators. The result is confessedly of small

* Washington Astronomical Observations for 1866, Appendix I, § 60 to § 67.

† § (65) App. I., Wn. Obs., 1865.

weight. Many of the determinations by opposing collimators were known to be influenced by temperature in the room varying at different altitudes, and such were rejected. It is not altogether improbable that the measures accepted may have been affected injuriously by the same cause, though in a smaller degree. They are also liable to error from other causes, among which may be mentioned personal error, and the error possibly arising from the small aperture of the collimators.* It would be difficult to estimate the probable error in the determination of F and F'; but perhaps enough has been said to show that a considerable correction to the adopted values is not altogether inadmissible.

The reflection-observations of 1867 and 1868 will first be examined to ascertain whether the differences ΔP (Ref) $- \Delta P$† will tolerate the supposition that they are caused wholly or mainly by a constant error in adopted zenith point combined with an error in the assumed coefficient of sin Z in the formula for flexure. And for the purpose of assigning proper weights to ΔP (Ref) $- \Delta P$ in each case ε, will be ascertained by approximation. In 1867 there are a few observations of "miscellaneous stars" by reflection, and as these are situated almost exclusively near the zenith they will afford additional evidence as to the character of the change near the zenith in the value of ΔP (Ref) $- \Delta P$. The following table exhibits the results from these stars arranged in order of zenith distance of stars observed directly, zenith distances being counted from 0° to 360°. The first column gives the name of the star; the second is P corrected wherever necessary by $-$ ″.34, to reduce to adopted zenith points; the third is seconds of P (Ref), reckoned from reflected pole through nadir, etc.; the fourth gives the number of observations respectively for P and P (Ref), separated by a hyphen; the fifth shows the respective weights on the unit whose probable error is 1″.00. These weights are deduced on the supposition that the value of ε, is $\pm$ ″.25. The sixth column shows the values of P (Ref) $- P$, and the last column shows the values of Z.

Name.	P			P(Ref)	Obs.	π'	P (Ref) $-$ P	Z
	°	′	″				″	°
B. A. C. 1144	24	52	46.60	46.16	2-1	2	$-$ .44	334
b Ursæ Majoris.....	27	33	15.02	13.48	1-1	1.5	$-$ 1.54	337
β Ursæ Majoris.....	32	55	18.32	16.99	2-2	2.5	$-$ 1.33	342
81 Ursæ Majoris.....	33	59	05.38	05.73	2-1	2	+ .35	343
21 Ursæ Majoris.....	35	25	36.07	36.85	2-1	2	+ .78	341
1 Can. Ven.........	35	50	31.17	30.97	3-1	2	$-$ .20	345
51 Draconis.........	36	48	07.39	08.28	2-1	2	+ .89	346
o Aurigæ	40	14	03.10	02.81	2-1	2	$-$ .29	349
χ Ursæ Majoris.....	41	29	61.03	58.57	1-2	2	$-$ 2.46	350
z Herculis	41	34	11.07	11.36	4-1	2	+ .29	350
Recapitulation (stars north of zenith)......................						20	$-$ .39 $\pm$ .23	344

* The aperture of the collimators is only $2\frac{1}{4}$ inches, while that of the telescope is 8.5 inches.
† $\Delta P = \Delta P_{,} + D$.

Name.	P			P(Ref)	Obs.	π′	P(Ref)	Z
	°	′	″				″	°
B. A. C. 4962	62	24	32.79	33.74	2-1	2	+ .95	11
B. A. C. 4809	62	41	46.97	47.64	2-1	2	+ .67	12
γ Cor. Borealis	63	17	29.45	28.28	2-1	2	— 1.17	12
d Bootis	64	17	29.63	29.70	3-1	2	+ .07	13
64 Leonis	65	58	27.11	28.04	3-1	2	+ .90	15
26 Bootis	67	19	60.39	59.80	2-1	2	— .59	16
B. A. C. 1970	67	47	30.42	31.71	2-1	2	+ 1.29	17
B. A. C. 2788	68	50	40.27	40.13	2-1	2	— .14	18
ζ Tauri	68	56	22.20	22.83	2-1	2	+ .63	18
B. A. C. 5620	74	00	47.13	46.32	2-1	2	— .81	23
30 Geminorum	76	38	37.05	36.77	2-1	2	— .28	25
ι Ophiuchi	79	37	07.15	07.43	2-1	2	+ .28	28
Recapitulation (stars south of zenith)						24	+ .15 ± .14	17

The probable errors are deduced from the actual residuals; had they been estimated from $\Sigma \pi'$ in each case, they would have been $\pm$ ″.22 and $\pm$ ″.20, respectively, for the northern and southern groups. At about 18° zenith distance on each side there are gaps without stars observed, more than 5° wide in each instance. Taking only the stars nearest the zenith, we have:—

	π	P (Ref) — P	Z
		″	°
Northern stars	16.5	— .27	346
[Same, excluding χ Ursæ Majoris.	14.5	+ .03	345]
Southern stars	18	+ .15	15

The evidence in favor of an abnormal change appears to be wanting. The result has, however, but small weight. Collecting now all the material which exists in 1867 and 1868 for determining ΔZ 67, ΔZ 68, and F, and collecting the values of ΔP (Ref) — ΔP into groups, including in each group a zone nearly 5° wide, we have the following tables:—

1867.

No.	Mean Z	Δ P(Ref) — Δ P + ″.16 sin Z	π′	I.	II.	III.
	°	″		″	″	″
(1)	303	— .54	15	— .49	— .13	+ .11
(2)	315	— .87	17	— .05	+ .21	+ .50
(3)	323	— .77	31	00	+ .12	+ .48
(4)	329	— .66	34	+ .02	+ .02	+ .43
(5)	334	— .56	31	+ .03	— .07	+ .39
(6)	345	— .29	28	+ .03	— .32	+ .26
(7)	350	— .81	22	+ .67	+ .21	+ .81
(8)	12	+ .58	40	— .15	+ .23	— .26
(9)	18	+ .48	28	+ .10	+ .35	— .08
(10)	25	+ .49	50	+ .25	+ .35	.00
(11)	32	+1.01	46	— .11	— .16	— .44
(12)	38	+1.65	15	— .61	— .79	—1.02
(13)	46	+1.49	20	— .42	— .61	— .78
(14)	49	+ .78	18	+ .41	+ .10	— .05
(15)	53	+1.13	6	+ .17	— .21	— .36

The correction $+''.16 \sin Z$, in column $\Delta P(\text{Ref}) - \Delta P$, is the reduction for difference of latitudes of instrument and reflecting surface in reflection observations. The weight, π', supposes $\pm 1''.00$ as the probable error of the unit. By successive trials it was found that, taking $\varepsilon_{,} = \pm ''.25$, the assumed and concluded probable errors of unit of weight in 1868 were exactly alike; and the latter for 1867 was $\pm 1''.07$, while from the assumption it should have been $\pm 1''.00$. The approximation is considered quite sufficient, especially when it is remembered that there is great uncertainty in the application of the law adopted to represent $\Delta P(\text{Ref}) - \Delta P$. We therefore have for any given number (n) of observations the weight

$$\pi' = \frac{1.00}{.0625 + \frac{\varepsilon^2}{n}}$$

The table gives:—

Values of π' with arguments ε and n.

$E = \pm 1.00$ $\qquad \varepsilon_{,} = \pm .25$

n	$\varepsilon = ''.52$	$''.54$	$''.60$	$''.70$	$''.80$	$''.90$	$1''.00$
1	3.0	2.8	2.4	1.8	1.4	1.1	.9
2	5.2	4.8	4.1	3.2	2.6	2.1	1.8
3	6.6	6.3	5.5	4.4	3.6	3.0	2.6
4	7.7	7.4	6.6	5.4	4.5	3.8	3.2
5	8.6	8.3	7.4	6.2	5.3	4.5	3.8
6	9.3	9.0	8.2	6.9	5.9	5.1	4.4
7	9.9	9.6	8.8	7.5	6.5	5.6	4.9
8	10.4	10.1	9.3	8.1	7.0	6.1	5.3
9	10.8	10.5	9.8	8.6	7.5	6.6	5.8
10	11.2	10.9	10.2	9.0	7.9	7.0	6.2
15	12.4	12.2	11.7	10.5	9.5	8.6	7.7
20	13.2	13.0	12.4	11.5	10.6	9.7	8.9
25	13.6	13.5	13.0	12.2	11.4	10.6	9.8
30	14.0	13.9	13.4	12.7	11.9	....	....
35	14.2	14.1	13.7	13.1	....	....	....
40	14.4	14.3	14.0	13.4	....	....	....
50	14.7	14.6	14.3	13.8	....	....	....

These can easily be converted into any other scale whose standard probable error is e, by means of the factor $\frac{e^2}{1.0}$. The value of ε is found on p. 49. The weight $\pi' = \frac{\pi'(\text{Dir.}) \times \pi'(\text{Ref.})}{\pi'(\text{Dir.}) + \pi'(\text{Ref.})}$ is taken to the nearest unit.

Recurring again to the table of comparisons, $\Delta P(\text{Ref}) - \Delta P$, (1867), the numbers in column headed I. are the residuals (calc. — obs.), which result from the employment of the following values deduced directly from the observations of 1867, assuming that the differences $\Delta P(\text{Ref}) - \Delta P$ are due to constant error and flexure.

$$\Delta Z = +''.06 \pm ''.027$$
$$F = +''.74 \pm ''.052.$$

The column marked II. is constructed on the supposition:—

$$\Delta Z' \text{ or } \Delta Z'' = \frac{\Delta P(\text{Ref.}) - \Delta P}{2} + ''.06 \sin Z;$$

i. e., assuming ΔZ to be different for northern and southern stars, and excluding the supposed flexure, except that of $+''.06$ deduced from opposing collimators. We have for northern stars, $\Delta Z' = -''.29$; for southern stars, $\Delta Z'' = +''.40$.

Professor Newcomb found*:—

$$\Delta Z' = -''.45 \quad \Delta Z'' = +''.15.$$

The difference is mainly the effect of the correction $-''.34$ to reduce systematically to zenith points derived from collimators. In the first solution the small value of ΔZ shows that the zenith points thus derived are practically free from constant error.

While the numbers in column I. do not show that agreement of fact with hypothesis, which is desirable, they ought to have some preference over those of column II., especially when we consider that the manner of using the corrections $\Delta Z'$ and $\Delta Z''$, is at least highly questionable on *a priori* grounds. It may be noted that of the eight comparisons making up line (7), we have:—

	Stars.	Z	ΔP (Ref.) $-\Delta P$, etc.	π'	I.
		°	"		"
1st	4	349	$-$ 1.51	13	$+$ 1.3
2d	4	352	$+$ .22	9	$-$ .4

Whatever the source of these anomalies it is undoubtedly quite irregular in its action, and is suggested with some probability by Faye's hypothesis† as to columns of heated air in the observing-room, which may principally or solely affect observations by reflection.

Explanation of column III. will follow later, (p. 57).

We have a similar table for 1868:—

No.	Mean Z	ΔP (Ref.) $-\Delta P$ $+.16 \sin Z$	π'	I.	II.	III.
	°	"		"	"	"
(16)	308	$-$ .72	6	$-$1.01	$-$ .69	$-$ .46
(17)	316	$-$ .70	3	$-$ .83	$-$ .69	$-$ .41
(18)	323	$-$1.03	14	$-$ .39	$-$ .34	$-$ .01
(19)	328	$-$1.75	20	$+$ .42	$+$ .40	$+$ .77
(20)	335	$-$1.40	13	$+$ .20	$+$ .06	$+$ .49
(21)	345	$-$1.14	10	$+$ .13	$-$ .16	$+$ .37
(22)	351	$-$1.30	16	$+$ .43	$+$ .02	$+$ .61
(23)	11	$+$ .28	16	$-$ .74	$-$ .27	$-$ .71
(24)	18	$+$ .23	20	$-$ .55	$-$ .22	$-$ .57
(25)	21	$-$ .67	21	$-$ .28	$+$ .10	$-$ .21
(26)	28	$-$ .10	23	$-$ .03	$+$ .15	$-$ .13
(27)	33	$-$ .51	23	$+$ .47	$+$ .58	$+$ .35
(28)	39	00	11	$+$ .06	$+$ .09	$-$ .10
(29)	48	$+$ .54	16	$-$ .34	$-$ .43	$-$ .55

* P. xix, Int. Wash. Ast. Obs., 1867.

† Faye, *Comptes Rendus*, xxi.

The explanations under 1867 apply. We have for I.:—

$$\Delta Z = -''.35 \pm ''.035$$
$$F = +''.60 \pm ''.070$$

For II.: $\Delta Z' = -''.62$ and $\Delta Z'' = -''.02$.

The difference between these numbers and those deduced by Newcomb,* $\Delta Z' = -''.78$ and $\Delta Z'' = -''.10$, is probably due to the changes in some of the zenith points (see p. 47,) and in the changes and additions produced by *errata*. There is apparently not much to choose between I. and II. I shall, therefore, proceed on the hypothesis that a portion of the discordance in question is due to atmospheric, or causes other than flexure depending on $\sin Z$. Furthermore, the method of obtaining value of F by comparison of direct and reflected observations of Z will be considered as of equal weight with the method which employs opposing collimators. If we take the mean by weights of the two values of F, deduced from observations of 1867 and 1868, we have $+''.69$, which gives as the mean by the two methods:—

$$F = +''.37.$$

The observations of 1869 are too few to afford a practical contribution to this result, and those of 1866 were deduced with a different circle.

By comparison of $\Delta P\,68 - \Delta P\,67$ we shall have an excellent determination of the quantities F' (or entire cosine flexure) and $\Delta Z\,68 - \Delta Z\,67$. To obtain most probable values of F, F', $\Delta Z\,67$ and $\Delta Z\,68$, it will be best to comprise in one set of conditional equations all determinations which contribute to a knowledge of either of the required quantities, so that each may exert its proper influence upon all others. Each comparison $\Delta P\,68 \sim \Delta P\,67$ furnishes an equation of the form $\Delta Z\,67 - \Delta Z\,68 + 2\,F' \cos Z = \Delta P\,68 - \Delta P\,67$, for direct observations, and $\Delta Z\,67 - \Delta Z\,68 + 2\,F' \cos Z = -\Delta P\,68 + \Delta P\,67$ for reflected observations. The results of 1867 and 1868 furnish 247† such equations of the total weight 908. Arranging them in the order of zenith distance in zones about 5° in width, we have 38 means or groups:—

1868–1867.

No.	Mean Z	$\Delta P\,68 - \Delta P\,67$ or $\Delta P\,67$ (Ref.) $- \Delta P\,68$ (Ref.)	π'	III.
	°	"		"
(30)	288	− .40	11	+ .42
(31)	294	− .57	22	+ .47
(32)	306	− .50	22	+ .20
(33)	311	− .33	23	− .04
(34)	316	− 1.29	9	+ .84
(35)	323	− .86	30	+ .32
(36)	328	− .60	34	00
(37)	332	− .56	19	− .08
(38)	337	+ .01	10	− .69
(39)	345	− .88	16	+ .15
(40)	351	− .45	22	− .31
(41)	360	− .19	33	− .58

* P. xx, Int. Wash. Ast. Obs., 1868.

† The comparisons of α Cassiop., S. P., and α Cephei, S. P., are rejected as of small weight.

1868–1867—Continued.

No.	Mean Z	ΔP 68 — ΔP 67 or ΔP 67 (Ref.) — ΔP 68 Ref.)	π'	III.
	°	″		″
(42)	7	— .26	22	+ .10
(43)	11	— 1.17	40	+ .42
(44)	17	— .83	44	+ .11
(45)	21	— .86	26	+ .17
(46)	24	— .71	50	+ .04
(47)	29	— .89	60	+ .26
(48)	33	— .42	72	— .16
(49)	40	— .06	43	— .44
(50)	47	— .42	65	+ .02
(51)	53	— .55	24	+ .24
(52)	59	+ .58	23	— .79
(53)	64	— .05	16	— .08
(54)	69	+ .92	7	— .96
(55)	231	+ .66	6	+ .44
(56)	224	+ .03	3	+ 1.17
(57)	217	+ 1.41	18	— .12
(58)	210	+ 1.82	14	— .46
(59)	205	+ 1.31	17	+ .10
(60)	195	+ 1.63	10	— .15
(61)	189	+ 1.21	12	+ .29
(62)	168	+ 1.13	13	+ .36
(63)	161	+ 1.22	12	+ .24
(64)	155	+ 1.34	20	+ .08
(65)	148	+ 1.86	21	— .52
(66)	140	+ 1.10	6	+ .15
(67)	132	+ 1.21	13	— .07

Finally we have from opposing collimators:—

	F	π'	″
(68)	$+$ ″.06	620	$+$ .32:

where π' is determined *a posteriori* in such a manner that it shall be equal to one-half the weight of F in the solution of normal equations.

Representing by $-n$, for convenience, the numbers in third column (in the three tables), we have the forms:—

(1867) $\{2\,\Delta Z\,67 + 2\,F\,\sin Z + n = 0\}\,\sqrt{\pi'}$

(1868) $\{2\,\Delta Z\,68 + 2\,F\,\sin Z + n = 0\}\,\sqrt{\pi'}$

(1868–1867) $\{\Delta Z\,67 - \Delta Z\,68 + 2\,F'\,\sin Z + n = 0\}\,\sqrt{\pi'}$

$\{F - {}''.06 = 0\}\,\sqrt{620}$

The solution of numerical equations formed in accordance with the above, leads to these normal equations.

$$\begin{array}{rrrrrr} 2552.0\,\Delta Z\,67 & -\ 908.0\,\Delta Z\,68 & +\ 904.6\,F' & +\ 100.0\,F & -\ 5''.71 & = 0 \\ -\ 908.0 & +\ 1756.0 & -\ 904.6 & +\ 94.2 & +\ 31.59 & = 0 \\ +\ 904.6 & -\ 904.6 & +\ 2493.9 & & +\ 1088.08 & = 0 \\ +\ 100.0 & +\ 94.2 & & +\ 1255.5 & -\ 459.40 & = 0 \end{array}$$

The solution gives,—

$$\begin{aligned} \Delta Z\,67 &= +\ ''.082 \pm ''.024 \\ \Delta Z\,68 &= -\ ''.290 \pm ''.030 \\ F' &= -\ ''.571 \pm ''.024 \\ F &= +\ ''.381\ [\pm ''.030] \\ E &= \pm\ 1''.07 \end{aligned}$$

It is hardly necessary to remark that the probable error as applied to F has no significance; but if we admit that the anomalous conditions affecting ΔP(Ref) — ΔP acted with tolerable uniformity in 1867 and 1868, then the probable error of the value of F' is quite real. The value of E is unfavorably influenced by the introduction of equation (68). Using (as in other cases) the separate residuals making up groups (30) to (54) inclusive, we have

$$E = \pm\ ''.994;$$

and from groups (55) to (67) inclusive

$$E = \pm\ 1''.031.$$

The agreement of E with assumed value is all that could be desired.

The numbers in column III. are the residuals arising from the adoption of the above values in the individual equations. From groups (30) to (67) there are no evidences of large outstanding errors of a systematic nature; nor, with one or two exceptions, of residuals larger than should be expected from the weights. Small errors in the division correction doubtless exist, and it is to me matter of surprise that these groups are so well represented by the simple law assumed. So much cannot be said of the first 29 groups. The outstanding residuals in column III. may be attributed to atmospheric disturbances, to error in assumed value of F, and to other possible causes, whose existence is not clearly defined.

It will be assumed that the difficulty is mainly with the reflection observation; and these will accordingly be excluded from all further participation in the definitive results for 1867 and 1868. Assuming the correctness of F, the value of ΔZ 69 will be deduced from the comparison of direct and reflected observations of 1869, given on p. xxiii, Int. Wash. Ast. Obs. Reversing the signs in column "D — R", correcting by — .64 sin Z, and taking one-half the mean by weights of the outstanding residuals, we have:—

$$\Delta Z\ 69 = +\ ''.44 \pm\ ''.06.$$

The circle was shifted at the beginning of the year 30′ relatively to the telescope. In computing flexure, no account was taken of this circumstance.

The observations of 1865 afford no opportunity for independent determination of the cosine flexure of the circle used. ΔZ 66 and the sine flexure (F) were found by Professor Newcomb from comparison of direct and reflected observations.* The values were—

$$\Delta Z\ 66 = -\ ''.72$$
$$F\ 66 = -\ ''.78$$

The result of the investigation for F 66 in the volume for 1865 is — 1″.12; and this was adopted in the reductions. I have adopted the mean of the two results

$$F\ 66 = -\ ''.95$$

The mean by weights of ΔP 67 and ΔP 68 corrected for ΔZ, F and F' was then taken

* Introduction to Washington Astronomical Observations for 1866, p. xxiii.

as standard, with which ΔP 66, corrected by $- ''.72 - ''.95 \sin Z$ was compared. Arranged in convenient groups the results are these:—

Group.	Mean Z	$\Delta P \begin{Bmatrix} 67 \\ 68 \end{Bmatrix}$ (corrected) $- \Delta P$ 66 (corrected).	π'	Calc.— obs.
	°	''		''
(1)	293	− .14	24	+ .06
(2)	307	− .07	32	− .03
(3)	312	+ .12	41	− .22
(4)	325	+ .02	70	− .13
(5)	334	− .25	35	+ .14
(6)	349	− .02	50	− .10
(7)	2	− .25	67	+ .13
(8)	13	+ .02	112	− .14
(9)	23	− .03	150	− .09
(10)	32	+ .01	166	− .12
(11)	44	− .35	150	+ .25
(12)	55	− .37	62	+ .28
(13)	65	− .38	42	+ .29
(14)	228	− .22	21	+ .20
(15)	214	+ .19	37	− .20
(16)	206	+ .15	28	− .16
(17)	192	+ .10	35	− .10
(18)	165	− .37	30	+ .37
(19)	153	+ .20	38	− .21
(20)	140	.00	14	− .01
(21)	132	− .02	22	00

The results from (14) to (21) are from reflection observations. The numbers in third column are too small and too irregular to exhibit any decided preference for a given law. It will be assumed that the above value of ΔZ 66 requires correction, and that a term should be introduced for cosine flexure. I have found:—

$$- ''.06 \, [\pm .04] - ''.06 \, [\pm .04] \cos Z.$$

The residuals in the last column are, on the whole, very satisfactory. Those in (11), (12), and (13), however, show a slight tendency to deviation from the assumed law. We have arrived at the following corrections to ΔP, which are adopted.

1866. $- ''.78 - ''.95 \sin Z - ''.06 \cos Z$

1867. $+ .08 + .38 \sin Z - .57 \cos Z +$ {Irregular correction for error of zenith points.}

1868. $- .29 + .38 \sin Z + .57 \cos Z +$ {Irregular corrections.}

1869. $+ .44 + .38 \sin Z - .57 \cos Z$

or more conveniently:

(A)

1866. $- ''.78 - ''.95 \sin \{ 312^\circ.5 + P \}$

1867. $+ .08 + .69 \sin \{ 252.6 + P \} +$ etc.

1868. $- .29 + .69 \sin \{ 5.2 + P \} +$ etc.

1869. $+ .44 + .69 \sin \{ 252.6 + P \}$

These corrections are applicable to polar distances from direct observation.

Latitude and Refraction.

In this series of observations, there is no material for examining the correctness of the adopted temperature coefficient of atmospheric expansion. Owing to the low elevation of the pole and the deficiency of observations at low altitudes of stars at lower transit, the determination of an independent constant of refraction is likewise out of the question. The process of obtaining $\Delta\varphi$ may be briefly summarized.

All polar distances by direct observation in each of the years were corrected by (A); and supposing the differences between corrected polar distances of the same star from upper and lower culmination to be due to error of assumed latitude and refraction constant, we have—

$$\left.\begin{array}{r}\Delta P\text{ (U. C.) corrected}\\ +\ \Delta P\text{ (L. C.) corrected}\end{array}\right\} = 2\,\Delta\varphi - (\rho + \rho')\,k$$

The results of all the years combined in one set of equations, and arranged in convenient groups following the order of polar distance, are these:

No.		π'	Calc.—obs.	Stars' name, or number of stars.
	$''$ $''$		$''$	
(1)	$2\ \Delta\phi - 143\,k + .69 = 0$	14	− .07	λ Ursæ Minoris.
(2)	$2\ \ \ \ - 143\ \ + .60$	29	− .16	σ Ursæ Minoris.
(3)	$2\ \ \ \ - 144\ \ + .75$	15	− .01	51 (H) Cephei.
(4)	$2\ \ \ \ - 144\ \ + 1.09$	22	+ .33	δ Ursæ Minoris.
(5)	$2\ \ \ \ - 150\ \ + 1.08$	10	+ .32	3
(6)	$2\ \ \ \ - 162\ \ + .66$	29	− .10	5
(7)	$2\ \ \ \ - 171\ \ + .85$	31	+ .09	7
(8)	$2\ \ \ \ - 185\ \ + .78$	13	+ .01	3
(9)	$2\ \ \ \ - 202\ \ + .30$	21	− .47	4
(10)	$2\ \ \ \ - 210\ \ + .72$	8	− .05	5
(11)	$2\ \ \ \ - 227\ \ + .91$	16	+ .14	4
(12)	$2\ \ \ \ - 236\ \ + .95$	5	+ .18	1
(13)	$2\ \ \ \ - 256\ \ + 1.23$	4	+ .45	2
(14)	$2\ \ \ \ - 320\ \ + .88$	4	+ .09	1

The coefficients of k are taken at their mean values for the mean temperature at Washington, those from (11) to (14) excepted, which are for lower culmination taken from the detailed observations. From the above equations result—

$$\Delta\varphi = -\,''.369 \pm ''.105\,;\ \text{or}\ -\,''.38 + 86''.9\,k$$
$$k = +\ .00014 \pm .00119$$

$$\{\text{Bessel's refractions}\} \times .99986 = \text{Washington.}$$

The probable error of k is thus nearly 10 times the quantity itself, and as the change in refraction would be practically insignificant, no use is made of it. The probable error of $\Delta\varphi$ is with respect to the uncertainty of k. Assuming k to be without error the probable error of $\Delta\varphi$ becomes $\pm\,''.03$. To get the deviations from $\Delta\varphi$ the numbers in column "Calc. — obs." must be divided by 2. Excluding all observations where $Z > 75°$, the results of separate years, for latitude are:

	″ ″
1866	− .46 ± .08
1867	− .26 ± .06
1868	− .46 ± .06
1869	− .22 ± .12
Mean by weights	− .37

The differences are not much greater than the probable errors would lead us to expect, especially when we consider the uncertainty of ΔZ for each year.

The adopted latitude, 38° 53′ 38″.43, is more than 0″.8 less than that found in 1845,* with the mural circle, and ″.35 less than the result with the same instrument in 1861–2–3–4.† The difference between the earliest and latest determination is apparently greater than the sum of any probable instrumental errors in the two series. If the flexure from opposing collimators had been adopted, the seconds of latitude would have been 38″.66 very nearly. If, on the other hand, we take the results of comparison of Me 68 with Wn 68, and suppose, accordingly, that the refractions of the latter ought to be multiplied by .9953 the seconds of latitude are 38″.83; leaving a difference not accounted for of ″.42; and this, too, under the extreme supposition that the refractions of 1845 are correct, while the same refractions for 1868 need to be multiplied by .9953.

Combining with table (A) the correction + ″.37, for $- \Delta\varphi$ already determined, we arrive at the following definitive correction to P and ΔP:

		″ ″	
(B)	1866	− .41 − .95 sin (312.5 + P)	
	1867	+ .45 + .69 sin (252.6 + P) +	{ − ″.34 to nadir values of P and ΔP. }
	1868	+ .08 + .69 sin (5.2 + P) +	{ Irregular corrections for error of zenith points. See p. 47. }
	1869	+ .81 + .69 sin (252.6 + P)	

Column (B) of the subjoined table is constructed from these. In column "Final" are found the systematic corrections necessary to reduce the *North Polar Distances*, after they are first corrected for division error and error of certain zenith points, to the Normal System of this paper. It is formed by subtracting from (B) the *declination* correction of Wn 68, taken from Table IX.

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*Appendix to Washington Astronomical Observations for 1845.
†Appendix to Washington Astronomical Observations for 1864.

Wn 66–*Wn* 69. *Table of corrections to Polar Distances by direct observation.**

	1866.		1867.		1868.		1869.	
P	(*B*)	Final.	(*B*)	Final.	(*B*)	Final.	(*B*)	Final.
°	″	″	″	″	″	″	″	″
335	+ .50	+ .70	— .05	+ .15	— .15	+ .05	+ .30	+ .50
340	+ .47	+ .62	— .09	+ .06	— .10	+ .05	+ .26	+ .41
345	+ .43	+ .53	— .13	— .03	— .04	+ .06	+ .23	+ .33
350	+ .39	+ .44	— .16	— .11	+ .02	+ .07	+ .20	+ .25
355	+ .34	+ .36	— .18	— .16	+ .03	+ .10	+ .17	+ .19
360	+ .29	+ .29	— .20	— .20	+ .14	+ .14	+ .15	+ .15
5	+ .23	+ .21	— .21	— .23	+ .20	+ .18	+ .14	+ .12
10	+ .17	+ .12	— .23	— .28	+ .26	+ .21	+ .13	+ .08
15	+ .10	00	— .23	— .33	+ .32	+ .22	+ .12	+ .02
20	+ .03	— .12	— .23	— .38	+ .37	+ .22	+ .12	— .03
25	— .04	— .24	— .23	— .43	+ .43	+ .23	+ .13	— .07
30	— .12	— .38	— .22	— .48	+ .48	+ .22	+ .14	— .12
35	— .20	— .52	— .20	— .52	+ .52	+ .20	+ .15	— .17
40	— .28	— .64	— .18	— .54	+ .57	+ .21	+ .17	— .19
45	— .37	— .76	— .16	— .55	+ .61	+ .22	+ .20	— .19
50	— .45	— .87	— .13	— .55	+ .64	+ .22	+ .22	— .20
55	— .53	— .98	— .09	— .54	+ .68	+ .23	+ .26	— .19
60	— .62	—1.09	— .05	— .52	+ .70	+ .23	+ .30	— .17
65	— .70	—1.20	— .01	— .51	+ .73	+ .23	+ .34	— .16
70	— .77	—1.30	+ .03	— .50	+ .74	+ .21	+ .39	— .14
75	— .85	—1.40	+ .08	— .47	+ .76	+ .21	+ .41	— .14
80	— .92	—1.49	+ .14	— .43	+ .76	+ .19	+ .49	— .08
85	— .99	—1.57	+ .19	— .39	+ .77	+ .19	+ .55	— .03
90	—1.05	—1.61	+ .25	— .34	+ .76	+ .19	+ .60	+ .01
95	—1.11	—1.70	+ .30	— .29	+ .76	+ .19	+ .66	+ .07
100	—1.16	—1.76	+ .36	— .24	+ .74	+ .14	+ .72	+ .12
105	—1.21	—1.84	+ .42	— .21	+ .72	+ .09	+ .78	+ .15
110	—1.25	—1.95	+ .48	— .22	+ .70	00	+ .84	+ .14
115	—1.29	—2.09	+ .51	— .26	+ .67	— .13	+ .90	+ .10
120	—1.32	—2.25	+ .60	— .33	+ .64	— .29	+ .95	+ .03
125	—1.34	—2.43	+ .66	— .43	+ .60	— .49	+1.01	— .08

* An explanation of the difference between the corresponding numbers contained in columns "(B)" and "Final" is suggested in the co uparisou of Washington and Melbourne polar distances. (See pp. 66 to 68.)

With the corrections in column (*B*), and the table of weights, on p. 53 the following catalogue is constructed, which appears to require no explanation, except that the definitive declinations converted from *N. P. D.* are first given, followed by their respective weights; and after these the seconds of declination converted in like manner for separate years:

Wn 68——Catalogue.

Star's name.	δ 1868.0.	π′	1866.		1867.		1868.		1869.	
			δ	π′	δ	π′	δ	π′	δ	π′
	° ′ ″		″		″		″		″	
α Andromedæ	+ 28 21 41.36	44	41.6	13	41.4	12	41.7	10	40.7	9
γ Pegasi	+ 14 26 57.84	45	58.4	12	58.0	14	56.9	10	57.9	9
α Cassiopeæ	+ 55 48 45.69	23	45.9	6	45.9	8	45.6	7	44.6	2
β Ceti	− 18 42 42.44	34	42.1	11	42.2	12	43.1	9	42.9	2
21 Cassiopeæ	+ 74 15 57.51	38	57.6	7	56.2	3	57.5	5	......	....
21 Cassiopeæ, S. P	....	......	58.3	6	57.3	8	57.1	5	58.1	4
ε Piscium	+ 7 10 42.72	35	43.0	14	42.6	12	42.4	9	......	....
ν Piscium	+ 26 34 08.94	7	......	....	08.9	7	......	....	......	....
α Ursæ Minoris	+ 88 36 20.33	112	20.7	15	20.2	15	20.2	14	19.9	12
α Ursæ Minoris S. P.	....	......	20.4	15	20.3	15	20.2	14	20.7	12
θ Ceti	− 8 51 55.48	28	55.6	10	55.4	10	55.4	8	......	....
A Cassiopeæ	+ 69 35 02.07	3	......	....	......	....	02.1	3	......	....
η Piscium	+ 14 39 51.18	39	51.3	13	50.7	14	51.3	10	52.6	2
ο Piscium	+ 8 29 31.44	37	32.3	11	30.9	13	31.2	10	31.5	3
β Arietis	+ 20 09 41.09	41	41.4	14	40.3	13	41.2	9	42.0	5
50 Cassiopeæ	+ 71 46 49.78	31	50.6	8	49.1	3	51.0	2	49.5	2
50 Cassiopeæ, S. P.	....	......	48.6	4	49.9	5	49.4	5	49.5	2
α Arietis	+ 22 50 12.29	47	12.5	14	12.1	14	12.1	9	12.5	10
ξ^1 Ceti	+ 8 13 33.38	32	33.9	8	33.3	12	33.3	9	33.0	3
ι Cassiopeæ	+ 66 43 22.85	17	23.4	6	22.2	3	22.6	6	23.0	2
γ Ceti	+ 2 40 39.92	31	40.0	10	40.1	12	39.9	7	38.8	2
τ Persei	+ 52 13 12.48	3	......	...	12.5	3	......	....	......	....
α Ceti	+ 3 34 12.14	38	12.7	12	12.2	13	12.2	8	10.5	5
Cephei (48 H)	+ 77 14 42.20	41	41.8	7	42.0	5	42.5	7	......	....
Cephei (48 H.) S. P.	....	......	42.8	7	42.1	7	41.5	6	43.5	2
ζ Arietis	+ 20 33 11.28	27	11.6	8	11.0	10	11.3	7	11.3	2
α Persei	+ 49 23 18.20	24	18.5	10	18.4	7	17.5	5	17.6	2
δ Persei	+ 47 21 43.94	8	......	....	......	....	43.3	6	46.0	2
η Tauri	+ 23 41 39.92	36	40.1	10	40.1	12	39.9	9	39.1	5
ζ Persei	+ 31 29 19.16	18	18.8	6	17.9	5	20.4	7	......	....
γ^1 Eridani	− 13 53 10.10	25	10.5	9	10.3	7	09.6	7	09.1	2
γ Tauri	+ 15 18 22.20	30	21.8	9	22.1	12	22.5	7	23.7	2
ε Tauri	+ 18 53 05.69	32	05.7	7	05.7	2	05.9	13	05.4	10
α Tauri	+ 16 14 28.12	45	28.1	13	28.2	14	28.4	10	27.7	8
α Camelopardalis	+ 66 06 49.30	19	49.4	7	49.0	5	49.4	5	49.5	2
ι Aurigæ	+ 32 57 13.72	36	13.8	9	13.8	12	14.1	8	13.0	7
11 Orionis	+ 15 13 02.29	26	02.9	9	02.0	9	01.6	6	03.0	2
α Aurigæ	+ 45 51 36.35	16	36.5	4	36.0	5	35.8	5	38.3	2
β Orionis	− 8 21 23.54	35	23.4	13	23.8	12	22.9	7	24.4	3
β Tauri	+ 28 29 33.98	44	34.2	13	34.0	13	33.9	11	33.7	7
Groombridge 966	+ 74 56 58.71	5	......	....	......	....	57.7	3	......	....
Groombridge 966, S. P.	....	......	......	....	......	....	60.3	2	......	....
δ Orionis	− 0 23 58.43	34	58.6	10	58.0	11	58.3	7	59.0	6
α Leporis	− 17 55 00.93	2	......	....	......	....	......	....	00.9	2
ε Orionis	− 1 17 20.12	36	19.7	12	20.3	11	20.4	8	20.1	5
α Columbæ	− 34 08 47.58	8	47.8	1	......	....	48.0	4	47.0	3
α Orionis	+ 7 22 46.37	42	46.6	14	46.3	13	46.6	7	45.9	8

W n 68—*Catalogue*—Continued.

Star's name.	δ 1868.0.	π'	1866. δ	1866. π'	1867. δ	1867. π'	1868. δ	1868. π'	1869. δ	1869. π'
	° ′ ″		″		″		″		″	
Camelopardalis (22 H)	+ 69 21 38.95	12	......	....	......	....	39.7	6	38.2	6
μ Geminorum	+ 22 34 41.69	26	41.7	10	41.6	8	41.6	4	41.9	4
γ Geminorum	+ 16 30 32.63	46	32.7	14	32.3	13	33.0	8	32.7	11
Cephei (51 H)	+ 87 14 28.83	68	29.0	12	28.5	12	29.4	7	28.4	7
Cephei (51 H.) S. P	....	......	28.8	12	29.4	8	28.5	10	......	....
ε Canis Majoris	− 28 47 40.55	32	40.3	10	40.3	9	41.2	5	40.7	8
δ Canis Majoris	− 26 11 08.42	15	07.8	7	......	....	08.9	7	09.2	1
λ Geminorum	− 16 46 30.87	3	30.9	3	......	....	......	....	......	....
δ Geminorum	+ 22 13 20.62	42	20.7	11	20.4	12	20.2	9	21.1	10
Pi. VII 67	+ 68 43 50.22	8	......	....	51.4	2	49.8	6	......	....
α² Geminorum	+ 32 10 29.41	41	23.9	11	29.7	11	29.4	11	29.8	8
β Geminorum	+ 28 20 32.07	48	31.9	14	32.2	13	32.2	12	32.0	9
φ Geminorum	+ 27 06 16.71	35	16.4	8	16.2	9	17.3	8	17.0	10
Ursæ Majoris (3 H)	+ 68 51 30.47	2	......	....	......	....	......	....	30.5	2
15 Argus	− 23 55 32.28	30	32.9	4	32.4	11	31.5	6	32.3	9
ε Hydræ	+ 6 54 03.44	39	03.3	7	03.7	12	03.5	9	03.3	11
ι Ursæ Majoris	+ 48 33 27.60	23	27.7	4	28.1	5	27.4	8	27.4	6
σ² Ursæ Majoris	+ 67 40 02.77	21	02.8	3	02.9	8	02.8	4	02.6	6
κ Cancri	+ 11 11 50.66	37	50.0	7	50.9	10	50.7	10	50.9	10
α Lyncis	+ 34 56 55.34	8	......	....	55.3	8	......	....	......	....
Draconis (1 H)	+ 81 54 20.17	20	......	....	19.6	6	21.8	3	......	....
Draconis (1 H.) S. P	....	......	......	....	19.9	7	20.3	4	......	....
α Hydræ	− 8 05 17.06	39	17.2	10	16.6	13	17.4	9	17.3	7
24 Ursæ Majoris	+ 70 24 27.62	3	......	....	......	....	27.6	3	......	....
θ Ursæ Majoris	+ 52 16 36.96	5	......	....	37.0	5	......	....	......	....
ε Leonis	+ 24 22 49.38	36	49.4	11	49.3	13	48.4	3	49.8	9
μ Leonis	+ 26 37 37.42	32	38.2	8	37.4	10	38.0	4	36.6	10
α Leonis	+ 12 36 39.55	45	39.7	13	39.6	14	39.1	8	39.7	10
32 Ursæ Majoris	+ 65 45 54.91	10	......	....	......	....	55.0	4	54.8	6
γ¹ Leonis	+ 20 30 28.65	42	29.1	11	28.2	13	28.5	8	28.9	10
Draconis (9 H)	+ 76 23 29.48	32	29.1	1	29.4	5	29.9	4	29.3	6
Draconis (9 H.) S. P	....	......	......	....	29.8	7	29.3	6	......	....
ρ Leonis	+ 9 59 04.99	35	05.1	9	05.0	10	05.3	9	04.4	7
ι Leonis	+ 11 14 31.02	36	34.1	11	33.4	9	34.6	8	34.0	8
β Ursæ Majoris	+ 57 05 20.36	5	......	....	20.4	5	......	....	......	....
α Ursæ Majoris	+ 62 27 46.23	30	45.1	7	46.1	11	47.1	5	46.9	7
δ Leonis	+ 21 14 46.61	41	46.8	12	46.4	14	47.0	6	46.3	9
δ Crateris	− 14 03 53.33	29	53.2	6	53.4	11	52.3	5	54.2	7
τ Leonis	+ 3 34 57.95	31	57.5	8	58.3	11	59.5	3	57.5	9
λ Draconis	+ 70 03 33.15	28	32.6	7	33.3	10	34.0	6	32.7	5
υ Leonis	− 0 05 43.50	34	44.5	9	43.3	11	42.5	5	43.3	9
χ Ursæ Majoris	+ 48 31 39.10	3	......	....	39.1	3	......	....	......	....
β Leonis	+ 15 18 34.72	44	34.7	13	34.8	14	34.7	8	34.8	9
γ Ursæ Majoris	+ 54 25 42.87	31	42.8	7	42.5	11	43.6	7	42.7	6
ο Virginis	+ 9 27 57.92	35	58.0	10	57.6	11	58.4	6	57.8	8
Draconis (4 H)	+ 78 20 59.70	37	59.7	6	59.4	10	59.9	7	59.7	4
Draconis (4 H.) S. P	....	......	60.3	4	59.8	4	59.1	2	......	....
η Virginis	+ 0 04 00.19	36	59.6	11	60.3	12	61.4	5	60.2	8
β Corvi	− 22 39 59.66	33	59.7	11	59.6	9	59.4	5	59.9	8
κ Draconis	+ 70 30 58.53	14	58.7	2	58.2	5	58.8	4	58.7	3
Camelopardalis (32 H)	+ 84 07 50.03	27	51.6	4	49.4	9	50.5	5	49.9	3
Camelopardalis (32 H.) S. P	....	......	......	....	......	....	49.6	6	......	....
α Canum Venaticorum	+ 39 01 54.03	46	54.1	13	54.0	14	53.8	12	54.0	7
θ Virginis	− 4 50 01.45	34	01.3	9	01.8	10	01.3	6	01.3	9

Wn 68.—*Catalogue*—Continued.

Star's name.	δ 1868.0.	π′	1866. δ	1866. π′	1867. δ	1867. π′	1868. δ	1868. π′	1869. δ	1869. π′
	° ′ ″		″		″		″		″	
α Virginis	— 10 28 17.23	48	17.4	14	17.5	14	16.7	11	17.1	9
ζ¹ Ursæ Majoris	+ 55 36 56.49	7	.....	....	56.5	7	.....	....	.....	....
ζ Virginis	+ 0 04 47.43	42	47.2	13	48.6	12	47.0	10	46.6	7
81 Ursæ Majoris	+ 56 01 31.96	5	.....	....	32.0	5	.....	....	.....	....
B. A. C. 4596	+ 41 45 05.79	8	.....	....	05.8	8	.....	....	.....	....
η Bootis	+ 19 03 37.23	44	37.0	14	37.1	13	37.6	10	37.5	7
η Ursæ Majoris	+ 49 58 22.25	32	22.7	8	22.0	12	23.0	7	21.3	5
11 Bootis	+ 28 01 31.09	7	.....	....	31.1	7	.....	....	.....	....
α Draconis	+ 65 00 26.27	26	25.6	6	26.6	9	26.9	4	26.0	7
d Bootis	+ 25 43 04.59	7	.....	....	04.6	7	.....	....	.....	....
α Bootis	+ 19 52 14.46	48	14.8	14	14.5	13	14.3	12	14.1	9
θ Bootis	+ 52 27 41.90	22	41.6	6	42.1	9	41.4	4	42.7	3
γ Bootis	+ 38 53 13.10	5	.....	....	13.1	5	.....	....	.....	....
5 Ursæ Minoris	+ 76 16 57.98	38	57.1	8	58.3	9	59.3	7	56.8	6
5 Ursæ Minoris, S. P.	.....	.....	.....	....	58.7	2	58.4	6	.....	....
B. A. C. 4827	+ 47 21 56.77	8	.....	....	56.8	8	.....	....	.....	....
ε¹ Bootis	+ 27 37 55.24	45	55.3	12	55.2	14	55.7	10	54.6	9
α² Libræ	— 15 29 29.70	38	29.8	11	29.6	11	29.6	8	29.8	8
B. A. C. 4897	+ 38 21 22.96	7	.....	....	23.0	7	.....	....	.....	....
β Ursæ Minoris	+ 74 41 41.58	48	42.4	8	41.6	11	41.8	7	41.4	8
β Ursæ Minoris, S. P.	.....	.....	40.8	5	40.9	5	41.7	4	.....	....
ι Bootis { 1st	(04.72)	(5)	.....	....	(04.7)	(5)	.....	....	.....	....
ι Bootis { 2d	+ 41 50 09.02	8	.....	....	09.0	8	.....	....	.....	....
β Bootis	+ 40 54 44.85	24	.....	....	45.1	10	45.2	7	44.1	7
β Libræ	— 8 53 38.79	40	38.3	12	39.7	12	38.3	8	38.7	8
μ¹ Bootis	+ 37 50 29.36	34	29.2	10	29.8	11	29.4	7	28.8	6
γ² Ursæ Minoris	+ 72 18 13.48	22	14.8	6	13.4	5	13.6	6	11.7	3
γ² Ursæ Minoris, S. P.	.....	.....	.....	....	.....	....	12.2	2	.....	....
α Coronæ Borealis	+ 27 09 37.30	46	37.5	14	36.9	14	37.9	9	37.1	9
B. A. C. 5157	+ 43 36 20.97	7	.....	....	21.0	7	.....	....	.....	....
φ Bootis	+ 40 47 04.51	7	.....	....	04.5	7	.....	....	.....	....
γ Coronæ Borealis	+ 26 42 54.00	5	.....	....	54.0	5	.....	....	.....	....
α Serpentis	+ 6 50 33.37	43	33.5	12	33.5	13	32.2	10	33.1	8
ε Serpentis	+ 4 52 36.73	35	36.5	9	36.8	12	36.9	8	36.8	6
ζ Ursæ Minoris	+ 78 11 57.04	27	57.8	8	56.9	5	56.3	5	56.4	4
ζ Ursæ Minoris, S. P.	.....	.....	.....	....	.....	....	57.3	5	.....	....
ε Coronæ Borealis	+ 27 15 41.54	4	.....	....	.....	....	.....	....	41.5	4
δ Scorpii	— 22 14 37.14	20	37.9	6	37.1	9	36.2	3	36.4	2
B. A. C. 5313	+ 55 07 25.31	8	.....	....	25.3	8	.....	....	.....	....
β¹ Scorpii	— 19 26 30.28	32	31.2	10	28.9	11	30.7	6	30.9	5
Groombridge 2320	+ 68 09 29.21	3	.....	....	.....	....	.....	....	29.2	3
δ Ophiuchi	— 3 21 08.86	36	08.9	10	08.5	12	08.9	9	09.5	6
16 Herculis	+ 19 08 35.21	7	.....	....	35.2	7	.....	....	.....	....
τ Herculis	+ 46 37 41.02	33	41.1	10	44.4	10	43.8	6	43.6	7
23 Herculis	+ 32 [illegible] 33.47	7	.....	....	33.5	7	.....	....	.....	....
α Scorpii	— 26 08 11.36	32	11.5	10	11.0	10	11.8	8	11.0	4
η Draconis	+ 61 48 48.77	14	.....	....	49.0	8	48.5	6	.....	....
15 Draconis (A)	+ 69 03 12.81	17	13.6	4	12.4	5	12.5	6	13.3	2
ζ Ophiuchi	— 10 17 50.81	30	50.7	10	50.9	10	50.7	6	51.2	4
η Herculis	+ 39 10 28.74	29	28.8	10	29.5	11	27.5	6	28.1	2
κ Ophiuchi	+ 9 31 56.06	37	55.8	10	57.0	11	55.7	9	55.5	7
δ Herculis	+ 33 45 39.36	9	.....	....	.....	....	39.0	7	40.5	2
ε Ursæ Minoris	+ 82 14 59.46	36	59.6	11	59.3	10	59.3	8	59.2	3
ε Ursæ Minoris, S. P.	.....	.....	.....	....	.....	....	59.9	4	.....	....

Wn 68——*Catalogue*—Continued.

Star's name.	δ 1868.0.	π′	1866. δ	1866. π′	1867. δ	1867. π′	1868. δ	1868. π′	1869. δ	1869. π′
	° ′ ″		″		″		″		″	
B. A. C. 5801	+ 55 56 11.70	5	......	....	11.7	5	......	....	......	....
α^1 Herculis	+ 14 32 34.23	38	34.1	13	33.8	12	34.6	9	35.0	4
ε Herculis	+ 37 25 52.74	7	......	....	52.7	7	......	....	......	....
B. A. C. 5874	+ 40 06 21.28	5	......	....	21.3	5	......	....	......	....
44 Ophiuchi	— 24 03 03.52	30	03.9	10	03.6	10	03.7	7	01.5	3
x Herculis	+ 48 22 19.83	7	......	....	19.8	7	......	....	......	....
β Draconis	+ 52 23 59.44	4	......	....	......	....	59.4	4	......	....
α Ophiuchi	+ 12 39 29.50	41	28.8	13	29.6	14	30.4	9	29.4	5
ω Draconis	+ 68 49 07.42	23	07.0	8	07.8	8	07.6	7	......	....
μ Herculis	+ 27 47 58.50	38	58.5	13	58.3	12	58.8	7	58.7	6
ψ^1 Draconis	+ 72 12 45.74	15	......	....	46.0	9	45.3	6	......	....
z Herculis	+ 48 25 51.15	8	......	....	51.1	8	......	....	......	....
γ Draconis	+ 51 30 19.41	27	19.1	8	19.4	10	19.7	9	......	....
γ^2 Sagittarii	— 30 25 21.12	9	20.9	5	......	....	21.2	4	......	....
μ^1 Sagittarii	— 21 05 25.63	25	26.3	7	25.0	7	26.0	9	24.7	3
δ Ursæ Minoris	+ 86 36 18.64	90	18.8	14	19.1	14	18.5	12	18.9	4
δ Ursæ Minoris, S. P	....	......	18.2	14	18.7	13	18.6	9	18.5	10
η Serpentis	— 2 55 50.61	18	51.4	7	50.1	6	50.3	5	......	....
1 Aquilæ	— 8 20 01.75	30	01.5	10	01.8	9	01.9	9	02.1	2
α Lyræ	+ 38 39 41.05	49	44.4	15	43.9	14	43.6	11	44.2	9
110 Herculis	+ 20 25 18.77	7	......	....	18.8	7	......	....	......	....
β Lyræ	+ 33 12 39.63	34	39.6	11	39.9	10	39.3	7	39.5	6
σ Sagittarii	— 26 27 27.97	22	27.8	7	28.0	8	28.1	7	......	....
50 Draconis	+ 75 16 36.67	27	36.3	8	36.6	8	37.4	5	......	....
50 Draconis, S. P	....	......	......	....	......	....	36.5	5	36.9	1
ζ Aquilæ	+ 13 40 09.68	31	09.7	9	09.8	11	10.0	9	07.7	2
17 Lyræ	+ 32 17 42.44	7	......	....	42.4	7	......	....	......	....
55 Draconis	+ 65 45 27.66	8	......	....	27.7	8	......	....	......	....
d Sagittarii	— 19 11 06.82	7	......	....	......	....	06.8	7	......	....
δ Draconis	+ 67 25 45.74	23	45.2	7	46.0	9	45.3	5	47.7	2
τ Draconis	+ 73 06 34.66	11	......	....	34.5	5	35.4	4	......	....
τ Draconis, SP	....	......	......	....	......	....	......	....	33.6	2
δ Aquilæ	+ 2 51 13.44	28	13.7	8	13.5	13	13.1	7	......	....
δ Cygni	+ 34 10 25.39	7	......	....	25.4	7	......	....	......	....
κ Aquilæ	— 7 19 07.38	29	07.2	9	07.2	10	07.7	10	......	....
B. A. C. 6748	+ 54 40 54.77	7	......	....	54.8	7	......	....	......	....
γ Aquilæ	+ 10 17 36.26	41	36.2	11	36.3	13	37.0	10	35.2	7
α Aquilæ	+ 8 31 17.88	42	18.1	13	17.5	13	18.7	11	16.4	5
ε Draconis	+ 69 55 53.81	14	......	....	54.1	8	53.4	6	......	....
β Aquilæ	+ 6 04 44.04	32	44.4	9	41.2	12	43.8	9	42.6	2
λ Ursæ Minoris	+ 88 54 44.93	72	44.6	11	45.1	13	44.9	11	......	....
λ Ursæ Minoris, S. P	....	......	45.2	8	44.9	7	44.8	11	45.1	11
τ Aquilæ	+ 6 54 26.07	25	26.0	9	26.6	8	25.6	8	......	....
α^2 Capricorni	— 12 57 06.64	33	06.9	12	06.7	11	06.3	10	......	....
κ Cephei	+ 77 18 41.85	25	......	....	45.2	5	44.8	7	......	....
κ Cephei, S. P	....	......	......	....	41.9	7	44.6	3	44.5	3
π Capricorni	— 18 38 32.68	28	32.9	9	32.1	10	33.2	9	......	....
40 Cygni	+ 38 00 28.51	8	......	....	28.5	8	......	....	......	....
42 Cygni	+ 36 00 55.14	7	......	....	55.1	7	......	....	......	....
ε Delphini	+ 10 51 22.68	28	22.3	8	23.3	11	22.3	9	......	....
α Cygni	+ 44 48 34.59	35	34.9	12	31.9	10	31.0	9	34.4	4
μ Aquarii	— 9 28 36.60	27	36.4	8	37.1	9	36.3	10	......	....
ν Cygni	+ 40 39 35.75	30	35.4	11	36.4	12	35.2	7	......	....
61^1 Cygni	+ 38 06 05.91	30	05.8	11	06.2	12	05.6	7	......	....
ζ Cygni	+ 29 41 11.90	38	11.9	11	12.2	12	11.7	9	11.5	6

Wn 68——*Catalogue*—Continued.

Star's name.	δ 1868.0.	π′	1866.		1867.		1868.		1869.	
			δ	π′	δ	π′	δ	π′	δ	π′
	° ′ ″		″		″		″		″	
α Cephei	+ 62 01 36.47	35	36.5	11	37.0	11	34.9	7	37.2	6
1 Pegasi	+ 19 14 27.54	27	27.8	8	27.3	11	27.5	8	......	....
β Aquarii	— 6 09 01.83	33	02.0	10	01.4	12	02.2	6	02.0	5
β Cephei	+ 69 58 53.66	22	53.7	8	53.6	7	53.5	4	53.9	3
72 Cygni	+ 57 56 35.91	7	......	....	35.9	7	......	....	......	....
ξ Aquarii	— 8 26 41.59	22	41.9	7	41.1	7	41.8	8	....	....
ε Pegasi	+ 9 16 15.44	41	15.6	10	15.6	13	15.1	9	15.3	9
11 Cephei	+ 70 42 14.27	20	14.4	8	14.1	7	14.3	5	....	....
μ Capricorni	— 11 10 19.12	27	19.1	8	18.4	12	20.3	7	....	....
79 Draconis	+ 73 04 40.94	25	......	....	41.2	8	40.2	8	......	....
79 Draconis, S. P.	....	......	......	....	42.2	5	40.4	3	40.3	1
α Aquarii	— 0 57 36.59	26	36.9	11	35.8	11	37.0	9	36.8	5
θ Aquarii	— 8 26 23.01	30	23.2	10	22.5	12	23.5	8	......	....
π Aquarii	+ 0 42 30.17	28	30.6	9	30.2	12	29.6	7	......	....
38 Pegasi	+ 31 53 51.40	6	51.4	6	......	....	......	....	......	...
α Lacertæ	+ 49 36 15.38	3	15.4	3	......	....	......	....	......	....
η Aquarii	— 0 47 50.03	30	49.9	11	49.7	10	50.7	7	50.2	2
Cephei (226 B)	+ 75 32 47.16	7	......	....	......	...	47.1	6	......	....
Cephei. (226 B), S. P.	....	......	......	....	......	....	47.3	1	......	....
ζ Pegasi	+ 10 08 34.33	29	34.0	10	34.0	10	35.3	7	34.1	2
ι Cephei	+ 65 30 24.08	17	23.6	8	24.1	3	24.6	6	......	....
λ Aquarii	— 8 16 53.20	24	53.6	7	52.5	8	53.5	9	......	....
α Piscis Australis	— 30 19 16.74	21	16.8	7	16.2	7	17.2	7	......	....
α Pegasi	+ 14 29 43.51	43	43.7	12	43.1	13	43.1	9	44.0	9
3 Andromedæ	+ 49 20 05.40	7	05.2	4	05.6	3	......	....	......	....
ο Cephei	+ 67 23 22.58	18	.....	....	23.0	9	22.2	9	......	....
θ Piscium	+ 5 39 14.32	28	13.9	9	14.6	10	14.5	9	......	....
ι Piscium	— 4 54 39.27	30	39.2	9	39.6	10	38.5	9	41.4	2
γ Cephei	+ 76 53 44.68	32	45.3	9	44.8	5	44.5	5	......	....
γ Cephei, S. P.	....	......	41.9	2	44.8	8	44.2	3	......	....
Groombridge 4163.	+ 73 40 32.42	7	......	....	......	....	32.4	7	......	....
ω Piscium	+ 6 07 56.46	30	56.8	9	56.1	12	56.6	9	......	....

The value of "*C*" in "Details of Corrections," etc., is computed from these declinations; and in column "obs." the values of π' are given instead of the number of observations.

A comparison of this catalogue with the polar distances of the Melbourne General Catalogue (Me 68) may not be devoid of interest. The mean epochs of observation in each are nearly identical, so that erroneous proper motions will be practically without influence in the comparison. In the comparison* by E. J. Stone, of Greenwich and Melbourne (to which reference is elsewhere made), the refraction at the latter place is supposed to be different for equal zenith distances north and south. From circumpolar stars observed at Melbourne, with a correction of $+''.15$ to ς, it was found that the adopted refractions should be multiplied by .99628. From comparisons of stars common to Greenwich and Melbourne the latter quantity was found to be .99086. These results were adopted in formation of Me 68. Though possible on *a priori* grounds, this hypothesis is open to serious objections, when we consider the difficulty

* E. J. Stone, Month. Not., 28, p. 27

of determining $(1-k)$ independently, at the latitude of Melbourne, and the small weight of the actual determination, with a circle which was throughout used in a single position. Before comparing I have, therefore, reduced the polar distances of Me 68 to those which would have resulted from circumpolar stars alone. This I have accomplished by the application of the correction $-.00542\,\rho$ to all polar distances less than 127° 50′. The individual weights are so uniform that to each comparison I have assigned weight 1, these excepted,— α Aurigæ, α Cygni, δ Scorpii, σ Sagittarii, and α Columbæ, which received weight 0.5; and α Persei and ι Ursæ Majoris, which were rejected for obvious reasons.

If ρ be the computed and $(1-k)\,\rho$ the required mean refractions at Washington for a given star, ρ' and $(1-k')\,\rho'$, the corresponding quantities for the same star at Melbourne, and if $-n = P\,(\mathrm{Wn}) - P\,(\mathrm{Me})$, we shall have from each comparison (n), π' being the weight:

$$\left\{\rho + 72.''\right)k + (\rho' + 75.'')\,k' + n = 0\right\}\sqrt{\pi'}$$

The two catalogues furnish 87 such equations which, though separately formed, are combined for convenience of solution in the following groups:

				Residuals after substitution.
″	″	″	π'	″
+ 65 k	+ 538 k'	− 3. 31 = 0	1	− 1. 06
72	314	− . 96	3	+ . 51
79	234	− . 73	4	+ . 49
83	205	− 1. 01	6	+ . 12
90	175	− 1. 02	9	+ . 03
95	159	− 1. 60	5	− . 58
100	148	− 1. 21	8	− . 21
105	138	− 1. 15	6	− . 16
109	132	− . 98	8	+ . 01
117	122	− . 80	7	+ . 18
124	115	− 1. 05	6	− . 05
136	107	− . 87	6	+ . 15
151	100	− 1. 13	5	− . 06
165	95	− . 72	2	+ . 40
176	91	− 1. 00	2. 5	+ . 15
191	88	− 1. 29	3. 5	− . 08
219	84	− 1. 47	2	− . 14
260	79	− 1. 79	0. 5	− . 29

The solution gives $k = +.00468 \pm .00061$

$k' = +.00362 \pm .00045$

Probable error (when $\pi' = 1$) $= \pm\ ''.41$

The refractions at Melbourne are already (as assumed), Bessel's (*Tab. Reg.*) × .99628. They now become 0.99628 × (1 − .00362), or .99267 × (Bessel's). Those at Washington become .99532 × (Bessel's). Admitting that ε, for Melbourne is only ± .20, the probable error of an average single P, (when $\pi' = 1$) for Me 68 is roughly $\pm\ ''.37$.

Judging from this, the hypothesis adopted to explain the differences Wn 68 — Me 68 is not repugnant to the facts, especially when we bear in mind that the Melbourne circle has remained in an invariable position during the period for which the comparison holds good. But, on the other hand, this very circumstance throws a doubt upon the whole discussion; for we can form but an imperfect idea of the degree to which our work may be affected by errors in adopted division and flexure correction, and by uncorrected flexure, such as has been suspected in the Cape circle. (Month. Not., vol. 33, p. 69.)

I have formed the following table of—

Corrections to polar distances of Wn 68 and Me 68.

P.	Wn 68.		Me 68.		P	Wn 68.		Me 68.	
	I.	II.	III.	IV.		I.	II.	III.	IV.
°	"	"	"	"	°	"	"	"	"
0	00	00	....	....	90	— .56	— .59	+ .19	+ .16
5	— .06	— .02	....	....	95	— .60	— .59	+ .20	+ .18
10	— .10	— .05	....	....	100	— .65	— .60	+ .22	+ .21
15	— .14	— .10	....	....	105	— .71	— .63	+ .23	+ .26
20	— .17	— .15	....	....	110	— .79	— .70	+ .24	+ .30
25	— .21	— .20	....	....	115	— .89	— .80	+ .25	+ .32
30	— .23	— .26	....	....	120	—1.04	— .93	+ .27	+ .36
35	— .26	— .32	....	....	125	—1.27	—1.09	+ .27	+ .38
40	— .29	— .36	....	....	130	....	....	+ .26	+ .40
45	— .31	— .39	....	....	135	....	....	+ .25	
50	— .33	— .42	— .20	— .67	140	....	....	+ .23	+ .34
55	— .36	— .45	— .06	— .48	145	....	....	+ .21	
60	— .38	— .47	+ .02	— .11	150	....	....	+ .19	+ .22
65	— .40	— .50	+ .07	+ .08	155	....	....	+ .16	
70	— .43	— .53	+ .11	+ .15	160	....	....	+ .14	+ .12
75	— .46	— .55	+ .13	+ .15	165	....	....	+ .11	
80	— .49	— .57	+ .16	+ .15	170	....	....	+ .08	+ .05
85	— .51	— .58	+ .17	+ .15	175	....	....	+ .04	
90	— .56	— .59	+ .19	+ .16	180	....	....	.00	.00

Column I. exhibits the results of the correction $(\rho + 72'') \times - .00468$ for Wn 68. Column II., for purposes of comparison, gives the final correction of Wn 68 to Normal System. Column III. shows the correction just established for Me 68 by comparison with Washington. For stars of north polar distance less than 127° 50′, this correction is $''.27 - .0018\rho$; for the remainder it is, $(\rho + 75'') \times .00362$. These corrections are applicable to the results as printed in the "General Catalogue." Column IV. gives the adopted correction of Me 68 to Normal System. The agreement between I. and II., as well as between III. and IV., is such as to strengthen the belief that a great part of the difference Wn 68 — Me 68 is due to error in the adopted refractions at each observatory.

Wn 72. The mean corrections to polar distance of American Ephemeris, or simply polar distance, with the correction for "Div. Flex., etc.," are taken as printed from sections entitled "Corrections to the Star Positions of the American Ephemeris," etc., and "Mean Places of Miscellaneous Stars," etc., without change for stars of polar distance less than 46°. From polar distance 56° southward certain corrections, which are included in the reductions on account of discordance between direct and reflected observations, are rejected. The effect of this is to apply the following corrections to polar distances, or what is the same thing, to the correction for "Div. Flex, etc.," before adding the latter to the polar distance:—

Year.	Correction.
	″
1870	+ .31
1871-2	00
1873	— .42
1874	— .82

Between the limits 56° and 46° (P. D.) these corrections are interpolated so as to become zero at the northern limit. By some accident the correction —″.82 for 1874 was neglected for stars between polar distances 102° and 125°. The effect of this has been, quite insignificant, however, since the preliminary systematic corrections depend chiefly on residuals of stars whose polar distance is less than 102°.

Proper motion has not been applied in the reductions of "Miscellaneous Stars." These, I have corrected accordingly.

As the results of separate years so taken exhibit considerable systematic discordances, for use in the discussion of systematic corrections I have pursued a course entirely analogous to that explained under Re 66 and 72. Following is a list of corrections to assumed places, thus resulting:—

	″		″		″
α Andromedæ	— .19	β Tauri	— .26	53 Leonis	— .61
γ Pegasi	— .43	δ Orionis	+ .20	α Ursæ Majoris	+1.00
α Cassiopeæ	— .68	α Leporis	— .21	δ Leonis	— .20
β Ceti	— .41	ε Orionis	+ .21	δ Crateris	— .17
ε Piscium	— .46	α Columbæ	— .52	τ Leonis	— .31
α Ursæ Minoris	+ .02	α Orionis	— .12	λ Draconis	+2.08
θ Ceti	— .32	η Geminorum	+1.23	υ Leonis	— .27
η Piscium	—1.14	μ Geminorum	— .41	β Leonis	— .24
ο Piscium	— .35	γ Geminorum	— .51	γ Ursæ Majoris	+ .53
β Arietis	— .54	ε Canis Majoris	— .41	ο Virginis	— .49
50 Cassiopeæ	+1.60	δ Canis Majoris	—1.11	η Virginis	— .91
α Arietis	— .34	δ Geminorum	— .85	β Corvi	— .50
ξ Ceti	+ .18	β Geminorum	+ .04	κ Draconis	+1.38
ν Ceti	— .17	φ Geminorum	— .25	α Canum Ven	— .50
α Ceti	— .34	ρ Argus	—1.10	θ Virginis	— .55
α Persei	— .12	ε Hydræ	— .72	α Virginis	+ .13
δ Persei	+1.49	ι Ursæ Majoris	+ .10	ζ Virginis	—1.25
η Tauri	+ .12	σ^2 Ursæ Majoris	+1.84	η Ursæ Majoris	— .17
γ^1 Eridani	—1.04	κ Cancri	— .72	η Bootis	— .67
ε Tauri	— .04	α Hydræ	+ .41	α Draconis	+ .09
α Tauri	— .30	ε Leonis	+ .49	α Bootis	— .74
α Camelopardi	— .45	μ Leonis	— .50	θ Bootis	— .50
ι Aurigæ	— .56	α Leonis	+ .18	5 Ursæ Minoris	+1.35
α Aurigæ	— .12	γ^1 Leonis	— .94	ε Bootis	+ .27
β Orionis	+ .57	ρ Leonis	— .16	α^2 Libræ	— .67

	″		″		″
β Ursæ Minoris	+ .31	γ^2 Sagittarii.........	− .51	β Cephei	+ .53
β Bootis............	+ .13	μ^1 Sagittarii.........	− .68	ε Pegasi............	+ .21
β Libræ	− .34	δ Ursæ Minoris.....	+ .28	μ Capricorni.......	−1.05
μ Bootis............	− .67	η Serpentis.........	− .58	α Aquarii	+ .32
γ^2 Ursæ Minoris.....	− .77	α Lyræ.............	+ .29	θ Aurigæ...........	− .81
α Coronæ Borealis ..	− .19	β Lyræ.............	− .33	η Aquarii	+ .07
α Serpentis.........	− .21	σ Sagittarii.........	− .58	ζ Pegasi............	+ .18
ε Serpentis.........	− .76	ζ Aquilæ...........	− .02	ι Cephei	+ .27
ζ Ursæ Minoris	− .43	43 Sagittarii.........	−3.82	λ Aquarii	− .81
δ Scorpii	− .22	τ Draconis	+ .19	α Piscis Australis ..	− .28
β^1 Scorpii	− .18	δ Aquilæ...........	+ .31	α Pegasi.............	− .28
δ Ophiuchi.........	− .22	κ Aquilæ...........	−1.81	υ Cephei	+1.33
τ Herculis..........	− .51	γ Aquilæ...........	+ .09	γ Cephei	+1.17
α Scorpii	− .31	α Aquilæ...........	+ .55		
η Draconis	− .57	β Aquilæ...........	− .92		
η Herculis..........	−1.01	α^2 Capricorni........	− .11		
κ Ophiuchi.........	+ .23	κ Cephei	+1.57		
α Herculis..........	+ .81	π Capricorni.......	−1.55		
41 Ophiuchi.........	− .72	α Cygni.	+ .41		
β Draconis	+ .86	μ Aquarii	−1.19		
α Ophiuchi.........	+ .31	ν Cygni	+ .11		
μ Draconis	+ .73	61 Cygni............	+ .80		
μ Herculis..........	− .04	ξ Cygni............	− .45		
ψ^1 Draconis	− .46	α Cephei	+ .10		
γ Draconis	− .05	β Aquarii...........	+ .13		

Discussion of 3669 residuals of stars most frequently observed in the years 1871–'73 gives for the probable error of pointing:—

$$\varepsilon = \sqrt{.4554\,(\pm .0122) + .0415\,(\pm .0076)\tan^2 Z}.$$

The values tabulated according to zenith distance are these:—

Z	ε	Z	ε	Z	ε
°	″	°	″	°	″
0	.675	40	.696	60	.762
10	.676	45	.705	65	.804
20	.679	50	.717	70	.877
30	.685	55	.735	75	1.02

In the final reductions, separate systematic corrections have been deduced for each year. These are shown in Table IX. With these corrections and the following system of weights, the definitive values of $C_{//}$ (*vide* "Details of Corrections to Assumed Declinations") have been computed:—

Weights for combination of Wn 70–74.

Number of observations.	Weight.	Number of observations.	Weight.
1	1	8 to 11	5
2	2	12 to 16	6
3	2.5	17 to 27	7
4	3	28 to 51	8
5 to 7	4	52, or more	9

Section VI.

FIRST APPROXIMATION TO NORMAL SYSTEM.

It will be assumed that the catalogues to be used in the formation of the Normal System have received all the corrections which can be applied solely on the authority of the observations composing each of them. It will also be taken for granted that the correction furnished by a given catalogue to the assumed declination is of the form:—

$$\Delta\delta + \Delta\mu' \frac{T' - T}{100},$$

where $\Delta\delta$ is the correction of δ for a given epoch, T (T' being the mean epoch of each catalogue), and $\frac{\Delta\mu'}{100}$ the correction to the assumed annual variation. This course is only proper when the path of proper motion does not deviate sensibly from the arc of a great circle. That there is such deviation in the cases of Sirius and Procyon has been pretty well established by Dr. Auwers and others; but these stars are omitted in our catalogue. It is possible that variable proper motion may ultimately be found in the large majority of cases, but, a few binary systems excepted, the evidence of such variability at present appears to be wanting.

If now no discrepancies of a constant character were found to exist between the determinations of different observatories, nothing further would remain except to determine the relative weights, and by means of conditional equations, derive a correction for each assumed declination. On the other hand, granting the existence of these differences, we should be justified in adopting the same course, if the declination of every star in a given catalogue were made with equal weight, and if each of the stars under consideration had been determined in each of the authorities. This, however, is by no means the case, and in order to prevent the undue influence of large systematic errors in case of stars for whose declinations there are few authorities, it remains to be ascertained what corrections of a constant and periodic character can be applied to each catalogue. This can be accomplished by means of comparison with standard declinations, which are free from any such error.

From the nature of the case this standard can never be attained. The best that can be done is to consider the combined testimony of all independent determinations available for the purpose. To take any two determinations as standard, to the exclusion of all others, would be manifestly an error, for it would be assuming that the weight of these selected catalogues in comparison with the remainder is as infinity to zero, while all experience teaches that the best independent determinations of declination are subject to comparatively large errors.

There is, however, great difference in the quality of these so-called independent determinations, which vary from such special investigations as those of Kg 21, Dt 24, Ao 30, and Pa 45, where every precaution has been exercised to remedy the inevitable defects of instruments by variety in the circumstances of observation, and the utmost skill and rigor in the computations, with determination of the various elements of atmospheric refraction,—to those which assume their refractions from alien authority, which are made with non-reversible instruments, and with little attention to those details of observation and reduction so essential in the delicate problem of measuring absolute declination. It seems but reasonable to suppose that declinations of the former class are entitled to much greater confidence than those of the latter. This I have endeavored to express through the following system of weights to be employed in the preliminary discussion:—

Weights.

Authority.	Weight.	Authority.	Weight.	Authority.	Weight.
Kg 21	4	Kg 43	2	Gh 57	2
Gh 22	1	Eh 43	1	CGH 58	1
Dt 24	5	Gh 45	2	Wn 64	1
Ao 29	5	Pa 45	10	Gh 64	2
Sh 31	1	Re 45	1	Lu 67	8
CGH 33	2	Wn 47	1	Me 68	2
Ce 34	1	Ce 48	1	Wn 68	3
Eh 37	1	Gh 51	1	Re 68	2
Kg 38	2	Ps 53	3	Gh 70	2
Gh 39	2	So 55	1	Wn 72	1
Ce 40	1	Wn 56	1		

For the purpose proposed in this section, weight zero was assigned to all other catalogues. A few are excluded on the ground that, although independent, their weight is so small that they would merely encumber the computation with useless material.

These weights are not those which might seem to be required by comparisons with an approximate mean system, but are derived from an independent study of each catalogue, considered solely on the basis of internal evidence, with the assistance of such critical reviews as have been found conveniently accessible.

They result from careful study, but are necessarily arbitrary, and can only be regarded as mere expressions of opinion concerning the relative contribution made by each determination to the problem of finding an absolute system of declinations. It would therefore be superfluous, and at all events a tedious task to mention in detail the facts and arguments relied upon in support of each individual weight.

It will be sufficient to notice some of the principles adopted, which are of general application and tolerably definite and well established.

An investigation, founded on a series of observations for declination, will be regarded as independent, or absolute, in proportion to its freedom from any assumption whatever founded upon results from other series of observations, having in view the same or any other purpose. Practically, however, the determination of aberration, nutation, and precession can be left to special investigations. On the other hand, it may be doubted whether the constant of refraction or of atmospheric expansion is sensibly the same for different regions and climates; even if it were, in practical influence on observations, much would still depend upon local conditions and upon the character and situation of the meteorological instruments. Add to this the uncertainty of any existing single determination, and it will hardly be maintained that any series of declination observations is strictly independent, which does not include the determination of refraction constant and coefficient of expansion for atmospheric air, by proper methods and adequate means, from the observations themselves.

Every series of observations professing to give independent declinations should contain satisfactory evidence as to the character and amount of its instrumental corrections. In this connection the excellence of the mechanical construction of the instrument becomes an important consideration. Thus the work of the older instruments labors under disadvantage. It is plain that the greater the variety of circumstances under which an instrument may be used, other things being equal, the greater will be the freedom from constant errors due to instrumental causes. Therefore, results from instruments which admit of reversal have received the preference over others. Furthermore, when the relation of the circle to the telescope is so altered that its readings for a given zenith distance vary from year to year, this has been regarded as a decided advantage. This consideration becomes of less importance, however, with finely graduated instruments read by a large number of microscopes. The real advantage of reflection observations is supposed to be an open question. It has been ably debated by Bessel, Faye, Döllen, Airy, Kaiser, and others. In cases where the discordance $R - D$ is large, and not accounted for by special investigations of the instrument, this circumstance has been regarded as just cause for suspicion.

Where we have a long series of observations made at the same observatory, or with the same instrument, the weight of each group is considerably reduced from that which would have been assigned to it when standing as the sole representative of the particular series.

Thoroughness and skill in the methods of reduction were allowed to have an important bearing upon the decision of these weights.

Lastly, the degree of liability to fortuitous errors is an element which has been considered. With the older catalogues it is a highly important one. The catalogue of Piazzi, for instance, is essentially independent, but its chance errors are such that had we been assured of its entire freedom from systematic error, it would still have received a weight practically insignificant by comparison with the determinations actually used in the present discussion. In a less degree the same is true of Bradley's declinations for 1755.

These weights were applied, without alteration, to all the declinations of the respective authorities, where the star was observed at least four times at a zenith distance of 70° or less; beyond 70°, weights were diminished by the use of empirical factors, diminishing nearly in proportion to the reciprocal of the square of the refraction; being zero for all zenith distances greater than 80°, and in cases where the weight multiplied by the factor is less than .5.

The results of the various series of determinations made by observatories in the southern hemisphere, were never used beyond 70° zenith distance; so that from the pole down to and including *α Virginis*, there was no diminution of weights for this cause.

The factors are these:

Z	Factor	Z	Factor.
°	"	°	"
70	1.0	76	.5
71	.9	77	.4
72	.8	78	.3
73	.7	79	.3
74	.6	80	.2
75	.6		

Two or three observations received half-weight; a single observation, weight zero.

Now while there is great disparity in the number of authorities relating to different stars, fortunately a considerable number of stars have been quite universally observed. They are known as the fundamental stars, to which may be added α Persei, γ Ursæ Majoris, γ Draconis, β Draconis, γ Ursæ Majoris, α Cassiopeæ, α Cephei, α Ursæ Majoris, β Cephei, β Ursæ Minoris, γ Cephei, ζ Ursæ Minoris, δ Ursæ Minoris, and α Ursæ Minoris. These have each been frequently observed in a majority of the series of observations enumerated above (Class 1). It will be possible, therefore, in the case of these stars, without the intervention of systematic corrections, to compute declinations which shall be measurably free from error, and thus answer the purpose of an approximate normal system, to be subsequently revised and improved.

The results of this preliminary discussion are exhibited in Table I. The first column contains the name of the star; the second and third, respectively, values of $[\Delta\delta]$ and $[\Delta\mu']$ determined in the following manner. For each catalogue an equation of condition was constructed of the form:

$$\Delta\delta + \frac{(T' - 1845)}{100}\,\Delta\mu' - C = 0$$

The values of C are those given in column C of Table A, "Details of Corrections to Assumed Declinations." The epoch 1845 is selected to facilitate the solution of the equations. T' is the designation for mean epoch and is sufficiently indicated in the numerical part of the designation of the catalogues concerned. These values of $[\Delta\delta]$ and $[\Delta\mu']$ are those which result from the use of Gh 1755, without final correction and with weight 1. The fourth and fifth columns contain $\Delta\delta$ and $\Delta\mu'$, with Bradley's declinations excluded; and these values are used in forming the preliminary system of corrections. The sixth and seventh columns contain, respectively, the probable errors of the adopted $\Delta\delta$ and $\Delta\mu'$. The eighth contains the probable error of the unit of weight. The last column contains the approximate declination for 1845.

TABLE I.

Name of star.	$[\Delta\delta]$	$[\Delta\mu']$	$\Delta\delta$	$\Delta\mu'$	$\varepsilon_{\Delta\delta}$	$\varepsilon_{\Delta\mu'}$	ε	δ
	$''$	$''$	$''$	$''$	$''$	$''$	$''$	$^\circ$
α Virginis	+ .045	− .848	+ .052	−1.003	.055	.345	.47	−10.4
β Orionis	+ .193	− .150	+ .157	− .014	.062	.390	.53	− 8.4
α Hydræ	+ .111	− .430	+ .128	− .784	.062	.387	.52	− 8.0
α Aquarii	− .022	− .148	− .009	− .405	.071	.441	.60	− 1.1
α Ceti	− .178	− .106	− .207	+ .487	.055	.340	.46	+ 3.5
β Aquilæ	− .149	− .493	− .136	− .740	.055	.345	.47	+ 6.0
α Serpentis	− .002	+ .023	+ .028	− .569	.059	.366	.70	+ 6.9
α Orionis	+ .022	− .075	+ .019	− .020	.053	.349	.47	+ 7.4
α Aquilæ	+ .022	+ .218	+ .040	− .104	.051	.319	.43	+ 8.5
γ Aquilæ	− .005	− .102	+ .003	− .251	.056	.348	.46	+10.2
α Leonis	+ .072	− .624	+ .056	−1.177	.062	.385	.52	+12.7
α Ophiuchi	+ .185	− .217	+ .111	−1.046	.053	.394	.53	+12.7
γ Pegasi	− .228	− .226	− .231	− .134	.061	.373	.51	+11.3
α Pegasi	+ .285	− .914	+ .330	−1.825	.058	.268	.35	+11.1
α^1 Herculis	+ .173	+ .111	+ .197	− .336	.060	.372	.51	+11.6
β Leonis	+ .229	−1.844	+ .259	−2.141	.047	.288	.39	+15.4
α Tauri	+ .032	− .219	+ .060	− .790	.057	.415	.56	+16.2

TABLE I—Continued.

Name of star.	[Δδ]	[Δμ′]	Δδ	Δμ′	$\varepsilon_{\Delta\delta}$	$\varepsilon_{\Delta\mu'}$	ε	δ
	″	″	″	″	″	″	″	″
α Bootis	— .265	—1.378	— .234	—2.020	.048	.297	.40	+20.0
α Arietis	— .138	— .459	— .128	— .649	.047	.293	.40	+22.7
α Coronæ Borealis	— .067	— .016	— .018	— .996	.052	.345	.43	+27.2
α Andromedæ	— .164	— .420	— .144	— .904	.056	.377	.46	+28.2
β Geminorum	— .220	— .164	— .206	— .430	.041	.254	.34	+28.4
β Tauri	— .297	— .182	— .247	+ .349	.047	.292	.39	+28.5
α Lyræ	+ .345	—1.258	+ .362	—1.627	.044	.273	.36	+38.6
α Cygni	+ .027	— .800	+ .031	— .880	.049	.309	.40	+44.7
α Aurigæ	— .006	— .241	+ .010	— .579	.063	.393	.51	+45.8
α Persei	— .223	+ .098	— .235	+ .333	.063	.396	.50	+49.3
η Ursæ Majoris	+ .090	— .899	+ .098	—1.013	.045	.276	.35	+50.1
γ Draconis	— .031	— .058	— .051	+ .347	.059	.361	.46	+51.5
β Draconis	+ .134	+ .343	+ .129	+ .411	.067	.428	.47	+52.4
γ Ursæ Majoris	+ .192	— .164	+ .196	— .251	.049	.301	.38	+54.6
α Cassiopeæ	+ .024	— .452	+ .023	— .428	.059	.366	.46	+55.7
α Cephei	— .024	+ .321	— .067	+1.682	.057	.355	.45	+61.9
α Ursæ Majoris	+ .042	— .775	+ .025	— .454	.053	.327	.41	+62.6
β Cephei	+ .060	— .088	— .014	+1.326	.038	.233	.29	+69.9
β Ursæ Minoris	— .009	— .099	— .070	+1.050	.043	.263	.33	+74.8
γ Cephei	+ .041	+1.196	+ .045	+1.122	.045	.279	.35	+76.8
ζ Ursæ Minoris	— .146	— .071	— .127	— .393	.041	.247	.31	+78.3
δ Ursæ Minoris	....	....	+ .009	+ .659	.06	.20	.....	+86.6
α Ursæ Minoris	....	....	+ .087	— .258	.03	.10	.....	+88.5
α^2 Capricorni	....	....	— .314	+ .593	.072	.449	.61	—13.0
α^2 Libræ	....	....	+ .063	—2.133	.081	.524	.71	—15.4
α Scorpii	....	....	— .020	+ .353	.086	.541	.45	—26.1
α Piscis Australis	....	....	— .505	— .380	.126	.782	.49	—30.4

The weights assigned in the case of the two polar stars α and δ Ursæ Minoris, are not those of the table, since the relative weights here depend on principles entirely different from those which have governed in the selections of weights to be used with equatorial stars. The weights are those given in column π of the tables for these two stars.

The four stars α^2 Capriconi, α^2 Libræ, α Scorpii and α Piscis Anstralis are not found in "table A," since the subsequent process with these is exactly the same as for other stars in the same region.

The formation of normal places for the limits — 30° to — 90° declination is reserved for a later period of the discussion, and the manner will be hereafter explained.

By the substitution in the equations of condition of the values of Δδ and Δμ′ contained in columns four and five, we derive the numbers in column "r", table A, "Details of Corrections," etc. These are the corrections to the catalogue declinations given by the approximate Normal System. These are arranged for each catalogue in the order of declination, and from them systematic corrections derived, which are exhibited in Table II

TABLE II.

Preliminary systematic corrections to fundamental catalogues, derived through comparison with the declinations of forty-four fundamental and circumpolar stars.

δ	Rg 21	Gb 22	Dt 23	Ao 25	S. H. 31.*	C. G. H. 33.	Ce 34	Eh 37	Rg 38	Gb 39	Ca 40	Rg 43	Eh 43	Gb 45	Pa 45	Re 45	δ
°	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	°
−30		.00	...	.....	+1.05	.00	−.40		+2.	...	−.40	.00	.....	.00	.....	.....	−30
−28		.00	...	.....	+1.07	.00	−.40	....	+2.00	+1.5[illegible]	−.40	.00	.....	.00	.....	....	−28
−26	+.26	.00	.....	.....	+1.09	.00	−.40	.00	+1.90	+1.54	−.40	.00	.....	.00	.....	....	−26
−24	+.26	.00	.....	.....	+1.11	.00	−.40	.00	+1.85	+1.33	−.40	.00	.00	.00	.....	....	−24
−22	+.25	.00	−1.10	....	+1.13	.00	−.40	.00	+1.80	+1.17	−.40	.00	.00	.00	.....	+.71	−22
−20	+.25	.00	−.94	−1.22	+1.15	.00	−.40	.00	+1.65	+1.04	−.40	.00	.00	.00	+.51	+.68	−20
−18	+.25	.00	−.82	−1.03	+1.17	.00	−.40	.00	+1.50	+.93	−.40	.00	.00	.00	+.50	+.65	−18
−16	+.25	.00	−.72	−.90	+1.19	.00	−.40	.00	+1.38	+.85	−.40	.00	.00	+.04	+.50	+.61	−16
−14	+.24	.00	−.65	−.80	+1.21	.00	−.40	.00	+1.26	+.76	−.40	.00	+.10	+.08	+.50	+.58	−14
−12	+.24	.00	−.59	−.72	+1.23	.00	−.40	.00	+1.18	+.70	−.40	.00	+.22	+.12	+.49	+.56	−12
−10	+.24	.00	−.54	−.65	+.94	+.25	−.40	+.07	+1.10	+.65	−.40	.00	+.40	+.16	+.49	+.54	−10
−8	+.24	.00	−.51	−.60	+.97	+.20	−.41	+.06	+1.04	+.60	−.41	+.02	+.39	+.16	+.49	+.51	−8
−6	+.24	.00	−.47	−.55	+1.00	+.16	−.42	+.05	+.98	+.56	−.42	+.05	+.39	+.16	+.48	+.48	−6
−5	+.23	.00	−.45	−.53	+1.02	+.16	−.42	+.04	+.92	+.53	−.42	+.06	+.38	+.16	+.48	+.46	−5
−4	+.23	.00	−.44	−.51	+1.07	+.15	−.43	+.04	+.88	+.51	−.43	+.07	+.38	+.16	+.48	+.42	−4
−2	+.23	.00	−.41	−.48	+1.09	+.15	−.44	+.03	+.81	+.48	−.44	+.09	+.37	+.16	+.47	+.33	−2
0	+.23	.00	−.39	−.45	+1.12	+.09	−.45	+.02	+.74	+.44	−.45	+.10	+.37	+.16	+.47	+.24	0
+2	+.23	.00	−.37	−.42	+1.16	+.03	−.46	+.01	+.68	+.41	−.46	+.11	+.35	+.17	+.46	+.14	+2
+4	+.22	.00	−.35	−.40	+1.17	−.02	−.48	.00	+.62	+.39	−.48	+.12	+.33	+.18	+.46	+.05	+4
+5	+.22	.00	−.34	−.39	+1.18	−.08	−.49	−.00	+.58	+.37	−.49	+.13	+.32	+.18	+.45	.00	+5
+6	+.22	.00	−.33	−.38	+1.19	−.13	−.50	−.01	+.55	+.36	−.50	+.14	+.31	+.18	+.44	−.04	+6
+8	+.21	.00	−.32	−.36	+1.21	−.21	−.52	−.02	+.47	+.34	−.52	+.15	+.29	+.19	+.44	−.12	+8
+10	+.21	.00	−.30	−.34	+1.24	−.30	−.53	−.03	+.43	+.31	−.53	+.16	+.27	+.20	+.43	−.20	+10
+15	+.19	.00	−.27	−.31	+1.31	−.31	−.58	−.06	+.28	+.26	−.61	+.18	+.20	+.21	+.41	−.34	+15
+20	+.18	.00	−.24	−.28	+1.44	−.28	−.65	−.09	+.14	+.22	−.70	+.20	+.14	+.22	+.39	−.47	+20
+25	+.17	.00	−.22	−.25	+1.53	−.12	−.70	−.11	+.05	+.18	−.78	+.21	+.07	+.17	+.37	−.56	+25
+30	+.16	.00	−.20	−.22	+1.52	−.05	−.75	−.14	+.07	+.14	−.82	+.23	.00	+.12	+.34	−.60	+30
+35	+.14	.00	−.18	−.20	+1.34	−.20	−.75	−.17	+.14	+.11	−.80	+.24	−.05	+.05	+.31	−.50	+35
+40	+.13	.00	−.15	−.18	+1.12	−.60	−.70	−.20	+.22	+.07	−.78	+.26	−.10	−.02	+.29	−.28	+40
+45	+.12	....	−.14	−.16	+1.02	...	−.61	−.22	+.28	+.04	−.66	+.27	−.13	−.06	+.26	−.10	+45
+50	+.11	....	−.13	−.15	+.94	...	−.53	−.25	+.28	+.01	−.54	+.29	−.10	−.10	+.23	+.02	+50
+55	+.08	....	−.11	−.13	+.98	...	−.41	−.27	+.19	.00	−.45	+.30	−.05	−.05	+.20	+.08	+55
+60	.00	....	−.10	−.11	+1.07	...	−.30	−.30	+.10	.00	−.27	.....	.00	.00	+.17	+.12	+60
+65	.00	....	−.08	−.09	+1.21	...	−.24	−.27	.00	.00	−.13	.....	.00	.00	+.14	+.23	+65
+70	.00	.....	−.07	−.08	......	...	−.18	−.25	−.10	.00	.00	....	.00	.00	+.11	+.38	+70
+75	.00	....	−.05	−.06	......	....	−.13	−.19	−.05	.00	.00	......	.00	.00	+.08	+.76	+75
+80	.00	...	−.04	−.04	......	...	−.09	−.13	.00	.00	.00	....	.00	.00	+.05	+.80	+80
+90	.00	.00	.00	.00	......	....	.00	.00	.00	.00	.00	....	.00	.00	.00	....	+90

* The correction to S. H. 31 is applicable to the declinations as printed in the catalogue.

NOTE.—These corrections are applicable, of course, to the catalogues as affected by the preliminary corrections explained in Section V.

TABLE II—Continued.

δ	Wn 42.	Ce 42.*	Gh. 51.	Ps 53.	So 55.	Wn 56.	Gh 57.	C. G. H. 58	Wn 64.	Gh 64.	Ln 67.	Me 68.	Wn 68.	Re 68.	Gh 70.	Wn 72.†	δ
°	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	°
−30	00	....	...	+.72	+.28	00	....	−.20	−.24	.....	......	−.27	+1.04	......	......	00	−30
−28	−.05	00	00	+.50	+.28	−.05	+.30	−.20	−.24	00	00	−.26	+.97	−.25	−1.40	00	−28
−26	−.10	00	00	+.29	+.28	−.10	+.30	−.20	−.21	00	00	−.26	+.92	−.25	−1.37	00	−26
−24	−.15	00	00	+.15	+.28	−.15	+.30	−.20	−.24	00	00	−.25	+.87	−.25	−1.34	00	−24
−22	−.20	00	00	+.02	+.28	−.20	+.30	−.20	−.24	00	00	−.24	+.83	−.25	−1.31	00	−22
−20	−.25	00	00	−.03	+.28	−.25	+.30	−.20	−.24	00	00	−.24	+.79	−.25	−1.28	00	−20
−18	−.30	00	00	−.09	+.28	−.30	+.30	−.20	−.24	00	00	−.23	+.75	−.25	−1.24	00	−18
−16	−.35	00	00	−.17	+.28	−.35	+.30	−.20	−.24	00	00	−.23	+.72	−.25	−1.21	00	−16
−14	−.40	00	00	−.24	+.28	−.40	+.30	−.20	−.21	−.06	00	−.22	+.70	−.25	−1.16	00	−14
−12	−.45	00	00	−.29	+.28	−.45	+.30	−.20	−.24	−.12	00	−.22	+.67	−.25	−1.12	−.05	−12
−10	−.50	−.30	+.05	−.34	+.28	−.70	+.30	−.20	−.24	−.18	+.13	−.22	+.65	−.26	−1.08	−.10	−10
−8	−.49	−.29	+.06	−.32	+.28	−.52	+.30	−.20	−.25	−.11	+.10	−.21	+.63	−.29	−1.03	−.10	−8
−6	−.48	−.28	+.08	−.30	+.28	−.50	+.20	−.20	−.25	−.11	+.07	−.20	+.61	−.32	−.98	−.10	−6
−5	−.47	−.27	+.08	−.29	+.28	−.49	+.30	−.20	−.25	−.09	+.05	−.20	+.60	−.34	−.96	−.10	−5
−4	−.47	−.27	+.09	−.28	+.28	−.49	+.30	−.20	−.26	−.07	+.04	−.20	+.59	−.36	−.94	−.10	−4
−2	−.46	−.26	+.11	−.26	+.28	−.47	+.30	−.20	−.26	−.04	+.01	−.20	+.57	−.39	−.89	−.10	−2
0	−.45	−.25	+.12	−.21	+.28	−.46	+.20	−.20	−.27	00	−.02	−.19	+.56	−.42	−.84	−.10	0
+2	−.41	−.25	+.14	−.22	+.28	−.45	+.30	−.20	−.28	+.03	−.05	−.18	+.54	−.44	−.80	−.11	+2
+4	−.42	−.25	+.16	−.20	+.28	−.4[illegible]	+.30	−.19	−.28	+.06	−.08	−.18	+.53	−.46	−.75	−.13	+4
+5	−.41	−.25	+.17	−.19	+.28	−.42	+.30	−.19	−.28	+.08	−.10	−.17	+.52	−.46	−.73	−.13	+5
+6	−.41	−.25	+.17	−.18	+.28	−.41	+.20	−.19	−.29	+.10	−.12	−.17	+.51	−.46	−.71	−.14	+6
+8	−.39	−.25	+.18	−.16	+.28	−.39	+.30	−.17	−.29	+.13	−.15	−.16	+.50	−.48	−.66	−.16	+8
+10	−.38	−.25	+.18	−.11	+.28	−.38	+.30	−.15	−.30	+.16	−.18	−.16	+.49	−.50	−.62	−.17	+10
15	−.34	−.32	+.17	−.09	+.28	−.34	+.30	−.10	−.29	+.18	−.26	−.13	+.46	−.50	−.53	−.18	15
20	−.30	−.40	+.10	−.04	+.28	−.30	+.30	−.06	−.26	+.20	−.29	−.11	+.43	−.46	−.45	−.20	20
25	−.26	−.50	+.01	+.01	+.28	−.25	+.30	−.09	−.21	+.17	−.30	−.07	+.40	−.37	−.38	−.20	25
30	−.22	−.60	−.08	+.06	+.28	−.21	+.30	−.12	−.16	+.14	−.30	−.02	+.38	−.26	−.34	−.20	30
35	−.18	−.65	−.11	+.11	+.28	−.17	+.30	−.22	−.08	+.09	−.30	+.06	+.36	−.15	−.31	−.20	35
40	−.14	−.70	−.15	+.16	+.28	−.13	+.30	...	00	+.01	−.30	+.20	+.33	−.04	−.29	−.20	40
45	−.10	−.66	−.14	+.22	......	−.07	+.29	....	00	00	−.30	......	+.31	+.06	−.28	−.20	45
50	−.06	−.62	−.13	+.28	..	−.02	+.28	..	00	00	−.28	....	+.29	+.13	−.28	−.20	50
55	−.01	−.51	−.11	+.30	.. .	+.07	+.26	.....	00	00	−.25	.....	+.26	+.17	−.28	−.18	55
60	+.04	−.40	−.10	+.33	......	+.17	+.25	....	00	00	−.21	......	+.23	+.21	−.28	−.17	60
65	+.12	−.27	−.08	+.31	......	+.26	+.23	....	00	00	−.16	......	+.21	+.22	−.26	−.14	65
70	+.20	−.15	−.06	+.30	.....	+.29	+.22	......	00	00	−.10	......	+.17	+.18	−.25	−.10	70
75	+.26	−.07	−.04	+.22	.....	+.28	+.16	...	00	00	00	......	+.14	+.09	−.20	−.05	75
80	+.25	00	−.03	+.15	......	+.26	+.11	....	00	00	00	....	+.10	00	−.16	00	80
90	+.10	00	00	00	......	+.20	00	....	00	00	00	......	00	00	00	00	90

* The correction actually used by mistake for Ce 48 between the limits of −13° and −30° was +″.13.
† As actually used, the correction from −13° to −30° was about −″.20. See explanation (p. 69).

The following explanations will serve to show the manner of computing these corrections. As the points of comparison were relatively few, sudden fluctuations in the values of the correction are to be avoided, unless they seem to be completely justified by the testimony of the observations. Whenever a general expression such as a (sin Z + sin Z'), or, a (tan Z + tan Z'), (where Z' is the zenith distance of the pole), was found to represent, approximately, the residuals, r, it was adopted. In the derivation of the corrections from −10° to +90° declination, only stars within those limits were used. From −10° to −34°, the corrections are very rough approximations, there being but four standard declinations within these limits to control the curves. In fact, the curves were continued, in many cases, according to the law adopted for them within the limits +90° to −10°, where this course was not too strongly opposed to the residuals given by the four southern stars.*

We proceed to notice such peculiarities in the individual corrections as appear to be worthy of remark.

* The methods used in deducing some of the corrections of Table II. are not entirely satisfactory to the writer, but were rendered practically unavoidable for reasons which are given in the introductory. (See p. [4].)

Kg 21. I have supposed that the systematic error in this catalogue is more likely to be due to error in the constant of flexure employed than to anything else. This is found to correspond well with the residuals. Assuming the correction to be of the form, a (sin Z + sin Z'), we have for a + ″.16. The use of this formula was continued to the extreme southern limit.

Gh 22. The correction is so small and so uncertain, that zero has been adopted for all declinations.

Dt 24. The correction is assumed to be of the form $\varkappa \frac{(\rho + \rho')}{100}$ where ρ and ρ' are respectively the mean refractions for a given star and the pole. We have:

$$\varkappa = - .299$$

The Dorpat observations are reduced with a refraction constant which is Bessel's multiplied by .99545.* From the formula we shall have as the true factor, .99545 × 1.00299 = .99843. The following table shows the agreement of the formula with the means of the several groups of residuals.

Mean δ of group.	Number of stars.	Mean value of r.	Formula.	Residual.
°		″	″	″
− 8.9	3	− .49	− .53	− .04
+ 5.2	6	− .53	− .34	+ .19
+ 13.8	8	− .21	− .27	− .06
+ 25.8	6	− .03	− .22	− .19
+ 43.0	3	− .17	− .15	+ .02
+ 52.3	5	− .25	− .13	+ .12
+ 62.3	2	− .18	− .10	+ .08
+ 75.0	4	− .08	− .06	+ .02

Ao 29. The process with this correction was exactly similar to that pursued with Dt 24. We have:—

$$\varkappa = - .333$$

and the following comparison:—

Mean δ of group.	Number of stars.	Mean value of r.	Formula.	Residual.
°			″	″
− 8.9	3	− .58	− .62	− .04
+ 5.2	6	− .34	− .39	− .05
+ 13.8	8	− .36	− .32	+ .04
+ 25.8	6	− .33	− .25	+ .08
+ 43.0	3	− .28	− .17	+ .11
+ 52.3	6	− .03	− .14	− .11
+ 62.3	2	− .02	− .10	− .07
+ 75.0	4	+ .06	− .06	− .11

S. H. 31. From declination +66° to −10°, the curve was formed by adding to the numbers given by Dr. Auwers for S. H. 31 (*Ast. Nach. Bd.* 64, *S.* 378), the difference

* *Pos. Med.* (Struve), p. xxxii, Int.

between the correction just deduced for Ao 29 and that given by Dr. Auwers (*ibid.*), the difference being taken in the sense Normal—Auwers. For the limits —10° to —30°, the catalogue places corrected to Bessel's refraction, were taken without change.

C. G. H. 33. The correction for this catalogue was formed in precisely the same manner as that of S. H. 31, and between the limits —10° and —30°, correction zero is arbitrarily adopted.

Ce 34. The residuals were plotted on a convenient scale as ordinates, both singly and in groups, with the mean declinations as abscissæ. A curve of the simplest form was then drawn by hand, passing as nearly as possible through the mean of the points.

Eh 37 and Eh 43. Constructed on similar principles to that of Ce 34.

Kg 38. A hand-curve was drawn, but was found to be very uncertain.

Gh 39. In the interval + 90° to + 52°, the correction zero was assumed. The remaining interval is well represented by the formula, — ″.61 tan Z, which is adopted.

Ce 40 and Ce 48. Process same as for Ce 34.

Kg 43. The formula of correction assumed is:—

$$K + \varkappa \frac{\rho}{100}.$$

The values derived are these: $K = +$ ″.30 ± ″.09; $\varkappa = -$ .24 ± .15. The correction zero is assumed between the limits — 10° and — 30°, though from the formula a small minus correction would result.

Pa 45. The adopted form of correction is a (sin Z + .503), the decimal number being the approximate sine of the co-latitude. This would closely represent the effect of an error in the adopted coefficient of sine flexure. There is room for reasonable doubt whether the constancy of the coefficient of flexure can be relied upon where the ocular and objective are interchanged as at Poulkova. At any rate, as will appear from the subjoined table of comparison, this formula accounts very accurately for the difference, Normal — Poulkova. The value of the constant is + ″.341 ± ″.015:—

Mean δ of group.	Number of stars.	Mean value of r.	Formula.	Residual.
		″	″	″
— 8.9	3	+ .49	+ .49	.00
+ 5.2	6	+ .43	+ .45	+ .03
+ 13.8	8	+ .48	+ .42	— .06
+ 25.8	6	+ .31	+ .36	+ .05
+ 43.0	3	+ .25	+ .27	+ .02
+ 52.3	6	+ .16	+ .21	+ .05
+ 62.3	2	+ .38	+ .16	— .22
+ 75.0	4	— .02	+ .08	+ .10

The use of this formula is continued to the southern limit.

Gh 45. A simple hand-curve is drawn.

Ke 45. Owing to the large probable error of this authority, and the uncertainty of the curve, a comparison with Pa 45 and Gh 45 is instituted for every star in common with these catalogues and that at the end of this paper. The comparisons are included within the limits + 90° and — 10° declination, and are in the sense of corrections to

Re 45. The weights were adopted without reference to the number of observations in Pa 45 or Gh 45, unless the number in the former is less than 4 and in the latter less than 5. With this exception, the weights are these:—

Observations in Re 45.	Weight.
1	.4
2	.6
3 or 4	.8
5 or more	1.0

These were multiplied by .5 when the number of observations in either of the other catalogues is 1, by .7 when in Gh 45 the number is 2, by .8 when in Pa 45 the number is either 2 or 3, and in Gh 45, 3 or 4. It was seldom necessary to use these factors. The following table contains in the first column the mean declinations of the groups Pa—Re; in the second, the mean residual Pa—Re for each group; in the third, the weight; in the fourth, the probable error of the unit of this weight determined from each group.

The fifth, sixth, and seventh columns contain corresponding particulars for Gh 45—Re 45, omitting the probable errors, which were not determined. The eighth and ninth columns show respectively the sums of numbers in columns two and six added to the corresponding corrections of Pa 45 and Gh 45, taken from Table II. The tenth column contains the means of columns eight and nine, giving the numbers in column eight double weight except for the first group. From this last column the curve of correction is constructed graphically by the usual method.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
°	″			°	″		″	″	″
− 8.4	− .33	6	± .60	− 8.6	+ .40	8	+ .16	+ .56	+ .36
− 0.8	+ .15	6	.45	− 1.3	+ .53	9	+ .62	+ .69	+ .64
+ 3.5	− .78	5	.41	+ 3.6	− .60	6	− .32	− .43	− .36
+ 8.1	− .66	15	.31	+ 8.0	− .18	15	− .22	00	− .15
+ 13.7	− .77	9	.43	+ 13.6	− .41	10	− .36	− .20	− .31
+ 18.1	− .42	6	.46	+ 18.3	− .23	6	− .02	− .01	− .02
+ 22.8	−1.10	9	.48	+ 22.9	− .89	9	− .72	− .70	− .71
+ 28.0	− .87	7	.40	+ 28.1	− .57	6	− .52	− .43	− .49
+ 35.1	−1.34	5	.46	+ 35.1	− .81	3	−1.03	− .76	− .94
+ 41.1	− .68	20	.45	+ 41.4	− .03	22	− .40	− .06	− .29
+ 47.2	− .34	19	.44	+ 47.2	+ .22	21	− .09	+ .14	− .01
+ 52.0	− .24	12	.35	+ 51.8	+ .12	15	− .02	+ .04	00
+ 56.8	− .07	10	.61	+ 56.7	+ .15	11	+ .12	+ .12	+ .12
+ 61.0	− .07	13	.21	+ 60.6	+ .06	21	+ .09	+ .06	+ .08
+ 65.0	+ .01	6	.13	+ 66.1	+ .25	9	+ .14	+ .26	+ .18
+ 70.9	+ .66	11	.32	+ 70.1	+ .64	10	+ .76	+ .66	+ .73
+ 76.5	+1.05	7	.33	+ 76.8	+ .52	9	+1.12	+ .52	+ .92
[85.8]	[− .12]	[7]	....	[85.7]	[+ .32]	[7]	......	......	......

The correction of the table is not considered applicable between the limits 80° and 90° declination when stars are observed both above and below the pole. Between the limits − 10° and − 22° the curve was constructed by the help of Dr. Auwers's table (*Ast. Nach.*, Bd. 64). Search for terms in the declination correction of Re 45, which depend upon the right ascension of the star for their magnitude, failed to discover any which it was thought safe to apply. Dr. Gould finds a considerable correction of this kind (*Ast. Nach.*, Bd. 65, s. 182), and Dr. Auwers (*Ast. Nach.*, Bd. 64, s. 335) finds by comparison with Ao 29: $+ ''.285 \sin \alpha - ''.146 \cos \alpha$. My comparison includes stars between -10° and $+74^\circ$ declination, and, after subtracting the difference of declination corrections from the separate differences Pa — Re and Gh — Re, I find:—

Pa 45 — Re 45.			Gh 45 — Re 45.		
Mean α of group.	Weight.	Difference.	Mean α of group.	Weight.	Difference.
h.		$''$	*h.*		$''$
0.2	14	− .11	0.1	17	− .02
2.2	17	+ .10	2.2	18	+ .21
4.2	13	+ .13	4.2	13	+ .21
5.8	11	− .12	5.8	13	− .18
8.1	10	+ .04	8.1	11	+ .06
10.1	15	− .38	10.1	14	− .52
12.1	8	− .01	12.2	14	+ .01
14.0	11	.00	14.1	14	+ .37
16.0	15	− .30	16.0	16	− .25
18.0	8	− .34	18.0	12	+ .15
19.9	15	+ .02	19.9	18	+ .26
22.0	15	− .06	22.0	24	+ .20

Wn 47, Wn 56, Wn 64. The corrections were derived by the graphical process. None of these curves are very certain for declinations north of 40°.

Gh 51, Gh 57, and Gh 64, Ps 53, C. G. H. 58, Ln 67, Re 68, and Wn 72 were also discussed by means of hand-curves.

So 55. A uniform value of the correction was adopted, since sufficient material for drawing the curve with requisite certainty was not available.

Me 68 and Wn 68. Comparison with the residuals r shows that the results of the discussion of Washington and Melbourne declinations (p. 68) answer sufficiently well for the first approximation to their respective corrections. This opinion is supported by the final discussions.

Gh 70. The empirical formula $a\,(\sin^3 Z + \sin^3 Z')$, which differs little in practical effect from that employed with Dt 24 and Ao 29, though it does not very closely represent the mean values of r, is adopted. Discussion of the separate residuals gives for $a - 1''.17$. The comparison with means is as follows:—

Mean δ of group.	Number of stars.	Mean r.	Formula.	c—o.
°		$''$	$''$	$''$
− 8.9	3	− 1.12	− 1.05	+ .07
+ 5.2	6	− .74	− .73	+ .01
+ 13.8	8	− .33	− .55	− .22
+ 25.8	6	− .35	− .39	− .04
+ 43.0	3	− .38	− .29	+ .09
+ 52.3	6	− .50	− .28	+ .22
+ 62.3	2	− .37	− .27	+ .10
+ 75.0	4	− .46	− .20	+ .26

If, for instance, observations have been corrected by the formula $a \sin Z \cos^2 Z$, when the true formula is $a \sin Z$, then the correction $a \sin^3 Z$ would be required for the polar distances, as published. The average correction to zenith distances by direct observation during the years 1868–'72 for $R - D$ is

$$+ {}''.75 \sin Z \cos^2 Z.$$

If we suppose that this correction should have been approximately $+ {}''.75 \sin Z$, then declinations would require the correction $- {}''.75 \sin^3 Z +$ (the proper correction for latitude).

It is, however, probable that a great part of the correction is due to error in the adopted constant of refraction.

SECTION VII.

CORRECTION OF BESSEL'S FUNDAMENTA ASTRONOMIÆ.

With the systematic corrections of Table II., and with the system of weights already used, we proceed to correct the assumed declinations of stars of class "*b*" (p. 8). The object of this is to secure a greater number of points with which to compare Bradley's declinations, and even this additional number is insufficient for the satisfactory solution of the problem. The criterion of selection of these additional stars is that there shall be none for which the weight of $\Delta\mu'$ is less than .5. The formation and solution of conditional equations was conducted on precisely the same principles as for the fundamental stars. The same authorities were used (Gh 1752 and 1755 being of course excluded), but they were first corrected by Table II. in order to diminish the effect of uneven distribution of systematic errors in the series of corrections for a given star.

The results are shown in Table III. where the adopted corrections of fundamental and circumpolar stars (Section VI.) are repeated for convenience. The explanation follows:

TABLE III.

Name of star.	1755. α	1755. δ	$\Delta\delta$	$\pi_{\Delta\delta}$	$\Delta\mu'$	$\pi_{\Delta\mu'}$	Cor. to Bradley.	π'	Residual.
	°	°	″		″		″		″
λ Ursæ Minoris	319.6	+88.5	+ .258	.....	+1.18	......	−1.1	.7	+ .3
α Ursæ Minoris	10.9	+88.0	+ .087	.....	− .26	......	−1.9	2.0	+ .3
δ Ursæ Minoris	282.7	+86.5	+ .009	......	+ .66	.....	−4.1	1.0	−2.3
Camelop. (32 H.)	192.0	+84.7	+ .569	......	+3.83	.....	− .2	1.0	+ .7
ε Ursæ Minoris	258.0	+82.4	+ .189	......	− .63	......	− .0	.4	− .7
ζ Ursæ Minoris	238.3	+78.5	− .127	57.9	− .39	1.56	−1.2	1.0	+ .6
γ Cephei	352.4	+76.3	+ .045	61.4	+1.12	1.60	+ .5	1.0	+2.2
5 Ursæ Minoris	217.1	+76.8	+ .605	27.0	+4.07	.83	−3.2	1.0	−1.3
β Ursæ Minoris	222.9	+75.2	+ .070	60.4	+1.05	1.59	−3.1	.4	−2.0
ι Draconis	276.4	+72.6	+ .456	26.3	−1.28	.79	+1.3	1.0	−1.8
γ² Ursæ Minoris	230.3	+72.7	− .073	13.4	−1.57	1.18	+4.0	1.0	+3.8
ψ¹ Draconis	266.6	+72.3	+ .086	15.9	− .30	.54	− .7	1.0	+1.0
λ Draconis	169.1	+70.7	+ .456	10.0	+1.17	.90	−3.5	1.0	−3.1
β Cephei	321.4	+69.5	− .014	61.0	+1.33	1.60	−3.7	1.0	−2.0
ω Draconis	261.6	+68.9	− .402	18.8	+2.90	.52	−3.6	1.0	−1.2

TABLE III—Continued.

Name of star.	1755.		$\Delta\delta$	$\pi_{\Delta\delta}$	$\Delta\mu'$	$\pi_{\Delta\mu'}$	Cor. to Bradley.	π'	Resdual.
	a	δ							
	°	°	″		″		″		″
σ² Ursæ Majoris	132.1	+68.1	+ .778	16.9	+4.46	.52	−3.8	.4	−4.3
δ Draconis	288.1	+67.2	+ .076	47.5	+1.01	1.14	−2.0	1.0	−1.1
ι Cephei	340.3	+64.9	+ .072	41.6	+1.18	.90	−1.5	1.0	0.0
α Draconis	209.4	+65.6	+ .242	48.2	+ .12	1.25	− .2	1.0	+ .2
ε Cassiopeiæ	24.3	+62.4	+ .201	40.6	− .07	1.00	− .2	1.0	+ .7
α Ursæ Majoris	162.1	+63.1	+ .025	61.4	− .45	1.60	− .8	1.0	− .6
α Cephei	318.2	+61.6	− .067	61.4	+1.68	1.60	−3.6	1.0	−2.3
η Draconis	245.2	+62.1	+ .203	49.2	−1.06	1.35	−1.6	.7	−1.7
η Cephei	310.1	+60.9	− .381	32.8	+1.64	.75	−2.0	1.0	− .5
ο Ursæ Majoris	122.4	+61.5	+ .067	31.0	+1.61	.57	−1.7	1.0	− .8
ν Cephei	324.6	+60.0	− .154	29.0	+1.52	.95	−2.2	1.0	− .6
ν Ursæ Majoris	143.3	+60.2	+ .328	43.3	− .08	1.05	− .5	1.0	− .3
ο Draconis	281.9	+59.1	+ .154	21.2	+ .27	.68	−2.6	0.4	−1.5
θ Draconis	239.3	+59.2	+ .019	44.0	+1.02	1.21	−1.6	1.0	− .8
δ Ursæ Majoris	97.2	+58.4	− .242	37.2	+1.37	.82	−4.2	1.0	−2.6
δ Cephei	335.0	+57.2	+ .009	30.2	+2.41	.54	−2.5	1.0	− .8
ζ Cephei	330.6	+57.0	+ .227	41.3	− .68	.97	−2.3	1.0	− .8
β Ursæ Majoris	161.7	+57.7	+ .444	35.9	−4.25	.87	+4.0	1.0	+1.9
4 Camelopardalis	66.9	+56.3	+ .175	16.0	+ .82	.60	−1.8	1.0	− .7
α Cassiopeiæ	6.7	+55.2	+ .023	62.7	− .43	1.63	− .1	1.5	− .9
ζ¹ Ursæ Majoris	198.5	+56.2	− .004	42.0	+ .53	1.08	− .4	1.5	− .2
γ Ursæ Majoris	175.2	+55.1	+ .196	61.1	− .25	1.59	+ .2	1.0	0.0
ζ Cassiopeiæ	5.9	+52.5	− .082	27.7	− .24	.70	+ .9	1.0	+1.0
κ Cygni	287.9	+52.9	− .352	32.6	+ .87	.78	−1.2	2.0	− .2
θ Bootis	214.2	+53.0	− .125	41.4	− .90	1.19	+ .7	1.0	+ .5
β Draconis	261.2	+52.5	+ .129	50.3	+ .41	1.23	− .1	2.0	+ .3
θ Ursæ Majoris	139.1	+52.8	− .346	45.4	+ .94	1.04	+ .2	1.0	− .4
γ Draconis	267.7	+51.5	− .051	60.2	+ .35	1.60	−1.1	2.0	− .6
ι² Cygni	290.9	+51.2	− .056	31.5	− .02	.74	+ .4	2.0	+1.6
η Ursæ Majoris	204.5	+50.5	+ .098	61.3	−1.01	1.60	+ .3	1.5	+ .4
θ Cygni	292.5	+49.7	− .445	31.8	+1.85	.96	−2.5	.4	−1.5
α Lacertæ	335.3	+49.0	+ .101	27.3	− .73	.69	+ .0	1.0	+ .3
α Persei	46.7	+49.0	− .235	62.7	+ .33	1.63	− .6	1.5	− .6
ι Ursæ Majoris	130.6	+49.0	− .278	44.8	+ .06	.85	−1.7	1.0	− .7
χ Ursæ Majoris	173.3	+49.1	+ .056	40.1	− .68	.97	− .8	1.0	+ .9
51 Andromedæ	20.8	+47.4	− .397	29.6	+ .60	.70	−1.5	1.0	−1.4
δ Persei	51.4	+47.0	− .264	39.3	+ .33	.97	− .5	1.5	− .3
λ Bootis	211.8	+47.2	− .431	27.8	+1.03	.59	− .7	.4	− .5
α Aurigæ	74.7	+45.7	+ .010	64.9	− .58	1.66	+ .9	2.0	+1.1
ψ Ursæ Majoris	163.9	+45.8	− .234	32.1	+ .52	.71	−2.4	.7	−1.6
β Aurigæ	85.4	+44.9	− .079	44.1	− .08	1.06	− .7	.7	− .6
α Cygni	308.3	+44.4	+ .030	66.1	− .88	1.69	+ .2	2.0	− .5
λ Ursæ Majoris	150.6	+44.1	− .591	28.3	+1.77	.91	−1.6	1.0	−1.0
ε Aurigæ	71.1	+43.4	+ .166	32.0	−1.59	.91	+1.9	1.0	−1.3
σ Herculis	246.6	+43.0	− .142	28.1	+ .06	.70	+1.8	1.0	+1.0
μ Ursæ Majoris	151.9	+42.7	+ .301	29.4	−1.69	.74	+1.8	1.0	+1.5
γ Andromedæ	27.2	+41.4	+ .262	30.6	+1.11	.73	− .2	1.0	− .5
η Aurigæ	72.3	+40.9	+ .242	37.4	−1.40	1.05	+ .9	1.0	+ .6
β Persei	43.1	+40.0	+ .461	39.8	−1.31	1.12	+1.6	1.0	+ .9
γ Cygni	303.4	+39.5	+ .428	45.3	−2.67	1.14	+2.4	1.5	+ .9

TABLE III—Continued.

Name of star.	1755. α	1755. δ	$\Delta\delta$	$\pi_{\Delta\delta}$	$\Delta\mu'$	$\pi_{\Delta\mu'}$	Cor. to Bradley.	π	Residual.
	°	°	"		"		"		"
ε¹ Lyræ	279.1	+39.4	− .731	28.0	+1.67	.60	−1.5	1.0	−1.6
η Herculis	248.6	+39.4	− .685	42.4	−3.20	1.12	+1.7	.7	+ .8
α Canum Venaticorum	191.1	+39.6	− .055	49.1	− .87	1.24	+ .4	.7	+ .2
α Lyræ	277.2	+38.6	+ .362	66.1	−1.63	1.69	+1.1	2.0	+ .2
61 Cygni	314.0	+37.6	+ .607	36.9	+ .15	.83	+ .8	1.0	− .1
β Andromedæ	14.0	+34.3	+ .254	36.0	−2.17	.71	+2.6	1.0	+1.7
β Trianguli	28.8	+33.8	− .284	20.9	− .68	.59	+1.2	1.0	+ .3
ε Cygni	309.1	+33.1	+1.897	29.4	−2.61	.93	+1.9	.7	+ .6
β Lyræ	280.3	+33.1	+ .140	46.2	−2.10	1.08	−1.7	1.0	−2.1
ι Aurigæ	70.3	+32.8	− .448	33.3	−1.05	.77	+1.1	1.0	+ .5
ζ Herculis	248.0	+32.1	+ .039	29.6	+ .18	.78	+1.5	.7	+ .3
ζ Cygni	315.6	+29.2	− .517	29.2	− .65	.55	− .9	1.0	−1.4
β Tauri	77.7	+28.4	− .242	69.4	+ .35	1.80	− .4	1.5	−2.0
β Geminorum	112.6	+28.6	− .206	70.3	− .43	1.83	+ .8	2.0	+ .3
α Andromedæ	358.9	+27.7	− .144	70.4	− .90	1.52	+1.1	1.0	+ .2
μ Herculis	264.2	+27.9	+ .094	18.2	−1.91	.67	+2.4	1.0	+ .6
ε Bootis	218.6	+28.1	− .121	32.4	+ .53	.76	+ .3	.7	− .6
α Coronæ	231.1	+27.6	− .018	69.7	−1.00	1.83	+2.9	1.0	−1.6
μ Leonis	144.7	+27.1	− .495	30.8	+1.23	.64	−2.5	1.0	−1.8
ε Leonis	143.0	+24.9	+ .046	30.1	−1.68	.70	+1.1	1.0	+ .1
η Tauri	53.2	+23.3	− .190	30.6	− .18	.57	− .7	1.0	− .8
α Arietis	28.4	+22.3	− .128	70.7	− .65	1.83	+ .5	1.0	− .3
μ Geminorum	92.0	+22.6	− .555	31.7	− .03	.59	−1.2	1.5	− .7
δ Geminorum	106.4	+22.4	− .172	30.5	−2.38	.59	+ .6	1.0	− .1
δ Leonis	165.3	+21.9	+ .142	43.2	−1.61	1.01	− .3	1.0	−1.0
γ¹ Leonis	151.6	+21.1	− .331	35.7	−3.11	.76	+1.1	1.0	0
α Bootis	211.1	+20.5	− .234	70.7	−2.02	1.83	+1.8	2.0	+ .3
η Bootis	205.8	+19.6	− .229	43.4	−1.22	1.03	+ .5	1.0	− .8
α Tauri	65.5	+16.0	+ .060	71.5	− .79	1.84	+1.7	2.0	+ .9
β Leonis	174.1	+15.9	+ .259	69.7	−2.44	1.84	+1.8	1.5	+ .3
α¹ Herculis	255.9	+14.7	+ .197	70.5	− .34	1.84	+1.4	1.0	− .3
α Pegasi	343.1	+13.9	+ .330	70.7	−1.82	1.83	+2.8	1.0	+1.7
γ Pegasi	0.2	+13.8	− .231	69.1	− .16	1.82	− .1	1.5	−1.1
ζ Aquilæ	283.5	+13.5	+ .149	30.9	− .67	.72	+2.1	1.0	+ .3
α Ophiuchi	260.9	+12.8	+ .111	70.3	−1.05	1.82	+3.0	1.0	+1.3
α Leonis	148.8	+13.2	+ .056	71.5	−1.18	1.84	+1.9	1.5	+ .4
γ Aquilæ	293.7	+10.0	+ .003	70.0	− .25	1.77	+1.2	1.5	− .4
ζ Pegasi	337.3	+ 9.6	− .140	29.7	+1.85	.68	+1.5	1.0	+ .3
κ Ophiuchi	251.5	+ 9.8	− .011	29.8	− .39	.83	+1.9	1.0	0
ε Pegasi	323.0	+ 8.8	+ .037	29.6	− .61	.68	+1.1	1.0	− .1
α Aquilæ	294.7	+ 8.2	+ .040	71.5	− .10	1.84	+1.7	2.0	+ .2
α Orionis	85.5	+ 7.3	+ .019	71.5	− .02	1.81	+1.0	2.0	+ .1
ε Piscium	12.6	+ 6.6	− .343	26.1	+ .32	.63	−1.5	.7	−1.6
ι Hydræ	128.4	+ 7.3	− .189	28.2	−3.46	.55	+3.3	1.0	+1.0
α Serpentis	233.1	+ 7.2	+ .028	71.5	− .57	1.84	+2.9	1.0	+1.0
ω Piscium	356.7	+ 5.5	− .515	35.1	− .11	.69	− .7	1.0	− .9
β Aquilæ	295.8	+ 5.8	− .136	71.5	− .71	1.84	+1.5	1.5	0
ι Piscium	351.8	+ 4.3	− .572	42.0	+1.58	.96	− .2	1.0	− .7
α Ceti	42.4	+ 3.1	− .207	71.5	+ .49	1.84	− .4	1.0	−1.0
δ Aquilæ	288.3	+ 2.6	+ .100	45.8	− .11	1.06	+3.3	1.0	+1.2

TABLE III—Continued.

Name of star.	1755. α	1755. δ	Δδ	πΔδ	Δμ′	πΔμ′	Cor. to Bradley.	π	Residual.
	°	°	″		″		″		″
γ Ceti	37.7	+ 2.2	− .390	37.4	−1.25	.80	+ .8	1.0	+ .1
β Virginis	174.5	+ 3.1	− .019	58.4	− .89	1.41	+1.6	1.5	− .2
ζ Virginis	200.6	+ 0.7	− .249	33.0	− .37	.72	+1.6	1.0	+1.6
η Virginis	181.8	+ 0.7	− .425	25.5	−1.42	.50	+1.3	1.0	− .4
δ Orionis	79.9	− 0.5	− .515	26.6	+1.51	.69	+ .0	1.0	− .1
η Aquarii	335.7	− 1.4	− .603	17.9	+1.82	.54	+1.6	1.0	+ .4
α Aquarii	328.3	− 1.5	− .009	71.5	− .40	1.84	+2.8	1.0	+1.6
ε Orionis	80.9	− 1.4	− .221	24.9	−1.51	.56	+3.5	1.0	+1.4
η Serpentis	272.2	− 2.9	+ .366	29.5	−2.04	.62	+1.7	1.0	0
δ Ophiuchi	240.4	− 3.0	− .329	32.7	+ .48	.75	+2.3	.7	+ .3
β Aquarii	319.7	− 6.6	+ .196	28.3	−1.39	.74	+3.5	1.0	+1.6
α Hydræ	138.9	− 7.6	+ .128	69.9	− .78	1.81	+1.6	1.0	+ .1
β Orionis	75.7	− 8.5	+ .187	71.5	− .01	1.84	− .0	2.0	− .6
θ¹ Ceti	17.9	− 9.5	+ .187	22.1	− .87	.63	+1.2	1.0	+ .6
β Libræ	226.0	− 8.5	+ .066	34.6	−1.23	.79	+2.7	1.0	+ .4
α Virginis	198.1	− 9.9	+ .052	71.5	−1.00	1.84	+ .9	1.5	−1.2
α² Capricorni	301.1	−13.0	− .316	......	+ .75	......	− .2	1.0	−1.4
δ Crateris	166.8	−13.9	− .644	......	+1.00	......	− .5	1.0	−1.3
γ¹ Eridani	56.7	−14.0	−0.417	......	+ .41	......	+ .6	1.0	+ .3
α² Libræ	219.3	−15.4	+ .050	......	−1.86	......	+1.9	1.0	0
α Leporis	80.5	−17.9	− .098	......	− .13	......	+1.2	1.0	− .7
β Ceti	07.8	−18.8	− .301	......	+1.43	......	− .8	1.0	− .2
β¹ Scorpii	237.8	−19.4	+1.620	.....	−5.84	......	+1.7	1.0	0
μ¹ Sagittarii	270.2	−21.1	− .567	......	+1.63	......	−1.2	1.0	−1.0
δ Scorpii	236.5	−22.2	+ .796	......	−4.14	......	+3.8	1.0	+ .8
β Corvi	185.4	−22.5	− .404	......	+ .45	......	+ .6	1.0	− .7
15 Argus	119.3	−23.9	+ .033	......	−1.69	.....	+3.2	1.0	+1.3
α Scorpii	243.6	−26.1	− .071	......	−1.66	......	+1.2	1.0	0
ε Canis Majoris	102.2	−28.8	− .663	......	+1.62	......	+1.1	0.5	+ .5
α Piscis Australis	341.0	−30.4	− .609	......	+1.34	......	− .5	1.0	+ .1

Columns one, two, and three require no explanation. Columns four and five contain the correction to the assumed declination for the epoch 1845, with the weight as determined from the equations of condition. Column six contains one hundred times the correction to the annual variation assumed, and column seven its weight. In reference to the weights, it should be remarked, that for the first five stars the weights were assumed on different principles from those which prevail with other stars. The manner of assigning weights to the stars from α^2 Capricorni to α Piscis Australis has been already explained. As they are not, therefore, strictly comparable with the preceding they are omitted. Column eight contains the correction to Gh 1752 and Gh 1755, resulting from the preceding values of $\Delta\delta$ and $\Delta\mu'$. The process of obtaining these corrections was this: The catalogue declinations were corrected for nutation as explained (p. 20). The declinations between + 14° and − 14°, have been corrected by

Bessel for certain quantities necessary to make them agree with Bradley's observations of the sun. The following table is given in *Fundamenta Astronomiæ* (p. 62).

δ	Correction.	δ	Correction.	δ	Correction.
°	"	°	"	°	"
−13	+ .71	−3	+ .67	+ 7	+ 1.22
−11	+ .63	−1	+ 2.36	+ 9	+ .47
−9	+ .24	+ 1	+ 1.03	+ 11	+ .93
−7	+ .72	+ 3	+ 1.48	+ 13	+ .49
−5	− .06	+ 5	+ .42		

These corrections I have subtracted from the catalogue declinations; by which means we are able to assume the same system for all stars south of Greenwich zenith. The standard declination for 1752 is equal to the assumed declination $+ \Delta\mu' - .93\,\Delta\mu'$. From the standard so formed is subtracted the corrected declination of the catalogue. The result is the "Correction to Bradley." For the stars enumerated below the corrections to declinations from lower culmination are given with reversed sign, as the above table deals with upper culmination only.

Stars observed sub polo.

Name.	$a + 180°$	Corr. to Bradley.	Weight.	Name.	$a + 180°$	Cor. to Bradley.	Weight.
	°	"			°	"	
λ Ursæ Minoris ...	139.6	+ .24	.4	γ Cephei	172.4	+ .89	.4
α Ursæ Minoris ...	190.9	−1.55	2.0	ψ Draconis	86.6	−2.24	.7
δ Ursæ Minoris ...	102.7	+1.13	1.0	δ Draconis	108.1	+1.17	1.0
Camelop. (32 H).	12.0	−2.74	1.0	η Draconis	65.2	−5.64	1.0
ε Ursæ Minoris ...	78.0	− .27	1.0	o Draconis	101.9	+2.04	1.0
ζ Ursæ Minoris ...	58.3	−2.85	1.0	θ Ursæ Majoris ...	319.1	− .24	1.0

The ninth column gives the weight used in solving the equations of condition. The following is the scale:

Obs.	Weight.
1	.4
2	.7
3–9	1.0
10–25	1.5
over 25	2.0

In estimating these weights, no account is taken of the uncertainty of the standard places. Their probable error seldom exceeds ″.45, and for the fundamental stars averages about ″.3. The probable error of the unit of weight for the additional stars is approximately ″.35.

Owing to the uncertain character of the residuals I did not think it safe to attempt the drawing of a curve. Careful preliminary examination showed that the error varies greatly with the Right Ascension, according to what law it is difficult to conjecture. I assumed at first the simple periodic formula of correction,

$$x \sin a + y \cos a.$$

The form of the declination correction (order of declination) especially for southern stars, appears to be tolerably well represented by the expression—

$$v + w \sin 2 Z + u \tan Z.$$

For southern stars alone the normal equations are these:

$$\begin{aligned}
+ 109.2\, v + 77.2\, w - 0.6\, x + 5.9\, y + 111.0\, u - 100.0'' &= 0 \\
+ 77.2\, v + 63.5\, w - 3.3\, x + 3.9\, y + 82.3\, u - 85.7 &= 0 \\
- 0.6\, v - 3.3\, w + 59.6\, x + 1.8\, y - 9.2\, u + 30.1 &= 0 \\
+ 5.9\, v + 3.9\, w + 1.8\, x + 49.6\, y + 4.2\, u + 8.5 &= 0 \\
+ 111.0\, v + 82.3\, w - 9.2\, x + 4.2\, y + 245.2\, u - 121.8 &= 0
\end{aligned}$$

From which—

$$\begin{aligned}
v &= - ''.21 \\
w &= + 1.50 \\
x &= - .41 \\
y &= - .25 \\
u &= + .08
\end{aligned}$$

Arranged in four nearly equal groups, we have the following values of v, x, and y, the residuals being first corrected for $+ 1''.50 \sin 2 Z + ''.08 \tan Z$.

Mean δ	v	x	y	Weight of y.	Adopted y.
°	''	''	''		''
− 13.0	− .20	− .17	− .88	10	− .98
+ 08.3	− .07	− .52	− .72	16	− .48
+ 25.6	− .42	− .49	+ .09	11	− .06
+ 43.4	− .19	− .29	+ .36	10	+ .37

The constancy of v and x is as good as we might expect, but such is not the case with y. In the uncertainty, I have supposed y to vary directly with the declination, and find—

$$y = - ''.24 \left(\frac{28° - \delta}{10}\right)$$

The equations for northern stars are:

$$\begin{aligned}
+ 60.9\, v - 27.6\, w - 13.1\, x + 0.5\, y - 28.9\, u + 63.8'' &= 0 \\
- 27.6\, v + 20.3\, w + 1.3\, x + 0.2\, y + 21.5\, u - 35.2 &= 0 \\
- 13.1\, v + 1.3\, w + 31.1\, x - 1.8\, y - 3.9\, u - 13.7 &= 0 \\
+ .5\, v + 0.2\, w - 1.8\, x + 29.8\, y - 2.8\, u + 17.2 &= 0 \\
- 29.0\, v + 21.5\, w - 3.9\, x - 2.8\, y + 43.9\, u - 31.5 &= 0
\end{aligned}$$

Whence—

$$\begin{aligned} v &= -\ .63'' \\ w &= +\ 1.25 \\ x &= +\ .04 \\ y &= -\ .61 \\ u &= -\ .35 \end{aligned}$$

The number of stars and the weights are too small to admit of any valid argument from the process of grouping; the residuals, however, are not remarkably well represented by the formula. The real correction is probably much more variable. The equality of the two values of w derived from northern and southern stars is quite striking. The smallness of u in each case is an argument that the refraction deduced by Bessel corresponds well with Bradley's observations. For the definitive correction I have dropped u and combined the equations for both northern and southern stars. Two sets of coefficients for sin α and cos α are separately determined. For northern stars these are denoted by x' and y'. y is introduced into the equations in order to eliminate its mean influence on the determination of the remaining quantities.

The equations follow.

$$\begin{array}{rrrrrrrl} +170.1\,v & +\ 49.6\,w & -\ 13.1\,x' & +\ 0.5\,y' & -\ 0.6\,x & +\ 5.9\,y & -\ 36.2'' & = 0 \\ +\ 49.6\,v & +\ 83.8\,w & +\ 1.3\,x' & +\ 0.2\,y' & -\ 3.3\,x & +\ 3.9\,y & -\ 121.0 & = 0 \\ -\ 13.1\,v & +\ 1.3\,w & +\ 31.1\,x' & -\ 1.8\,y' & 0.0\,x & 0.0\,y & -\ 13.7 & = 0 \\ +\ 0.5\,v & +\ 0.2\,w & -\ 1.8\,x' & +\ 29.8\,y' & 0.0\,x & 0.0\,y & +\ 17.2 & = 0 \\ -\ 0.6\,v & -\ 3.3\,w & 0.0\,x' & 0.0\,y' & +\ 59.6\,x & +\ 1.8\,y & +\ 30.1 & = 0 \\ +\ 5.9\,v & +\ 3.9\,w & 0.0\,x' & 0.0\,y' & +\ 1.8\,x & +\ 49.6\,y & +\ 8.5 & = 0 \end{array}$$

The solution gives:

$$\begin{aligned} v &= -\ .21'' \pm .06'' \\ w &= +\ 1.56 \pm .10 \\ x' &= +\ .25 \pm .16 \\ y' &= -\ .57 \pm .16 \\ x &= -\ .41 \pm .10 \\ y &= -\ .25 \end{aligned}$$

The probable error of the unit of weight is $\pm\ ''.79$. For northern stars it is $\pm\ 1''.03$; and for southern $\pm\ ''.65$. These probable errors are somewhat larger than can fairly be ascribed to Bradley's declinations, since they include the effect of the probable error of the normal places themselves. In order to be on the safe side I have adopted the following weights in final discussion, the supposed probable error of the unit being $\pm\ ''.30$, as will be explained hereafter.

Weight.	Number of observations.	
	Northern stars.	Southern stars.
00	1	1
.05	2 to 8	....
.1	9, or more.	2, or 3
.2	....	4 to 20
.3	....	21, or more.

In computing Table V., weight .5 is assigned to 4 or more observations, and weight .3 to less than that number. Declinations of Gb 1752–55, from one observation are rejected. If the corrections above determined are combined with those for nutation we have—

For northern stars (north of 51°.5 δ)

$$-\,''.21 + 1''.56 \sin Z + ''.05 \sin \alpha - ''.29 \cos \alpha.$$

For southern stars (south of 51°.5 δ)

$$-\,.21 + 1.56 \sin Z - ''.82 \sin \alpha - .24 \left(\frac{28^\circ - \delta}{10}\right) \cos \alpha.$$

Z is reckoned in the usual direction from 0° to 360°.

For convenience the following tables have been constructed :

Table IV.

Definitive corrections for Bessel's Fundamenta Astronomiæ.

Northern stars, + 51°.5 *to* + 90°.

	δ	Correction. Above pole.	Correction. Below pole.
	°	″	″
A	50	− .13	+ .82
	55	− .40	+ 1.06
	60	− .66	+ 1.27
	65	− .92	+ 1.46
	70	− 1.15	+ 1.60
	75	− 1.35	+ 1.70
	80	− 1.52	+ 1.76
	85	− 1.65	+ 1.77
	90	− 1.73	+ 1.73

Note.—The corrections are applicable to declinations directly, whether observed above or below pole. The entire correction for northern stars is $A + B$.

	α	Corr.	α
	h	″	h
B	0	− .29	12
	1	− .27	13
	2	− .23	14
	3	− .17	15
	4	− .10	16
	5	− .03	17
	6	+ .05	18
	7	+ .12	19
	8	+ .19	20
	9	+ .24	21
	10	+ .28	22
	11	+ .30	23
	12	+ .29	24

From 12^h to 24^h the correction has the opposite sign.

C*.

For stars south of 51°.5 δ.

A. R.	DECLINATION.																
	+50°	+45°	+40°	+35°	+30°	+25°	+20°	+15°	+10°	+05°	+00°	−05°	−10°	−15°	−20°	−25°	−30°
	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″	″
0	+ .42	+ .56	+ .71	+ .82	+ .92	+ .98	+1.01	+ .99	+ .93	+ .82	+ .66	+ .46	+ .21	− .08	− .40	− .75	−1.12
1	+ .18	+ .34	+ .48	+ .60	+ .70	+ .77	+ .80	+ .78	+ .73	+ .62	+ .46	+ .27	+ .02	− .26	− .58	− .92	−1.29
2	− .07	+ .09	+ .25	+ .39	+ .49	+ .58	+ .61	+ .61	+ .57	+ .48	+ .33	+ .14	− .09	− .36	− .67	−1.00	−1.35
3	− .33	− .15	+ .03	+ .19	+ .31	+ .42	+ .47	+ .49	+ .46	+ .39	+ .26	+ .10	− .12	− .37	− .66	− .97	−1.31
4	− .58	− .37	− .17	+ .01	+ .16	+ .29	+ .37	+ .41	+ .41	+ .36	+ .26	+ .12	− .07	− .30	− .56	− .85	−1.16
5	− .79	− .55	− .32	− .11	+ .05	+ .22	+ .33	+ .40	+ .43	+ .41	+ .34	+ .23	+ .06	− .14	− .37	− .63	− .91
6	− .96	− .69	− .43	− .19	+ .62	+ .21	+ .34	+ .45	+ .50	+ .52	+ .48	+ .40	+ .27	− .10	− .10	− .33	− .58
7	−1.08	− .77	− .48	− .21	+ .03	+ .25	+ .42	+ .55	+ .64	+ .69	+ .66	+ .62	+ .53	+ .39	+ .22	+ .02	− .20
8	−1.13	− .79	− .48	− .18	+ .09	+ .34	+ .54	+ .70	+ .82	+ .89	+ .91	+ .89	+ .82	+ .71	+ .57	+ .40	+ .22
9	−1.10	− .75	− .41	− .05	+ .21	+ .49	+ .71	+ .90	+1.04	+1.14	+1.18	+1.19	+1.14	+1.06	+ .94	+ .80	+ .63
10	−1.02	− .65	− .28	+ .06	+ .37	+ .67	+ .91	+1.12	+1.28	+1.39	+1.40	+1.48	+1.45	+1.39	+1.29	+1.17	+1.02
11	− .87	− .49	− .11	+ .24	+ .57	+ .88	+1.13	+1.34	+1.52	+1.65	+1.72	+1.76	+1.77	+1.69	+1.61	+1.49	+1.36
12	− .68	− .29	+ .09	+ .45	+ .78	+1.09	+1.35	+1.57	+1.75	+1.88	+1.96	+2.00	+1.99	+1.94	+1.86	+1.75	+1.62
13	− .44	− .06	+ .32	+ .68	+1.00	+1.31	+1.56	+1.78	+1.95	+2.08	+2.17	+2.19	+2.18	+2.12	+2.04	+1.92	+1.79
14	− .19	+ .19	+ .55	+ .89	+1.21	+1.50	+1.75	+1.95	+2.11	+2.22	+2.29	+2.32	+2.29	+2.22	+2.13	+2.00	+1.85
15	− .07	+ .43	+ .77	+1.09	+1.39	+1.66	+1.89	+2.07	+2.22	+2.31	+2.30	+2.36	+2.32	+2.23	+2.12	+1.97	+1.81
16	+ .32	+ .65	+ .97	+1.27	+1.52	+1.79	+1.99	+2.15	+2.27	+2.34	+2.36	+2.34	+2.27	+2.16	+2.02	+1.85	+1.66
17	+ .53	+ .83	+1.12	+1.39	+1.64	+1.80	+2.03	+2.16	+2.25	+2.29	+2.28	+2.23	+2.13	+2.00	+1.83	+1.63	+1.41
18	+ .70	+ .97	+1.23	+1.47	+1.68	+1.87	+2.01	+2.11	+2.19	+2.18	+2.14	+2.06	+1.93	+1.76	+1.56	+1.33	+1.08
19	+ .82	+1.05	+1.28	+1.49	+1.67	+1.83	+1.94	+2.01	+2.04	+2.01	+1.97	+1.84	+1.67	+1.47	+1.24	+ .98	+ .70
20	+ .87	+1.07	+1.28	+1.46	+1.61	+1.74	+1.82	+1.86	+1.86	+1.81	+1.71	+1.59	+1.38	+1.15	+ .89	+ .60	+ .29
21	+ .84	+1.03	+1.21	+1.36	+1.49	+1.59	+1.65	+1.66	+1.64	+1.56	+1.44	+1.27	+1.06	+ .80	+ .52	+ .20	− .13
22	+ .76	+ .93	+1.08	+1.22	+1.33	+1.41	+1.45	+1.44	+1.40	+1.31	+1.16	+ .98	+ .75	+ .47	+ .17	− .17	− .52
23	+ .61	+ .77	+ .91	+1.04	+1.13	+1.20	+1.23	+1.22	+1.16	+1.05	+ .90	+ .70	+ .45	+ .17	− .15	− .49	− .85
24	+ .42	+ .57	+ .71	+ .83	+0.92	+ .99	+1.01	+ .99	+0.93	+0.82	+ .66	+ .46	+ .21	− .08	− .40	− .75	−1.12

* Between +14° and −14°, δ, the entire correction is, C+ correction taken with opposite sign from table, p. 62, *Fund. Ast.*

SECTION VIII.

DISCUSSION OF FINAL CORRECTIONS AND WEIGHTS.

With the correction just deduced, we shall be able to add a considerable number of standard stars to the list embraced in Table III. The places of the four extreme southern stars of Table I., as well as the additional stars of Table III., will be revised by the addition of Gh, 1752 or '55, as an authority. Forty fundamental and circumpolar stars of Table I. would not be materially affected by this addition. For the present, their declinations as already corrected, will be regarded as standard.

Two or three stars, which should have been included in the list, were omitted by accident.

The manner of deducing $\Delta\delta$ and $\Delta\mu'$ has been sufficiently explained under sections VI. and VII. Their values will be found to be not materially different from those finally deduced.

Table V.

Values of Δδ and Δμ′ adopted in computing final systematic corrections for the principal catalogues.

Star's name.	1845. Δδ	1845. Δμ′	Star's name.	1845. Δδ	1845. Δμ′
	″	″		″	″
α Andromedæ	— .14	— .90	α Leporis	— .14	+ .17
β Cassiopeæ	— .31	+1.11	ε Orionis	— .35	— .24
γ Pegasi	— .23	— .16	α Orionis	+ .02	— .02
ζ Cassiopeæ	— .13	+ .47	β Aurigæ	— .05	— .60
α Cassiopeæ	+ .02	— .43			
β Ceti	— .23	+1.20	η Geminorum	— .02	+ .21
η Cassiopeæ	—1.20	+1.62	μ Geminorum	— .46	—1.15
γ Cassiopeæ	— .39	+2.68	γ Geminorum	+ .22	—1.59
ε Piscium	— .26	— .39	Cephei, (51 H)	+ .12	— .67
β Andromedæ	+ .24	—1.97	ε Canis Majoris	— .67	+2.00
α Ursæ Minoris	+ .09	— .26	ζ Geminorum	+ .72	—1.54
δ Cassiopeæ	+ .05	+ .82	δ Geminorum	— .17	—2.48
θ^1 Ceti	+ .13	— .29	β Canis Minoris	+ .09	— .73
η Piscium	— .52	—2.36	κ Geminorum	+ .81	—1.51
51 Andromedæ	— .35	+ .06	β Geminorum	— .21	— .43
54 Andromedæ	+ .43	—2.92	φ Geminorum	+ .01	—1.49
ο Piscium	— .13	—1.59	ρ Argus	— .10	— .62
ε Cassiopeæ	+ .18	+ .25	β Cancri	— .31	+ .04
β Arietis	— .04	—1.76	ο Ursæ Majoris	+ .06	+ .95
50 Cassiopeæ	+ .44	+2.02	δ Cancri	+ .03	—1.08
γ Andromedæ	+ .26	+ .96	ε Hydræ	— .27	—2.54
α Arietis	— .13	— .65	ι Ursæ Majoris	— .27	— .22
β Trianguli	— .31	— .38	σ^2 Ursæ Majoris	+ .78	+4.46
ξ^1 Ceti	+ .04	— .57	κ Cancri	— .12	—2.72
ξ^2 Ceti	- .13	+ .40	α Lyncis	— .12	— .20
γ Ceti	— .40	—1.14	α Hydræ	+ .13	— .78
α Ceti	— .21	+ .49	θ Ursæ Majoris	— .33	+ .60
β Persei	+ .44	— .92	ο Leonis	+ .47	— .60
α Persei	— .23	+ .33	ε Leonis	+ .03	—1.57
ξ Tauri	+1.37	+ .58	υ Ursæ Majoris	+ .33	— .20
δ Persei	— .25	+ .01	μ Leonis	— .39	— .15
η Tauri	— .13	— .84	α Leonis	+ .06	—1.18
γ Eridani	— .44	+ .66	λ Ursæ Majoris	— .58	+1.46
ε Tauri	+ .18	—1.35	γ^1 Leonis	— .33	—3.10
α Tauri	+ .06	— .79	μ Ursæ Majoris	+ .26	—1.11
4 Camelopardalis	+ .25	+ .20	ρ Leonis	— .28	—1.11
α Camelopardalis	+ .36	—2.12	53 Leonis	— .36	—2.26
ι Aurigæ	— .47	— .76	β Ursæ Majoris	+ .29	—2.16
β Camelopardalis	+ .23	— .12	α Ursæ Majoris	+ .02	— .45
ε Aurigæ	+ .13	— .91	ψ Ursæ Majoris	— .15	— .51
η Aurigæ	+ .23	—1.14	δ Leonis	+ .19	—2.09
α Aurigæ	+ .01	— .58	δ Crateris	— .59	+ .30
β Orionis	+ .19	— .01	τ Leonis	— .11	—1.80
β Tauri	— .24	+ .35	λ Draconis	+ .42	+3.23
δ Orionis	— .48	—1.18			

TABLE V—Continued.

Star's name.	1845.		Star's name.	1845.	
	$\Delta\delta$	$\Delta\mu'$		$\Delta\delta$	$\Delta\mu'$
	″	″		″	″
ν Leonis	−.68	+1.08	ε Herculis	+.35	−2.31
χ Ursæ Majoris	+.04	−.43	ε Ursæ Minoris	+.19	−.63
β Leonis	+.26	−2.44	α^{1} Herculis	+.20	−.34
β Virginis	−.01	−1.00	ρ^{2} Herculis	−.11	−1.14
γ Ursæ Majoris	+.20	−.25	β Draconis	+.13	+.41
ο Virginis	−.40	−2.54	α Ophiuchi	+.11	−1.05
δ Ursæ Majoris	−.14	−.16	ω Draconis	−.31	+1.76
η Virginis	−.39	−1.76	μ Herculis	+.02	−1.47
β Corvi	−.34	−.06	ψ^{1} Draconis	−.01	+.59
κ Draconis	−.63	+2.80	γ Draconis	−.05	+.35
B. A. C. 4342	+.57	+3.83	μ Sagittarii	−.42	+.34
ε Ursæ Majoris	+.31	+3.43	δ Ursæ Minoris	+.01	+.66
α Canum Venaticorum	−.06	−.83	η Serpentis	+.36	−2.02
θ Virginis	−.08	−2.54	χ Draconis	+.46	+.08
α Virginis	+.05	−1.00	α Lyræ	+.36	−1.63
ζ^{1} Ursæ Majoris	+.00	+.35	ε^{1} Lyræ	−.68	+.91
ζ Virginis	−.33	−2.70	β Lyræ	+.21	−2.85
η Ursæ Majoris	+.10	−1.01	σ Sagittarii	−.02	−.05
η Bootis	−.21	−1.45	ο Draconis	+.25	−.84
α Draconis	+.23	+.22	ε Aquilæ	−.23	+.35
α Bootis	−.23	−2.02	λ Aquilæ	+.13	−.73
λ Bootis	−.43	+1.03	ζ Aquilæ	+.13	−.47
θ Bootis	−.14	−.70	δ Draconis	+.11	+.81
ρ Bootis	+.22	−1.14	κ Cygni	−.33	+.60
γ Bootis	+1.02	−1.41	τ Draconis	+.42	+1.17
5 Ursæ Minoris	+.63	+3.32	δ Aquilæ	+.05	+.45
ε^{1} Bootis	−.09	+.28	ι^{2} Cygni	−.03	−.43
α^{2} Libræ	+.05	−1.87	κ Aquilæ	−1.27	−2.84
β Ursæ Minoris	−.07	+1.05	θ Cygni	−.45	+1.85
β Bootis	−.02	−.70	γ Aquilæ	+.00	−.25
β Libræ	+.04	−.97	δ Cygni	+.20	−2.61
μ Bootis	−.30	−.57	α Aquilæ	+.04	−.10
γ^{2} Ursæ Minoris	−.10	−.13	β Aquilæ	−.14	−.74
ι Draconis	+.12	−.28	λ Ursæ Minoris	+.26	+1.18
α Coronæ Borealis	−.02	−1.00	o^{2} Cygni	−.21	+.40
α Serpentis	+.03	−.57	α^{2} Capricorni	−.30	+.53
ε Serpentis	−.22	−1.85	κ Cephei	+.36	+2.50
ζ Ursæ Minoris	−.13	−.39	γ Cygni	+.42	−1.97
δ Scorpii	+.61	−2.74	ο Cephei	+.10	+.74
β^{1} Scorpii	+1.62	−5.77	α Delphini	+.61	−1.76
θ Draconis	+.03	+.73	α Cygni	+.03	−.88
δ Ophiuchi	−.34	+.59	ε Cygni	+1.89	−2.41
τ Herculis	−.30	−.36	η Cephei	−.39	+1.37
α Scorpii	−.05	−1.20	μ Aquarii	−.68	−2.84
η Draconis	+.16	−.48	ν Cygni	−2.57	+1.41
15 Draconis	+.01	+.84	61^{1} Cygni	+.61	+.10
σ Herculis	−.17	+.45	ζ Cygni	−.45	−1.39
ζ Herculis	+.03	+.28	α Cephei	−.07	+1.68
η Herculis	−.69	−3.00	β Aquarii	+.07	−.34
κ Ophiuchi	−.01	−.39	β Cephei	−.01	+1.33

TABLE V—Continued.

Star's name.	1845.		Star's name.	1845.	
	$\Delta\delta$	$\Delta\mu'$		$\Delta\delta$	$\Delta\mu'$
	"	"		"	"
ε Pegasi	+ .04	— .65	ζ Pegasi	— .46	+2.01
ν Cephei	— .13	+1.20	λ Pegasi	— .10	— .01
16 Pegasi	+ .06	— .72	ι Cephei	+ .07	+1.20
α Aquarii	— .10	— .40	λ Aquarii	— .37	—2.07
ζ Cephei	+ .24	—1.09	α Piscis Australis	— .66	+1.75
θ Aquarii	— .36	—1.53	α Pegasi	+ .33	—1.82
γ Aquarii	— .16	+ .49	ο Cephei	+ .53	+4.63
δ² Cephei	+ .00	+1.77	ι Piscium	— .54	+1.21
α Lacertæ	+ .08	— .43	γ Cephei	+ .04	+1.12
η Aquarii	— .66	+2.20	ω Piscium	— .47	—1.04

The general condition in the selection of the stars of Table V. is, that the weight of $\Delta\mu'$ as determined by the adopted weights (p. 72) shall be at least .5. In two or three instances it fell below this amount by trifling quantities. Column $C_{,,}$ "Details of Corrections to Assumed Declinations," contains the values of C, corrected for the proper quantities taken from Tables II. and IV. From these $\Delta\,\delta$ and $\Delta\,\mu'$ are computed. With the help of $\Delta\,\delta$ and $\Delta\,\mu'$, the correction to the assumed declination was computed for every epoch required. Denoting these corrections by $\Delta\,\delta'$, we have:

$$r = \Delta\,\delta' - C.$$

These are the corrections* to various catalogues given by the standard declinations of Table V; and from these, arranged by catalogues and successively in the order of declination and right ascension, the definitive systematic corrections are derived for all catalogues; a few excepted which were of small weight, or which contained few observations of standard stars.

Determination of Definitive Systematic Corrections and weights.

For convenience the residuals were combined in groups embracing generally not more than 5°, when discussed in order of declination, and two hours in order of right ascension. To effect these combinations, weights are assigned in each particular case, which are based either on special investigations made in this paper, or elsewhere; or upon an empirical law derived from a consideration of the circumstances surrounding the observations, or their reduction. The usual form of this law has been:

$$\pi' = \frac{E^2}{\varepsilon^2_{,} + \dfrac{\varepsilon^2}{n}}$$

Where E is the probable error of a single observation, or of the unit of weight, and the other quantities have the same signification as in the discussion of Washington

* For the values of r consult "Details of Corrections," etc.

declinations (p. 46). For the ratio $\frac{\varepsilon}{\varepsilon_{\prime}}$, an integer was always used, since it must necessarily be a mere approximation. The weights attached to means of groups were made use of in the graphic process, by means of which the corrections in order of declination are invariably deduced. The choice of scale in plotting the residuals, depends upon the accuracy of the catalogue places under consideration, and was always such, that the relative weights could be clearly represented by circles drawn about the points to which they respectively belong.

It was my original intention to investigate nearly all the corrections by the use of periodic formulæ; but the time at my disposal proved too limited for the purpose, and it may be doubted whether such a course is really desirable for the corrections which depend upon the order of declination.

Extreme accuracy is not to be expected in the corrections derived from graphic process. The temptation to make abrupt changes in direction of the curve, in order to represent what may be mere accidental accumulation of errors, has been steadily resisted. On the other hand, where even a slight peculiarity is found to be persistent for a number of catalogues under the same circumstances (*i. e.*, at the same observatory or with the same instrument), it has been respected. Such peculiarities have been noticed in the later Greenwich and Radcliffe catalogues, and in others. Theoretical considerations have sometimes received weight in deciding the *general direction* of curves, especially where refraction exerts an important influence.

Corrections depending on right ascension have generally been viewed with suspicion. In many cases, however, they are important and clearly indicated, and in others they might have been safely expected. Where the correction appears to follow approximately the same law in successive catalogues of the same series we may adopt it without hesitation. The separation of the residuals into two or more zones has always been made before accepting a correction as definitive.

The adopted form,—

$$x \sin \alpha + y \cos \alpha,$$

has some support in theory, and is here invariably adopted in corrections of this class.

Corrections to Declinations from —30° to —90°.

The continuation of the curves of correction from —30° to —90° offers only a rough approximation.

The corrections to C. G. II. 31, S. II. 31, C. G. II. 33, So 51, So 55, C. G. II. 58, Me 62, and Me 68, were first approximately determined between the limits —10° and—30°. These approximations are almost identically those of the final table, and are formed on the same basis—the only difference being that the general direction of the curve of correction was better ascertained after its approximate character was known for the southern limit. A value of the correction being assumed for declination —30°, the remaining values were directly interpolated from this point, so as to have the value zero at declination —90°. These preliminary values are in some cases quite different from those of the definitive table (IX.). The following table contains these preliminary corrections as actually used. Under the designation of each authority, is also given the weight assigned to it in the discussion of $\Delta\delta$ and $\Delta\mu'$. When the number of observations is three or four, the weight is one-half that which otherwise would have been assigned; when it is two, the weight is three-tenths, and one observation is always rejected.

TABLE VI.

δ	C. G. H. 31.	S. H. 31.	C. G. H. 33.	So 51	So 55	C. G. H. 58.	Me 62.	Me 68.
°		"	"	"	"	"	"	"
— 30	00	+ .50*	+ .90	+ .80	— .50	00	+ .87	— .57
— 40	00	+ .42	+ .75	+ .67	— .42	00	+ .73	— .48
— 50	00	+ .31	+ .60	+ .53	— .34	00	+ .58	— .38
— 60	00	+ .25	+ .45	+ .40	— .25	00	+ .41	— .29
— 70	00	+ .17	+ .30	+ .26	— .17	00	+ .29	— .19
— 80	00	+ .08	+ .15	+ .13	— .08	00	+ .15	— .10
— 90	00	+ 00	00	00	00	00	00	00
Weight..	1	2	2	2	2	4	2	3

* The corrections S. H. 31 are applicable directly to catalogue places.

For convenience, the epoch of $\Delta\,\delta$ is taken for these few stars at 1850. The values of $\Delta\,\delta$ and $\Delta\,\mu'$ thus determined, are shown in Table VII., which contains only stars whose declinations are given both in S. H. 31 and C. G. H. 33.

TABLE VII.

First approximation to $\Delta\delta$ and $\Delta\mu'$ for stars between —30° and—90°.

Star's name.	$\Delta\delta$ 1850.	$^{\pi}\Delta\delta$	$\Delta\mu'$	$^{\pi}\Delta\mu'$
	"		"	
β Hydri	— .02	17.7	+ .57	.32
γ Phœnicis	+ .27	7.1	—2.71	.18
α Eridani	+ .33	15.9	—1.13	.32
θ^1 Eridani	— .13	10.5	— .81	.22
α Columbæ	— .34	15.9	— .27	.32
β Columbæ	+ .07	11.3	— .85	.25
α Argus	— .43	17.7	+1.32	.32
ζ Argus	— .05	8.5	— .70	.21
λ Argus	+ .32	10.5	—2.13	.22
ι Argus	— .33	12.9	+1.30	.25
η Argus	— .08	16.2	— .43	.28
β Chameleontis	+ .31	16.1	+ .04	.27
α^1 Crucis	+ .15	12.6	—2.69	.29
β Centauri	+1.13	16.4	—5.27	.32
α^2 Centauri	+ .51	13.0	—8.28	.22
α Triang. Australis	+ .72	14.4	—4.58	.27
η Scorpii	— .42	9.4	+ .23	.20
σ Octantis	[+ .11]	....	[— .76]	....
α Pavonis	+ .46	11.7	—2.29	.26
α Gruis	— .37	12.7	+2.06	.28

I estimate the probable error of the unit of weight to be ± .4. This would give for average probable error of $\Delta\,\delta$ ± .1, and for $\Delta\,\mu'$ ± .8.

In discussing the probable error of the unit of weight for each catalogue, the stars from — 30° to — 90° were not used in any case.

Discussion of Individual Catalogues.

The examination of the systematic corrections and probable errors of each catalogue will now be presented. A brief explanation will probably suffice to make the process easily understood. The relative weights of the individual values of r for a given catalogue, were first assigned, usually, by deciding upon a value for $\frac{\varepsilon}{\varepsilon_{\prime}}$. The following table is constructed with the arguments, number of observations, and $\frac{\varepsilon}{\varepsilon_{\prime}}$, where ε is that part of the probable error, which is supposed to diminish in proportion to $\frac{1}{\sqrt{n}}$, n being number of observations, and $\varepsilon_{\prime}$ the minimum probable error, or probable error when n is a maximum.

TABLE VIII.

$\frac{\varepsilon}{\varepsilon_{\prime}}=2$		$\frac{\varepsilon}{\varepsilon_{\prime}}=3$		$\frac{\varepsilon}{\varepsilon_{\prime}}=4$	
n	π'	n	π'	n	π'
1	1	1	1	1	1
2 and 3	2	2	2	2	2
4	2.5	3	2.5	3 and 4	3
5 to 9	3	4	3	5	4
10 to 35	4	5 to 7	4	6 and 7	5
36, or more.	5	8 to 11	5	8 and 9	6
		12 to 16	6	10 to 12	7
		17 to 27	7	13 to 16	8
		28 to 51	8	17 to 20	9
		52, or more.	9	21 to 25	10
				26 to 33	11
				34 to 44	12
				45 to 62	13
				63 to 92	14
				93, or more.	15

With the chosen weights, the values of r were combined in order of declination into convenient groups, r_0, embracing generally not more than 5° of declination. From these the curve is carefully drawn. The values in column C_0 are taken from this curve.

The outstanding residuals r' (formed by subtracting from the individual values of r the correction from the curve) are then arranged in order of right ascension and in groups, embracing each about two hours. Mean a is usually given to nearest hour, unless the fractional difference is more than two or three tenths. In discussion, the nearest degree of a was taken. In order to facilitate examination, the corrections in order of a have been in all cases arranged in two or more *zones* of declination, but where such an arrangement is of no particular interest it is here omitted.

In a few cases the correction in order of declination has been rediscussed after subtracting from r the respective values of $x \sin a + y \cos a$, but this has not usually been considered necessary.

Following the discussion of correction of each catalogue is a statement of the probable error, derived from the outstanding residuals after subtracting the proper systematic correction from the separate values of r. The result of no star was taken, which at the given observatory culminates at a zenith distance greater than 70°. These probable errors are somewhat too small for the catalogues used in forming Table V., and slightly too large for all others. The former difficulty is remedied in a few instances by the adoption of probable errors founded on special discussions. Kg 21, Dt 24, Pa 45, Wn 68, and Wn 72, are examples of this kind. These probable errors are, of course, not the absolute probable errors; they express simply liability to fortuitous errors, after systematic corrections have been applied. They are required for the purpose of constructing a table of relative weights to be used in the discussion of definitive places.

In deriving the probable error (E) of a single observation, a quantity m was always subtracted from the number of residuals before dividing the sum of squares multiplied by weights—that is, the probable error of the unit is derived on the estimate that an equal degree of accordance could have been secured with a formula of correction containing m terms.

Po 1800.

Each declination is supposed to be entitled to the same weight. The groups embrace each about 2° of δ.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	Mean δ	π'	r_0	C_0
°		″	″	°		″	″
+ 86.7	5	− .23	.00	+ 23.9	4	− 1.70	− 1.22
+ 76.3	6	+ .90	.00	+ 22.1	6	− .88	− 1.27
+ 72.0	5	− .71	.00	+ 19.6	6	− .94	− 1.41
+ 69.5	4	− .54	.00	+ 15.3	8	− 2.02	− 1.83
+ 67.2	4	+ .26	.00	+ 13.5	5	− 2.17	− 1.85
+ 65.3	2	+ .15	.00	+ 10.3	9	− 1.79	− 1.61
+ 62.0	7	+ .35	.00	+ 8.4	8	− 1.35	− 1.36
+ 59.7	8	− .11	.00	+ 6.6	5	− .20	− 1.20
+ 57.3	8	− .24	− .05	+ 3.6	7	− .71	− 1.13
+ 55.3	3	+ .12	− .05	− 0.5	7	− 2.04	− 1.59
+ 52.4	7	+ .19	− .15	− 3.6	5	− 2.72	− 2.04
+ 49.4	7	− .60	− .22	− 7.2	3	− 2.20	− 2.24
+ 46.8	5	− .30	− .40	− 9.1	7	− 1.76	− 2.22
+ 44.5	6	− .82	− .54	− 14.1	4	− 2.40	− 1.79
+ 41.7	5	− .24	− .90	− 18.7	3	− .80	− 1.25
+ 39.5	7	−1.19	−1.04	− 22.4	4	− 1.12	− 1.05
+ 37.7	3	−3.33	−1.19	− 27.1	3	− 1.08	− 1.00
+ 34.0	6	−2.05	−1.44	− 30.0	1	− 1.40	− 1.00
+ 31.4	3	−1.19	−1.45	− 35.0	2	+ .08	− 1.00
+ 28.4	6	− .77	−1.30	− 42.1	5	− 2.21	− 1.00
+ 26.6	4	−1.33	−1.23				

In drawing the curve much assistance was derived from the comparison of Ao 29 and Po 1800, made by Argelander (Abo Catalogue, p. xi). If we denote by β the correction to Gh 1755, and by β' the definitive correction to Ao 29 (Table IX.), we shall have $\frac{29}{74}(\beta-\beta')+\beta'$ for stars south of 51°.5 declination, and $\frac{29}{77}(\beta-\beta')+\beta'$ for the remainder, as the correction to be applied to the comparison. The drawing of the curve proved to be extremely difficult, but its values are adopted in the discussion of all stars except the few reserved for treatment with catalogues of Class III.

The separate outstanding residuals, grouped in the order of α, give:—

Residuals in order of right ascension.

Mean α	Declination limits. -30° to $+40^\circ$		Declination limits. -30° to $+6^\circ$		Declination limits. -30° to $+90^\circ$		
	π'	r_0'	π'	r_0'	π'	r_0'	C_0'
h.		"		"		"	"
1	11	+ .78	2	+ .90	23	+ .35	− .04
3	7	+ .54	3	+ .47	10	+ .42	+ .25
5	10	+ .63	4	+ .90	16	+ .46	+ .46
7	12	+ .44	2	− .80	13	+ .29	+ .56
9	9	+ .67	1	+1.00	14	+ .71	+ .50
11	10	− .41	4	− .75	19	− .16	+ .31
13	7	+ .79	5	+ .72	12	+ .42	+ .04
15	12	+ .40	5	+ .50	20	+ .52	− .25
17	10	− .91	2	− .50	19	− .89	− .46
19	13	− .99	5	− .82	21	− .89	− .56
21	11	− .91	4	− .90	21	− .39	− .50
23	10	− .93	5	− .74	16	− .47	− .31

The values of r_0' taken between the limits -30° and $+90^\circ$ of declination give the following correction:—

$$-''.04 + (''.53 \pm ''.085) \sin \alpha - (''.18 \pm ''.085) \cos \alpha.$$

The formula reduces the sums of squares from 351″ to 312″. With $m = 10$,

$$E = \pm ''.85.$$

To derive the final curve (order of δ) for use with stars of Section X., the residuals resulting from the definitive places of 380 stars were first diminished by the value of the periodic term $+ ''.53 \sin \alpha - ''.18 \cos \alpha$. The result of no star is accepted where the probable error of $\Delta \mu'$ is estimated to be greater than ″.8, and where the same is between ″.6 and ″.8 the corresponding residual is given half weight.

Never more than 5°, and generally not more than 4°, of declination were included in a single group. The results follow:—

Residuals in order of declination.

Mean δ	π'	r_0''	C_0	Mean δ	π'	r_0''	C_0
°		"	"	°		"	"
+ 85	7*	− .15	+ .13	+ 21	25	− 1.22	− 1.57
+ 78	9	+ .71	+ .36	+ 16	19	− 2.03	− 1.62
+ 73	12	+ .30	+ .47	+ 11	14	− 1.84	− 1.40
+ 69	16	+ .44	+ .52	+ 6	20	− .86	− 1.30
+ 61	12	+ .85	+ .51	+ 1	12	− 1.43	− 1.51
+ 59	20	+ .31	+ .15	− 5	5	− 2.17	− 1.86
+ 51	15	+ .35	+ .30	− 9	11	− 2.05	− 1.94
+ 49	25	+ .17	+ .02	− 14	5	− 2.18	− 1.85
+ 44	19	− .29	− .10	− 19	5	− .76	− 1.56
+ 39	30	−1.23	− .85	− 23	5	− 1.70	− 1.30
+ 34	16	−1.13	−1.04	− 28	6	− .78	− 1.11
+ 30	20	− .72	−1.10	− 35	2	− .70	− 1.21
+ 26	22	−1.30	−1.11	− 42	5	− 2.08	− 1.5

* Polaris is given weight 2.

Of the 380 stars employed, 50 received weight .5. The curve is still very uncertain. From 0° to 40° declination it is particularly unsatisfactory. By making abrupt changes in the direction of the curve at + 35°, + 30°, + 15°, and + 5°, the observations would be much better represented. I did not, however, feel justified in taking this course. The plus residuals from 40° to 90° average much larger than in the former discussion. This appears to be almost solely due to accidental causes. Had r_0'' been constructed without correction for terms in α, the plus residuals would have been reduced less than one-tenth of a second. The probable error of the unit of weight, using only the 329 residuals with weight 1, north of — 30°, is ± ″.78, and considerably smaller than before. For stars from + 40° to + 90° it is ± ″.88, + 30° to + 40° ± 1″.02, and from — 30° to + 30° ± ″.66. I did not think it worth while to repeat the investigation of terms in α.

Bh 1810.

From r_0 a preliminary correction was derived and used before discussing terms in α. Column r_0'' is formed, taking into account the effect of these terms. C_0 contains values derived from the definitive curve.

Residuals in order of declination.

Mean δ	π′	r_0	r_0''	C_0	
°		″	″	″	
86.5	24	+ .35	+ .07	+ .10	$\frac{\varepsilon}{\varepsilon_{\prime}}=2$
76.2	21	+ .66	+ .38	+ .36	
70.8	33	+ .57	+ .33	+ .31	
66.5	22	— .07	+ .25	+ .19	
60.8	58	+ .16	.00	+ .01	
56.7	50	— .04	— .08	— .02	
50.9	65	+ .25	+ .18	+ .10	
45.6	55	+ .03	+ .08	+ .10	
40.2	57	+ .06	— .01	.00	

The residuals are arranged in order of α without separation into zones of δ. As has been stated, they result from the use of a preliminary correction derived from column r_0.

Residuals in order of right ascension.

Mean α	π′	r_0'
h.		″
0.99	49	— .10
3.22	13	— .06
5.09	34	— .13
9.34	30	—1.20
11.78	48	— .30
14.48	49	— .10
16.79	52	+ .10
19.63	73	+ .73
22.30	37	+ .57

The discussion gives, in fair accordance with those of Argelander and Auwers, this correction:

$$-\,''.080 \pm ''.051 - (''.534 \pm ''.077) \sin \alpha + (''.401 \pm ''.073) \cos \alpha.$$

With $m = 7$, we have:—

$$E = \pm\ 1''.03.*$$

Kg 21.

Within the groups the variation in precision is small. Each r is therefore given weight 1.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
$''$		$''$	$''$
+ 87.6	2	− .13	+ .01
+ 76.6	3	− .09	+ .08
+ 70.8	4	+ .37	+ .12
+ 60.9	7	+ .03	+ .18
+ 56.3	4	+ .39	+ .17
+ 51.1	7	− .03	+ .14
+ 41.7	3	− .07	+ .09
+ 40.0	7	+ .12	+ .06
+ 28.1	4	+ .29	+ .06
+ 21.3	2	− .08	+ .10
+ 14.5	7	+ .07	+ .13
+ 8.2	4	+ .16	+ .17
+ 4.0	3	+ .36	+ .20
− 1.1	1	+ .44	+ .27
− 9.1	3	+ .29	+ .41
− 14.2	2	+ .36	+ .53
− 27.6	2	+1.25	+ .84

With catalogue probable errors as an argument, and with the probable error of unit of weight ± .30, taking $m = 4$, we have from the outstanding residuals $E = \pm\ .30$. The probable errors given in the catalogue are therefore adopted in the construction of definitive weights.

Residuals in order of right ascension.

Declination limits. −30° to +90°			Declination limits. −30° to +90°		
Mean α	π'	r_0'	Mean α	π'	r_0'
		$''$			$''$
1	6	+ .15	13	3	− .03
3	3	− .13	15	8	− .26
5	7	− .21	17	8	− .08
7	1	+ .10	19	8	− .17
9	2	− .05	21	8	+ .14
11	5	+ .26	23	4	+ .08

* In forming an opinion as to the precision of the declination determinations of various catalogues it is, of course, necessary to consider the value of E in connection with the ratio $\frac{\varepsilon}{\varepsilon'}$. In many cases the value of E does not refer at all to the probable error of a single observation; and when it can be so construed, it is often and necessarily a rough approximation. The most that can be said is that the adopted law of probable errors for a given catalogue is calculated to give with tolerable fidelity the probable errors due to the numbers of observation most frequently occurring with the stars of Table V.

Gh 22.

The use of the correction zero adopted in Section VI. is continued, since no further material is available. The correction — ″.11 actually results.

Residuals in order of right ascension.

Mean α	π′	r_0'	Mean α	π′	r_0'
		″			″
1	3	— .06	13	1	— .10
3	1	— .70	15	4	+ .10
5	4	+ .08	17	3	— .12
7	1	.00	19	3	+ .08
9	2	— .65	21	3	— .22
11	1	— .20	23	2	— .35

Dt 24.

The weights correspond to the probable errors of the catalogue, and the unit of weight, to a probable error of ± ″.25.

Residuals in order of declination.

Mean δ	π′	r_0	C_0
°		″	″
+ 86.5	10	— .07	— .04
+ 76.3	11	— .04	— .16
+ 71.1	13	— .27	— .20
+ 66.1	11	— .19	— .23
+ 61.4	16	— .32	— .25
+ 56.4	16	— .29	— .27
+ 50.4	18	— .25	— .25
+ 45.2	12	— .23	— .22
+ 40.0	13	— .23	— .19
+ 32.1	3	— .74	— .14
+ 28.1	8	— .09	— .13
+ 21.3	4	+ .14	— .14
+ 14.6	14	— .19	— .22
+ 8.2	8	— .48	— .32
+ 4.0	6	— .66	— .40
— 1.1	2	— .50	— .51
— 9.1	6	— .49	— .70
— 14.0	1	— .59	— .82
— 26.1	2	—1.32	....

Excluding α and δ Ursæ Minoris, and with $m = 4$, we have:—

$$E = \pm\ ''.26.$$

The catalogue probable errors are adopted.

Residuals in order of right ascension.

Declination limits. -30° to $+90^\circ$			Declination limits. -30° to $+90^\circ$		
Mean α	π'	r_0'	Mean α	π'	r_0'
		$''$			$''$
1	13	$-.06$	13	16	$+.02$
3	7	$+.06$	15	24	$+.10$
5	17	$-.10$	17	19	$-.53$
7	2	$+.50$	19	18	$-.02$
9	11	$+.11$	21	18	$-.07$
11	19	$-.02$	23	11	$+.12$

Va 29.

Each *r* receives weight 1.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
$^\circ$		$''$	$''$
$+74.8$	1	$+.50$	$+.40$
$+69.9$	1	$+.81$	$+.40$
$+62.2$	2	$-.39$	$+.40$
$+55.1$	2	$+.80$	$+.38$
$+50.3$	3	$+.61$	$+.31$
$+45.2$	2	$-.03$	$+.24$
$+38.7$	1	$+.81$	$+.14$
$+28.1$	4	$-.19$	$-.08$
$+21.3$	2	$-.31$	$-.19$
$+14.3$	7	$+.05$	$-.15$
$+8.2$	4	$-.14$	$-.13$
$+4.8$	2	$-.08$	$-.10$
-1.1	1	$-.53$	$-.06$
-9.1	3	$-.13$	$-.01$

No attempt is made to discuss terms in α. With $m = 4$, we have:—

$$E = \pm\, ''.47.$$

Ao 29.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 88.9	7	+ .20	00	$\frac{\varepsilon}{\varepsilon_{\prime}}=3$
+ 76.6	33	+ .00	00	
+ 71.6	34	— .01	00	
+ 66.3	33	+ .02	00	
+ 61.2	80	— .05	00	
+ 56.5	58	— .02	00	
+ 50.6	74	+ .09	— .02	
+ 45.6	77	— .13	— .07	
+ 39.3	60	— .15	— .14	
+ 34.0	46	— .21	— .17	
+ 27.4	47	— .20	— .24	
+ 20.9	43	— .30	— .23	
+ 14.4	68	— .33	— .32	
+ 8.4	41	— .32	— .38	
+ 4.6	53	— .47	— .44	
— 1.5	25	— .67	— .54	
— 9.1	27	— .58	— .66	
— 14.0	21	— .88	— .70	
— 18.8	5	— .30	— .70	
— 26.1	9	— .70	....	

With $m = 4$, we have:—

$$E = \pm\ ''.46.$$

Residuals in order of right ascension.

Declination limits. — 30° to + 90°			Declination limits. — 30° to + 90°		
Mean α	π'	r_0'	Mean α	π'	r_0'
h.		"	h.		"
1	119	— .16	13	49	+ .08
3	32	— .05	15	90	+ .02
5	69	— .02	17	80	+ .06
7	9	.00	19	88	— .09
9	71	+ .34	21	93	+ .07
11	79	.00	23	56	— .05

Gh 30.

Each r is given equal weight.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		"	"
+ 86.3	6	+ .55	+ .11
+ 76.7	5	− .18	+ .15
+ 70.8	9	+ .22	+ .13
+ 66.0	4	− .17	+ .09
+ 60.8	15	− .05	+ .03
+ 57.5	10	− .18	− .06
+ 50.9	14	+ .03	− .28
+ 45.7	12	− .47	− .50
+ 39.9	16	−1.00	− .76
+ 33.1	9	−1.14	−1.02
+ 27.2	11	−1.29	−1.19
+ 21.2	14	−1.09	−1.29
+ 14.6	13	−1.51	−1.31
+ 9.0	19	−1.36	−1.31
+ 4.1	9	−1.11	−1.34
− 1.8	12	−1.51	−1.41
− 8.5	10	−1.28	−1.62
− 14.1	4	−2.00	−1.91
− 18.7	3	−2.10	−2.36
− 22.4	4	−2.75	−2.67
− 27.9	4	−2.9	−2.9
− 34.1	1	+9.3	....

With $m = 5$, we have:—

$$E = \pm\, ''.33.$$

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. +40° to −30°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	2	− .25	11	+ .15	21	+ .20
3	3	+ .43	7	+ .24	10	+ .18
5	4	+ .57	10	+ .12	16	− .04
7	2	+ .50	12	+ .13	13	+ .33
9	1	− .30	9	− .16	13	+ .06
11	4	− .10	10	− .11	19	− .07
13	5	+ .12	7	+ .09	13	.00
15	5	+ .32	12	+ .03	20	− .04
17	2	− .80	10	− .45	20	− .35
19	5	− .06	13	− .15	21	− .03
21	4	− .17	10	− .18	20	− .16
23	5	+ .30	9	+ .17	11	+ .08

A small correction, depending on the right ascension, may be indicated. The discussion was not, however, undertaken.

C. G. H. 31.

Residuals in order of declination.

Mean δ	π′	r_0	C_0	
°		″	″	
+ 12.7	2	— .88	+ .35	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2.$
+ 8.2	9	+ .00	+ .35	
+ 3.3	3	+ .61	+ .35	For the last five groups the weights are estimated.
— 0.7	7	+ .55	+ .35	
— 8.4	11	+ .27	+ .35	
— 17.9	2	+1.02	+ .35	
— 21.1	4	— .60	+ .35	
— 26.5	3	+ .61	+ .35	
— 35.0	2	+1.08	+ .17	
— 41.4	2	— .51	+ .03	
— 52.6	1	+ .38	.00	
— 59.9	5	— .40	.00	
— 78.1	1	+ .90	.00	

The correction is extremely uncertain, owing to the small number of observations, as well as large probable error. The value of E is estimated to be $\pm$ 1″.2.

The declinations have not been employed in the reduction of any stars between the limits of declination + 90° and — 30.°

S. H. 31.

The values of r are applicable to the catalogue places as reduced with Young's refractions.

Residuals in order of declination.

Mean δ	π′	r_0	C_0	
°		″	″	
+ 73.1	15	+ 1.0	+ 1.30	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2$
+ 65.1	4	+ .1	+ 1.30	
+ 62.4	10	+ 1.37	+ 1.30	
+ 56.2	11	+ 1.20	+ 1.30	
+ 51.0	19	+ 1.76	+ 1.30	
+ 44.7	7	+ 1.20	+ 1.30	
+ 38.7	8	+ .90	+ 1.30	
+ 33.2	6	+ 1.21	+ 1.30	
+ 27.9	33	+ 1.18	+ 1.30	
+ 21.3	18	+ 1.85	+ 1.30	
+ 14.6	53	+ 1.26	+ 1.30	
+ 8 2	35	+ 1.60	+ 1.26	
+ 4.1	24	+ 1.35	+ 1.21	
— 2.4	55	+ .79	+ 1.13	
— 8.5	70	+ 1.22	+ 1.00	
— 14.1	30	+ 1.32	+ .86	
— 18.5	18	+ .24	+ .74	
— 22.9	17	— 1.09	+ .65	
— 28.1	31	+ .71	+ .61	
— 35.0	2	— .13	+ .60	
— 42.1	5	+ .69	+ .60	
— 50.4	2	+ 1.41	+ .60	
— 59.2	6	+ .66	+ .41	
— 74.8	3	+ .14	+ .35	

There appears to be a well-marked correction depending on a, as is shown in the following table:—

Residuals in order of right ascension.

Declination limits. −30° to +5°			Declination limits. +5° to +60°			Declination limits. −30° to +60°		
Mean a	π'	r_0'	Mean a	π'	r_0'	Mean a	π'	r_0'
h.		″	h.		″	h.		″
1.0	16	+ .25	23.8	29	+ .58	0.7	46	+ .46
3.3	16	+ .73	2.5	16	+ .98	3.6	32	+ .86
5.8	25	+ .26	5.2	18	+ .30	5.7	42	+ .02
7.4	11	− .89	7.6	9	+ .10	8.3	21	− .25
9.3	9	− .10	11.2	21	− .75	11.3	31	− .46
11.2	7	+ .50	....	....	....	13.2	31	− .10
13.0	22	− .39	11.9	34	− .38	15.5	69	− .66
15.6	41	− .61	18.0	36	− .12	18.2	52	− .23
18.9	28	− .28	19.9	32	− .10	19.9	56	− .16
21.8	56	+ .18	....	....	....	22.3	52	+ .38

r_0' in limits −30° to +60° gives the correction $+''.27 \sin a + ''.47 \cos a$. The probable error of each coefficient is $\pm ''.09$.

With $m = 6$, we have:—

$$E = \pm 1''.34.$$

C. G. H. 33.

Each r is given weight 1.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		″	″
+ 33.2	1	+ .35	+ .31
+ 27.7	7	+ .41	+ .54
+ 21.7	7	+ .69	+ .48
+ 14.2	8	− .25	+ .11
+ 8.4	7	− .22	− .09
+ 3.7	6	+ .29	− .14
− 2.2	5	− .16	− .10
− 8.6	6	− .02	+ .10
− 11.1	4	+ .32	+ .40
− 18.7	3	+ .70	+ .65
− 22.4	4	+1.05	+ .79
− 27.9	4	+ .92	+ .89
− 35.0	2	+1.15	+ .71
− 42.1	5	+ .04	+ .32
− 55.1	2	− .60	+ .05
− 59.2	7	+ .04	+ .01
− 75.1	3	− .11	− .09

With $m = 6$, we have:—

$$E = + ''.30.$$

Residuals in order of right ascension.

Declination limits. +40° to —30°			Declination limits. +40° to —30°		
Mean a	π'	r_0'	Mean a	π'	r_0'
h.		"	h.		"
0.35	5	+.10	13.40	4	+.25
3.00	5	—.12	15.53	9	+.02
5.41	8	+.19	18.31	7	+.09
7.66	5	—.34	19.72	5	—.04
10.67	7	+.09	22.06	7	—.33

Ce 34.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+87.9	25	—.08	.00	$\frac{\varepsilon}{\varepsilon_l}=3$
+75.5	14	+.06	—.04	
+69.7	14	—.25	—.14	
+66.2	17	—.18	—.24	
+61.2	31	—.59	—.38	
+56.6	43	—.28	—.52	
+50.3	23	—.71	—.70	
+45.0	21	—.87	—.78	
+39.4	15	—.79	—.83	
+33.2	8	—.57	—.82	
+27.8	48	—.83	—.86	
+20.4	50	—.46	—.56	
+14.3	52	—.47	—.39	
+8.5	57	—.25	—.36	
+4.1	24	—.46	—.40	
—0.8	22	—.19	—.49	
—8.4	36	—.85	—.70	
—14.0	12	—1.22	—.85	
—19.2	10	—.62	—.96	
—21.7	9	—.79	—.99	
—28.4	13	—1.25	—1.00	
—34.1	2	—1.4	....	

With $m=5$, we have:—

$$E \pm {''}.70.$$

Residuals in order of right ascension.

	Declination limits. +40° to −30°		Declination limits. +40° to +90°		Declination limits. −30° to +5°		Declination limits −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	35	+ .16	32	− .23	3	− .70	67	− .01
3	22	+ .58	10	− .44	8	+ .30	32	+ .26
5	31	− .21	11	− .35	5	− .20	42	− .25
7	24	+ .04					24	+ .04
9	22	+ .39	5	− .50	8	+ .40	27	+ .23
11	32	+ .03	34	+ .11	8	+ .05	66	+ .09
13	26	+ .11	25	+ .23	20	+ .20	54	+ .17
15	50	− .06	9	+ .20	11	+ .42	59	− .02
17	22	+ .03	9	+ .12	7	+ .48	31	+ .06
19	49	− .13	17	− .05	7	− .54	66	− .41
21	25	− .12	33	+ .10	25	− .12	58	.00
23	21	− .45	7	− .06	4	− .25	28	− .35

No certain correction following α appears to be indicated.

Mh 34.

In *Observationes Astronomicæ*, 1833 and 1834, Lamont compares his declinations of fundamental stars with those of Bessel and Struve. The comparisons are used in finding the curve of correction, but no use is made of the declinations of the stars so compared.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
		″	″	
+ 71.4	12	− .29	− .29	$\frac{\epsilon}{\epsilon_1} = 3$
+ 62.6	14	− .36	− .49	
+ 57.6	7	− .68	− .56	
+ 49.6	27	− .74	− .62	
+ 40.1	36	− .55	− .54	
+ 32.0	15	− .28	− .24	
+ 27.7	50	+ .01	+ .01	
+ 21.0	66	+ .27	+ .29	
+ 11.6	72	+ .43	+ .47	
+ 9.1	79	+ .63	+ .50	
+ 4.3	42	+ .94	+ .49	
− 1.5	49	− .14	+ .38	
− 9.0	43	+ .58	+ .17	
− 14.2	19	+ .70	− .01	
− 19.7	9	− .43	− .49	
− 26.2	20	− .61	− .5	

Inadvertently the nutation correction was not applied to the values of r previous to the above discussion. The outstanding residuals are:—

Residuals in order of right ascension.

Declination limits. $-25°$ to $+5°$			Declination limits. $+5°$ to $+75°$		Declination limits. $+75°$ to $-25°$	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	2	+ 1.70	42	+ .49	44	+ .53
3	10	+ .82	9	+ .01	19	+ .44
5	17	— .11	28	+ .11	45	+ .03
7	4	— 1.50	45	— .32	49	— .42
9	19	+ .10	28	+ .16	37	+ .14
11	20	— .45	55	— .40	75	— .41
13	20	— .04	7	— .03	27	— .04
15	17	+ .34	55	+ .17	72	+ .21
17	4	— .40	44	— .17	48	— .19
19	13	+ .05	31	+ .22	41	+ .17
21	18	— .07	20	+ .17	38	+ .06
23	19	+ .41	11	+ .63	30	+ .49

Discussed for terms in a, the last column ($+75°$ to $-25°$) gives:—

$$+ ''.03 \sin a + ''.27 \cos a,$$

which agrees well with the nutation correction $+ ''.02 \sin a + .18 \cos a$. The latter is therefore adopted.

With $m = 5$, we have:—

$$E = \pm 1''.05.$$

Eh 37.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 86.9	24	— .18	— .21	$\frac{\varepsilon}{\varepsilon_1} = 2$
+ 76.6	15	— .37	— .23	
+ 70.4	7	— .18	— .23	
+ 66.3	6	— .66	— .22	
+ 61.4	26	— .14	— .21	
+ 56.0	21	— .18	— .18	
+ 50.8	30	— .22	— .16	
+ 45.4	16	+ .01	— .15	
+ 39.3	16	— .10	— .16	
+ 33.5	10	— .43	— .18	
+ 27.6	36	— .15	— .20	
+ 21.2	45	— .31	— .18	
+ 14.5	46	— .25	— .01	
+ 9.0	56	+ .31	+ .03	
+ 3.9	27	+ .07	— .03	
— 1.3	29	— .24	— .17	
— 8.6	32	— .51	— .26	
— 14.1	15	— .23	— .26	
— 18.7	9	— .25	— .18	
— 21.9	9	+ .80	— .09	
— 28.6	7	+ .44	+ .2	

With $m = 8$, we have:—

$$E = \pm ''.52.$$

Residuals in order of right ascension.

Declination limits. −30° to +5°			Declination limits. +5° to +40°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	6	−1.05	26	+ .14	15	+ .16	47	.00
3	10	+ .25	10	+ .08	5	− .04	25	+ .12
5	14	+ .16	20	− .56	12	+ .30	46	− .11
7	.....	....	24	+ .08	5	− .02	29	+ .06
9	4	+ .20	18	− .17	11	+ .11	33	− .02
11	13	+ .02	20	+ .11	16	− .05	49	+ .03
13	15	+ .19	8	− .15	10	.00	33	+ .03
15	14	+ .66	18	− .43	9	− .32	41	+ .34
17	6	− .15	11	− .04	19	.00	36	− .01
19	7	− .42	27	− .01	7	+ .11	41	− .06
21	15	− .23	17	+ .09	23	− .11	55	− .08
23	13	− .31	18	+ .21	10	− .06	41	− .02

A correction is indicated, such as might be due to an error in the adopted temperature coefficient in refraction. Very little correction is shown in the summary. I have thought it safest to neglect the discussion of terms in α. (*Vide* Eh 43).

Kg 38.

Each r was given equal weight. The numbers in column r_0'' result from a rediscussion adopting the value of the periodic formula deduced below for terms in α.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	r_0''
°		″	″	″
+ 87.5	2	− .05	− .05	− .07
+ 75.8	2	− .21	− .26	− .11
+ 71.2	2	− .75	− .32	− .54
+ 62.2	2	− .69	− .24	− .60
+ 55.1	2	+ .44	+ .10	+ .40
+ 51.1	7	+ .65	+ .24	+ .84
+ 45.9	3	+ 1.03	+ .30	+ .80
+ 39.8	6	− .08	+ .22	− .01
+ 28.1	4	− .07	+ .08	− .17
+ 21.3	2	− .01	+ .13	− .01
+ 14.3	7	+ .39	+ .27	+ .42
+ 8.2	4	+ .29	+ .46	+ .41
+ 1.0	3	+ 1.10	+ .59	+ 1.10
− 1.1	1	+ 1.10	+ .77	+ 1.05
− 9.1	3	+ .99	+ 1.09	+ .97
− 14.2	2	+ 1.36	+ 1.31	+ 1.62
− 26.1	1	+ 2.8	+ 1.8	+ 3.16

The declination curve founded on r_0 is adopted.

Residuals in order of right ascension.

Declination limits. −30° to +90°			Declination limits. −30° to +90°		
Mean δ	π′	r_0'	Mean δ	π′	r_0'
h.		″	h.		″
0.9	6	+.27	13.3	2	−.45
3.1	4	+.75	14.9	7	−.44
5.2	5	+.50	17.1	5	+.42
7.6	1	+.20	19.3	8	+.13
9.7	2	−.05	20.9	5	+.04
11.5	4	−.30	23.3	2	+.15

The correction depending on a is quite marked. The result is $+ ''.14 + ''.24 \sin a + ''.32 \cos a$. The probable errors of the terms in a are each ± .07. The formula of correction is adopted.

With $m = 8$, we have:—

$$E = \pm ''.39.$$

Gh 39.

Residuals in order of declination.

Mean δ	π′	r_0	C_0	
°		″	″	
+86.5	79	+.07	+.01	$\frac{\varepsilon}{\varepsilon_1} = 4$
+76.7	71	+.05	+.04	
+70.5	67	+.10	+.08	
+66.2	62	−.10	+.09	
+60.9	176	+.06	+.10	
+56.8	147	+.07	+.11	
+50.9	138	+.20	+.12	
+45.5	136	+.02	+.12	
+39.7	98	+.07	+.13	
+32.9	54	+.22	+.14	
+27.4	114	+.19	+.16	
+21.1	131	+.15	+.19	
+14.5	130	+.26	+.24	
+8.9	135	+.29	+.29	
+3.9	85	+.37	+.35	
−1.6	90	+.40	+.43	
−8.6	97	+.53	+.56	
−14.1	51	+.71	+.68	
−18.7	36	+.53	+.80	
−22.5	44	+1.04	+.90	
−28.1	44	+1.24	+1.05	

With $m = 4$, we have:—

$$E = \pm ''.71.$$

Residuals in order of right ascension.

	Declination limits. —30° to +5°		Declination limits. +40° to —30°		Declination limits. —30° to +90°	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	25	— .21	96	— .15	212	— .13
3	39	— .13	57	— .24	95	— .13
5	48	— .41	107	— .20	174	— .18
7	25	+ .31	89	+ .11	103	+ .10
9	13	— .30	73	— .11	127	— .11
11	33	+ .01	89	+ .13	207	+ .13
13	48	+ .17	71	+ .08	152	+ .09
15	45	+ .11	108	+ .20	202	+ .12
17	25	— .04	72	+ .09	168	+ .05
19	26	+ .20	119	— .17	201	+ .05
21	45	+ .27	89	— .21	212	— .06
23	36	— .13	84	— .10	144	— .11

A tolerably well-marked correction depending on a is indicated. No discussion is undertaken, however, as the correction would in any case be very small.

Ce 40.

The weights formed in the manner explained in Section V. evidently increase too rapidly with the number of observations.

Residuals in order of declination.

Mean δ	π	r_0	C_0
°		"	
+ 86.6	75	+ .02	.00
+ 76.6	55	+ .12	.00
+ 70.2	33	— .11	— .07
+ 65.8	34	— .08	— .16
+ 61.2	134	— .38	— .29
+ 56.2	65	— .37	— .40
+ 49.6	57	— .54	— .55
+ 45.3	91	— .62	— .65
+ 39.0	74	— .75	— .77
+ 32.9	21	— .83	— .85
+ 27.7	85	— .83	— .89
+ 21.2	113	— .78	— .82
+ 14.4	118	— .57	— .58
+ 8.9	116	— .37	— .47
+ 3.7	56	— .51	— .54
— 1.3	57	— .78	— .64
— 8.6	70	— .65	— .70
— 11.1	25	— .93	— .68
— 19.4	11	— .35	— .56
— 21.9	8	— .43	— .50
— 26.3	7	— .07	— .4

π' is therefore formed in this manner:

Weight computed according to Section V.	π'
1 to 5	1 to 5
6	6
7	6
8 and 9	7
10 and 11	8
12 to 14	9
15 to 17	10
18 to 21	11
22 to 25	12
26 to 30	13
31 to 35	14
36 to 40	15
41 to 46	16
47 to 52	17
53 to 58	18
59 to 65	19
66 to 72	20
73 to 80	21
81 to 88	22
89 to 96	23
97 to 105	24
106, or more	25

Residuals in order of right ascension.

Declination limits. −30° to +5°			Declination limits. +5° to +40°		Declination limits. +40° to −30°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"		"		"
1	6	+ .45	62	− .09	68	− .04	79	+ .06	147	+ .01
3	20	+ .16	13	− .15	33	+ .04	30	− .07	63	− .01
5	16	+ .23	43	+ .09	59	+ .13	44	− .11	103	+ .03
7	......	....	54	+ .26	54	+ .26	......	....	54	+ .26
9	9	+ .40	44	+ .31	53	+ .35	32	− .28	85	+ .11
11	13	+ .39	48	+ .04	61	+ .12	78	− .12	139	− .02
13	20	+ .14	24	− .03	44	+ .05	46	+ .19	90	+ .12
15	29	+ .02	63	+ .14	92	+ .10	46	− .02	138	+ .06
17	10	+ .06	42	− .02	52	− .01	45	− .02	97	− .01
19	14	− .06	86	− .04	100	− .04	50	− .11	150	− .07
21	41	− .30	32	− .19	73	− .25	76	+ .01	149	− .12
23	24	− .13	30	− .28	54	− .21	32	+ .25	86	− .04

A correction varying with the right ascension is well marked in the zone +40° to −30° (and is supported in some degree by Ce 34). I find $+ (''.15 \pm .025) \sin \alpha - (''.15 \pm .025) \cos \alpha$.

With $m = 8$, we have:—

$E = \pm\, ''.46$, Ce 48 gives $\pm\, ''.62$, and Ce 56 $\pm\, ''.60$. I have adopted $E = \pm\, 60$.

Ah 41 and Ah 52.

These were at first treated as separate catalogues, but the experiment proved that there exists between them no difference, which can be safely predicated from the material. Oöms's very thorough comparison of Robinson's Armagh Catalogue (*Ast. Nach.* Bd. 59, p. 248), after the proper correction, has been relied upon to a great extent in drawing the curve.

Residuals in order of declination.

Direct comparison.				Through Ao 29.			
Mean δ	π'	r_0	C_0	Mean δ	Number of stars.	Difference uncorrected, applicable to Armagh declination.	Difference corrected.
°		"	"	°		"	"
+ 76.2	11	+ .21	+ .20	+ 81.2	4	+ .52	+ .88
+ 71.2	20	+ .05	+ .20	+ 77.1	6	+ .23	+ .56
+ 66.4	17	— .06	+ .20	+ 72.4	8	+ .34	+ .63
+ 61.0	38	+ .11	+ .17	+ 66.7	8	— .39	— .16
+ 56.5	32	+ .08	+ .05	+ 62.4	11	+ .38	+ .56
+ 51.4	38	+ .07	— .10	+ 57.5	15	— .35	— .23
+ 45.5	46	— 1.13	— .71	+ 51.6	15	— .31	— .27
+ 40.1	49	— .40	— .81	+ 47.5	15	— .69	— .75
+ 32.9	20	— .66	— .54	+ 42.9	22	— .85	— 1.02
+ 26.5	24	— .20	— .30	+ 37.5	32	— .18	— .49
+ 21.0	25	— .16	— .27	+ 32.7	17	— .10	— .52
+ 15.1	16	— .83	— .47	+ 27.4	29	+ .04	— .47
+ 9.3	41	— .61	— .78	+ 22.3	23	+ .41	— .18
+ 3.7	15	— .24	— 1.08	+ 17.7	31	+ .30	— .36
— 1.7	22	— 1.14	— 1.21	+ 12.4	18	+ .08	— .56
— 8.2	14	— .54	— 1.15	+ 7.6	22	— .45	— 1.05
				+ 3.0	31	— .46	— 1.07
				— 2.5	17	— 1.21	— 1.98
				— 7.7	14	+ .38	— .58
				— 13.1	19	— .21	— 1.24
				— 16.8	24	+ .58	— .47
				— 23.6	2	— 2.05	— 3.0

π' is formed with $\frac{\varepsilon}{\varepsilon_{,}} = 2$.

With $m = 6$, we have:—

$$E = \pm 1''.1.$$

Residuals in order of right ascension.

Mean α	π'	r_0'	Mean α	π'	r_0'
h.		"	*h.*		"
1	48	— .03	13	27	— .16
3	19	+ .05	15	40	+ .05
5	33	— .34	17	35	— .37
7	20	— .02	19	35	+ .18
9	34	+ .64	21	48	+ .01
11	59	+ .03	23	38	+ .26

Kg 43.

The correction in order of declination is adopted as it results from the discussion in Section VI. (Table II.). In the following table, each value of r' is supposed to have an equal degree of precision.

Residuals in order of right ascension.

Declination limits. $-30°$ to $+42°$			Declination limits. $-30°$ to $+42°$		
Mean a	π'	r_0'	Mean a	π'	r_0'
h.		"	h.		"
0.7	3	$-.40$	13.3	1	$-.20$
2.9	1	$-.40$	15.0	4	$-.12$
5.4	5	$+.14$	17.0	3	$+.10$
7.6	1	$-.30$	19.4	4	$+.40$
9.7	2	$-.20$	20.9	3	$+.40$
11.7	1	$-.30$	22.9	1	$+.20$

The division into two zones, which was made, is of no interest, owing to the small number of stars. From the above is found as a correction:—

$$-(''.16 \pm ''.06) \sin a + (''.13 \pm ''.07) \cos a;$$

and this is adopted.

Dr. Auwers found (*Ast. Nach.*, Bd 65, S. 230):—

$$-''.139 \sin (a - 25° 38') - ''.239 (\sin 2a + 65° 27').$$

The term depending on $2a$ is indeed indicated, but I have preferred to neglect it, since the number of residuals is small.

With $m = 4$, we have:—

$$E = \pm ''.26.$$

Eh 43.

Residuals in order of declination.

Mean δ	π′	r_0	C_0
°		″	″
+ 86.8	156	+ .06	.00
+ 76.5	85	+ .14	.00
+ 70.5	24	— .44	.00
+ 66.5	7	— .20	— .01
+ 61.3	33	— .08	— .04
+ 56.5	51	— .14	— .07
+ 50.6	54	+ .07	— .08
+ 45.5	38	— .19	— .06
+ 39.4	42	+ .03	— .03
+ 33.3	18	+ .33	+ .02
+ 27.4	66	+ .14	+ .09
+ 21.3	66	— .10	+ .17
+ 14.2	68	+ .18	+ .28
+ 8.6	66	+ .40	+ .35
+ 4.1	42	+ .10	+ .36
— 1.4	52	+ .40	+ .31
— 8.7	65	+ .26	+ .16
— 14.1	31	— .07	+ .04
— 18.8	21	— .50	— .06
— 22.0	17	— .38	— .12
— 27.0	10	+ .0	— .02

The weights (π′) are constructed according to Section V., which supposes:

$$\frac{\varepsilon}{\varepsilon_i}=2.$$

The argument for forming π′ is not therefore the total number of observations, but the sum of the values of π′ in each year.

Residuals in order of right ascension.

Declination limits. — 30° to + 5°			Declination limits. + 5° to + 40°		Declination limits. + 40° to — 30°		Declination limits. + 40° to + 90°		Declination limits. — 30° to + 90°	
Mean α	π′	r_0'	π′	r_0'	π′	r_0'	π′	r_0'	π′	r_0'
h.		″				″		″		″
1	15	— .54	40	— .35	55	— .40	75	— .11	130	— .24
3	19	— .40	6	— .10	25	— .54	15	— .13	40	— .39
5	30	+ .01	24	+ .12	54	+ .61	21	+ .04	75	+ .05
7	6	+ .50	40	+ .03	46	+ .09	24	.00	70	+ .06
9	9	+ .60	37	+ .09	46	+ .19	14	+ .23	60	+ .20
11	16	— .39	25	+ .20	41	— .03	37	+ .05	78	+ .01
13	14	— .30	17	+ .61	31	+ .22	31	+ .06	62	+ .14
15	28	— .07	36	+ .24	64	+ .10	63	+ .30	127	+ .20
17	12	— .05	27	+ .02	39	— .01	54	+ .22	93	+ .13
19	21	+ .11	42	— .07	63	.00	43	+ .06	106	+ .02
21	33	— .08	20	— .15	53	— .11	57	— .09	110	— .10
23	20	+ .03	18	— .22	38	— .09	31	— .27	69	— .17

A correction depending on α is quite well marked in all the zones. The discussion gives :—

$$-(''.05 \pm ''.03)\sin\alpha - (''.19 \pm ''.03)\cos\alpha.$$

Dr. Auwers found (*Ast. Nach.*, Bd 64, S. 343) — ″.002 sin α — ″.310 cos α for the Edinburgh declinations, 1835–1839, assuming Ao 29 and Gh 1755 to require no correction. This corresponds tolerably well with Eh 37, between the declination limits — 30°

to + 5°, as exhibited above. Later (*Ast. Nach.*, Bd 65, p. 227), Dr. Auwers finds that two-thirds of the correction best corresponds with residuals derived from his discussion of fundamental stars. This accords almost perfectly with the formula given above for Eh 43. But Dr. Auwers supposes this formula not to be applicable to the later observations of Henderson.

With $m = 8$, we have:—

$$E = \pm {''}.67.$$

± ″.66 results from the discussion in Section V. The former is adopted.

Gh 45.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.8	75	− .47	.00	
+ 76.7	54	+ .10	+ .01	$\frac{\varepsilon}{\varepsilon_{\prime}} = 4$
+ 70.2	37	− .16	+ .04	
+ 66.2	49	+ .07	+ .05	
+ 60.9	150	+ .11	+ .08	
+ 56.7	116	+ .21	+ .07	
+ 50.6	122	− .15	+ .01	
+ 45.3	94	− .01	− .04	
+ 39.9	107	− .11	− .02	
+ 32.8	25	+ .27	+ .08	
+ 27.5	111	+ .28	+ .14	
+ 21.3	118	+ .14	+ .14	
+ 14.5	120	+ .12	+ .09	
+ 8.9	162	− .04	+ .05	
+ 4.0	83	+ .28	+ .06	
− 1.5	83	+ .14	+ .09	
− 8.6	87	+ .19	+ .14	
− 14.0	47	+ .18	+ .17	
− 18.7	35	+ .08	+ .21	
− 22.4	31	+ .24	+ .24	
− 28.1	39	+ .28	+ .28	
− 34.1	10	+1.98	....	

From the equator to the pole it is a matter of indifference whether any correction be applied or not. The correction $\frac{R - D}{2}$ at Greenwich was neglected as insensible during this period.

With $m = 5$, we have:—

$$E = \pm {''}.65.$$

Residuals in order of right ascension.

Declination limits. −30° to +90°			Declination limits. −30° to +90°		
Mean α	π'	r_0'	Mean α	π'	r_0'
h.		″	h.		″
1	179	+ .06	13	130	+ .03
3	87	+ .01	15	185	+ .12
5	146	+ .05	17	152	− .03
7	101	+ .02	19	200	− .10
9	116	+ .12	21	181	− .12
11	164	+ .12	23	120	− .13

A slight correction following the right ascension is indicated. It differs, however, quite sensibly from that shown in Gh 39, and I have, therefore, undertaken no discussion.

Pa 45.

In forming π', one observation is given weight 1; two to five, weight 2; six or more, weight 3.

Residuals in order of declination.

Mean δ	π'	r_0	*Form.*	C_0
		″	″	″
+ 86.6	13	− .02	+ .03	.00
+ 76.0	12	+ .04	+ .07	.00
+ 70.9	21	.00	+ .10	+ .05
+ 66.0	12	+ .18	+ .13	+ .11
+ 60.7	41	+ .18	+ .16	+ .17
+ 56.8	29	+ .21	+ .19	+ .21
+ 50.8	39	+ .27	+ .23	+ .25
+ 45.6	31	+ .24	+ .26	+ .29
+ 39.9	44	+ .36	+ .29	+ .33
+ 33.0	21	+ .40	+ .32	+ .36
+ 26.9	28	+ .29	+ .36	+ .38
+ 21.0	35	+ .34	+ .39	+ .39
+ 14.5	38	+ .45	+ .41	+ .42
+ 9.1	46	+ .42	+ .43	+ .44
+ 4.3	19	+ .59	+ .46	+ .47
− 1.9	22	+ .60	+ .47	+ .51
− 8.4	17	+ .54	+ .49	+ .57
− 14.1	10	+ .59	+ .50	+ .66
− 19.4	3	+ .38	....	+ .82
− 23.9	3	[+1.01]	....	[+1.0]
− 26.1	3	[+1.7]	....	[+1.3]

Column "*Form*" is derived from the expression (Section VI.)

$$+ ''.34 (\sin Z + .503)$$

Had the constant + ″.34 been increased to + ″.37, the accord with C_0 would have been almost perfect down to − 8°.4. The curve from which C_0 is taken was drawn without the slightest reference to the previous correction.

The value of E, taken from the outstanding residuals, is of no interest, since, on account of the great weight given to Pa 45 in the discussion of standard places, it would be entirely too small. In the introduction to the fourth volume of Poulkova observations, we have a thoroughly reliable discussion of the probable error of the declinations. The final weights were founded on these probable errors, which increase rapidly with the zenith distance.

From the final residuals ($r_{,}$) of 37 fundamental and circumpolar stars (excluding α and δ Ursæ Minoris), I derive $\pm$ ″.273 as the probable error of the unit of adopted weights. Supposing the average weight of a Poulkova declination 4, and of the final $\Delta\delta$ for 1845, 80, we should have approximately $\pm$ ″.29 as the probable error of the unit corresponding to a probable error of $\pm$ ″.30, as given in the introduction of volume iv. A like discussion of the residuals ($r_{,}$) of 59 other stars, for which the weight of a position for 1845 is 40, or greater (averaging about 50), gives $\pm$ ″.285, or about $\pm$ ″.305 for the corrected probable error, which should correspond to the $\pm$ ″.30 assumed. It may therefore be assumed that the weights for Pa 45, constructed in the manner explained above, are entirely reliable, and correspond well with the general system adopted in the definitive discussion of $\Delta\delta$ and $\Delta\mu'$.

Residuals in order of right ascension.

Declination limits. —20° to +90°			Declination limits. —20° to +90°		
Mean α	π'	r_0'	Mean α	π'	r_0'
h.		″	h.		″
1	56	+.11	13	30	+.03
3	20	—.11	15	51	—.04
5	37	+.01	17	50	.00
7	33	—.06	19	50	+.10
9	33	—.06	21	45	—.09
11	47	—.02	23	31	+.05

Re 45.

Residuals in order of declination.

Mean δ	π′	r_0	C_0	
°		″	″	
+ 86.6	[27]	[+ .18]	[+ .17]	
+ 76.3	22	+ .53	+ .62	
+ 70.5	28	+ .72	+ .61	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2$
+ 66.4	21	+ .23	+ .47	
+ 60.8	45	+ .05	+ .30	
+ 56.8	36	+ .30	+ .16	
+ 50.8	45	+ .02	− .04	
+ 45.6	38	− .06	− .18	
+ 40.0	42	− .47	− .34	
+ 33.4	10	− .31	− .51	
+ 27.4	27	− .44	− .58	
+ 21.1	33	− .68	− .59	
+ 14.3	32	− .22	− .41	
+ 8.8	53	− .22	− .14	
+ 3.9	25	− .02	+ .08	
− 1.4	26	+ .63	+ .31	
− 8.6	27	+ .29	+ .49	
− 14.0	10	+ .95	+ .48	
− 19.0	3	+ .18	+ .36	
− 22.3	9	+ .36	+ .25	
− 28.1	13	− .31	+ .06	

There is some doubt about the correction from + 75° to + 90°. For stars observed both above and below the pole, it is probably quite small.

With $m = 5$, we have:—

$$E = \pm\, ''.73$$

I adopt ± ″.77, the mean between this determination and that for Re 58.

Residuals in order of right ascension.

	Declination limits. − 30° to + 6°		Declination limits. + 40° to − 30°		Declination limits. + 40° to + 90°		Declination limits. − 30° to + 90°	
Mean α	π′	r_0'	π′	r_0'	π′	r_0'	π′	r_0'
h.		″		″		″		″
1	3	+ .10	29	+ .31	37	+ .05	66	+ .16
3	7	− .44	17	− .03	8	+ .22	25	+ .06
5	9	− .10	26	+ .11	20	− .12	46	+ .01
7	6	− .47	26	+ .06	5	− .17	31	+ .03
9	4	−1.70	30	− .42	16	− .34	46	− .39
11	10	+ .16	22	− .05	30	− .22	52	− .15
13	13	+ .33	17	+ .45	21	+ .40	38	+ .42
15	9	+ .66	26	− .06	24	− .33	50	− .19
17	6	+ .03	16	+ .09	34	− .11	50	− .05
19	7	− .53	26	+ .11	26	+ .20	52	+ .15
21	12	+ .60	22	+ .07	32	+ .14	54	+ .11
23	14	− .21	28	− .19	19	− .04	47	− .13

The previous discussion (Section VI.) is substantially confirmed.

Wn 47.

The weights are adopted as they result from the combination of separate years in the manner explained in Section V. This supposes $\frac{\varepsilon}{\varepsilon_{\prime}} = 3$.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		″	″
+ 86.9	72	+ .10	+ .13
+ 76.6	51	+ .46	+ .14
+ 69.9	19	+ .24	+ .10
+ 62.3	35	+ .07	+ .02
+ 55.3	31	— .14	— .05
+ 50.6	73	— .16	— .05
+ 45.1	31	— .23	— .05
+ 38.5	58	— .05	— .05
+ 33.2	20	+ .66	— .06
+ 27.8	89	— .01	— .11
+ 21.6	83	— .21	— .19
+ 14.2	122	— .35	— .28
+ 8.6	111	— .35	— .34
+ 3.9	74	— .37	— .35
— 1.6	49	— .54	— .33
— 8.5	63	— .16	— .28
— 14.1	54	— .30	— .24
— 19.1	22	+ .06	— .19
— 22.3	36	— .35	— .15
— 28.5	49	— .05	— .05

Residuals in order of right ascension.

Declination limits. — 30° to + 5°			Declination limits. + 40° to — 30°		Declination limits. + 40° to + 90°		Declination limits. — 30° to + 90°	
Mean α	π'	r_0	π'	r_0	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	10	+ .02	56	+ .19	43	— .10	99	+ .06
3	49	+ .01	56	— .08	18	— .70	74	— .23
5	24	— .33	70	— .56	12	— .40	82	— .53
7	25	— .13	58	— .20	10	+ .10	68	— .16
9	10	— .50	46	— .20	11	+ .21	57	— .12
11	11	— .60	37	— .34	29	+ .02	66	— .18
13	18	— .02	37	— .10	14	+ .50	51	+ .06
15	43	+ .34	102	+ .30	28	+ .65	130	+ .37
17	31	+ .15	58	+ .25	35	+ .16	93	+ .21
19	30	+ .15	149	+ .25	13	.00	162	+ .23
21	44	— .01	95	+ .06	66	— .04	161	+ .02
23	27	— .04	60	— .08	23	— .10	83	— .08

From discussion of the values of r_0' in the final grouping (— 30° to + 90°), I derive:—

$$- {}''.27 \sin \alpha - {}''.08 \cos \alpha.$$

Examination of Wn 56 and Wn 64 shows that they are in need of a similar correction; and the separation into zones renders it highly probable that this correction is almost equally applicable to all limits of declination.

For Wn 56, we have:—

$$-''.16 \sin \alpha - ''.19 \cos \alpha;$$

and for Wn 64,

$$-''.22 \sin \alpha - ''.12 \cos \alpha.$$

The same form of correction is indicated in Wn 70.

It is undoubtedly real and sensibly constant for the Washington mural circle throughout the period of its use. From the combined residuals (— 30° to + 90°) of Wn 47, 56, and 64, we have:—

$$-(''.21 \pm ''.03) \sin \alpha - (''.12 \pm ''.03) \cos \alpha$$

as the correction; and it is adopted.

It reduces the sums of squares as follows:—

Year.	Before.	After.
1847	144	101
1856	258	236
1864	179	165

From the final residuals for 1847, with $m = 7$, we have:—

$$E = \pm ''.74.$$

Ce 48.

The weights are derived in the manner explained under Ce 40.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		''	''
+ 87.9	35	+ .28	.00
+ 76.9	15	— .15	.00
+ 70.2	19	— .01	.00
+ 65.6	20	+ .03	— .09
+ 61.0	62	— .21	— .23
+ 56.6	36	— .44	— .37
+ 49.5	49	— .51	— .58
+ 45.4	64	— .58	— .68
+ 39.0	35	—1.19	— .82
+ 32.6	16	— .71	— .86
+ 27.8	58	— .78	— .75
+ 21.3	60	— .42	— .41
+ 14.5	82	— .02	— .09
+ 9.1	68	— .02	— .05
+ 4.2	29	— .22	— .05
— 1.0	27	— .02	— .08
— 8.6	38	— .15	— .12
— 14.1	15	+ .13	— .12
— 18.5	9	+ .20	— .09
— 21.5	6	— .9	— .09
— 26.2	3	— .8	— .03

With $m = 5$, we have:—

$$E = \pm ''.62$$

± .60 is adopted, as explained under Ce 40.

Residuals in order of right ascension.

Declination limits. −30° to +90°			Declination limits. −30° to +90°		
Mean α	π'	r_0'	Mean α	π'	r_0'
h.		"	h.		"
1	84	+ .07	13	52	+ .10
3	29	− .19	15	50	− .08
5	74	+ .06	17	47	− .09
7	47	− .03	19	119	− .09
9	53	− .04	21	79	− .02
11	73	+ .01	23	35	+ .21

Gh 51.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 86.6	77	− .16	− .13	$\frac{\varepsilon}{\varepsilon_{\prime}} = 4$
+ 76.4	55	− .07	− .14	
+ 70.6	56	− .25	− .15	
+ 66.4	23	− .22	− .16	
+ 61.1	95	− .14	− .17	
+ 56.7	78	− .17	− .19	
+ 50.9	102	− .15	− .21	
+ 45.6	62	− .26	− .20	
+ 39.4	98	− .17	− .15	
+ 32.5	82	+ .05	− .03	
+ 27.3	147	− .04	+ .06	
+ 21.2	147	+ .15	+ .16	
+ 14.5	165	+ .28	+ .18	
+ 9.0	218	+ .23	+ .15	
+ 4.1	102	.00	+ .10	
− 1.7	129	− .01	+ .03	
− 8.5	110	− .07	.00	
− 14.1	52	+ .01	+ .03	
− 18.8	36	+ .17	+ .11	
− 22.4	48	+ .31	+ .16	
− 28.2	43	− .03	+ .22	

With $m = 5$, we have:—

$$E = \pm\ ''.70.$$

There is a trace of the same peculiarity in the values of r_0', as has appeared with Gh 45. In any case, the required correction is so small that its neglect is of little consequence to the final result.

Residuals in order of right ascension.

	Declination limits. -30° to $+5^\circ$		Declination limits. -30° to $+90^\circ$	
Mean α	π'	r_0'	π'	r_0'
h.		"		"
1	27	− .04	214	− .15
3	38	− .14	94	+ .04
5	47	+ .01	157	+ .06
7	25	− .15	131	− .11
9	14	− .20	129	+ .01
11	39	+ .06	177	+ .14
13	60	+ .10	126	+ .13
15	54	+ .01	195	+ .03
17	27	− .20	169	− .06
19	52	+ .05	183	+ .03
21	40	− .31	174	− .02
23	54	− .06	139	− .01

No 51.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 45.8	4	+ 1.06	....	
+ 38.6	13	− .03	+ .44	$\frac{\epsilon}{\epsilon_1} = 2$
+ 33.2	4	− .04	+ .58	
+ 27.5	33	+ .77	+ .74	
+ 21.3	40	+ .88	+ .87	
+ 14.5	46	+ .92	+ .99	
+ 8.7	42	+ 1.23	+ 1.05	
+ 3.7	26	+ 1.01	+ 1.09	
− 2.2	14	+ 1.09	+ 1.12	
− 8.5	28	+ 1.22	+ 1.12	
− 14.1	15	+ 1.16	+ 1.10	
− 18.9	12	+ .81	+ 1.06	
− 22.5	16	+ .95	+ 1.08	
− 28.2	17	+ .90	+ 1.00	
− 34.2	1	+ .25	+ .96	
− 41.9	2	+ 1.24	+ .91	
− 52.6	1	+ .94	+ .79	
− 59.6	6	+ .82	+ .62	
− 75.1	3	+ .28	+ .28	

Residuals in order of right ascension.

Declination limits. − 30° to + 40°			Declination limits. − 30° to + 40°		
Mean a	π'	r_0'	Mean a	π'	r_0'
h.		″	h.		″
0.9	24	− .37	13.1	21	− .16
3.1	22	+ .15	14.9	30	− .07
5.1	29	+ .49	16.7	19	− .31
7.1	32	+ .07	19.0	40	− .16
9.3	27	+ .10	21.2	22	− .19
11.3	22	+ .53	22.9	18	− .66

There is an evident progression of r_0' with a. The discussion gives, as the correction to be applied:—

$$+ (''.24 \pm ''.07) \sin a - (''.185 \pm ''.075) \cos a.$$

There is some reason to expect such a correction for this series, and it is adopted. With $m = 6$, we have:—

$$\pm ''.86.$$

Ps 53.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.3	37	− .10	+ .06	$\frac{\varepsilon}{\varepsilon_l} = 3$
+ 76.7	23	+ .18	+ .19	
+ 70.6	31	+ .38	+ .25	
+ 66.0	18	+ .20	+ .28	
+ 61.9	29	+ .40	+ .29	
+ 56.5	40	+ .29	+ .28	
+ 50.6	33	+ .05	+ .23	
+ 46.0	16	+ .48	+ .19	
+ 39.5	26	+ .17	+ .12	
+ 33.2	13	− .03	+ .05	
+ 27.7	30	− .08	− .03	
+ 21.5	38	− .15	− .10	
+ 14.4	38	− .01	− .19	
+ 8.7	49	− .31	− .28	
+ 3.9	33	− .41	− .34	
− 1.2	28	− .15	− .37	
− 9.0	19	− .47	− .31	
− 14.1	19	− .16	− .21	
− 18.7	13	− .21	− .06	
− 22.3	10	+ .12	+ .12	
− 28.6	13	+ .92	+ .6	

With $m = 5$, we have:—

$$E = \pm ''.57.$$

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. +40° to −30°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″
1	9	− .08	39	− .02	59	− .05
3	16	+ .35	24	+ .10	41	+ .18
5	17	− .02	31	+ .26	42	+ .02
7	6	+ .20	25	+ .17	31	+ .15
9	3	+ .60	18	− .09	27	− .02
11	8	− .45	22	− .26	56	− .11
13	13	+ .13	20	+ .10	44	− .11
15	16	− .22	27	− .14	55	− .11
17	8	+ .05	20	− .44	50	− .18
19	9	.00	36	− .21	48	+ .12
21	10	− .10	35	+ .01	61	+ .15
23	15	+ .10	5	+ .60	24	+ .35

So 55.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 45.8	1	− .56	....	$\frac{\varepsilon}{\varepsilon_i} = 2.$
+ 38.3	2	+1.19	+ .50	
+ 24.5	4	+ .67	+ .48	
+ 20.9	13	+ .51	+ .45	
+ 14.2	27	+ .30	+ .29	
+ 8.3	29	− .03	+ .18	
+ 3.8	15	+ .46	+ .18	
− 1.9	12	+ .45	+ .32	
− 8.7	20	+ .35	+ .39	
− 11.0	12	+ .55	+ .17	
− 19.0	7	− .07	− .03	
− 22.2	11	− .58	− .10	
− 28.6	12	− .31	− .05	
− 42.8	....	+ .34	+ .27	
− 51.8	1	+ .42	+ .24	
− 59.3	3	+ .19	+ .12	
− 78.3	2	− .49	.00	

With $m = 6$, we have:—

$$E = \pm\ ''.91.$$

Residuals in order of right ascension.

Declination limits. — 30° to + 40°			Declination limits. — 30° to + 40°		
Mean δ	π'	r_0'	Mean δ	π'	r_0'
h.		″	*h.*		″
1.1	7	+ .04	12.9	12	— .41
2.5	13	— .17	15.2	16	+ .61
5.0	14	— .09	16.7	16	— .15
7.0	8	— .38	19.2	25	+ .02
9.4	13	— .39	21.2	13	+ .40
11.3	19	— .16	22.7	8	+ .21

If there is a real variation of the correction, proceeding with the right ascension, it is apparently of an entirely different nature from that adopted for So 51. The weights are small, and the observations are assumed to be practically free from any error of this kind.

Wn 56.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.1	63	— .18	— .07	$\frac{\varepsilon}{\varepsilon_i} = 4$
+ 76.7	20	— .05	+ .10	
+ 70.2	6	+ .55	+ .17	
+ 66.3	4	+ .30	+ .18	
+ 62.1	27	+ .50	+ .17	
+ 56.1	15	+ .24	+ .14	
+ 50.3	51	— .16	+ .10	
+ 45.3	30	— .10	+ .05	
+ 38.9	64	+ .08	— .01	
+ 32.6	15	+ .37	— .06	
+ 27.6	80	— .05	— .11	
+ 21.5	79	— .23	— .17	
+ 14.5	75	— .16	— .24	
+ 8.7	86	— .16	— .26	
+ 4.2	62	— .69	— .27	
— 1.5	57	— .26	— .25	
— 8.5	58	— .13	— .19	
— 14.0	34	— .08	— .11	
— 18.9	20	— .28	— .04	
— 22.2	20	+ .09	+ .02	
—.28.5	31	+ .19	+ .13	

The probable error, E, is derived from the outstanding residuals corrected further for the effect of terms in a given under Wn 47.

With $m = 6$, we have:—

$$E = \pm\, ''.88.$$

With a smaller value of $\frac{\varepsilon}{\varepsilon_i}$, we should have a smaller and probably more accurate value of E.

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. +40° to −30°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		''		''		''		''
1	19	− .35	61	− .07	22	− .10	83	− .08
3	27	− .77	42	− .75	10	−1.00	52	− .80
5	18	− .64	48	− .41	12	− .45	60	− .41
7	12	− .22	49	− .01	14	− .10	63	− .04
9	3	− .30	24	+ .25	10	+ .13	34	+ .21
11	16	+ .19	40	+ .17	25	+ .46	65	+ .28
13	30	− .02	47	.00	12	+ .08	59	+ .02
15	26	+ .48	72	+ .34	21	− .23	93	+ .21
17	17	+ .27	53	+ .28	28	+ .05	81	+ .20
19	18	− .25	81	− .04	21	− .19	102	− .07
21	32	+ .22	76	+ .07	38	− .05	114	+ .03
23	43	+ .18	70	+ .12	11	− .06	81	+ .11

For further explanation see Wn 47.

Ps 56.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		''	''	$\frac{\varepsilon}{\varepsilon_{,}} = 2$
+ 86.6	26	− .35	− .32	
+ 76.6	15	− .31	− .22	
+ 70.8	15	− .04	− .16	
+ 66.2	10	+ .06	− .13	
+ 61.0	30	− .22	− .10	
+ 56.7	32	− .17	− .09	
+ 50.1	25	+ .05	− .11	
+ 45.2	30	− .05	− .15	
+ 39.1	25	− .47	− .21	
+ 33.0	26	− .52	− .26	
+ 27.6	37	− .17	− .30	
+ 21.1	18	− .26	− .35	
+ 14.5	53	− .37	− .36	
+ 8.9	70	− .38	− .36	
+ 4.0	32	− .32	− .35	
− 1.7	47	− .31	− .33	
− 8.5	43	− .29	− .23	
− 14.1	15	− .07	− .08	
− 18.8	12	+ .11	+ .12	
− 21.9	13	+ .20	+ .12	
− 28.1	17	+ .42	+ .50	

After the further correction depending on α (to be explained), the outstanding residuals, with $m = 7$, give:—

$$E = \pm 1''.16.$$

Residuals in order of right ascension.

	Declination limits. -30° to $+6^\circ$		Declination limits. $+40^\circ$ to -30°		Declination limits. $+40^\circ$ to $+90^\circ$		Declination limits. -30° to $+90^\circ$	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"		"
1	8	− .15	21	+ .05	25	+ .23	46	+ .15
3	11	+ .15	23	+ .13	13	+ .01	36	+ .08
5	15	+ .07	37	+ .09	13	+ .12	50	+ .10
7	4	+ .70	32	+ .17	4	+ .10	36	+ .16
9	4	+ .30	24	+ .25	4	+ .30	28	+ .25
11	10	+ .55	33	+ .11	27	+ .09	60	+ .10
13	22	+ .21	30	+ .15	22	− .11	52	+ .04
15	19	+ .04	40	− .05	23	− .01	63	− .03
17	10	− .35	33	− .25	19	− .13	52	− .21
19	20	− .28	50	− .31	14	− .01	64	− .25
21	19	+ .01	44	− .17	20	− .03	64	− .13
23	25	− .30	38	− .24	11	− .23	49	− .23

The dependence of r_0' on right ascension is undoubted.

From the column -30° to $+90^\circ$, I derive:—

$$+''.19 \sin \alpha - ''.07 \cos \alpha.$$

From the tables exhibited successively under Ps 60, Ps 64, and Ps 66, I find:—

Year.	Formula of correction.
	"
1860	$+ .18 \sin \alpha - .04 \cos \alpha$
1864	$+ .17 \sin \alpha - .00 \cos \alpha$
1866	$+ .19 \sin \alpha - .10 \cos \alpha$

From the proper combination of the four sets, we have:—

$$+ (''.20 \pm ''.01) \sin \alpha - (''.05 \pm ''.01) \cos \alpha.$$

This is adopted as the definitive correction for each of the four catalogues, since there appears to be no marked increase with the time.

This correction might be approximately computed in the following manner:—

If in the definitive formula of correction* for the declinations of the *Fundamenta* south of $+51^\circ.5$ we substitute 30° for δ, we shall have for that part of the correction depending on α:—

$$-''.82 \sin \alpha + ''.07 \cos \alpha.$$

If, further, we suppose that the mean declination of the stars of the Paris standard catalogue, chiefly used for obtaining zenith points, is about $+36^\circ$, that the catalogues making up the Paris standard are free from errors depending on α, and that their mean epoch is about 1845, we shall have for the epoch 1861 (about the mean of the entire Paris series) as a correction to Paris observed declinations:—

$$(+''.82 \sin \alpha + ''.07 \cos \alpha) \times \frac{16}{90} = +''.146 \sin \alpha - ''.012 \cos \alpha.$$

Of course, if the mean epoch of the catalogues making up the standard is earlier than 1845, this correction will be larger.

* Section VII.

Bs 56.

Residuals in order of declination.

Mean δ	π	r_0	C_0	
″		″	″	
+ 86.9	27	+ .50	+ .24	$\frac{\varepsilon}{\varepsilon_{\prime}} = 3$
+ 76.4	19	+ .23	+ .31	
+ 69.8	11	+ .63	+ .31	
+ 61.8	20	+ .30	+ .25	
+ 56.9	17	+ .15	+ .13	
+ 50.6	39	— .07	— .10	
+ 45.6	16	— .93	— .33	
+ 38.3	20	— .64	— .52	
+ 32.8	24	— .35	— .50	
+ 27.4	36	— .23	— .41	
+ 21.2	31	— .71	— .45	
+ 14.2	37	— .54	— .64	
+ 8.5	36	— .44	— .72	
+ 4.6	24	—1.50	— .74	
— 2.0	21	— .73	— .59	
— 8.4	18	+ .18	— .30	
— 14.1	18	— .23	— .21	
— 19.3	9	— .11	— .23	
— 22.2	11	— .37	— .24	
— 28.7	10	— .73	— .29	

With $m = 7$, we have:—

$$E = \pm\ ''.95$$

Residuals in order of right ascension.

	Declination limits. + 40° to — 30°		Declination limits. + 40° to + 90°		Declination limits. — 30° to + 90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″
1	21	— .50	19	— .17	40	— .36
3	13	—1.76	6	— .17	19	—1.25
5	14	+ .41	7	+ .21	21	+ .35
7	10	+ .92	1	+ .20	11	+ .85
9	25	+ .11	13	+ .40	38	+ .26
11	22	— .16	16	+ .32	38	+ .04
13	10	— .01	11	+ .11	21	+ .05
15	46	+ .28	13	— .08	59	+ .21
17	30	+ .03	19	+ .09	49	+ .05
19	43	+ .06	12	— .04	55	+ .04
21	25	— .29	25	— .13	50	— .21
23	34	— .05	10	— .24	44	— .09

A considerable correction depending on α is indicated. The residuals from limits — 30° to + 90° give:—

$$-\ ''.04 \sin \alpha - ''.28 \cos \alpha.$$

But, since this result is entirely opposed to that derived from the later Brussels work, the correction is neglected. This could do but little harm, since the observations receive small weight.

Ce 56.

The weights are formed as in the two preceding Cambridge catalogues.

Residuals in order of declination.

Mean δ	π′	r_0	C_0
°		″	″
+ 87.5	32	− .10	− .22
+ 75.8	12	− .50	− .30
+ 70.7	12	− .51	− .35
+ 65.7	11	− .03	− .43
+ 60.7	44	− .64	− .53
+ 56.9	30	− .45	− .69
+ 49.2	28	−1.25	−1.16
+ 45.4	30	−1.39	−1.36
+ 39.3	28	−1.47	−1.45
+ 32.7	14	−1.22	−1.35
+ 27.9	42	−1.21	−1.22
+ 20.5	28	− .96	− .92
+ 14.5	52	− .59	− .66
+ 8.9	33	− .56	− .58
+ 5.2	9	− .96	− .57
− 0.9	10	− .53	− .55
− 8.3	19	− .68	− .50
− 13.9	12	− .32	− .47
− 19.1	4	− .29	− .43
− 21.6	3	+ .77	− .41
− 26.2	4	− .47	− .38

With $m = 5$, we have:—

$$E = \pm {}''.60.$$

Residuals in order of right ascension.

Declination limits. −30° to +90°			Declination limits. −30° to +90°		
Mean α	π′	r_0'	Mean α	π′	r_0'
h.		″	h.		″
1	41	+ .09	13	39	+ .33
3	8	+ .06	15	54	− .11
5	22	+ .02	17	44	− .10
7	27	+ .01	19	64	+ .12
9	41	− .24	21	51	− .09
11	48	− .02	23	26	+ .29

Gh 57.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.7	45	+ .04	+ .02	$\frac{\varepsilon}{\varepsilon_{\prime}} = 3$
+ 76.2	39	+ .07	+ .08	
+ 70.4	42	+ .19	+ .15	
+ 66.7	31	+ .34	+ .19	
+ 61.2	68	+ .21	+ .23	
+ 56.7	34	+ .18	+ .22	
+ 51.0	66	+ .26	+ .16	
+ 45.4	36	+ .10	+ .11	
+ 40.2	63	+ .05	+ .11	
+ 32.5	54	+ .26	+ .20	
+ 27.3	94	+ .25	+ .29	
+ 21.2	110	+ .31	+ .36	
+ 14.6	110	+ .39	+ .38	
+ 9.0	146	+ .42	+ .31	
+ 4.1	71	+ .20	+ .26	
— 1.5	84	— .04	+ .17	
— 8.6	69	+ .22	+ .20	
— 14.1	30	+ .31	+ .25	
— 18.8	22	+ .43	+ .26	
— 22.3	31	+ .39	+ .26	
— 28.2	29	+ .02	+ .22	

With $m = 6$, we have:—

$$E = \pm\ ''.46.$$

The same quantity for 1864 is $\pm\ ''.49$; $\pm\ ''.48$ is adopted in constructing the definitive system of weights. Mr. Stone finds (Month. Not., 29–324) for zenithal value of $\varepsilon \pm\ ''.47$, and this becomes $\pm\ ''.85$ at 70°. It is probable, therefore, that $\frac{\varepsilon}{\varepsilon_{\prime}}$ is taken too small.

Residuals in order of right ascension.

	Declination limits. —30° to +5°		Declination limits. —30° to +40°		Declination limits. —30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″
1	16	— .25	80	+ .01	129	— .03
3	20	+ .08	45	+ .07	55	+ .05
5	24	+ .01	78	+ .07	109	+ .08
7	14	+ .15	82	+ .15	91	+ .15
9	8	+ .20	60	+ .06	85	+ .08
11	30	— .12	73	— .05	99	.00
13	39	— .25	56	— .25	78	— .16
15	39	+ .11	83	— .01	108	— .02
17	16	— .45	66	— .02	127	+ .02
19	21	+ .07	90	— .05	131	— .05
21	27	— .04	77	— .05	146	— .03
23	38	— .06	71	+ .05	93	+ .10

C. G. II. 58.

Residuals in order of declination.

Mean δ	π′	r_0	C_0	
°		″	″	
+ 49.8	3	− 3.47	....	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2$
+ 44.7	3	− 1.27	....	The weights of the last five groups are arbitrarily selected, and have no reference to the scale adopted above.
+ 38.6	8	.00	− .66	
+ 32.9	10	− .23	− .16	
+ 27.2	35	+ .10	− .05	
+ 21.2	48	− .21	− .09	
+ 14.5	45	− .13	− .15	
+ 8.9	58	− .20	− .18	
+ 3.9	31	− .19	− .21	
− 0.8	31	− .23	− .23	
− 8.5	38	− .26	− .26	
− 14.1	19	− .38	− .21	
− 18.9	12	+ .21	− .16	
− 22.4	19	+ .17	− .13	
− 28.0	20	− .08	− .07	
− 34.9	2	− .01	.00	
− 42.1	4	+ .18	+ .09	
− 52.1	2	− .30	+ .17	
− 58.7	6	+ .43	+ .25	
− 75.1	3	+ .36	+ .19	

With $m = 4$, we have:—

$$E = \pm\ ''.50.$$

Dr. Gylden finds (V. J. S., X, 197) for ε from 15°.2 to 41°.4 zenith distance ± ″.45, and but a slight increase to 60° Z. D. Assuming $\varepsilon_{\prime}$ to be $\pm \frac{''.24^*}{\sqrt{2}} = \pm\ ''.17$, we have:—

$$E = \pm\ ''.48,$$

for the zenith. The above value, ± ″.50, appears to be quite trustworthy.

Residuals in order of right ascension.

	Declination limits. − 30° to +5°		Declination limits. + 5° to + 40°		Declination limits. − 30° to + 40°	
Mean α	π′	r_0'	π′	r_0'	π′	r_0'
h.		″		″		″
1	10	+ .15	27	+ .14	37	+ .14
3	12	+ .03	9	− .16	21	− .05
5	18	+ .10	22	− .19	40	− .07
7	10	+ .20	30	+ .13	40	+ .15
9	5	+ .10	21	− .01	26	+ .01
11	17	+ .21	19	− .07	36	− .12
13	19	.00	3	− .17	22	− .02
15	19	+ .37	14	− .08	33	+ .14
17	9	+ .04	15	− .10	24	− .05
19	14	+ .20	25	+ .01	39	+ .10
21	14	− .22	12	+ .52	26	+ .12
23	21	− .08	10	− .03	31	− .07

* Dr. Gylden finds ± ″.24 as the probable minimum error of a difference of declination, Gh 57 − C. G. II. 58 (V. J. S., X. 200).

Re 58.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.3	17	[− .02]	+ .40	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2$
+ 75.8	14	[+ .11]	+ .62	
+ 71.3	12	+ .82	+ .71	
+ 66.9	11	+ .76	+ .71	
+ 61.1	24	+ .55	+ .62	
+ 56.7	26	+ .52	+ .51	
+ 50.6	27	+ .35	+ .23	
+ 45.8	15	+ .48	− .07	
+ 39.4	30	− .67	− .45	
+ 33.1	24	− .63	− .71	
+ 27.4	30	− .82	− .77	
+ 21.1	34	− .63	− .60	
+ 14.6	35	− .41	− .32	
+ 9.1	48	− .11	− .03	
+ 4.3	23	+ .18	+ .24	
− 1.5	29	+ .59	+ .57	
− 8.5	22	+ .92	+ .76	
− 15.9	17	+ .6	+ .77	
− 22.4	11	+1.1	+ .54	
− 27.9	12	− .6	+ .22	

With $m = 5$, we have:—

$$E = \pm\, ''.80.$$

$\pm\, ''.77$ is adopted. (See Re 45.)

In drawing the curve I have been much assisted by the very complete discussion of this catalogue in Volume V. of the *Vierteljahrsschrift der Ast. Ges.* The examination for terms in α, however, fails to confirm Table IV., given in the place cited, as will appear from the following:

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. −30° to +40°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″
1	4	−1.45	28	− .35	54	− .01
3	7	− .37	13	− .30	19	+ .02
5	12	− .32	28	− .54	37	− .32
7	6	− .15	31	+ .05	34	− .01
9	3	+ .90	25	− .04	37	− .12
11	9	+ .23	25	− .02	37	− .25
13	11	+ .04	19	+ .25	32	+ .26
15	13	− .06	29	+ .17	45	− .18
17	5	− .06	25	− .35	44	− .32
19	9	− .31	34	− .07	44	+ .04
21	9	+ .83	27	+ .53	41	+ .54
23	14	− .03	26	+ .27	43	+ .36

The correction depending on α, if it exists, is so uncertain, from the small weight, that no attempt at discussion is made. The probable error of the residuals in last column varies from $\pm\, ''.12$ to $\pm\, ''.18$.

Ps 60.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86.8	20	− .15	− .19	$\frac{\varepsilon}{\varepsilon_i}=2$
+ 76.6	13	− .47	− .12	
+ 70.8	13	− .03	− .05	
+ 66.2	8	+ .02	.00	
+ 60.8	29	+ .05	+ .04	
+ 56.6	28	+ .03	+ .06	
+ 49.7	25	+ .07	+ .10	
+ 45.2	27	+ .23	+ .10	
+ 39.5	26	− .12	+ .10	
+ 33.0	31	− .19	+ .03	
+ 27.4	47	− .06	− .03	
+ 21.1	57	− .03	− .11	
+ 14.6	58	− .12	− .16	
+ 9.1	86	− .26	− .19	
+ 4.1	33	− .15	− .20	
− 1.7	52	− .16	− .16	
− 8.7	45	− .08	− .06	
− 14.1	17	+ .03	+ .07	
− 18.9	12	+ .35	+ .24	
− 21.9	13	+ .21	+ .41	
− 27.9	16	+ .76	+ .62	

The outstanding residuals are first corrected for the effect of terms in a, as found for the entire Paris series. (See Ps 56.)

With $m = 7$, we have:—

$$E = \pm\, ''.35.$$

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. −30° to +40°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	10	− .05	47	.00	26	+ .08	73	+ .03
3	13	+ .07	26	− .10	11	+ .32	37	+ .02
5	15	+ .25	44	+ .16	12	+ .21	56	+ .17
7	4	+ .50	39	+ .17	1	+ .50	40	+ .18
9	5	.00	35	+ .23	5	− .02	40	+ .20
11	12	+ .25	40	+ .12	24	+ .08	64	+ .10
13	23	+ .07	32	+ .02	15	− .09	47	− .02
15	19	− .04	43	− .11	24	− .13	67	− .12
17	10	− .10	37	− .14	31	− .11	68	− .13
19	19	− .24	49	− .25	35	− .15	84	− .21
21	20	− .07	50	− .27	20	− .05	70	− .20
23	25	− .02	40	+ .01	8	− .10	48	.00

For general explanation see Ps 56.

Bs 60.

Residuals in order of declination.

Mean δ	π	r_0	C_0	
°		″	″	
+ 86.7	38	+ .21	+ .24	$\frac{\varepsilon}{\varepsilon_1}=3$
+ 76.6	19	+ .31	+ .36	
+ 71.4	18	+ .61	+ .40	
+ 66.4	7	+ .32	+ .39	
+ 61.6	32	+ .53	+ .30	
+ 56.2	31	+ .03	+ .14	
+ 51.2	43	— .15	— .11	
+ 45.6	19	— .47	— .28	
+ 38.6	32	— .44	— .31	
+ 33.0	27	— .20	— .21	
+ 27.5	57	— .14	— .01	
+ 21.5	64	+ .11	— .03	
+ 14.8	65	— .32	— .08	
+ 9.2	83	— .01	— .09	
+ 3.2	38	— .27	— .05	
— 1.6	53	+ .10	— .02	
— 8.5	45	— .10	.00	
— 14.0	21	+ .03	.00	
— 18.8	14	+ .13	.00	
— 22.4	19	+ .21	.00	
— 28.2	19	— .25	.00	

The curve from which C_0 is taken is derived from the mean of Bs 60 and Bs 65, since there is no reason for supposing the two to differ.

Residuals in order of right ascension.

	Declination limits. —30° to +5		Declination limits. —30° to +40°		Declination limits. +40° to +90°		Declination limits. —30° to +90°	
Mean α	π′	r_0'	π′	r_0'	π′	r_0'	π′	r_0'
h.		″		″		″		″
1	11	— .05	47	— .16	29	+ .01	76	— .10
3	18	— .24	30	+ .07	8	+ .20	38	+ .10
5	18	+ .31	50	+ .16	12	— .08	62	+ .11
7	11	+ .75	46	+ .40	6	+ .60	52	+ .42
9	7	— .10	33	— .09	18	+ .12	51	— .02
11	15	+ .05	43	+ .05	18	— .31	61	— .05
13	28	— .28	40	— .17	14	— .39	54	— .23
15	18	— .11	54	— .22	14	— .32	68	— .24
17	12	— .40	49	— .28	25	+ .09	74	— .16
19	16	+ .43	53	— .07	20	— .17	73	— .10
21	20	+ .04	46	— .02	34	+ .09	80	+ .03
23	20	+ .15	46	— .12	12	— .12	58	— .12

There is a tolerably well-marked correction indicated, which is substantiated by the examination of Bs 65. From the combined values of r_0' in the limits — 30° to + 90°, we have:—

$$-(''.17 \pm ''.03)\sin\alpha + (''.005 \pm ''.03)\cos\alpha.$$

This is very nearly what might have been predicted from the discussion of Bradley's declination, the zenith-points at Brussels being derived from a standard catalogue of a much earlier epoch, with proper motions computed from the *Fundamenta*.

Correcting the values of r for the curve and the above formula, with $m = 8$, we have for Bs 60:—

$$E = \pm\ ''.59,$$

Me 62.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		$''$	$''$	
+ 48.6	3	− 1.77	....	$\frac{\varepsilon}{\varepsilon_1} = 2$
+ 45.4	5	− .99	....	
+ 38.7	4	+ .98	+ .49	
+ 32.4	10	+ .58	+ .44	
+ 27.1	25	+ .54	+ .40	
+ 21.0	28	+ .36	+ .38	
+ 14.7	37	+ .22	+ .38	
+ 9.2	39	+ .35	+ .56	
+ 4.2	22	+ .75	+ .74	
− 1.2	31	+ 1.13	+ .88	
− 8.5	24	+ .83	+ .87	
− 14.0	15	+ .48	+ .77	
− 18.6	11	+ 1.33	+ .66	
− 22.6	12	+ .90	+ .57	
− 28.2	14	+ .33	+ .46	
− 34.8	2	+ .52	+ .21	
− 41.1	1	− .08	+ .06	
− 50.1	2	− .12	− .04	
− 59.4	6	− .30	− .20	
− 75.1	3	− .19	− .14	

The correction here determined is applicable in addition to the correction given in Introduction to Williamstown, 1861–'63 (pp. xxi and xxii).

With $m = 6$, we have:—

$$E = \pm\ ''.90.$$

This large probable error, nearly twice that of Me 68, found in precisely the same way, may be partly owing to the neglect of correction proceeding according to α. The observations themselves are known to be less exact* than those of Me 68, but apparently not in the ratio indicated above.

In the comparison of Gh 57 — Me 62† Dr. Gylden finds:—

$$+\ ''.07 \cos \alpha + ''.14 \sin \alpha - ''.40 \cos 2\alpha - ''.34 \sin 2\alpha.$$

Something like this is indicated in the examination below, and probably has a real existence. On the whole, I thought it not advisable to investigate the correction, whatever it is, depending on α.

* *Vide* V. J. S., vol. v, p. 289. † *Ibid.*, p. 291.

Residuals in order of right ascension.

	Declination limits. — 30° to + 5°		Declination limits. + 5° to + 40°		Declination limits. — 30° to + 40°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	7	— .17	19	— .08	26	— .10
3	11	— .20	3	— .30	14	— .24
5	16	+ .18	26	— .64	42	— .33
7	8	+ .10	18	— .13	26	— .06
9	4	+ .10	11	+ .15	18	+ .14
11	10	+ .12	14	+ .41	24	+ .29
13	14	+ .69	2	+ .60	16	+ .65
15	9	+ .28	10	+ .92	19	+ .62
17	6	— .70	12	— .19	18	— .36
19	7	— .05	14	— .25	21	— .31
21	12	+ .37	10	+ .29	22	— .07
23	18	+ .19	10	+ .12	28	+ .16

Wn 64.

The weights (π') are constructed as explained in Section V.

Residuals in order of declination.

Mean δ	π'	r_0'	C_0
°		"	"
+ 87.1	95	+ .10	+ .10
+ 76.1	56	+ .26	+ .11
+ 70.7	51	+ .27	+ .08
+ 66.1	38	— .03	+ .06
+ 62.0	43	— .41	+ .03
+ 56.2	19	— .07	— .01
+ 50.6	26	+ .32	— .05
+ 45.7	22	+ .11	— .09
+ 38.8	21	+ .08	— .14
+ 33.0	11	— .01	— .21
+ 27.4	59	— .33	— .29
+ 21.4	67	— .44	— .38
+ 14.5	79	— .31	— .45
+ 8.9	80	— .59	— .46
+ 4.5	38	— .41	— .44
— 1.3	40	— .11	— .39
— 8.8	37	— .38	— .29
— 13.9	15	— .60	— .21
— 18.9	8	+ .4	— .12
— 21.4	5	+ .0	— .07
— 28.2	15	— .1	+ .06

Correcting the outstanding residuals by the formula embracing terms in α (see Wn 47) and with $m = 6$, we have:—

$$E = \pm\ ''.71.$$

Residuals in order of right ascension.

Declination limits. −30° to +5°			Declination limits. −30° to +40°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_1'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	3	− .50	50	− .19	62	− .05	112	− .12
3	8	− .25	22	− .12	8	− .36	30	− .18
5	11	+ .04	36	− .53	17	− .03	53	− .37
7	2	− .20	29	− .24	11	− .50	40	− .31
9	2	+ .20	29	+ .17	10	+ .48	39	+ .25
11	6	− .20	35	− .16	29	− .32	64	− .23
13	20	+ .47	34	+ .32	32	+ .28	66	+ .30
15	16	+ .33	45	+ .40	48	+ .25	93	+ .31
17	12	+ .10	41	+ .31	32	+ .26	73	+ .30
19	12	− .37	54	− .08	31	− .37	85	− .19
21	20	+ .21	41	− .02	45	+ .23	86	+ .11
23	30	− .09	51	+ .05	25	− .06	76	+ .01

The general explanation is given under Wn 47.

Gh 64.

Residuals in order of declination.

Mean δ	π'	r_1	C_0	
°		″	″	
+ 86.7	47	+ .11	.00	$\frac{\varepsilon}{\varepsilon_1} = 3$
+ 76.5	41	− .23	.00	
+ 70.7	47	− .12	.00	
+ 66.4	41	+ .06	.00	
+ 61.4	54	+ .07	.00	
+ 55.9	28	− .14	.00	
+ 51.0	53	+ .20	.00	
+ 45.6	53	− .12	.00	
+ 40.2	68	+ .12	.00	
+ 32.8	55	− .03	+ .07	
+ 27.2	87	+ .16	+ .12	
+ 21.1	101	+ .13	+ .15	
+ 14.6	102	+ .15	+ .12	
+ 8.9	122	+ .05	+ .05	
+ 4.2	50	+ .19	.00	
− 1.2	64	− .22	− .09	
− 8.6	65	− .07	− .03	
− 14.1	26	+ .07	+ .11	
− 18.8	17	+ .61	+ .24	
− 22.1	21	+ .25	+ .32	
− 28.1	23	+ .55	+ .49	

With $m = 5$, we have:—

$$E = \pm\, ''.49.$$

$\pm\, ''.48$ is adopted for the definitive weights, as explained under Gh 57.

Residuals in order of right ascension.

	Declination limits. — 30° to + 5°		Declination limits. — 30° to + 40°		Declination limits. — 30° to + 90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	11	+ .57	76	+ .14	114	+ .05
3	16	+ .09	37	— .09	54	— .01
5	25	— .01	73	+ .03	104	+ .04
7	7	— .49	68	— .15	77	— .13
9	7	— .40	58	— .14	76	— .02
11	21	— .14	60	— .05	91	— .11
13	33	— .14	49	— .12	79	— .05
15	28	— .06	76	+ .01	116	— .03
17	9	.00	61	+ .11	103	+ .09
19	22	+ .02	78	— .02	121	— .06
21	27	+ .23	69	+ .18	138	+ .14
23	33	+ .05	60	+ .13	85	+ .04

For remarks see Bn 66.

Ps 64.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 86.6	20	— .18	— .22	$\frac{\varepsilon}{\varepsilon_{\prime}}=2$
+ 76.6	12	— .40	— .26	
+ 70.7	11	— .16	— .27	
+ 66.2	8	— .04	— .27	
+ 61.1	21	— .30	— .25	
+ 56.3	21	— .17	— .22	
+ 50.6	30	— .17	— .22	
+ 45.3	25	— .33	— .26	
+ 39.5	25	— .39	— .30	
+ 32.8	33	— .31	— .28	
+ 27.2	47	— .15	— .16	
+ 21.0	56	— .03	— .06	
+ 14.6	53	— .06	— .07	
+ 9.1	77	— .21	— .16	
+ 4.0	25	— .29	— .22	
— 1.8	51	— .16	— .21	
— 8.5	40	— .15	— .13	
— 14.1	15	+ .02	+ .04	
— 18.9	10	+ .41	+ .29	
— 21.9	13	— .08	+ .43	
— 27.9	15	+1.01	+ .90	

With the correction depending on α, and with $m = 9$, we have:—

$$E = \pm\ ''.37.$$

From Ps 66, we have:—

$$E = \pm\ ''.41.$$

The mean is adopted, since both series are essentially the same.

Residuals in order of right ascension.

	Declination limits. $-30°$ to $+5°$		Declination limits. $-30°$ to $+40°$		Declination limits. $+40°$ to $+90°$		Declination limits. $-30°$ to $+90°$	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	8	− .25	42	+ .04	25	+ .14	67	+ .08
3	12	+ .13	24	+ .05	13	+ .05	37	+ .05
5	16	+ .38	45	+ .19	9	− .07	54	+ .14
7	4	+ .60	40	+ .13	1	+ .30	41	+ .14
9	5	+ .20	36	+ .08	8	+ .30	44	+ .12
11	10	+ .22	37	− .01	23	+ .16	60	+ .05
13	23	− .10	32	− .03	14	+ .03	46	− .01
15	20	+ .03	42	− .15	15	− .09	57	− .14
17	10	− .06	34	− .15	15	− .17	49	− .16
19	13	− .05	48	− .27	12	− .24	60	− .27
21	21	+ .05	39	− .19	17	− .01	56	− .14
23	16	− .08	32	+ .50	4	.00	36	+ .04

The correction is derived under Ps 56.

Bs 65.

Residuals in order of declination.

Mean δ	π	r_0	C_0	
°		″	″	
+ 87.0	22	+ .27	+ .24	$\frac{\varepsilon}{\varepsilon_{\prime}} = 3$
+ 76.6	18	+ .22	+ .36	
+ 70.5	9	+ .47	+ .40	
+ 67.3	1	+ .45	+ .39	
+ 61.8	16	+ .37	+ .31	
+ 55.9	17	− .01	+ .10	
+ 50.2	30	− .06	− .17	
+ 45.2	21	− .22	− .29	
+ 39.0	26	− .30	− .31	
+ 32.5	26	+ .12	− .19	
+ 27.4	51	− .05	− .03	
+ 21.3	47	+ .27	+ .04	
+ 14.4	48	− .08	− .08	
+ 8.8	67	+ .07	− .09	
+ 4.2	27	+ .14	− .05	
− 1.6	47	− .12	− .02	
− 8.6	42	+ .02	.00	
− 14.0	22	+ .26	.00	
− 18.8	15	+ .15	.00	
− 22.3	18	+ .13	.00	
− 28.2	8	− .05	.00	

From the final residuals, corrected as in the case of Bs 60, we have (with $m = 8$):—

$$E = \pm\ ''.44.$$

I have considered this large increase in precision to be real, and have adopted the respective values of E, as determined, in constructing the definitive table of weights for Bs 60 and Bs 65.

Residuals in order of right ascension.

Declination limits. −30° to +5°			Declination limits. −30° to +40°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″
1	11	+ .35	43	+ .16	20	− .09	63	+ .08
3	13	+ .55	23	+ .39	7	+ .10	30	+ .32
5	13	+ .12	37	+ .35	7	+ .13	44	+ .32
7	5	+ .50	28	+ .32	3	+ .20	31	+ .31
9	7	.00	28	+ .14	10	+ .29	38	+ .18
11	12	+ .12	36	+ .20	18	+ .26	54	+ .22
13	26	− .20	38	− .06	10	+ .10	48	− .03
15	20	+ .04	41	.00	13	+ .07	54	+ .01
17	10	− .06	44	− .04	15	− .11	59	− .06
19	13	− .05	45	− .18	7	+ .19	52	− .13
21	21	+ .05	43	+ .05	19	− .07	62	+ .01
23	16	− .08	34	.00	8	− .34	42	− .06

For further explanations see Bs 60.

Ps 66.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 87.4	16	− .32	− .20	$\frac{\varepsilon}{\varepsilon_{\prime}}=2$
+ 76.7	7	− .10	− .20	
+ 70.9	5	− .15	− .18	
+ 66.0	5	− .19	− .12	
+ 60.9	19	+ .01	− .03	
+ 56.5	19	+ .07	.00	
+ 50.4	20	+ .14	− .01	
+ 45.2	27	− .13	− .07	
+ 39.4	26	− .26	− .15	
+ 32.9	31	− .19	− .16	
+ 27.4	47	− .06	− .10	
+ 21.2	51	− .03	− .06	
+ 14.7	52	− .11	− .16	
+ 9.1	78	− .29	− .25	
+ 4.1	26	− .32	− .27	
− 1.8	48	− .21	− .24	
− 8.5	41	− .25	− .19	
− 14.1	14	+ .01	− .09	
− 18.7	12	− .11	+ .02	
− 21.9	12	+ .11	+ .14	
− 27.9	15	+ .56	+ .39	

In the same manner as with Ps 64, we have:—

$$E=\pm\ ''.41.$$

± .39 is adopted, as previously explained.

Residuals in order of right ascension.

	Declination limits. −30° to +5°		Declination limits. −20° to +40°		Declination limits. +40° to +90°		Declination limits. −30° to +90°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"		"
1	8	+ .35	45	− .08	18	+ .18	63	.00
3	10	− .22	22	− .21	13	+ .18	35	− .07
5	16	+ .10	42	+ .26	8	+ .05	50	+ .26
7	3	+1.40	36	+ .28	0	.00	36	+ .28
9	4	+ .30	33	+ .11	8	− .07	41	+ .08
11	10	+ .52	32	+ .24	16	+ .12	48	+ .20
13	22	+ .14	31	+ .10	11	+ .37	42	+ .17
15	16	− .15	40	− .17	12	+ .27	52	− .07
17	9	+ .39	35	− .20	9	+ .02	44	− .15
19	19	− .11	45	− .21	10	− .64	55	− .29
21	16	− .08	46	− .14	16	− .22	62	− .16
23	20	+ .04	36	+ .03	7	− .31	43	− .02

The discussion of correction is given under Ps 56.

Bn 66.

Each value of *r* receives weight one.

Residuals in order of declination.

Mean δ	π	r_0	C_0
°		"	"
+ 85.6	2	+ .34	+ .41
+ 76.3	4	+ .47	+ .67
+ 71.0	6	+ .82	+ .71
+ 66.1	3	+ .72	+ .57
+ 62.0	5	+ .26	+ .25
+ 56.0	4	− .45	− .28
+ 50.6	10	− .58	− .54
+ 45.4	6	− .63	− .59
+ 39.2	3	− .62	− .56
+ 32.8	5	− .27	− .45
+ 27.0	5	− .58	− .32
+ 20.7	9	− .19	− .25
+ 15.0	4	− .43	− .20
+ 9.0	8	.00	− .21
+ 4.1	4	− .34	− .27
− 1.3	8	− .36	− .35
− 8.2	4	− .35	− .40
− 14.0	2	+ .05	− .40
− 18.7	3	− .76	− .40
− 22.5	3	− .4ˢ	− .40
− 28.8	1	[+ .51]	[− .40]

The correction in order of declination, as well as right ascension, appears to reproduce in proper proportion and with opposite signs the peculiarities noticed in the correction for Bradley's declinations.

Residuals in order of right ascension.

	Declination limits. -30° to $+6^\circ$		Declination limits. -30° to $+40^\circ$		Declination limits. $+40^\circ$ to $+90^\circ$	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		$''$		$''$		$''$
1	2	− .30	6	− .20	5	+ .14
3	2	+ .25	4	+ .37	2	+ .10
5	3	+ .13	6	+ .07	4	+ .08
7	2	+ .60	5	+ .48		
9			3	+ .03	4	+ .12
11	2	+ .65	6	+ .57	4	− .33
13	4	+ .07	6	.00	2	+ .25
15	2	− .55	4	− .45	4	− .30
17	1	− .30	4	− .10	5	− .14
19	2	− .64	4	− .31	2	+ .90
21	1	+ .10	5	− .32	6	− .30
23	4	− .10	5	− .06	3	− .03

The "Northern stars" were reduced on other principles than those adopted for the zone -30° to $+40^\circ$. Argelander has given (in Volume VI. of the *V. J. S. der Ast. Ges.*, p. 100) the results of a very careful comparison of the difference of declination between Gh 64 and Bn 66. He finds (p. 114, *ibid*) for the zone -30° to $+40^\circ$:—

$$(1)\quad -''.425 + 0''.313 \sin \alpha - 0''.201 \cos \alpha,$$

as the difference "Gr. — Bonn." From the above table, declination limits -30° to $+40^\circ$, I find:—

$$(2)\quad +0''.309 \sin \alpha - 0''.151 \cos \alpha,$$

as the correction to Bn 66. This coincidence between the periodic terms of (1) and (2) tends to prove that the discrepancy between Gh 64 and Bn 66 is almost wholly due to error of the latter.

Taking the mean epoch of the catalogues upon which are based the declinations of Wolfer's *Tabulæ Reductionum* (also *Berlin Jahrbuch*, on which Argelander's (1866) declinations are founded) to be 1832, and assuming their mean to be practically free from error, proceeding according to right ascension, we shall have as the correction to these declinations (*Berlin Jahrbuch*) for 1866, and for $+20^\circ$ declination:—

$$\frac{34}{77} \times (+''.84 \sin \alpha + ''.17 \cos \alpha) = +''.37 \sin \alpha + ''.06 \cos \alpha.*$$

Considering the great uncertainty of the individual positions of Wolfer's catalogue for 1866, this may be regarded as a very fair approximation to (2), which is adopted as the definitive correction for the zone -30° to $+40^\circ$. The Northern stars appear to require no such correction.

With $m = 8$, we have:—

$$E = \pm ''.31.$$

* Argelander finds (V. J. S., Vol. V., p. 110.) Gr. 1864 — Wolfer's $= +0''.475 \sin (\alpha - 2^\circ 58'.)$

Re 66.

Owing to the extreme uncertainty of the individual corrections, the comparisons with definitive curves are of little interest, and for convenience they are here omitted. The residuals were all plotted on a single sheet, so that peculiarities common to all the years were easily detected.

Residuals in order of declination.

$$\frac{\varepsilon}{\varepsilon_{/}} = 2.$$

Mean δ	Re 62.		Re 63.		Re 64.		Re 65.		Re 66.		Re 67.		Re 68.		Re 69.	
	π′	r_0	π′	r_0	π′	r_0	π′	r_0	π′	r_0	π′	r_0	π′	r_0	π′	r_0
°		″		″		″		″		″		″		″		″
+ 87	34	— .25	38	— .12	34	+ .33	27	+ .21	22	+ .84	29	+ .16	32	+ .08	36	+ .05
+ 76	12	— .63	8	—1.41	18	+ .32	8	+ .94	8	+1.46	21	— .01	17	+ .05	21	— .04
+ 70	.5	+ .60	8	— .55	9	— .42	4	+1.30	8	+1.36	26	+ .15	28	+ .74	41	— .03
+ 65	....	......	2	— .15	4	+ .30	5	+ .53	2	+1.40	9	+ .07	8	— .47	17	— .48
+ 62	5	—1.53	4	—1.60	17	—1.09	18	+ .12	4	+1.60	20	— .10	21	+ .02	39	— .16
+ 56	....	....	1	—3.10	7	— .93	1	+1.00	3	+ .90	14	— .17	23	+ .34	49	— .10
+ 51	6	—1.60	1	—1.00	....	....	6	— .32	5	+1.90	17	— .82	19	— .16	36	— .46
+ 45	5	—1.50	1	+ .60	2	—1.10	3	+1.03	9	+ .14	6	—1.03	6	+1.26	22	— .44
+ 39	4	—1.45	6	+ .05	....	....	7	— .37	9	— .63	14	— .55	10	— .40	32	— .22
+ 32	17	—1.77	13	— .37	10	— .55	20	— .53	24	— .43	12	— .62	7	— .01	24	—2.75
+ 27	52	—1.31	41	— .63	33	— .60	34	+ .02	41	— .05	33	— .29	30	+ .12	52	— .29
+ 21	44	—1.51	52	—1.15	32	— .48	27	+ .11	41	— .56	38	— .51	31	+ .12	34	— .37
+ 15	58	—1.78	56	—1.32	24	— .48	43	— .40	44	— .58	38	— .26	37	— .15	54	— .65
+ 9	56	—1.80	63	—1.16	33	— .49	54	— .41	52	—1.26	46	— .98	29	+ .07	54	— .55
+ 4	30	—1.44	28	— .37	24	+ .43	26	— .16	19	— .67	12	—1.80	10	—1.14	18	— .58
— 1	31	— .85	40	+ .15	24	+ .07	23	+ .22	29	—1.16	14	— .67	15	— .71	27	— .70
— 8	34	— .61	31	— .27	18	+ .86	30	+ .46	21	— .56	18	— .83	14	— .64	19	— .24
— 14	12	— .38	18	— .21	8	+ .58	15	+ .55	13	—1.04	1	+ .60	3	+ .43	10	— .25
— 19	10	+ .01	10	— .16	6	— .45	9	+ .72	10	—1.80	6	—1.18	4	—1.02	7	— .67
— 22	11	— .63	16	+ .14	7	+ .46	8	— .47	10	—1.96	2	—1.80	3	+ .30	7	— .57
— 28	10	+2.85	7	+ .83	4	+ .18	7	+ .06	4	—2.67	5	—2.79	3	— .66	10	+ .15

For the earlier years the curve of correction for stars from + 35° to + 90° is necessarily largely ideal.

With various values of m, I deduce roughly.

$$E = \pm\ 1''.1.$$

From Re 72, we have:—

$$E = \pm\ ''.9.$$

The mean ± 1″.00 is adopted in forming the definitive table of weights.

Residuals in order of right ascension.

Mean α	Re 62.		Re 63.		Re 64.		Re 65.		Re 66.		Re 67.		Re 68.		Re 69.	
	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″		″		″		″		″		″
1	37	+ .18	37	— .11	38	— .25	44	+ .53	40	+ .05	33	— .04	40	— .19	61	+ .17
3	18	— .04	21	— .30	11	+ .04	16	+ .24	19	+ .22	21	— .89	8	— .29	18	+ .28
5	37	+ .29	31	— .18	12	— .60	22	— .06	50	+ .18	26	— .19	26	+ .79	21	+ .13
7	32	+ .41	36	+ .30	22	— .39	21	— .36	36	— .43	30	— .19	22	+ .67	24	— .28
9	27	+ .52	26	— .50	19	— .07	14	+ .13	11	— .02	16	+ .35	11	— .05	39	— .10
11	26	+ .09	34	— .24	28	— .25	27	— .03	23	— .12	38	+ .37	37	+ .39	57	— .05
13	27	+ .06	30	+ .28	17	— .25	17	— .21	21	+ .12	30	+ .03	21	— .04	52	+ .20
15	52	— .11	45	+ .10	31	+ .15	44	— .02	37	+ .18	44	+ .27	46	— .06	69	+ .11
17	39	— .65	45	+ .17	15	+ .77	31	— .98	45	— .25	46	+ .06	43	+ .02	88	— .06
19	51	— .48	43	+ .34	33	+ .31	37	— .66	38	— .58	35	+ .12	30	— .28	74	— .15
21	54	+ .13	52	— .07	50	— .19	53	+ .17	31	+ .19	32	— .39	38	— .21	56	+ .16
23	34	— .04	39	+ .32	37	+ .50	41	+ .44	20	+ .31	25	— .08	22	— .88	46	+ .11

There appears to be no consistent, well-defined correction depending on A.R. The division into zones proved equally unavailing for the discovery of such a correction.

Lc 67.

Each value of r receives weight one.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		″	″
+ 86.7	5	+ .38	+ .38
+ 76.8	4	+ .82	+ .87
+ 71.0	6	+ 1.20	+ .99
+ 66.4	5	+ 1.18	+ .93
+ 60.8	13	+ .89	+ .74
+ 56.5	8	+ .36	+ .52
+ 50.9	14	.00	+ .23
+ 45.6	11	— .23	— .01
+ 40.1	11	+ .10	— .23
+ 33.3	8	— .09	— .40
+ 27.5	9	— .49	— .50
+ 21.2	10	— .81	— .55
+ 15.5	11	— .48	— .53
+ 8.8	13	— .33	— .46
+ 4.0	7	— .35	— .43
— 1.7	11	— .54	— .43
— 8.6	7	— .51	— .43
— 14.0	2	— .32	— .40
— 18.7	3	.00	— .32
— 22.5	3	— .32	— .24
— 28.8	1	— .40	— .08

With $m = 8$, we have:—

$$E = \pm\ ''.27.$$

Residuals in order of right ascension.

	Declination limits. — 30° to + 5°		Declination limits. — 30° to + 40°		Declination limits. — 30° to + 90°	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'
h.		″		″		″
1	2	— .05	10	.00	18	— .03
3	3	+ .07	5	+ .12	8	— .04
5	4	+ .25	10	+ .14	17	+ .16
7	2	.00	7	+ .01	8	— .01
9	1	.00	5	+ .22	10	+ .06
11	3	+ .10	8	.00	17	— .15
13	5	— .28	7	— .33	10	— .12
15	2	+ .05	7	+ .14	14	+ .04
17	1	+ .10	7	+ .21	15	+ .16
19	3	+ .20	10	+ .07	18	+ .04
21	2	— .30	8	+ .09	16	+ .02
23	4	— .20	8	— .19	12	— .14

Ln 67.

Each value of r receives equal weight.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		″	″
+ 86.7	5	± .00	.00
+ 76.8	3	+ .04	— .01
+ 69.9	1	— .22	— .05
+ 66.3	3	— .16	— .09
+ 60.7	10	— .23	— .16
+ 56.4	7	— .20	— .21
+ 51.1	13	— .25	— .24
+ 45.6	10	— .33	— .26
+ 40.0	11	— .09	— .26
+ 33.6	5	— .26	— .26
+ 27.2	8	— .21	— .26
+ 20.7	7	— .40	— .26
+ 14.5	9	— .22	— .24
+ 8.6	11	— .37	— .22
+ 3.9	5	— .19	— .16
— 2.2	6	+ .06	— .09
— 8.6	6	+ .17	+ .01
— 14.1	3	— .14	+ .09

With $m = 4$, we have:—

$$E = \pm\ ''.137.$$

The weight (on the adopted scale) from this value of E is 4.8 As the fundamental and circumpolar stars are, without doubt, more exactly determined than others at Leiden, to them in definitive discussion, is assigned weight 5.0, and to all others weight 4.0.

Residuals in order of right ascension.

	Declination limits. —30° to +5°		Declination limits. —30° to +40°		Declination limits. —30° to +90°	
Mean a	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	1	+ .46	11	— .05	28	— .01
3	3	— .22	4	— .24	14	— .02
5	2	+ .04	14	+ .04	29	— .03
7	…	…	8	+ .08	12	+ .11
9	2	+ .17	8	+ .02	14	— .03
11	2	+ .07	6	— .06	26	+ .01
13	2	+ .08	4	+ .03	13	— .05
15	3	— .12	11	— .05	23	— .01
17	2	— .08	22	— .01	39	— .05
19	4	+ .19	16	+ .14	32	+ .07
21	6	+ .08	16	+ .11	35	+ .03
23	4	+ .34	12	+ .07	20	+ .06

Me 68.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		"	"	
+ 49.0	2	[+ 1.8]	+ 1.2	$\frac{\varepsilon}{\varepsilon_{\prime}} = 2$
+ 45.8	11	+ 1.1	+ 1.0	
+ 38.6	12	+ .63	+ .61	
+ 32.3	16	+ .47	+ .23	
+ 27.4	36	+ .06	+ .01	
+ 21.1	40	— .06	— .14	
+ 14.6	44	— .46	— .15	
+ 8.8	50	— .03	— .15	
+ 4.4	29	— .12	— .15	
— 1.3	39	— .09	— .17	
— 8.6	30	— .24	— .20	
— 14.4	17	— .41	— .25	
— 18.8	13	— .06	— .29	
— 22.6	16	— .45	— .31	
— 28.1	17	— .33	— .34	
— 34.8	2	— .27	— .38	
— 42.1	3	— .48	— .39	
— 50.1	2	+ .09	— .34	
— 59.2	7	— .36	— .23	
— 75.1	3	— .05	— .09	

With $m = 5$, we have:—

$$E = \pm\ ''.47.$$

Dr. Gylden found, from the results of 1863–'75:—

$$^{*}E = \sqrt{(0.26)^2 + \frac{1}{n}\left\{0.263 + 0.0467\left[\frac{\text{refr.}}{100}\right]^2\right\}}$$

This would give nearly $\pm\ ''.6$ as the probable error corresponding to E above.

As it is probable that in later work the accuracy of observation improved, the value for E, $\pm\ ''.47$, is adhered to.

* V. J. S., Bd. IV, S. 102.

Residuals in order of right ascension.

	Declination limits. +5° to −30°		Declination limits. +5° to +30°		Declination limits. −30° to +40°	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	8	+ .05	24	+ .15	32	+ .11
3	12	.10	8	+ .15	20	.00
5	16	+ .10	24	.00	40	+ .04
7	10	− .15	16	+ .50	26	− .03
9	4	− .30	12	+ .20	16	+ .07
11	9	+ .12	20	− .10	29	− .03
13	22	− .02	8	− .10	30	− .04
15	20	+ .25	20	− .02	40	− .12
17	10	+ .15	20	− .14	30	− .04
19	10	− .10	26	.00	36	− .03
21	13	− .19	27	+ .06	30	− .03
23	18	+ .02	12	− .43	30	− .16

For further remarks see Section V., comparison of Me 68 and Wn 68.

Wn 68.

The weights are adopted from the discussion in Section V.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		"	"
+ 87.0	405	+ .04	+ .01
+ 76.5	181	− .02	+ .08
+ 70.7	172	+ .15	+ .14
+ 66.7	124	+ .10	+ .18
+ 62.1	79	+ .34	+ .24
+ 55.3	66	+ .23	+ .32
+ 50.4	155	+ .42	+ .35
+ 45.7	84	+ .35	+ .39
+ 39.1	247	+ .36	+ .43
+ 33.2	78	+ .41	+ .46
+ 27.6	406	+ .43	+ .48
+ 21.1	399	+ .51	+ .52
+ 14.5	410	+ .50	+ .56
+ 8.9	526	+ .69	+ .57
+ 4.2	220	+ .45	+ .58
− 1.3	336	+ .76	+ .59
− 8.7	311	+ .47	+ .60
− 14.1	125	+ .57	+ .62
− 19.1	68	+ .54	+ .69
− 22.5	109	+ .64	+ .75
− 27.8	107	+ .95	+ .88

The values of r_0 would have been very well represented by the correction derived in Section V. from a comparison of Wn 68 and Me 68.

I find:—

$$E = \pm\,''.91.$$

The weights were constructed on a unit whose probable error was supposed to be $\pm$ 1''.00. The latter value for E is adopted.

Residuals in order of right ascension.

	Declination limits. — 30° to + 5°		Declination limits. — 30° to + 40°		Declination limits. + 40° to + 90°		Declination limits. — 30° to + 90°	
Mean a	π	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"		"
1	62	— .23	350	— .05	177	.00	527	— .03
3	94	— .56	162	— .18	24	+ .54	186	— .08
5	85	+ .07	307	— .02	35	— .13	342	— .03
7	62	+ .17	259	+ .03	90	+ .16	349	+ .07
9	39	— .08	236	+ .14	49	— .30	285	+ .06
11	94	+ .18	327	+ .07	97	— .04	424	+ .05
13	193	— .12	283	— .06	118	— .14	401	— .09
15	130	+ .02	351	+ .01	181	— .02	532	.00
17	68	+ .19	251	+ .05	136	.00	387	+ .04
19	101	— .16	296	— .21	113	+ .12	409	— .12
21	129	— .12	238	— .13	219	+ .18	457	+ .01
23	135	+ .14	237	+ .11	140	+ .13	377	+ .12

Gh 70.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	*Form.*	
°		"	"	"	
+ 86.6	48	— .15	— .06	— .05	$\frac{\varepsilon}{\varepsilon_{/}}=3$
+ 76.4	42	— .51	— .19	— .19	
+ 70.6	59	— .09	— .24	— .21	
+ 66.4	31	— .04	— .29	— .26	
+ 61.1	89	— .31	— .33	— .28	
+ 56.6	36	— .91	— .36	— .28	
+ 51.1	71	— .40	— .39	— .28	
+ 45.6	61	— .29	— .41	— .28	
+ 39.8	82	— .55	— .42	— .29	
+ 32.9	61	— .42	— .40	— .32	
+ 27.3	87	— .32	— .35	— .36	
+ 21.1	96	— .21	— .33	— .43	
+ 14.6	97	— .41	— .41	— .54	
+ 8.9	126	— .55	— .54	— .64	
+ 4.3	51	— .67	— .69	— .75	
— 1.7	73	—1.15	— .87	— .88	
— 8.7	52	—1.15	—1.15	—1.05	
— 11.1	19	—1.05	—1.38	—1.16	
— 18.6	15	—1.61	—1.60	—1.25	
— 22.6	20	—1.28	—1.80	—1.32	
— 27.8	19	—2.11	—2.1	—1.4	

The preliminary correction $-1''.17\ (\sin{}^3z + \sin{}^3z')$ found from the fundamental and circumpolar stars is unusual; column "Form" is therefore computed from it in order to show its general agreement with the definitive curve. A slight increase of the coefficient would make the agreement better.

With $m = 5$, we have:—

$$E = \pm\ ''.58.$$

This increase over the values of E found for Gh 57 and Gh 64 is most likely due to the error in microscope micrometers, lately discovered at Greenwich.

Residuals in order of right ascension.

	Declination limits. — 30 to + 5°		Declination l mits. — 30° to + 40°		Declination limits. — 30° to + 90°	
Mean α	π′	r_0'	π′	r_0'	π′	r_0'
h.		″		″		″
1	11	— .02	74	+ .01	146	— .03
3	11	+ .53	33	+ .23	46	+ .17
5	24	+ .11	70	— .04	111	+ .02
7	5	+ .88	65	— .09	74	— .08
9	7	— .20	55	+ .02	82	— .01
11	17	— .14	60	+ .01	121	— .14
13	33	— .18	49	— .02	84	— .08
15	32	.00	78	+ .01	128	— .13
17	15	— .17	72	— .05	133	+ .05
19	23	+ .40	84	+ .09	116	+ .11
21	18	+ .02	64	— .03	129	.00
23	29	— .33	59	— .26	84	— .14

Re 72.

The corrections for this series of annual catalogues are determined in the same manner as those for Re 66.

Residuals in order of declination.

Mean δ	Re 70.		Re 71.		Re 72.		Re 73.	
	π′	r_0	π′	r_0	π′	r_0	π′	r_0
°		″		″		″		″
+ 87	36	+ .21	31	+ .27	36	+ .21	34	+ .20
+ 76	22	— .06	19	+ .26	20	+ .30	21	+ .63
+ 70	32	+ .31	32	+ .38	33	+ .46	30	+ .52
+ 65	15	+ .22	16	+ .97	19	+ .79	15	+ .85
+ 62	45	— .10	46	+ .38	46	+ .40	28	+ .71
+ 56	38	+ .33	39	+ .58	40	+ .92	39	+1.09
+ 51	35	+ .09	28	+ .45	33	+ .42	27	+ .39
+ 45	30	+ .25	21	— .01	19	+ .42	17	+ .59
+ 39	28	— .29	21	+ .29	26	+ .17	27	+ .08
+ 32	31	— .66	20	— .23	20	— .29	29	— .01
+ 27	53	— .68	60	— .29	56	— .22	53	— .35
+ 21	43	— .56	44	— .11	48	— .02	38	+ .17
+ 15	51	— .01	51	+ .17	55	+ .33	59	+ .22
+ 9	60	+ .45	60	+ .48	54	+ .46	60	+ .31
+ 4	22	— .11	22	+ .25	24	+ .23	19	— .33
— 1	26	— .15	30	+ .14	28	+ .37	31	+ .07
— 8	25	— .46	22	— .04	22	+ .13	18	— .97
— 14	11	— .90	9	+ .01	10	+ .15	10	— .12
— 19	5	—1.01	6	— .70	3	+ .17	7	+ .02
— 22	6	— .15	7	+ .30	9	— .32	5	—1.56
— 28	8	—1.65	6	— .38	6	— .40	9	+ .12

We have :-

$$E = \pm {}''.9.$$

± 1″.00 is adopted, as previously explained.

Residuals in order of right ascension.

Mean α	Re 70.		Re 71.		Re 72.		Re 73.		Re 62–73.
	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'	r_0'
h.		″		″		″		″	″
1	67	+ .03	64	− .93	58	+ .55	59	+ .46	+ .10
3	25	+ .03	17	+ .49	20	+ .37	22	+ .37	+ .01
5	46	+ .55	35	+ .37	36	− .14	41	+ .40	+ .19
7	32	− .28	43	− .05	41	− .15	27	+ .09	− .07
9	29	− .21	32	+ .24	30	+ .15	26	+ .23	+ .03
11	60	− .09	57	− .17	48	− .21	59	+ .04	− .04
13	36	− .11	52	− .02	45	+ .06	35	− .09	+ .04
15	67	− .27	76	+ .03	66	− .24	69	− .08	− .01
17	71	− .20	55	+ .05	65	− .07	59	− .46	− .12
19	69	+ .33	56	− .23	70	− .15	72	− .45	− .12
21	75	+ .14	59	− .08	76	− .04	67	− .02	.00
23	39	− .09	44	+ .06	42	+ .60	36	− .01	+ .16

For Re 73 there is an apparently well-marked correction depending on α; but as it is not supported by the results of other years, I have thought it best to omit the discussion.

Wn 72.

The residuals are computed from the standard places for each year. In the discussion. $\frac{\varepsilon}{\varepsilon_{\prime}} = 3$ is assumed.

Residuals in order of declinatio

DECLINATION SUB POLO.

Mean δ	Wn 70.			Wn 71–2.			Wn 73.			Wn 74.*		
	π'	r_0	C_0	π	r_0	C_0	π'	r_0	C_0	π'	r_0	C_0
°		″	″		″	″		″	″		″	″
68	5	− .10	00	9	− .03	00	....	....	....	8	− .25	+ .5
75	14	+ .57	00	12	+ .00	00	7	− .30	00	19	+ .36	+ .38
87	21	+ .07	00	35	+ .24	00	27	.00	00	34	+ .76	+ .21
ABOVE POLE.												
+ 87	27	+ .12	00	36	− .39	00	29	+ .20	00	33	− .24	− .21
+ 76	16	+ .14	00	8	+ .34	00	4	+ .20	+ .02	18	− .35	− .26
+ 70	12	− .56	00	9	− .03	00	6	− .29	+ .04	14	− .19	− .33
+ 65	22	− .09	00	23	+ .15	00	10	+ .31	+ .07	31	− .48	− .41
+ 56	5	+ .62	00	2	+ 1.19	− .04	7	− .16	+ .13	10	− .72	− .55
+ 50	25	− .45	− .06	24	− .01	− .10	13	+ .36	+ .18	24	− .45	− .62
+ 46	15	− .45	− .08	18	+ .09	− .15	16	− .15	+ .23	20	− .72	− .67
+ 39	29	+ .00	− .11	32	− .25	− .23	32	+ .38	+ .32	44	− .76	− .74
+ 33	9	− .18	− .13	13	− .60	− .28	13	+ .15	+ .41	15	− .58	− .79
+ 27	54	− .11	− .15	69	− .35	− .31	51	+ .19	+ .49	63	− .91	− .82
+ 21	56	.00	− .16	71	− .27	− .34	56	+ .56	+ .63	72	− .85	− .84
+ 14	41	− .36	− .16	76	− .53	− .33	58	+ .60	+ .56	73	− .69	− .81
+ 9	67	− .27	− .16	9	− .26	− .32	63	+ .48	+ .57	95	− .64	− .76
+ 4	29	+ .19	− .11	39	− .06	− .31	33	+ .81	+ .59	43	− .87	− .76
− 1	46	+ .02	− .09	56	− .29	− .30	37	+ .51	+ .63	46	− .74	− .83
− 8.5	37	+ .08	− .02	60	− .49	− .28	49	+ .79	+ .75	50	− 1.09	− .85
− 11	16	+ .04	00	23	− .09	− .25	16	+ .86	+ .81	20	− 1.18	− .78
− 19	6	− .59	00	11	− .43	− .23	8	+ 1.57	+ .92	12	− .36	− .67
− 22	14	+ .41	00	13	− .24	− .22	12	+ 1.81	+ .98	16	− .78	− .60
− 28	13	− .24	00	15	− .69	− .20	11	+ 52	+ 1.1	18	− .32	− .45
− 34	1	− 1.3		2	+ .6	....	....	....	....	2	+ 1.1	....

* See explanation, p. 157.

The probable error is derived by comparing the corrected residuals (collected as one for each star) with the standard $\Delta\delta'$.

With $m = 4$, we have:—

$$E = \pm\ ''.84.$$

Taking ε as found in Section V., and $\varepsilon_{,}$ as found for Wn 68 in the same section, we have:—

$$E = \pm\ \sqrt{(.70)^2 + (.25)^2} = \pm\ ''.74.$$

The agreement is far from satisfactory. The former result, $\pm\ ''.84$, is adopted.

The combined results of all the years are next arranged in order of right ascension.

Residuals in order of right ascension.

	Declination limits. $-30°$ to $+5°$		Declination limits. $+5°$ to $+40°$		Declination limits. $+40°$ to $+90°$		Declination limits. $-30°$ to $+90°$	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'	π'	r_0'
h.		''		''		''		''
1	39	+ .34	162	+ .16	88	+ .37	289	+ .25
3	15	+ .08	40	− .18	35	− .07	90	− .10
5	64	− .35	109	+ .23	24	+ .25	197	+ .04
7	33	+ .15	119	+ .05	42	− .36	194	− .02
9	20	− .13	88	− .14	19	− .08	127	− .13
11	58	− .16	131	− .09	36	− .57	225	− .18
13	119	− .05	53	+ .23	60	+ .12	232	+ .06
15	87	+ .08	121	+ .16	100	+ .01	308	+ .09
17	33	− .05	113	− .29	80	+ .03	226	− .14
19	64	+ .01	148	+ .01	70	− .02	282	+ .00
21	68	− .44	62	− .10	111	− .14	241	− .22
23	69	+ .05	51	+ .39	27	− .17	147	+ .13

As shown under Wn 68, the correction in order of A. R. found for the declinations of the mural circle is peculiar to that instrument or observing-room alone.

The following tables exhibit the results deduced for systematic correction and weight of the various catalogues.

TABLE IX.—*Corrections to declinations.*

ORDER OF DECLINATION.

δ	Po 1830.*	Bb 1810.	Kg 21.†	Gh 22.‡	Dt 21.‖	Va 29.	Ao 29.	Gh 30.	C. G. H. 31.	S. H. 31.**	C. G. H. 33.	Ce 34††	Mh 31.	Eh 37.	δ
°	"	"	"	"	"	"	"	"	"	"	"	"	"	"	°
+90	00	00	00	....	00	.....	00	+ .10	.....	....	.....	00	.....	−.19	+90
+85	00	+.14	+.08	....	−.05	.....	00	+ .12	.....	....	.....	00	.....	−.22	+85
+80	00	+.29	+.06	....	−.12	.....	00	+ .15	.....	....	.....	00	.....	−.22	+80
+75	00	+.38	+.10	....	−.17	+.40	00	+ .15	.....	....	.....	− .04	−.28	−.23	+75
+70	00	+.30	+.13	....	−.21	+.40	00	+ .13	.....	....	.....	− .14	−.38	−.23	+70
+65	00	+.14	+.16	....	−.24	+.40	00	+ .08	.....	[+1.30]	.....	− .27	−.46	−.22	+65
+60	00	−.02	+.18	....	−.26	+.40	00	00	.....	+1.30	.....	− .42	−.52	−.20	+60
+55	− .05	−.01	+.16	....	−.27	+.38	00	− .12	.....	+1.30	.....	− .57	−.60	−.18	+55
+50	− .20	+.12	+.13	....	−.25	+.31	−.02	− .31	.....	+1.30	−2.00	− .70	−.62	−.16	+50
+45	− .50	+.10	+.09	....	−.22	+.24	−.07	− .54	.....	+1.30	−1.10	− .78	−.60	−.15	+45
+40	−1.00	.00	+.06	00	−.19	+.17	−.13	− .76	.....	+1.30	− .34	− .83	−.54	−.16	+40
+35	−1.40	.....	+.06	00	−.15	+.07	−.18	− .95	.....	+1.30	+ .20	− .84	−.38	−.17	+35
+30	−1.40	.....	+.06	00	−.13	−.03	−.22	−1.12	.....	+1.30	+ .52	− .80	−.14	−.20	+30
+25	−1.20	.....	+.07	00	−.12	−.16	−.25	−1.24	.....	+1.30	+ .57	− .70	+.17	−.21	+25
+20	−1.40	.....	+.10	00	−.15	−.20	−.29	−1.30	.....	+1.30	+ .43	− .54	+.32	−.17	+20
+15	−1.85	.....	+.13	00	−.21	−.17	−.32	−1.31	.....	+1.30	+ .14	− .40	+.47	−.05	+15
+10	−1.60	.....	+.16	00	−.29	−.14	−.30	−1.31	+.35	+1.28	− .06	− .35	+.50	+.04	+10
+ 5	−1.10	.....	+.19	00	−.38	−.10	−.43	−1.33	+.35	+1.22	− .14	− .38	+.50	00	+05
± 0	−1.50	.....	+.25	00	−.49	−.07	−.52	−1.37	+.35	+1.17	− .14	− .47	+.41	−.15	0
− 5	−2.15	.....	+.33	00	−.60	−.03	−.60	−1.49	+.35	+1.09	− .04	− .60	+.30	−.24	− 5
−10	−2.20	.....	+.43	00	−.72	00	−.68	−1.68	+.35	+ .96	+ .10	− .74	+.14	−.27	−10
−15	−1.70	.....	+.55	00	−.84	.....	−.70	−1.97	+.35	+ .84	+ .40	− .88	−.03	−.25	−15
−20	−1.15	.....	+.67	00	−.96	.....	−.70	−2.50	+.35	+ .70	+ .71	− .98	−.20	−.15	−20
−25	−1.00	....	+.78	00	.....	.....	.....	−2.85	+.35	+ .62	+ .88	−1.00	−.40	00	−25
−30	−1.00	.....	+.90	....	.....	.....	.....	−2.95	+.32	+ .60	+ .90	−1.00	.....	+.2	−30
−35	−1.00	.....	.....	....	.....	.....	.....	....	+.17	+ .60	+ .71	......	.....	......	−35
−40	−1.00	.....	.....	....	.....	.....	.....	....	00	+ .60	+ .47	......	.....	......	−40
−50	......	.....	.....	....	.....	.....	.....	....	00	+ .60	+ .10	......	.....	......	−50
−60	......	.....	.....	....	.....	.....	.....	....	00	+ .50	± .00	......	.....	......	−60
−70	......	.....	.....	....	.....	.....	.....	....	00	+ .40	− .08	......	.....	......	−70
−80	......	.....	.....	....	.....	.....	.....	....	00	+ .30	− .10	......	.....	......	−80
−90	......	.....	.....	....	.....	.....	.....	....	00	+ .20	.06	......	.....	......	−90

* This correction is subsequently revised with the definitive $\Delta\delta$ and $\Delta u'$.

† Döllen's reduction.

‡ A small minus correction deduced.

‖ This correction is considered as applicable to Dt 30, after "*correctiones ultimæ*" (p. 357, Struve's *Pos. Med.*) have been added.

** The correction for S H 31 is applicable directly to the catalogue results as reduced with Young's refractions.

†† For the years 1833 and 1834 corrections must be applied for defective reading of barometer (see Cambridge Observations, 1835). To get actual corrections to catalogue results for those years, the effect of this correction must be added to the above.

TABLE IX.—*Corrections to declinations*—Continued.

ORDER OF DECLINATION.

δ	Kg 38.	Gh 39.	Ce 40.*	Ah 41.	Kg 43.	Eh 43.†	Gh 45.	Pa 45.	Re 45.	Wn 47.‡	Ce 48.‖	Gh 51.	So 51.	Ps 53.	δ
°	″	″	″	″	″	″	″	″	″	″	″	″	″	″	°
+90	00	00	00	00	.....	00	00	00	00	+.10	00	—.12	......	00	+90
+85	— .10	+ .01	00	+ .10	.....	00	00	00	+.25	+.14	00	—.13	......	+.08	+85
+80	— .20	+ .03	00	+ .20	....	00	00	00	+.50	+.15	00	—.13	......	+.14	+80
+75	— .27	+ .05	00	+ .20	.....	00	+.02	00	+.66	+.14	00	—.14	......	+.21	+75
+70	— .33	+ .08	—.07	+ .20	.....	00	+.04	+ .06	+.60	+.10	00	—.15	......	+.26	+70
+65	— .36	+ .09	—.18	+ .20	.....	—.02	+.06	+ .12	+.42	+.06	—.10	—.16	......	+.28	+65
+60	— .15	+ .10	—.32	+ .16	.....	—.05	+.08	+ .18	+.28	—.02	—.26	—.18	......	+.29	+60
+55	+ .10	+ .11	—.43	00	+.30	—.08	+.06	+ .23	+.10	—.05	—.42	—.20	......	+.27	+55
+50	+ .28	+ .12	—.54	— .35	+.29	—.08	+.00	+ .26	—.07	—.05	—.57	—.21	......	+.22	+50
+45	+ .30	+ .12	—.65	— .75	+.27	—.06	—.04	+ .30	—.20	—.05	—.69	—.20	......	+.18	+45
+40	+ .22	+ .13	—.75	— .81	+.26	—.03	—.02	+ .33	—.34	—.05	—.81	—.16	+ .40	+.12	+40
+35	+ .11	+ .14	—.83	— .63	+.24	00	+.05	+ .35	—.48	—.05	—.87	—.08	+ .53	+.07	+35
+30	+ .08	+ .15	—.88	— .42	+.23	+.05	+.12	+ .37	—.56	—.08	—.84	+.02	+ .68	+.01	+30
+25	+ .09	+ .17	—.90	— .25	+.21	+.12	+.15	+ .38	—.60	—.14	—.65	+.10	+ .80	—.06	+25
+20	+ .15	+ .19	—.80	— .27	+.20	+.19	+.14	+ .39	—.59	—.21	—.33	+.17	+ .90	—.12	+20
+15	+ .25	+ .23	—.60	— .47	+.18	+.27	+.10	+ .41	—.45	—.29	—.10	+.18	+ .99	—.18	+15
+10	+ .41	+ .28	—.46	— .74	+.16	+.34	+.05	+ .44	—.20	—.34	—.05	+.16	+1.04	—.26	+10
+ 5	+ .56	+ .34	—.50	—1.04	+.13	+.36	+.05	+ .46	+.04	—.35	—.05	+.11	+1.08	—.33	+ 5
± 0	+ .73	+ .41	—.62	—1.20	+.10	+.34	+.08	+ .49	+.26	—.34	—.07	+.04	+1.11	—.37	+ 0
— 5	+ .92	+ .49	—.70	—1.24	+.06	+.25	+.12	+ .53	+.44	—.31	—.11	00	+1.13	—.36	— 5
—10	+1.13	+ .59	—.70	—1.11	00	+.13	+.15	+ .59	+.51	—.27	—.13	00	+1.12	—.30	—10
—15	+1.34	+ .70	—.68	— .87	.....	+.02	+.18	+ .68	+.47	—.23	—.12	+.05	+1.09	—.19	—15
—20	+1.55	+ .83	—.55	— .48	.....	—.08	+.22	+ .84	+.33	—.18	—.08	+.13	+1.06	—.02	—20
—25	+1.77	+ .97	—.4	......	.....	—.15	+.26	[+1.1]	+.16	—.11	—.04	+.20	+1.02	+.27	—25
—30	+2.00	+1.10	—.3	......	.....	—.21	+.30	......	00	—.03	00	+.24	+ .99	+.7	—30
—35	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .95	.....	—35
—40	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .92	.....	—40
—50	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .85	......	—50
—60	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .63	......	—60
—70	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .38	......	—70
—80	......	......	......	......	.....	.....	.....	......	......	......	......	......	+ .19	......	—80
—90	......	......	......	......	.....	.....	.....	......	......	......	......	......	± 00	......	—90

* To the declinations of years 1836 and 1837 —″.09 was added before deriving the above.

† Applicable to declinations as reduced in this paper (pp. 27 to 32).

‡ To declinations of Wn 1845, —″.25 was first added for error of assumed latitude, before deriving the above table.

‖ The correction —″.43 was first applied to all declinations on the authority of latitude discussion made in this paper (p. 26). The true correction to catalogue-places is therefore —″.43 + values taken from the above table for Ce 48.

TABLE IX.—*Corrections to declinations*—Continued

ORDER OF DECLINATION.

δ	So 55.	Wn 56.	Ps 56.	Bs 56.	Ce 56.	Gh 57.	C. G. H. 58.	Re 58.	Ps 60.	Bs 60.	Me 62.*	Wn 64.†	Gh 64.	δ
°	"	"	"	"	"	"	"	"	"	"	"	"	"	°
+90		−.15	−.35	+.22	−.20	00		+.30	−.20	+.20		+.08	00	+90
+85		−.05	−.30	+.26	−.23	+.02		+.44	−.19	+.26		+.11	00	+85
+80		+.05	−.25	+.30	−.26	+.05		+.56	−.16	+.32		+.12	00	+80
+75		+.12	−.20	+.31	−.31	+.09		+.66	−.10	+.38		+.11	00	+75
+70		+.17	−.15	+.31	−.36	+.15		+.73	−.04	+.40		+.08	00	+70
+65		+.18	−.12	+.30	−.44	+.21		+.70	+.01	+.39		+.05	00	+65
+60		+.16	−.10	+.22	−.55	+.23		+.60	+.04	+.26		+.02	00	+60
+55		+.13	−.09	+.07	−.77	+.21		+.46	+.07	+.06		−.02	00	+55
+50		+.10	−.11	−.13	−1.12	+.15	[−2.4]	+.20	+.10	−.17		−.05	00	+50
+45		+.05	−.15	−.36	−1.40	+.11	[−1.5]	−.12	+.10	−.29		−.09	00	+45
+40	+.50	00	−.20	−.52	−1.45	+.11	−.80	−.42	+.08	−.32	+.50	−.13	00	+40
+35	+.50	−.04	−.24	−.52	−1.41	+.15	−.30	−.65	+.04	−.27	+.46	−.18	+.05	+35
+30	+.49	−.09	−.28	−.46	−1.29	+.24	−.06	−.80	00	−.11	+.42	−.25	+.10	+30
+25	+.48	−.13	−.33	−.37	−1.12	+.33	−.05	−.74	−.06	+.01	+.39	−.33	+.13	+25
+20	+.44	−.18	−.35	−.47	−.87	+.37	−.10	−.56	−.12	+.03	+.38	−.40	+.15	+20
+15	+.31	−.23	−.36	−.62	−.67	+.38	−.15	−.35	−.15	−.08	+.38	−.45	+.12	+15
+10	+.20	−.26	−.36	−.70	−.58	+.35	−.18	−.09	−.19	−.10	+.52	−.46	+.07	+10
+05	+.15	−.27	−.35	−.75	−.57	+.28	−.20	+.20	−.20	−.06	+.71	−.44	−.02	+05
0	+.27	−.26	−.34	−.68	−.55	+.20	−.23	+.51	−.18	−.03	+.87	−.40	−.09	0
−5	+.40	−.23	−.30	−.45	−.53	+.15	−.26	+.70	−.13	00	+.90	−.35	−.10	−5
−10	+.39	−.17	−.20	−.23	−.49	+.21	−.26	+.79	−.04	00	+.86	−.28	−.00	−10
−15	+.12	−.10	−.05	−.20	−.46	+.26	−.20	+.79	+.10	00	+.75	−.19	+.11	−15
−20	−.07	−.02	+.14	−.23	−.42	+.26	−.15	+.68	+.28	00	+.63	−.10	+.27	−20
−25	−.14	+.06	+.35	−.27	−.39	+.25	−.10	+.40	+.50	00	+.50	00	+.40	−25
−30	−.02	+.16	+.60	−.30	[−.35]	[+.20]	−.05	[+.10]	+.70	00	+.44	+.10	[+.55]	−30
−35	+.13						00				+.21			−35
−40	+.27						+.05				+.08			−40
−50	+.27						+.15				−.14			−50
−60	+.11						+.27				−.20			−60
−70	00						+.26				−.20			−70
−80	00						+.13				−.08			−80
−90	00						00				00			−90

* The correction for error of assumed latitude, flexure, division, &c., given in the introduction to the Williamstown catalogue, must also be applied. The true correction is, therefore: Correction taken from introduction Me 62 + correction of above table.

† To the catalogue declinations from direct observations above pole for 1861 and 1862 was first added the correction −".68 (+".68, below pole); and to the declinations of years 1863–1865 ∓".47, according as the declination results from observations above or below the pole. The actual correction is, therefore: These quantities + corrections from above table.

TABLE IX.—*Corrections to declinations*—Continued.

ORDER OF DECLINATION.

δ	Ps 64.	Bs 65.	Ps 66.	Bn 66.	Lc 67.	Ln 67.	Me 68.	Wn 68.*	Gh 70.	Wn 70.†	Wn 71–2.	Wn 73.	Wn 74.‡	δ
°	″	″	″	″	″	″	″	″	″	″	″	″	″	°
+90	— .20	+.20	—.20	+.40	+ .22	00	....	00	00	.00	00	00	+.07	+90
+85	— .23	+.26	—.20	+.41	+ .47	00	....	+ .02	— .09	.00	00	00	—.04	+85
+80	— .25	+.32	—.20	+.55	+ .72	00	....	+ .05	— .15	.00	00	00	—.14	+80
+75	— .26	+.38	—.20	+.71	+ .94	—.01	....	+ .10	— .20	.00	00	+ .02	—.24	+75
+70	— .27	+.40	—.17	+.71	+1.00	—.05	....	+ .15	— .25	.00	00	+ .04	—.33	+70
+65	— .27	+.39	—.11	+.54	+ .90	—.10	....	+ .20	— .30	.00	00	+ .07	—.41	+65
+60	— .25	+.26	—.01	+.05	+ .70	—.17	....	+ .26	— .34	.00	00	+ .10	—.49	+60
+55	— .21	+.06	00	—.36	+ .44	—.22	....	+ .32	— .37	— .03	—.05	+ .14	—.56	+55
+50	— .22	—.17	—.01	—.56	+ .18	—.25	[+1.25]	+ .36	— .40	— .06	—.10	+ .18	—.62	+50
+45	— .26	—.29	—.07	—.60	— .04	—.26	[+1.00]	+ .39	— .41	— .09	—.16	+ .24	—.68	+45
+40	— .30	—.32	—.15	—.57	— .23	—.26	[+ .67]	+ .42	— .42	— .11	—.22	+ .30	—.73	+40
+35	— .30	—.27	—.18	—.50	— .37	—.26	+ .48	+ .45	— .42	— .13	—.26	+ .38	—.77	+35
+30	— .22	—.11	—.14	—.38	— .47	—.26	+ .11	+ .47	— .37	— .14	—.30	+ .46	—.81	+30
+25	— .10	+.04	—.06	—.28	— .54	—.26	— .08	+ .50	— .33	— .15	—.33	+ .51	—.83	+25
+20	— .05	+.03	—.06	—.24	— .55	—.26	— .15	+ .53	— .33	— .16	—.34	+ .54	—.84	+20
+15	— .06	—.08	—.15	—.20	— .52	—.25	— .15	+ .55	— .40	— .16	—.33	+ .56	—.82	+15
+10	— .15	—.10	—.24	—.20	— .47	—.23	— .15	+ .57	— .52	— .16	—.32	+ .57	—.76	+10
+05	— .22	—.06	—.27	—.25	— .43	—.19	— .15	+ .58	— .65	— .15	—.31	+ .58	—.75	+05
0	— .23	—.03	—.28	—.33	— .43	—.12	— .16	+ .59	— .80	— .10	—.30	+ .61	—.82	0
— 5	— .19	00	—.24	—.40	— .43	—.05	— .18	+ .59	—1.00	— .05	—.29	+ .69	—.85	— 5
—10	— .10	00	—.17	—.40	— .43	+.03	— .21	+ .60	—1.20	.00	—.27	+ .77	—.86	—10
—15	+ .07	00	—.07	—.40	— .39	+.11	— .26	+ .63	—1.43	00	—.25	+ .86	—.76	—15
—20	+ .35	00	+.07	—.40	— .30	......	— .30	+ .70	—1.66	00	—.23	+ .94	—.65	—20
—25	+ .66	00	+.25	—.40	— .18	......	— .32	+ .80	—1.93	00	—.21	+1.03	—.53	—25
—30	+1.00	00	+.48	[—.40]	— .05	......	— .36	+ .93	[—2.20]	00	—.19	+1.11	—.40	—30
—35	+1.35	......	+.75	......	......	......	— .38	+1.09	....	00	—.17	......	—.29	—35
—40	......	......	......	......	......	......	— .40	......	....	......	......	......	......	—40
—50	......	......	......	......	......	......	— .34	......	....	......	......	......	......	—50
—60	......	......	......	......	......	......	— .22	......	....	......	......	......	......	—60
—70	......	......	......	......	......	......	— .12	......	....	......	......	......	......	—70
—80	......	......	......	......	......	......	— .05	......	....	......	......	......	......	—80
—90	......	......	......	......	......	......	00	......	....	......	......	......	......	—90

*Applicable to declinations derived in this paper (Section V.).

† Applicable to declinations of annual catalogues after correction, as explained in Section V.

‡ As explained elsewhere the correction, $+''.82$, to the declinations of 1874, south of Wn. zenith was neglected by accident for stars south of -12° declination, and the error discovered too late to be corrected in the succeeding results. As actually used in making up the definitive $C_{,,}$ of the final dis-

TABLE IX.—*Corrections to declinations*—Continued.

RADCLIFFE ANNUAL CATALOGUES.

δ	62.*	63.	64.	65.	66.	67.	68.	69.	70.	71.	72.	73.	δ
°	″	″	″	″	″	″	″	″	″	″	″	″	°
+90	00	00	+.40	+..10	+ .74	00	+ .10	00	+ .10	+.23	+.17	.00	+90
+85	— .26	— .17	+.26	+ .27	+1.00	00	+ .15	00	+ .13	+.27	+.24	+.21	+85
+80	— .48	— .34	+.13	+ .38	+1.26	00	+ .18	00	+ .17	+.31	+.32	+.39	+80
+75	— .66	— .50	00	+ .41	+1.43	00	+ .19	—.03	+ .19	+.36	+.40	+.52	+75
+70	— .86	— .63	—.13	+ .40	+1.50	00	+ .20	—.06	+ .20	+.40	+.48	+.67	+70
+65	—1.03	— .73	—.26	+ .31	+1.41	00	+ .18	—.12	+ .19	+.42	+.50	+.80	+65
+60	—1.21	— .81	—.40	+ .20	+1.21	00	+ .13	—.23	+ .17	+.44	+.51	+.86	+60
+55	—1.36	— .87	—.55	+ .08	+ .96	— .10	+ .08	—.30	+ .12	+.41	+.49	+.82	+55
+50	—1.49	— .90	—.70	— .03	+ .60	— .22	00	—.34	+ .11	+.35	+.42	+.70	+50
+45	—1.56	— .90	—.75	— .10	+ .47	— .37	— .06	—.32	— .01	+.23	+.33	+.47	+45
+40	—1.60	— .90	—.80	— .14	+ .20	— .46	— .10	—.27	— .22	+.10	+.15	+.21	+40
+35	—1.60	— .85	—.74	— .18	— .02	— .48	— .09	—.28	— .50	—.10	—.07	—.02	+35
+30	—1.52	— .85	—.62	— .18	— .14	— .47	+ .03	—.28	— .63	—.27	—.21	—.13	+30
+25	—1.51	—1.00	—.55	— .18	— .30	— .49	+ .12	—.33	— .65	—.25	—.17	—.06	+25
+20	—1.60	—1.20	—.50	— .21	— .51	— .58	+ .07	—.48	— .40	—.10	+.08	+.10	+20
+15	—1.68	—1.23	—.50	— .33	— .88	— .73	— .06	—.62	00	+.20	+.32	+.21	+15
+10	—1.67	—1.20	—.42	— .42	—1.06	— .88	— .10	—.66	+ .26	+.40	+.44	+.23	+10
+ 5	—1.54	— .87	—.20	— .26	—1.11	—1.00	— .10	—.56	+ .20	+.36	+.40	+.11	+ 5
0	—1.14	— .38	+.25	+ .13	— .93	— .88	— .10	—.47	00	+.18	+.30	—.09	0
— 5	— .78	+ .10	+.48	+ .40	— .91	— .74	— .20	—.40	— .25	+.02	+.18	—.26	— 5
—10	— .59	+ .02	+.56	+ .53	—1.06	— .79	— .35	—.40	— .50	—.11	+.07	—.34	—10
—15	— .43	+ .09	+.56	+ .62	—1.30	— .89	— .51	—.40	— .65	—.24	—.02	—.35	—15
—20	— .30	+ .13	+.58	+ .80	—1.57	—1.05	— .67	—.40	— .80	—.34	—.11	—.30	—20
—25	— .20	+ .16	+.65	+ .90	—1.83	—1.22	— .83	—.35	— .90	—.42	—.20	—.25	—25
—30	— .10	+ .18	+.72	+1.00	—2.10	—1.40	—1.00	—.30	—1.00	—.50	—.28	—.20	—30

cussion of declinations, Wn 74 was used as above from + 90° to + 15°. From that point the corrections were virtually computed according to this table:

δ	Corr.	δ	Corr.
°	″	°	″
+ 10	— .78	— 15	— .99
+ 5	— .72	— 20	— .77
00	— .65	— 25	— .55
— 05	— .55	— 30	— .34
— 10	— .38	— 35	— .13

That is, as actually used, a declination of Wn 74 (+ 10° to — 35°), as given in the catalogue, was corrected by + ″.82 + the values given in this table.

*As explained under Re 66, the corrections from + 35° to + 90°, for the annual catalogues Re 62 - Re 66 are deserving of little confidence.

TABLE X.—*Corrections to declinations.*

ORDER OF RIGHT ASCENSION.

a	Po 1800.	Bh 10	S H 31.	Kg 38.	Ce 40.*	Kg 43.	Eh 43.	Wn 47, 56, and 64.	So 51.	Ps 56, etc.	Bs 60 and 65.	Bn 66.*	a
h.	"	"	"	"	"	"	"	"	"	"	"	"	h.
0	—.18	+.40	+.47	+.32	—.15	+.13	—.19	—.12	—.18	—.05	+.01	—.15	12
1	—.04	+.25	+.53	+.38	—.11	+.08	—.19	—.17	—.12	00	+.05	—.07	13
2	+.11	+.08	+.55	+.40	—.06	+.03	—.19	—.21	—.04	+.05	+.09	+.02	14
3	+.25	—.09	+.53	+.40	—.00	—.02	—.17	—.23	+.04	+.10	+.12	+.11	15
4	+.37	—.26	+.47	+.37	+.06	—.07	—.14	—.24	+.12	+.14	+.15	+.19	16
5	+.46	—.41	+.39	+.32	+.11	—.12	—.09	—.24	+.19	+.17	+.16	+.26	17
6	+.53	—.53	+.27	+.24	+.15	—.16	—.05	—.21	+.24	+.20	+.17	+.31	18
7	+.56	—.62	+.14	+.15	+.18	—.19	00	—.18	+.28	+.20	+.16	+.34	19
8	+.55	—.66	00	+.05	+.20	—.20	+.05	—.13	+.30	+.19	+.14	+.34	20
9	+.50	—.66	—.14	—.06	+.21	—.20	+.10	—.07	+.30	+.17	+.12	+.33	21
10	+.42	—.62	—.27	—.16	+.20	—.19	+.14	—.00	+.28	+.14	+.08	+.29	22
11	+.31	—.53	—.39	—.25	+.18	—.16	+.17	+.06	+.24	+.10	+.04	+.23	23
12	+.18	—.40	—.47	—.32	+.15	—.13	+.19	+.12	+.18	+.05	—.01	+.15	24

NOTE.—When a is taken from right-hand (12*h* to 24*h*) the signs of the table are reversed.

* The corrections for Ce 40 and Bn 66 are applicable only within the declination limits —30° to + 40°.

In computing from the values of E, given in the preceding pages, the definitive weights to be used in the final discussion, $\pm$ ″.30 was taken as the probable error of the unit, and 5 (corresponding to a probable error of $\pm$ ″.134) as the maximum weight. Weight .05 is used in a few cases. As the probable errors are somewhat uncertain, especially in their respective relation to number of observations, only the denominations of weight presented in the table were actually used.

For convenience, a few weights deduced in Section IX. are also collated here.

With the "Catalogue" as an argument, the corresponding horizontal line is followed until the number of observations is reached, or, at least, the limits which include it. At the top of the column is found the corresponding weight.

The second argument is, however, often a probable error (as Kg 21, Dt 24, etc.), or weight resulting from the system of compilation (as with Ce 40, Eh 43, etc.).

TABLE XI.—*Weights used in discussion*

Catalogue.	Weights.								
	.05	.1	.2	.3	.4	.5	.6	.7	.8
	Number of observations, prelim								
Gh 1752	2 to 8	9 or more							
Gh 1755		2 or 3	4 to 20	21 or more					
Po 1800		All							
Bh 1810		1 or 2	3 to 5	6 to 18	19 or more				
Kg 21	Probable	errors				.44 to .41	.40 to .37	.36 or 35	.34 or .33
Gh 22									
Dt 24 and 30	Same as	Kg 21 or	An 29, acco	rding as pro	bable error	or number	of observati	ons is the	argument
Va 29					All				
Ao 29					1				2
Gh 30									All
C. G. H. 31		1 and 2	3 to 9	10 or more					
S. H. 31	1	2 or 3	4 to 9	10 to 21	22 to 85	85 or more			
C. G. H. 33									
Ce 34			1	2		3	4	5 and 6	7
Mh 34		1 and 2	3	4 to 6	7 to 11	12 to 18	19 to 35	36 or more	
Ms 35		2 or 3	4 or more						
Eh 37				1			2	3	4
Kg 38							All		
Gb 39			1	2		3	4	5	6
Ce 40	Weights			1		2			3
Kg 43									
Eh 43		Weights	1		2		3		4
Gh 45			1		2		3	4	
Pa 45	See table	below							
Re 45			1	2 or 3	4 and 5	6 to 10	11 to 23	24 or more	
Ah 44 and 52		1	2 to 4	5 to 14	15 or more				
Wn 47	Weights		1	2		3		4	5
Ce 48	Same as	Ce 40							
Wn 48 (P. V.)			1		2		3	4	
Ms 50				3 to 5					
Gh 51	Same as	Gh 39							
So 51		1	2	3 to 5	6 to 11	12 to 37	38 or more		
Ps 53				1		2		3	
So 55		1	2 and 3	4 to 7	8 to 19	20 or more			
Wn 56		1	2	3	4	5 and 6	7	8 and 9	10 to 12
Ps 56					1			2	
Bs 56		1	2	3 and 4	5 to 7	8 and 9	10 to 16	17 to 27	28 to 52
Ce 56	Same as	Ce 40							
Gh 57					1			2	
C. G. H. 58					1		2		3
Re 58	Same as	Re 45							
Eh 58			1	2	3	4 or 5	6 to 8	9 to 15	16 or more
Ps 60									1
Bs 60				1		2	3		4
Me 62		1	2 and 3	4 to 6	7 to 17	18 or more			
Pa 62 (P.V.)									
Eh 63	Same as	Eh 58							
Wn 64	Weights		1		2	3		4	
Gh 64	Same as	Gh 57							
Ps 64							1		
Bs 65						1			2
Ps 66	Same as	Ps 64							
Bn 66									
Le 67									
Ln 67									
Eh 67		2 to 5	6 or more						
Me 68					1			2	
Wn 68	Weights	1	2	3	4 and 5	6	7	8	9
Re 66 and 72		1	2 or 3	4 or 5	6 to 9	10 to 14	15 to 23	24 to 44	45 to 152
Gh 70				1		2		3	4
Wn 70		1 or 2	3 to 5	6 or more					
Wn 72	Weights	1		2	3	4	5		6

of definitive declinations.

Weights.								Catalogue.
1.0	1.5	2.0	2.5	3 0	3.5	4.0	5.0	
inary weight, or probable error.								
								Gh 1752.
								Gh 1755.
								Po 1800.
								Bh 1810.
.32 to .27	.26 to .23	.22 to .20	.19	.18 and .17	.16	.15	.14 or less	Kg 21.
All								Gh 22.
								Dt 24 and 30.
								Va 29.
3	4 to 6	7 to 10	11 to 16	17 to 29	30 to 68	68 or more		Ao 29.
								Gh 30.
								C. G. H. 31.
								S. H. 31.
All								C. G. H. 33.
8 to 18	19 or more.							Ce 34.
								Mh 34.
								Ms 35.
5 to 12	13 or more.							Eh 37.
								Kg 38.
7 to 11	12 to 21	22 to 45	46 to 156	157 or more				Gh 39.
4	5 to 8	9 to 13	14 to 19	20 to 28	29 to 38	39 to 55	56 or more	Ce 40.
	All							Kg 43.
5 and 6	7 and 8	9 to 11	12 and 13	14 to 16	17 and 18	19 to 22	23 or more	Eh 43.
5 to 8	9 to 14	15 to 26	27 to 50	51 to 139	140 or more			Gh 45.
								Pa 45.
								Re 45.
								Ah 41 and 52.
6 and 7	8 to 10	11 to 13	14 to 16	17 to 19	20 to 22	23 to 27	28 or more	Wn 47.
								Ce 48.
5 and 6	7 and 8							Wn 48 (P.V.)
								Ms 50.
								Gh 51.
								So 51.
4 to 7	8 to 15	16 to 39	40 or more.					Ps 53.
								So 55.
13 to 27	28 to 124	125 and more						Wn 56.
3 to 5	6 to 18	19 or more						Ps 56.
53 or more								Bs 56.
								Ce 56.
3 and 4	5 to 7	8 to 12	13 to 21	22 to 44	45 to 207	208 or more		Gh 57.
4 to 9	10 or more.							C. G. H. 58.
								Re 58.
								Eh 58.
2	3	4 to 6.	7 to 12	13 to 30	31 or more			Ps 60.
5 to 8	9 to 18	19 to 60	61 or more.					Bs 60.
								Me 62.
	1				2		3 or more	Pa 62 (P.V.)
								Eh 63.
5 and 6	7 to 9	10 to 12	13 to 15	16 to 18	19 and 20			Wn 64.
								Gh 64.
2	3 to 5	6 to 12	13 to 52	53 or more				Ps 64.
3	4 and 5	6 to 8	9 to 13	14 to 21	22 to 37	38 and more		Bs 65.
								Ps 66.
All								Bn 66.
All								Lc 67.
						All not fundamental or circumpolar.	Fundamental and circumpolar.	Ln 67.
								Eh 67.
3 to 6	7 to 24	25 or more						Me 68.
10 to 13	14 to 19	20 to 25	26 to 30	31 to 36	37 to 41	42 to 49	50 or more	Wn 68.
153 or more								Re 66 and 72.
5 to 7	8 to 17	18 to 47	48 or more.					Gh 70.
								Wn 70.
7 to 9	10 to 13	14 to 17	18 to 21	22 to 25	26 to 29	30 to 35	36 or more	Wn 72.

NOTE 1.—The Poulkova observations are weighted according to the probable errors given on pp. (29) and (30) of introduction (Vol. V.). The weight is slightly reduced in two cases. Following is the table of weights. Between +55° and +65° declination, when the observations are above the pole, the weights of the first line are multiplied by .4:

δ	1 obs.	2 obs.	4 obs.	8 obs.	16 obs.
+40° to 55° and 65° to 80° ...	1	2	3	4	5
+30° or +90°	1	2	3	4	5
+20° or +80° S. P.	1	2	3	4	5
+10° or +70° S. P.	.8	1.5	2.5	3.5	4
+00 or +60° S. P.	.5	1.0	1.5	2.5	3.5
−10° or +50° S. P.	.3	.5	1.0	1.5	2.5
−15° or +45° S. P.	.2	.3	.7	1.0	2.0

NOTE 2.—When the zenith distance of a star observed at a given observatory is greater than 70° the above weights are multiplied by the following arbitrary numbers:

Z D	Factor.	*Z D*	Factor.
°		°	
70	1.0	76	.5
71	.9	77	.4
72	.8	78	.3
73	.7	79	.3
74	.6	80	.2
75	.5		

NOTE 3.—In using the later Greenwich catalogues (Gh 57, 64, and 70), Ps 64 and Ps 66, and Bs 60 and Bs 65, a considerable modification of the above weights takes place, whenever the same star is observed in two or more series at each observatory. The maximum weight given to Gh 57, 64, and 70 combined, is 7.0; to Ps 64 and Ps 66, 4.0; and to Bs 60 and Bs 65, 5.0. Where the combined weights were smaller than these totals, arbitrary reductions of each are made; these reductions being proportionally less, the fewer the observations. This course is taken because, strictly speaking, the catalogues of the respective groups are really parts of the same series and have to some extent the same errors. Of course, when either of the above-mentioned catalogues stands as the sole representative of its observatory it receives the full tabular weight. In a less degree this reduction of weights is applicable to groups of catalogues not included in the above enumeration; but in all such cases it is believed that the reduction of weights required is without practical consequence to the final result.

With the values of C computed in Section V., and with the corrections and weights of Tables IX., X., and XI., the definitive values of $\Delta\delta$ and $\Delta\mu'$ are next computed for 436 stars. α and δ Ursæ Minoris are allowed to stand as first computed, and 62 others are reserved until systematic corrections shall have been derived for certain authorities from the definitive places.

The conditional equations are so constructed as to give $\Delta\delta$ for 1875. Much care has been exercised in these computations, and the usual checks have been faithfully employed.

Column $C_{\prime\prime}$ in "Details of Corrections to Assumed Declinations" is computed from $C_{\prime}$ by the addition of corrections taken from Tables IX. and X. Column π is next formed from Table XI., subject to the limitations expressed in notes 2 and 3 above. The epochs are taken from column "Cat." The resulting values of $\Delta\delta$ and $\Delta\mu'$ are given in the catalogue at the end of this paper. With these, column $r_{,}$ is computed from the expression:—

$$\Delta\delta + \Delta\mu'\left(\frac{T'-1875}{100}\right) - C_{,,}.$$

By the addition of $\Delta\delta$ and $\frac{\Delta\mu'}{100}$, respectively, to the declination and annual variation at the head of the table for each star ("Details of Corrections," etc.), we derive the definitive values of those quantities given on the right-hand pages of the catalogue.

The probable errors there given do not result from the sums of squares of residuals, but are computed from the weights of $\Delta\delta$ and $\Delta\mu'$; assuming the probable error of the unit to be ± .30. A few trials showed that these probable errors are a little larger, on the average, than those which actually result from the sums of squares of $r_{,}$. In deriving these sums accurately the full weight must be given to each of the catalogues of the Brussels, Paris, and Greenwich series, though as explained (note 3, p. 162), less than the tabular values of the weights are sometimes assigned to them.

For the fundamental and principal circumpolar stars, the probable error of the unit of weight, as it actually results from the residuals of each star, is given below. It will be seen that in the mean it is much smaller than the standard, ± ″.30, to which it should correspond. The difference is not so great for the remaining stars.

Probable errors of unit of π, derived from values of $r_{,}$.

α Andromedæ	± ″.24	α Orionis	± ″.27	β Ursæ Minoris	± ″.28	α Aquilæ	± ″.25
γ Pegasi	.31	β Geminorum	.23	α Coronæ Borealis	.26	β Aquilæ	.24
α Cassiopeæ	.25	α Hydræ	.29	α Serpentis	.26	α Cygni	.25
α Arietis	.23	α Leonis	.30	ζ Ursæ Minoris	.29	α Cephei	.24
α Ceti	.25	α Ursæ Majoris	.29	η Draconis	.24	β Cephei	.24
α Persei	.28	β Leonis	.23	α Herculis	.32	α Aquarii	.28
α Tauri	.30	γ Ursæ Majoris	.31	α Ophiuchi	.24	α Pegasi	.27
α Aurigæ	.27	α Virginis	.27	γ Draconis	.26	γ Cephei	.30
β Orionis	.23	η Ursæ Majoris	.29	α Lyræ	.25		
β Tauri	.24	α Bootis	.24	γ Aquilæ	.22		

It must be understood, of course, that the uncertainty of the Normal System is not represented in these probable errors. This uncertainty will vary with the polar distance, being least at the north pole of the heavens, and probably greatest in the zone − 20° to − 50° declination, or in that vicinity. From − 30° to − 90°, with our present means of information, very little can be known of the systematic corrections required. But northward, from − 10° declination, we can form an approximate judgment as to the degree of accuracy attained. I estimate the probable error for 1875 of the Normal System for the Equatorial region to be not greater than ± ″.15, and less than this for any given point between the Equator and the North Pole. By actual computation, using the Equatorial systematic corrections of the 32 catalogues upon which the system is based, with the same weights as were used in Section VI., we find that the system best corresponds to 1847.5. For that epoch its probable error is ± ″.05. For 1875 it is ± .10; and for 1900, ± ″.17. But these probable errors may be somewhat too small since more than half the determinations are reduced with the same refractions (Bessel's), and only five* may be regarded as fundamental determinations in a rigorous sense.

It would have been for me a pleasant task to have undertaken, with the help of the places now available, a third approximation to the systematic corrections and weights. But the real object of the work has been already sufficiently accomplished, and the time is not at my disposal for the purpose. Indeed, some few experiments taught me that the changes to be thereby induced were likely to be few and unimportant, except for some of the weights, for which the relation to number of observations can now be ascertained with considerable precision. The systematic correction of one catalogue, Po 1800, has, however, received a new examination, the results of which have already been given.

SECTION IX.

CORRECTIONS TO CATALOGUES OF CLASS III.

There are a few additional catalogues either of small weight, or with few observations of standard stars (described under Class III), which will prove desirable auxiliaries in the computation of $\Delta\delta$ and $\Delta\mu'$ for the remaining 62 stars.

These we proceed to enumerate, and under each will be given a brief examination of the systematic correction required.

The corrections to the catalogue declinations were found by subtracting from the definitive $\Delta\delta'$ for the required epoch the corresponding value of *C*.

Ms 35.

Weight one is assigned to all declinations, which at Madras depend on more than 5 observations, and for which the weight of a standard declination at 1875 is 1.5, or more. To all declinations, from two or three observations at Madras, weight .5 is assigned; and the same weight to a few others from four or five observations.

* These are: Bessel's, 1821; Struve's, 1824; Argelander's, 1829; Peter's and Gylden's (Poulkova), 1845; and Kaiser's, 1867.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		"	"
+ 86	5	+ .43	+ .54
+ 78	8	+ .62	+ .62
+ 73	10	+ .92	+ .67
+ 69	15	+ .78	+ .69
+ 64	12	+ .41	+ .64
+ 59	22	+ .44	+ .60
+ 54	14	+ .59	+ .62
+ 49	27	+ .80	+ .72
+ 44	20	+ .71	+ .70
+ 39	30	+ .47	+ .59
+ 34	17	+ .06	+ .44
+ 30	21	+ .69	+ .26
+ 26	22	— .05	+ .04
+ 21	24	— .28	— .26
+ 16	19	— .88	— .53
+ 11	14	— .50	— .66
+ 6	20	— .42	— .67
+ 1	11	— .88	— .62
— 5	7	— .37	— .57
— 9	11	— .72	— .51
— 14	5	— .42	— .42
— 19	5	00	— .32
— 23	5	+ .68	— .22
— 28	5	— .99	— .10
— 35	2	+ .70	+ .05
— 42	5	+ .18	+ .20
— 50	2	+ .45	+ .40
— 59	6	+ .54	+ .62
— 69	[0]	[+ .53]	....

Three hundred and thirty-two residuals, from $-35°$ to $+90°$, which received weight one, give, with $m = 8$:—

$$E = \pm\ ''.62.$$

Residuals in order of right ascension.

	Declination limits. $+15°$ to $+90°$		Declination limits. $+15°$ to $-35°$		Declination limits. $-35°$ to $+90°$	
Mean α	π'	r_0'	π'	r_0'	π'	r_0'
h.		"		"		"
1	28	— .26	6	— .45	34	— .29
3	22	— .34	7	+ .14	29	— .32
5	19	— .14	7	+ .31	26	— .02
7	15	+ .07	3	— .07	18	+ .05
9	13	.00	6	— .25	19	— .08
11	16	— .39	8	+ .08	24	— .24
13	13	— .39	5	— .02	18	— .09
15	26	+ .78	7	+ .89	33	+ .80
17	30	+ .49	8	+ .16	38	+ .42
19	25	— .12	13	+ .14	38	— .03
21	33	— .38	13	— .08	46	— .30
23	23	— .18	11	— .11	34	— .15

Wn 48 (*prime vertical transit*).

Sixty-one observations in 1847 of 13 stars gave as the mean correction:—

$$-''.82 \pm ''.09.$$

The probable error, E, of a single observation, is $\pm ''.70$.

Ms 50.

The correction is ascertained from the declinations of the principal stars given in the introduction. Each residual is given weight one.

Residuals in order of declination.

Mean δ	π'	r_0	C_0
°		″	″
+ 87	5	+ .10	+ .06
+ 75	4	+ .37	+ .25
+ 63	2	+ .54	+ .30
+ 52	8	+ .16	+ .30
+ 41	5	+ .37	+ .23
+ 29	8	— .06	— .08
+ 22	8	— .41	— .40
+ 14	8	— .96	— .73
+ 08	9	— .64	— .92
0	7	—1.17	—1.05
— 9	6	— .99	— .99

With $m = 4$, we have, probable error of a single declination:—

$$E = \pm ''.32.$$

If we assume $\frac{\varepsilon}{\varepsilon_{/}} = 2$, we shall have for 3 to 5 observations, approximately, weight .3 in the system of Table XI.

Residuals in order of right ascension.

Mean α	π'	r_0'	Mean α	π'	r_0'
h.		″	h.		″
1	5	— .17	13	4	.00
3	5	— .20	15	7	+ .19
5	6	— .29	17	6	— .01
7	5	+ .28	19	9	+ .35
9	5	— .37	21	8	+ .40
11	5	— .34	23	4	— .26

Eh 58, Eh 63, and Eh 67. $\frac{\varepsilon}{\varepsilon_{\prime}}=2.$

Eh 58.				Eh 63.				Eh 67.			
Mean δ	π'	r_0	C_0	Mean δ	π'	r_0	C_0	Mean δ	π'	r_0	C_0
°		″	″	°		″	″	°		″	″
+ 89	4	—.63	....	+ 89	2	—.40	....	+ 89	2	+ .86	....
+ 73	3	—.94	....	+ 73	1	+.27	....	+ 67	5	+1.34	....
+ 55	20	+.06	—.33	+ 55	19	+.37	+.51	+ 54	16	+ .38	00
+ 32	26	—.52	—.33	+ 32	20	+.35	+.51	+ 32	18	— .45	00
+ 19	26	+.53	—.33	+ 19	30	+.72	+.51	+ 19	28	+ .50	00
+ 7	31	—.36	—.33	+ 9	18	+.59	+.51	+ 07	17	+ .61	00
— 5	37	—.22	—.33	— 1	14	+.39	+.51	+ 05	17	—1.30	00

The corrections to these catalogues can only be roughly ascertained. It is assumed to be constant from $-10°$ to $+60°$. We have, $E=\pm\,''.60$ for Eh 58 (excluding β Lyræ), $\pm\,''.77$ for Eh 63, and $\pm\,1''.33$ for Eh 67. $\pm\,''.69$ is adopted in constructing weights for Eh 58 and Eh 63.

Pa 62 (*prime vertical transit*).

Twenty-one observations of 5 stars give the correction:—

$$+\,''.25 \pm\,''.05;$$

and for probable error of single observation $\pm\,''.23$, which is considerably larger than the value supposed in the third volume of Poulkova observations (pp. 213, 214). But even this requires the maximum weight (5.0) for 3 observations, and is adopted.

Pa 71.

But one declination is used from this catalogue—that given for B. A. C. 5313. For its correction, I find $+\,''.50$ from eight stars between $+50°$ and $+60°$ declination. For this declination the arbitrary weight 1.0 is assigned in deducing corrections to assumed place.

Wn 70.

Residuals in order of declination.

Mean δ	π'	r_0	C_0	
°		″	″	
+ 86	21	+ .22	00	$\frac{\varepsilon}{\varepsilon_{\prime}}=2$
+ 75	57	— .04	00	
+ 65	67	— .43	— .25	
+ 55	17	+ .12	— .43	
+ 45	31	— .63	— .57	
+ 35	20	— .44	— .66	
+ 25	33	— .72	— .73	
+ 15	24	— .42	— .75	
+ 05	29	—1.08	— .70	
— 07	14	— .05	— .36	

With $m = 4$, we have:—

$$E = \pm 1''.01.$$

The curve resembles that of Wn 56 closely, except that its minus values are about ″.40 larger. From -16° southward, Wn 56 — ″.40 can probably be used without serious error.

Residuals in order of right ascension.

	Declination limits. -10° to $+40^\circ$		Declination limits. $+40^\circ$ to $+90^\circ$		Declination limits. -10° to $+90^\circ$		
Mean a	π'	r_0'	π'	r_0'	π'	r_0'	C_0'
h.		″		″		″	″
1	11	+ .21	25	— .14	36	— .04	— .17
3	12	+ .02	15	— .59	27	— .32	— .23
5	4	— .75	13	— .77	17	— .76	— .24
7	14	+ .09	5	— .30	19	— .01	— .18
9	9	+ .20	11	— .21	20	— .03	— .07
11	4	— .75	15	— .29	19	— .38	+ .06
13	9	— .36	15	— .23	24	— .28	+ .17
15	6	+ .70	19	+ .80	25	+ .78	+ .23
17	12	+ .60	20	+ .33	32	+ .43	+ .24
19	15	— .78	17	+ .26	32	— .23	+ .18
21	16	+ .35	21	+ .04	37	+ .18	+ .07
23	12	— .26	18	— .16	30	— .20	— .06

Column C_0' is taken from the correction found to be applicable to the previous series of observations with the Washington mural circle. There is sufficient resemblance between it and the values of r_0' in the last column to justify its continued use for this catalogue.

TABLE XII.—*Corrections to catalogues of Class III* (and to Po 1800).

ORDER OF DECLINATION.

Mean δ	Po 1800	Ms 35.	Ms 50.	Wn 70.*	Mean δ	Po 1800.	Ms 35.	Ms 50.	Wn 70.
°	″	″	″	″	°	″	″	″	″
+ 90	00	+ .50	00	00	+ 15	—1.62	— .56	— .70	— .75
+ 85	+ .16	+ .55	+ .10	00	+ 10	—1.35	— .68	— .86	— .75
+ 80	+ .30	+ .60	+ .20	00	+ 05	—1.29	— .67	—1.00	— .70
+ 75	+ .44	+ .65	+ .25	00	0	—1.56	— .61	—1.05	— .59
+ 70	+ .52	+ .70	+ .30	— .14	— 05	—1.86	— .57	—1.05	— .44
+ 65	+ .52	+ .65	+ .30	— .25	— 10	—1.96	— .50	— .97	— .25
+ 60	+ .48	+ .60	+ .30	— .37	— 15	—1.82	— .40	....	....
+ 55	+ .35	+ .60	+ .30	— .43	— 20	—1.50	— .30	....	....
+ 50	+ .10	+ .72	+ .30	— .50	— 25	—1.16	— .17	....	....
+ 45	— .30	+ .72	+ .28	— .57	— 30	—1.08	— .05	....	....
+ 40	— .80	+ .62	+ .22	— .62	— 35	—1.21	+ .05	....	....
+ 35	—1.03	+ .48	+ .10	— .66	— 40	—1.40	+ .15	....	....
+ 30	—1.10	+ .26	— .04	— .70	— 50	....	+ .10	....	....
+ 25	—1.36	— .02	— .26	— .73	— 60	....	+ .65	....	....
+ 20	—1.62	— .32	— .49	— .75					

* If the actual correction for Wn 1872 and 1873 is desired, + ″.45 must be added to the quantities given in the above table for Wn 70.

TABLE XII.—Continued.

Catalogue.	Correction.	Remarks.
	″	
Wn 48	— .82	Constant.
Eh 58	— .33	Constant from — 10° to + 60°.
Eh 63	+ .51	Constant from — 10° to + 60°.
Pa 62	+ .25	Constant.
Eh 67	00	Constant from — 10° to + 60°.

The corrections in order of α for Po 1800 and Wn 70 are to be taken from Table X. With these additional corrections the values of $\Delta\delta$ and $\Delta\mu'$ were computed for the 62 remaining stars. These are sufficiently indicated in the "Details of Corrections to Assumed Declinations" by the use of one or more of the catalogues of Class III.

SECTION X.

GENERAL REMARKS RESPECTING THE CORRECTIONS AND PROBABLE ERRORS OF STARS USED BY THE NORTHERN BOUNDARY SURVEY FOR LATITUDE.

The preceding pages afford the means, to some extent, for answering the question as to the probable errors of the declinations used in latitude work on the Northern Boundary. These declinations in the general catalogue of 500 stars at the end of this paper are distinguished by an asterisk, affixed to the current number. Opposite each star, on the right-hand page (and in the third column), will be found its probable error estimated in the manner described in Section VIII. This, taken together with the corresponding value of $\Delta\delta$, given on the left-hand page, will aid in forming some judgment as to the probable limits within which any correction is likely to be included. These values of $\Delta\delta$ refer to the declinations adopted in the work of 1874. Those of the preceding years are less accurate, and differ slightly from these, but the differences are not systematic.

The general correction required by the latitude work of 1874 has been roughly computed in three different ways:—

First. Fifty different pairs (100 stars) were observed for latitude during the year. Six of these, however, were used but once; one, three times; three, four times; nine, five times; and others more frequently—eighteen times being the maximum. Taking the simple mean of all the values of $\Delta\delta$ for the one hundred stars, we have:—

$$+\,''.042$$

as the common correction to the declinations actually used; and this is, of course, applicable to the latitudes.

Second. If, however, we take into account the number of times each pair was used, giving weights proportional to the numbers, we have:—

$$+\,''.068$$

as the common correction to all the latitudes.

Third. If, still further, we take into account the weights of the stars as computed in this paper, and if we suppose that each observation of a pair with the zenith telescope gives an instrumental probable error for latitude of $\pm''.3$, we have as the mean correction:—

$$+''.002.$$

I regard it as quite improbable that a common correction larger than $\pm''.1$ is needed for the latitudes as actually established in the field. In this paper the stars of the latitude list were reduced without the slightest reference to the previous work performed on them—even the seconds of declinations being transcribed from the various catalogues anew. Under these circumstances the present work may be regarded as an efficient check on the values of declination adopted in the former discussion.

EXPLANATION OF TABLES.

RECAPITULATION OF SYSTEMATIC CORRECTIONS.

This table shows as nearly as possible the total systematic corrections applied by me (either before or after discussion of Normal System) to the catalogue places as I find them. If to these be added errata and corrections due to proper motion, with a few corrections specified in the notes at the end of the table, we shall have declinations according to the system adopted in this paper. In order, however, to ascertain the degree of confidence to be placed in certain values from the curves (especially those from $-10°$ to $-30°$), it will be necessary to recur to the detailed reductions.

DETAILS OF CORRECTIONS TO ASSUMED DECLINATIONS.

These embrace Table A, Table B, and Table C.

Table A contains particulars of reduction for the fundamental and principal circumpolar stars. However, four southern stars, usually regarded as fundamental, and α^2 Geminorum will be found elsewhere.

Table B contains details for all other stars (*i. e.*, stars not included in Table A) situated between $+90°$ and $-10°$ declination. In this region the weights are in no case affected by the question of zenith distance.

Table C contains details for all stars situated south of $-10°$ declination.

With one exception the construction of all the tables is alike. At the head of the tabular statement for each star is given its assumed right ascension and declination, with the annual variation of each as computed in Sections II. and III.

Column "Cat." contains the designation of each catalogue or series of observations. The explanation of these designations is found in Section IV. It is sufficient here to state that the figures refer to the mean year of observation, and the letters are usually the first and last in the name of the observatory according to the English spelling.

Column "Obs." contains either the number of observations, weight, or probable error, according as either is made an argument for computation of weight from Table XI.

Column C contains the correction to assumed declination given by the respective catalogues in the manner detailed in Sections III. and V. For the later Radcliffe catalogues, and for Wn 72, values of C are contained in Section V.

Column $C_{,}$ in Tables B and C, contains for a limited number of stars the sum of C and of the systematic correction taken from Table II.

The place of this is supplied in Table A by column $r_{,,}$, which contains the correction given to each authority by the declination computed according to the principles of Section VI., but with the addition of the *Fundamenta* as an authority, with weight *one*.

Column r contains the quantities from which definitive systematic corrections were computed. It is formed by subtracting C from the value of the expression $\Delta\delta + \left(\frac{T'-1845}{100}\right)\Delta\mu'$, $\Delta\delta$ and $\Delta\mu'$ being taken from Tables V. and VII.

Column $C_{,,}$ is formed by the addition of the systematic corrections of Tables IX. and X. to column C. For Re 66 and Re 72, as well as Wn 72 and S H 31, the value of $C_{,,}$ is specially computed.

Column π contains the weight computed from Table XI., with the argument in column "Obs."

Column $r_{,}$ contains the outstanding residual found by subtracting $C_{,,}$ from $\Delta\delta + \Delta\mu'\left(\frac{T-1875}{100}\right)$, where $\Delta\delta$ and $\Delta\mu'$ are to be taken from the left-hand page of the "Catalogue of 500 Stars" at the end of this paper.

CATALOGUE OF 500 STARS.

On the left-hand page:

Columns 1, 2, 3, and 4 appear to require no explanation except the caution that the latter column is simply copied from the catalogue of the British Association.

Column 5 contains the approximate right ascension as deduced in Section VII.

Column 6 contains the annual variation, and column 7 the secular variation in Right Ascension given in units of the fifth decimal place.

The eighth and ninth columns give $\Delta\delta$ and $\Delta\mu'$ as they result from the final computation, using columns $C_{,,}$ and π of "Details," etc.

On the right-hand page, in column 1, the current number is repeated for convenience.

Column 2 is the definitive declination formed from the assumed declination given with each star in "Details," etc., by the addition of $\Delta\delta$ from the preceding page.

Column 3 contains the probable error ascertained in the manner explained near the end of Section VIII. In a few cases this column is left blank. It is to be understood in such cases that a definite estimate is declined, either because the error is large or cannot readily be ascertained.

Column 4 contains the weight to nearest unit, from which the preceding column is estimated. The probable error of this unit is supposed to be uniformly $\pm$ ″.30. It is likely to be smaller than larger (p. 163). When this column is left blank it is to be understood that the computed weight is less than .5

Column 5 contains the definitive annual variation, computed by adding to the annual variation of "Details," etc., $\frac{\Delta\mu'}{100}$; $\Delta\mu'$ being taken from the left-hand page.

Column 6 contains the probable error of the annual variation computed from the weight of $\Delta\mu'$ in conditional equations.

Columns 7 and 8 contain the secular variation and third term of precession in declination which are given respectively to the sixth and eighth places of decimals. The mode of their computation is fully explained in Section III.

Column 9 contains the proper motion formed by subtracting from the annual variations $20''.0542 \cos \alpha$. The number is Peters' constant of precession (n) for 1875.

RECAPITULATION

OF

SYSTEMATIC CORRECTIONS TO DECLINATIONS.

RECAPITULATION OF SYSTEMATIC CORRECTIONS.

δ	Po 1800.	Bh 1810.	Kg 21 (Döllen).	Kg 21 (Bessel).	Gh 22.	Dt 24 or Dt 30. (a)	Va 29.	Ao 29.	Gh 30.	C. G. H. 31.	δ
+ 90°	″00	″00	″00	″00	″........	″00	″........	″00	+ ″.10	″........	+ 90°
+ 85	+ .16	+ .14	+ .03	+ .04	....	— .05	....	00	+ .12	....	+ 85
+ 80	+ .30	+ .29	+ .06	+ .11	....	— .12	....	00	+ .15	....	+ 80
+ 75	+ .44	+ .38	+ .10	+ .20	....	— .17	+ .40	00	+ .15	....	+ 75
+ 70	+ .52	+ .30	+ .13	+ .28	....	— .21	+ .40	00	+ .13	....	+ 70
+ 65	+ .52	+ .14	+ .16	+ .36	....	— .24	+ .40	00	+ .08	....	+ 65
+ 60	+ .48	— .02	+ .18	+ .43	....	— .26	+ .40	00	00	....	+ 60
+ 55	+ .35	— .01	+ .16	+ .46	....	— .27	+ .38	00	— .12	....	+ 55
+ 50	+ .10	+ .12	+ .13	+ .48	....	— .25	+ .31	— .02	— .31	....	+ 50
+ 45	— .30	+ .10	+ .09	+ .49	....	— .22	+ .24	— .07	— .54	....	+ 45
+ 40	— .80	00	+ .06	+ .51	00	— .19	+ .17	— .13	— .76	....	+ 40
+ 35	—1.03	....	+ .06	+ .56	00	— .15	+ .07	— .18	— .95	....	+ 35
+ 30	—1.10	....	+ .06	+ .61	00	— .13	— .03	— .22	—1.12	....	+ 30
+ 25	—1.36	....	+ .07	+ .66	00	— .12	— .16	— .25	—1.24	....	+ 25
+ 20	—1.62	....	+ .10	+ .74	00	— .15	— .20	— .29	—1.30	....	+ 20
+ 15	—1.62	....	+ .13	+ .81	00	— .21	— .17	— .32	—1.31	....	+ 15
+ 10	—1.35	....	+ .16	+ .88	00	— .29	— .14	— .36	—1.31	+ .35	+ 10
+ 5	—1.29	....	+ .19	+ .95	00	— .38	— .10	— .43	—1.33	+ .35	+ 5
0	—1.56	....	+ .25	+1.04	00	— .49	— .07	— .52	—1.37	+ .35	0
— 5	—1.86	....	+ .33	+1.15	00	— .60	— .03	— .60	—1.49	+ .35	— 5
— 10	—1.96	....	+ .43	+1.31	00	— .72	00	— .68	—1.68	+ .35	— 10
— 15	—1.82	....	+ .55	+1.44	00	— .84	....	— .70	—1.97	+ .35	— 15
— 20	—1.50	....	+ .67	+1.59	00	— .96	....	— .70	—2.50	+ .35	— 20
— 25	—1.16	....	+ .78	+1.76	00	....	....	....	—2.8	+ .35	— 25
— 30	—1.08	....	....	....	....	....	....	....	—2.9	+ .32	— 30
— 35	—1.21	....	....	....	....	....	....	....	....	+ .17	— 35
— 40	—1.40	....	....	....	....	....	....	....	....	00	— 40
— 50	....	....	....	....	....	....	....	....	....	00	— 50
— 60	....	....	....	....	....	....	....	....	....	00	— 60
— 70	....	....	....	....	....	....	....	....	....	00	— 70
— 80	....	....	....	....	....	....	....	....	....	00	— 80
— 90	....	....	....	....	....	....	....	....	....	00	— 90

A. R.	Po 1800.	Bh 1810.	Kg 21 (Döllen).	Kg 21 (Bessel).	Gh 22.	Dt 24.	Va 29.	Ao 29.	Gh 30.	C. G. H. 31.	A. R.
h.											h.
0	— ″.18	+ ″.40	— ″.03	— ″.03	— ″.13	″........	— ″.04	— ″.04	″........	+ ″.08	12
1	— .04	+ .25	— .09	— .09	— .18	....	+ .02	+ .02	....	+ .13	13
2	+ .11	+ .08	— .15	— .15	— .20	....	+ .09	+ .09	....	+ .18	14
3	+ .25	— .09	— .19	— .19	— .22	....	+ .14	+ .14	....	+ .21	15
4	+ .37	— .26	— .22	— .22	— .22	....	+ .19	+ .19	....	+ .23	16
5	+ .46	— .41	— .24	— .24	— .21	....	+ .22	+ .22	....	+ .23	17
6	+ .53	— .53	— .24	— .24	— .18	....	+ .24	+ .24	....	+ .22	18
7	+ .56	— .62	— .22	— .22	— .14	....	+ .24	+ .24	....	+ .19	19
8	+ .55	— .66	— .19	— .19	— .09	....	+ .23	+ .23	....	+ .15	20
9	+ .50	— .66	— .15	— .15	— .03	....	+ .20	+ .20	....	+ .10	21
10	+ .42	— .62	— .09	— .09	+ .03	....	+ .15	+ .15	....	+ .04	22
11	+ .31	— .53	— .03	— .03	+ .08	....	+ .10	+ .10	....	— .02	23
12	+ .18	— .40	+ .03	+ .03	+ .13	....	+ .04	+ .04	....	— .08	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	S. H. 31.	C. G. H. 33.	Ce 33, Ce 34.	Ce 35.	Mh. 34.	Ms 35.	Eh 34 to Eh 39.	Kg 38.	Gh 39.	Ce 36, Ce 37.	δ
°	″	″	″	″	″	″	″	″	″	″	°
+ 90	....	....	00	00	....	+ .50	— .19	00	00	— .09	+ 90
+ 85	....	....	— .02	00	....	+ .55	— .22	— .10	+ .01	— .09	+ 85
+ 80	....	....	— .05	00	....	+ .60	— .22	— .20	+ .03	— .09	+ 80
+ 75	....	....	— .11	— .04	— .28	+ .65	— .23	— .27	+ .05	— .09	+ 75
+ 70	....	....	— .23	— .14	— .38	+ .70	— .23	— .33	+ .08	— .16	+ 70
+ 65	[+1.30]	....	— .38	— .27	— .46	+ .65	— .22	— .36	+ .09	— .27	+ 65
+ 60	+1.30	....	— .55	— .42	— .52	+ .60	— .20	— .15	+..10	— .41	+ 60
+ 55	+1.30	....	— .72	— .57	— .60	+ .60	— .18	+ .10	+ .11	— .52	+ 55
+ 50	+1.30	—2.00	— .86	— .70	— .62	+ .72	— .16	+ .28	+ .12	— .63	+ 50
+ 45	+1.30	—1.10	— .95	— .78	— .60	+ .72	— .15	+ .30	+ .12	— .74	+ 45
+ 40	+1.30	— .34	—1.02	— .83	— .54	+ .62	— .16	+ .22	+ .13	— .84	+ 40
+ 35	+1.30	+ .20	—1.05	— .84	— .38	+ .48	— .17	+ .11	+ .14	— .92	+ 35
+ 30	+1.30	+ .52	—1.03	— .80	— .11	+ .26	— .20	+ .08	+ .15	— .97	+ 30
+ 25	+1.30	+ .57	— .95	— .70	+ .17	— .02	— .21	+ .09	+ .17	— .99	+ 25
+ 20	+1.30	+ .43	— .81	— .54	+ .32	— .32	— .17	+ .15	+ .19	— .89	+ 20
+ 15	+1.30	+ .14	— .70	— .40	+ .47	— .56	— .05	+ .25	+ .23	— .69	+ 15
+ 10	+1.28	— .06	— .68	— .35	+ .50	— .68	+ .04	+ .41	+ .28	— .55	+ 10
+ 5	+1.22	— .14	— .75	— .38	+ .50	— .67	00	+ .56	+ .34	— .59	+ 5
0	+1.17	— .14	— .87	— .47	+ .41	— .61	— .15	+ .73	+ .41	— .71	0
— 5	+1.09	— .04	—1.06	— .60	+ .30	— .57	— .21	+ .92	+ .49	— .79	— 5
— 10	+ .96	+ .16	—1.26	— .74	+ .14	— .50	— .27	+1.13	+ .59	— .79	— 10
— 15	+ .84	+ .46	—1.50	— .88	— .03	— .40	— .25	+1.34	+ .70	— .77	— 15
— 20	+ .70	+ .71	—1.73	— .98	— .20	— .30	— .15	+1.55	+ .83	— .64	— 20
— 25	+ .62	+ .88	—1.98	—1.00	— .40	— .17	00	+1.77	+ .97	— .5	— 25
— 30	+ .60	+ .90	....	....	....	— .05	+ .2	+2.00	+1.10	— .4	— 30
— 35	+ .60	+ .71	....	....	....	+ .05	....	....	....	....	— 35
— 40	+ .60	+ .47	....	....	....	+ .15	....	....	....	....	— 40
— 50	+ .60	+ .10	....	....	....	+ .40	....	....	....	....	— 50
— 60	+ .50	± .00	....	....	....	+ .65	....	....	....	....	— 60
— 70	+ .40	— .08	....	....	....	....	....	....	....	....	— 70
— 80	+ .30	— .10	....	....	....	....	....	....	....	....	— 80
— 90	+ .20	00	....	....	....	....	....	....	....	....	— 90

A. R.	S. H. 31.	C. G. H. 33.	Ce33, Ce34.	Ce 35.	Mh 34.	Ms 35.	Eh 37.	Kg 38.	Gh 39.	Ce 40 (+40° to +90°).	A. R.
h.	″	″	″	″	″	″	″	″	″	″	h.
0	+ .47	— .07	— .07	— .06	+ .18	....	— .06	+ .34	— .03	— .04	12
1	+ .53	— .07	— .07	— .05	+ .18	....	— .05	+ .34	— .02	— .03	13
2	+ .55	— .07	— .06	— .05	+ .17	....	— .04	+ .30	— .01	— .03	14
3	+ .53	— .06	— .05	— .04	+ .15	....	— .03	+ .24	— .01	— .02	15
4	+ .47	— .05	— .03	— .02	+ .11	....	— .02	+ .17	00	— .01	16
5	+ .39	- .03	— .02	— .01	+ .07	....	00	+ .09	+ .01	00	17
6	+ .27	— .01	— 00	+ .01	+ .02	....	+ .02	— .01	+ .02	+ .02	18
7	+ .14	+ .01	+ .02	+ .02	— .02	....	+ .03	— .10	+ .02	+ .03	19
8	00	+ .03	+ .04	+ .03	— .07	....	+ .04	— .18	+ .03	+ .03	20
9	— .14	+ .04	+ .05	+ .04	— .11	....	+ .05	— .25	+ .04	+ .04	21
10	— .27	+ .05	+ .06	+ .05	— .15	....	+ .06	— .31	+ .03	+ .04	22
11	— .39	+ .06	+ .07	+ .06	— .17	....	+ .05	— .31	+ .03	+ .04	23
12	— .47	+ .07	+ .07	+ .06	— .18	....	+ .06	— .34	+ .03	+ .04	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Ce 38 to Ce 44.	Ah 41 and Ah 52.	Kg 43.	Eh 41.	Eh 42.	Eh 43.	Eh 44.	Gh 45.	Pa 45.	Re 45. (*b*)	δ
°	"	"	"	"	"	"	"	"	"	"	°
+ 90	00	00	......	+ .23	− .94	+1.29	− .36	00	00	00	+ 90
+ 85	00	+ .10	......	+ .28	− .80	+1.18	− .34	00	00	+ .25	+ 85
+ 80	00	+ .20	......	+ .28	− .67	+1.01	− .31	00	00	+ .50	+ 80
+ 75	00	+ .20	......	+ .25	− .56	+ .90	− .28	+ .02	.00	+ .66	+ 75
+ 70	− .07	+ .20	......	+ .16	− .44	+ .75	− .26	+ .04	+ .06	+ .60	+ 70
+ 65	− .18	+ .20	......	+ .03	− .38	+ .57	− .26	+ .06	+ .12	+ .42	+ 65
+ 60	− .32	+ .16	......	− .13	− .36	+ .41	− .28	+ .08	+ .18	+ .28	+ 60
+ 55	− .43	.00	+ .30	− .31	− .38	+ .27	− .31	+ .06	+ .23	+ .10	+ 55
+ 50	− .54	− .35	+ .29	− .47	− .41	+ .18	− .31	+ .00	+ .26	− .07	+ 50
+ 45	− .65	− .75	+ .27	− .60	− .46	+ .14	− .27	− .04	+ .30	− .20	+ 45
+ 40	− .75	− .81	+ .26	− .70	− .54	+ .14	− .23	− .02	+ .33	− .34	+ 40
+ 35	− .83	− .63	+ .24	− .78	− .65	+ .18	− .16	+ .05	+ .35	− .48	+ 35
+ 30	− .88	− .42	+ .23	− .81	− .73	+ .23	− .05	+ .12	+ .37	− .56	+ 30
+ 25	− .90	− .25	+ .21	− .79	− .82	+ .32	+ .10	+ .15	+ .38	− .60	+ 25
+ 20	− .80	− .27	+ .20	− .74	− .90	+ .42	+ .28	+ .14	+ .39	− .59	+ 20
+ 15	− .60	− .47	+ .18	− .66	− .96	+ .54	+ .48	+ .10	+ .41	− .45	+ 15
+ 10	− .46	− .74	+ .16	− .58	−1.00	+ .62	+ .68	+ .05	+ .44	− .20	+ 10
+ 5	− .50	−1.04	+ .13	− .53	−1.07	+ .66	+ .83	+ .05	+ .46	+ .04	+ 5
0	− .62	−1.20	+ .10	− .53	−1.14	+ .65	+ .93	+ .08	+ .49	+ .26	0
− 5	− .70	−1.24	+ .06	− .59	−1.26	+ .56	+ .96	+ .12	+ .53	+ .44	− 5
− 10	− .70	−1.11	00	− .69	−1.38	+ .45	+ .92	+ .15	+ .59	+ .51	− 10
− 15	− .68	− .87	......	− .78	−1.48	+ .35	+ .85	+ .18	+ .68	+ .47	− 15
− 20	− .55	− .48	......	− .88	−1.56	+ .27	+ .75	+ .22	+ .84	+ .33	− 20
− 25	− .4	......	......	− .95	−1.61	+ .23	+ .66	+ .26	+1.1	+ .16	− 25
− 30	− .3	......	......	−1.00	−1.65	+ .24	+ .53	+ .30	......	00	− 30
− 35	......	......	......	......	......	......	......	......	......	......	− 35
− 40	......	......	......	......	......	......	......	......	......	......	− 40
− 50	......	......	......	......	......	......	......	......	......	......	− 50
− 60	......	......	......	......	......	......	......	......	......	......	− 60
− 70	......	......	......	......	......	......	......	......	......	......	− 70
− 80	......	......	......	......	......	......	......	......	......	......	− 80
− 90	......	......	......	......	......	......	......	......	......	......	− 90

A. R.	Ce 40 (−30° to +40°).	Ah 41.	Kg 43.	Eh 41.	Eh 42.	Eh 43.	Eh 44.	Gh 45.	Pa 45.	Re 45.	A. R.
h.	"	"	"	"	"	"	"	"	"	"	*h.*
0	− .19	......	+ .13	− .24	− .23	− .21	− .19	− .02	......	......	12
1	− .14	......	+ .08	− .24	− .22	− .21	− .19	− .02	......	......	13
2	− .09	......	+ .03	− .23	− .22	− .21	− .19	− .02	......	......	14
3	− .02	......	− .02	− .19	− .19	− .18	− .17	− .02	......	......	15
4	+ .05	......	− .07	− .15	− .15	− .15	− .14	− .01	......	......	16
5	+ .11	......	− .12	− .09	− .09	− .10	− .09	− .01	......	......	17
6	+ .17	......	− .16	− .03	− .04	− .05	− .05	− .01	......	......	18
7	+ .21	......	− .19	+ .03	+ .02	+ .01	00	00	......	......	19
8	+ .23	......	− .20	+ .09	+ .08	+ .06	+ .05	00	......	......	20
9	+ .25	......	− .20	+ .15	+ .13	+ .11	+ .10	+ .01	......	......	21
10	+ .24	......	− .19	+ .19	+ .17	+ .16	+ .14	+ .01	......	......	22
11	+ .22	......	− .16	+ .22	+ .21	+ .19	+ .17	+ .02	......	......	23
12	+ .19	......	− .13	+ .24	+ .23	+ .21	+ .19	+ .02	......	......	24

When the argument is 12[h] to 21[h] the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Wn 45.	Wn 46 to Wn 48.	Wn 48 (P. V. T.).	Ce 45 to Ce 51.	Gh 51.	So 51.	Ms 50.(e)	Ps 53.	So 55.	Wn 54 to Wn 58.	δ
°	″	″	″	″	″	″	″	″	″	″	°
+ 90	− .15	+ .10	....	− .43	− .12	....	00	00	....	− .15	+ 90
+ 85	− .11	+ .14	....	− .43	− .13	....	+ .10	+ .08	....	− .05	+ 85
+ 80	− .10	+ .15	....	− .43	− .13	....	+ .20	+ .14	....	+ .05	+ 80
+ 75	− .11	+ .14	....	− .43	− .14	....	+ .25	+ .21	....	+ .12	+ 75
+ 70	− .15	+ .10	....	− .43	− .15	....	+ .30	+ .26	....	+ .17	+ 70
+ 65	− .19	+ .06	....	− .53	− .16	....	+ .30	+ .28	....	+ .18	+ 65
+ 60	− .27	− .02	....	− .69	− .18	....	+ .30	+ .29	....	+ .16	+ 60
+ 55	− .30	− .05	....	− .85	− .20	....	+ .30	+ .27	....	+ .13	+ 55
+ 50	− .30	− .05	....	−1.00	− .21	....	+ .30	+ .22	....	+ .10	+ 50
+ 45	− .30	− .05	....	−1.12	− .20	....	+ .28	+ .18	....	+ .05	+ 45
+ 40	− .30	− .05	− .82	−1.24	− .16	+ .40	+ .22	+ .12	+ .50	.00	+ 40
+ 35	− .30	− .05	− .82	−1.30	− .08	+ .53	+ .10	+ .07	+ .50	− .04	+ 35
+ 30	− .33	− .08	....	−1.27	+ .02	+ .68	− .04	+ .01	+ .49	− .09	+ 30
+ 25	− .39	− .14	....	−1.08	+ .10	+ .80	− .26	+ .06	+ .48	− .13	+ 25
+ 20	− .46	− .21	....	− .76	+ .17	+ .90	− .49	− .12	+ .44	− .18	+ 20
+ 15	− .54	− .29	....	− .53	+ .18	+ .99	− .70	− .18	+ .31	− .23	+ 15
+ 10	− .59	− .34	....	− .48	+ .16	+1.04	− .86	− .26	+ .20	− .26	+ 10
+ 5	− .60	− .35	....	− .48	+ .11	+1.08	−1.00	− .33	+ .15	− .27	+ 5
0	− .59	− .34	....	− .50	+ .04	+1.11	−1.05	− .37	+ .27	− .26	0
− 5	− .56	− .31	....	− .54	00	+1.13	−1.05	− .36	+ .40	− .23	− 5
− 10	− .52	− .27	....	− .56	00	+1.12	− .97	− .30	+ .38	− .17	− 10
− 15	− .48	− .23	....	− .55	+ .05	+1.09	....	− .19	+ .12	− .10	− 15
− 20	− .43	− .18	....	− .51	+ .13	+1.06	....	− .02	− .07	− .02	− 20
− 25	− .36	− .11	....	− .47	+ .20	+1.02	....	+ .27	− .14	+ .06	− 25
− 30	− .28	− .03	....	− .43	+ .24	+ .99	....	+ .7	− .02	+ .16	− 30
− 35	....	....	....	....	....	+ .96	....	....	+ .13	....	− 35
− 40	....	....	....	....	....	+ .92	....	....	+ .27	....	− 40
− 50	....	....	....	....	....	+ .85	....	....	+ .27	....	− 50
− 60	....	....	....	....	....	+ .63	....	....	+ .11	....	− 60
− 70	....	....	....	....	....	+ .38	....	....	00	....	− 70
− 80	....	....	....	....	....	+ .19	....	....	00	....	− 80
− 90	....	....	....	....	....	00	....	....	00	....	− 90

A. R.	Wn 45.	Wn 46 to Wn 48.	Wn 48 (P. V. T.).	Ce 45 to Ce 51.	Gh 51.	So 51.	Ms 50.	Ps 53.	So 55.	Wn 54 to Wn 58.	A. R.
h.	″	″	″	″	″	″	″	″	″	″	*h.*
0	− .27	− .17	....	− .05	− .05	− .18	....	....	....	− .12	12
1	− .27	− .23	....	− .05	− .05	− .12	....	....	....	− .17	13
2	− .26	− .27	....	− .05	− .04	− .04	....	....	....	− .21	14
3	− .23	− .28	....	− .05	− .01	+ .04	....	....	....	− .23	15
4	− .19	− .29	....	− .04	− .03	+ .12	....	....	....	− .24	16
5	− .14	− .28	....	− .03	− .02	+ .19	....	....	....	− .24	17
6	− .07	− .23	....	− .02	− .01	+ .24	....	....	....	− .21	18
7	00	− .19	....	− .01	00	+ .28	....	....	....	− .18	19
8	+ .07	− .13	....	00	+ .01	+ .30	....	....	....	− .13	20
9	+ .14	− .05	....	+ .02	+ .03	+ .30	....	....	....	− .07	21
10	+ .20	+ .03	....	+ .03	+ .03	+ .28	....	....	....	00	22
11	+ .21	+ .10	....	+ .04	+ .04	+ .24	....	....	....	+ .06	23
12	+ .27	+ .17	....	+ .05	+ .05	+ .18	....	....	....	+ .12	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Ps 54 to Ps 57.	Bs 55 and Bs 56.	Ce 52 to Ce 60.	Gh 57.	C. G. H. 58.	Re 58. (*d*)	Ps 58 to Ps 62.	Bs 57 to Bs 67.	Me 62. (*e*)	Pa 62 (P. V. T.).	δ
°	″	″	″	″	″	″	″	″	″	″	°
+ 90	— .35	+ .22	— .20	00	......	+ .30	— .20	+ .20	......	......	+ 90
+ 85	— .30	+ .26	— .23	+ .02	......	+ .44	— .19	+ .26	......	......	+ 85
+ 80	— .25	+ .30	— .26	+ .05	......	+ .56	— .16	+ .32	......	......	+ 80
+ 75	— .20	+ .31	— .31	+ .09	......	+ .66	— .10	+ .38	......	......	+ 75
+ 70	— .15	+ .31	— .36	+ .15	......	+ .73	— .04	+ .40	......	......	+ 70
+ 65	— .12	+ .30	— .44	+ .21	......	+ .70	+ .01	+ .39	......	......	+ 65
+ 60	— .10	+ .22	— .55	+ .23	......	+ .60	+ .04	+ .26	......	+ .25	+ 60
+ 55	— .09	+ .07	— .77	+ .21	......	+ .46	+ .07	+ .06	......	......	+ 55
+ 50	— .11	— .13	—1.12	+ .15	[+2.4]	+ .20	+ .10	— .17	......	......	+ 50
+ 45	— .15	— .36	—1.40	+ .11	[—1.5]	— .12	+ .10	— .29	......	......	+ 45
+ 40	— .20	— .52	—1.45	+ .11	— .80	— .42	+ .08	— .32	+ .50	......	+ 40
+ 35	— .24	— .52	—1.41	+ .15	— .30	— .65	+ .04	— .27	+ .46	......	+ 35
+ 30	— .28	— .46	—1.29	+ .24	— .06	— .80	.00	— .11	+ .42	......	+ 30
+ 25	— .33	— .37	—1.12	+ .33	— .05	— .74	— .05	+ .04	+ .39	......	+ 25
+ 20	— .35	— .47	— .87	+ .37	— .10	— .56	— .12	+ .03	+ .38	......	+ 20
+ 15	— .36	— .62	— .67	+ .38	— .15	— .35	— .15	— .08	+ .38	......	+ 15
+ 10	— .36	— .70	— .58	+ .35	— .18	— .09	— .19	— .10	+ .52	......	+ 10
+ 5	— .35	— .75	— .[illegible]7	+ .28	— .20	+ .20	— .20	— .06	+ .71	......	+ 5
0	— .34	— .68	— .55	+ .20	— .23	+ .51	— .18	— .03	+ .87	......	0
— 5	— .30	— .45	— .53	+ .15	— .26	+ .70	— .13	00	+ .90	......	— 5
— 10	— .20	— .23	— .49	+ .21	— .26	+ .79	— .04	00	+ .86	......	— 10
— 15	— .05	— .20	— .46	+ .26	— .20	+ .79	+ .10	00	+ .75	......	— 15
— 20	+ .14	— .23	— .42	+ .26	— .15	+ .68	+ .28	00	+ .63	......	— 20
— 25	+ .35	— .27	— .39	+ .25	— .10	+ .40	+ .50	00	+ .50	......	— 25
— 30	+ .60	— .30	[— .35]	[+ .20]	— .05	[+ .10]	+ .70	00	+ .44	......	— 30
— 35	......	......	......	......	.00	......	......	......	+ .21	......	— 35
— 40	......	......	......	......	+ .05	......	......	......	+ .08	......	— 40
— 50	......	......	......	......	+ .15	......	......	......	— .14	......	— 50
— 60	......	......	......	......	+ .27	......	......	......	— .20	......	— 60
— 70	......	......	......	......	+ .26	......	......	......	— .20	......	— 70
— 80	......	......	......	......	+ .13	......	......	......	— .08	......	— 80
— 90	......	......	......	......	.00	......	......	......	00	......	— 90

A. R.	Ps 54 to Ps 57.	Bs 55 and Bs 56.	Ce 52 to Ce 60.	Gh 57.	C. G. H. 58.	Re 58.	Ps 58 to Ps 62.	Bs 57 to Bs 67.	Me 62.	Pa 62 (P. V. T.).	A. R.
h.	″	″	″	″	″	″	″	″	″	″	*h.*
0	— .05	— .03	......	......	......	......	— .05	+ .01	......	......	12
1	00	— .03	......	......	......	......	.00	+ .05	......	......	13
2	+ .05	— .02	......	......	......	......	+ .05	+ .09	......	......	14
3	+ .10	— .01	......	......	......	......	+ .10	+ .12	......	......	15
4	+ .14	00	......	......	......	......	+ .14	+ .15	......	......	16
5	+ .17	+ .01	......	......	......	......	+ .17	+ .16	......	......	17
6	+ .20	+ .02	......	......	......	......	+ .20	+ .17	......	......	18
7	+ .20	+ .03	......	......	......	......	+ .20	+ .16	......	......	19
8	+ .19	+ .03	......	......	......	......	+ .19	+ .14	......	......	20
9	+ .17	+ .04	......	......	......	......	+ .17	+ .12	......	......	21
10	+ .14	+ .04	......	......	......	......	+ .14	+ .08	......	......	22
11	+ .10	+ .04	......	......	......	......	+ .10	+ .04	......	......	23
12	+ .05	+ .03	......	......	......	......	+ .05	— .01	......	......	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Wn 61 and Wn 62.	Wn 63 to Wn 65.	Gb 64.	Ps 64.	Bs 65.	Ps 66.	Eh 54 to Eh 60.	Eh 61 to Eh 64.	Eh 65 to Eh 69.	Bn 66.(*f*)	δ
°	″	″	″	″	″	″	″	″	″	″	°
+ 90	— .60	— .39	00	— .20	+ .20	— .20	......	......	......	+ .40	+ 90
+ 85	— .57	— .36	00	— .23	+ .26	— .20	......	......	......	+ .41	+ 85
+ 80	— .56	— .35	00	— .25	+ .32	— .20	......	......	......	+ .55	+ 80
+ 75	— .57	— .36	00	— .26	+ .38	— .20	......	......	......	+ .71	+ 75
+ 70	— .60	— .39	00	— .27	+ .40	— .17	......	......	......	+ .71	+ 70
+ 65	— .63	— .42	00	— .27	+ .39	— .11	......	......	......	+ .54	+ 65
+ 60	— .66	— .45	00	— .25	+ .26	— .01	— .33	+ .51	00	+ .05	+ 60
+ 55	— .70	— .49	00	— .21	+ .06	00	— .33	+ .51	00	— .36	+ 55
+ 50	— .73	— .52	00	— .22	— .17	— .01	— .33	+ .51	00	— .56	+ 50
+ 45	— .75	— .56	00	— .26	— .29	— .07	— .33	+ .51	00	— .60	+ 45
+ 40	— .81	— .60	00	— .30	— .32	— .15	— .33	+ .51	00	— .57	+ 40
+ 35	— .86	— .65	+ .05	— .30	— .27	— .18	— .33	+ .51	00	— .50	+ 35
+ 30	— .93	— .72	+ .10	— .22	— .11	— .14	— .33	+ .51	00	— .38	+ 30
+ 25	—1.01	— .80	+ .13	— .10	+ .04	— .06	— .33	+ .51	00	— .28	+ 25
+ 20	—1.08	— .87	+ .15	— .05	+ .03	— .06	— .33	+ .51	00	— .24	+ 20
+ 15	—1.13	— .92	+ .12	— .06	— .08	— .15	— .33	+ .51	00	— .20	+ 15
+ 10	—1.14	— .93	+ .07	— .15	— .10	— .24	— .33	+ .51	00	— .20	+ 10
+ 5	—1.12	— .91	— .02	— .22	— .06	— .27	— .33	+ .51	00	— .25	+ 5
0	—1.08	— .87	— .09	— .23	— .03	— .28	— .33	+ .51	00	— .33	0
— 5	—1.03	— .82	— .10	— .19	00	— .24	— .33	+ .51	00	— .40	— 5
— 10	— .96	— .75	00	— .10	00	— .17	— .33	+ .51	00	— .40	— 10
— 15	— .87	— .66	+ .14	+ .07	00	— .01	......	......	......	— .40	— 15
— 20	— .78	— .57	+ .27	+ .35	00	+ .07	......	......	......	— .40	— 20
— 25	— .68	— .47	+ .40	+ .66	00	+ .25	......	......	......	— .40	— 25
— 30	— .58	[— .37	[+ .55]	[+1.00]	00	+ .48	......	......	......	[— .40]	— 30
— 35	......	......	......	......	......	+ .75	......	......	......	......	— 35
— 40	......	......	......	......	......	......	......	......	......	......	— 40
— 50	......	......	......	......	......	......	......	......	......	......	— 50
— 60	......	......	......	......	......	......	......	......	......	......	— 60
— 70	......	......	......	......	......	......	......	......	......	......	— 70
— 80	......	......	......	......	......	......	......	......	......	......	— 80
— 90	......	......	......	......	......	......	......	......	......	......	— 90

A. R.	Wn 61 and Wn 62.	Wn 63 to Wn 65.	Gb 64.	Ps 64.	Bs 65.	Ps 66.	Eh 58.	Eh 63.	Eh 67.	Bn 66 (—30° to +40°).	A. R.
h.	″	″	″	″	″	″	″	″	″	″	*h.*
0	— .12	— .12	......	— .05	+ .01	— .05	......	......	......	— .15	12
1	— .17	— .17	......	00	+ .05	00	......	......	......	— .07	13
2	— .21	— .21	......	+ .05	+ .09	+ .05	......	......	......	+ .02	14
3	— .23	— .23	......	+ .10	+ .12	+ .10	......	......	......	+ .11	15
4	— .24	— .24	......	+ .14	+ .15	+ .14	......	......	......	+ .19	16
5	— .24	— .24	......	+ .17	+ .16	+ .17	......	......	......	+ .26	17
6	— .21	— .21	......	+ .20	+ .17	+ .20	......	......	......	+ .31	18
7	— .18	— .18	......	+ .20	+ .16	+ .20	......	......	......	+ .34	19
8	— .13	— .13	......	+ .19	+ .11	+ .19	......	......	......	+ .34	20
9	— .07	— .07	......	+ .17	+ .12	+ .17	......	......	......	+ .33	21
10	.00	.06	......	+ .14	+ .08	+ .11	......	......	......	+ .29	22
11	+ .06	+ .06	......	+ .10	+ .04	+ .10	......	......	......	+ .23	23
12	+ .12	+ .12	......	+ .05	— .01	+ .05	......	......	......	+ .15	24

When the argument is 12h to 24h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Lc 67.	Ln 67.	Me 68.	Gh 70.	Wn 66, transit circle. (g)	Wn 67 (to June 1), transit circle. (g)	Wn 67 (after June 1), transit circle. (g)	Wn 68, transit circle. (g)	Wn 69, transit circle. (g)	δ
°	"	"	"	"	"	"	"	"	"	°
+ 90	+ .22	00	....	00	− .29	+ .20	+ .54	− .14	− .15	+ 90
+ 85	+ .47	00	....	− .09	− .21	+ .23	+ .57	− .18	− .12	+ 85
+ 80	+ .72	00	....	− .15	− .12	+ .28	+ .62	− .21	− .08	+ 80
+ 75	+ .94	− .01	....	− .20	00	+ .33	+ .67	− .22	− .02	+ 75
+ 70	+1.00	− .05	....	− .25	+ .12	+ .38	+ .72	− .22	+ .03	+ 70
+ 65	+ .90	− .10	....	− .30	+ .24	+ .43	+ .77	− .23	+ .07	+ 65
+ 60	+ .70	− .17	....	− .34	+ .38	+ .48	+ .82	− .22	+ .12	+ 60
+ 55	+ .44	− .22	....	− .37	+ .52	+ .52	+ .86	− .20	+ .17	+ 55
+ 50	+ .18	− .25	[+1.25]	− .40	+ .64	+ .54	+ .88	− .21	+ .19	+ 50
+ 45	− .04	− .26	[+1.00]	− .41	+ .76	+ .55	+ .89	− .22	+ .19	+ 45
+ 40	− .23	− .26	[+ .67]	− .42	+ .87	+ .55	+ .89	− .22	+ .20	+ 40
+ 35	− .37	− .26	+ .48	− .42	+ .98	+ .54	+ .88	− .23	+ .19	+ 35
+ 30	− .47	− .26	+ .11	− .37	+1.09	+ .52	+ .86	− .23	+ .17	+ 30
+ 25	− .54	− .26	− .08	− .33	+1.20	+ .51	+ .85	− .23	+ .16	+ 25
+ 20	− .55	− .26	− .15	− .33	+1.30	+ .50	+ .84	− .21	+ .14	+ 20
+ 15	− .52	− .25	− .15	− .40	+1.40	+ .47	+ .81	− .21	+ .11	+ 15
+ 10	− .47	− .23	− .15	− .52	+1.49	+ .43	+ .77	− .19	+ .08	+ 10
+ 5	− .43	− .19	− .15	− .65	+1.57	+ .39	+ .73	− .19	+ .03	+ 5
0	− .43	− .12	− .16	− .80	+1.64	+ .34	+ .68	− .19	− .01	0
− 5	− .43	− .05	− .18	−1.00	+1.70	+ .29	+ .63	− .19	− .07	− 5
− 10	− .43	+ .03	− .21	−1.20	+1.76	+ .24	+ .57	− .14	− .12	− 10
− 15	− .39	+ .11	− .26	−1.43	+1.84	+ .21	+ .55	− .09	− .15	− 15
− 20	− .30	....	− .30	−1.66	+1.95	+ .22	+ .56	00	− .14	− 20
− 25	− .18	....	− .32	−1.93	+2.09	+ .26	+ .60	+ .13	− .10	− 25
− 30	− .05	....	− .36	[−2.20]	+2.25	+ .33	+ .67	+ .29	− .03	− 30
− 35	....	....	− .38	....	+2.43	+ .43	+ .77	+ .49	+ .08	− 35
− 40	....	....	− .40	....	....	....	....	....	....	− 40
− 50	....	....	− .34	....	....	....	....	....	....	− 50
− 60	....	....	− .22	....	....	....	....	....	....	− 60
− 70	....	....	− .12	....	....	....	....	....	....	− 70
− 80	....	....	− .05	....	....	....	....	....	....	− 80
− 90	....	....	.00	....	....	....	....	....	....	− 90

A. R.	Lc 67.	Ln 67.	Me 68.	Gh 70.	Wn 66.	Wn 67, to June 1.	Wn 67, after June 1.	Wn 68.	Wn 69.	A. R.
h.	"	"	"	"	"	"	"	"	"	h.
0	....	....	....	....	....	....	....	....	....	12
1	....	....	....	....	....	....	....	....	....	13
2	....	....	....	....	....	....	....	....	....	14
3	....	....	....	....	....	....	....	....	....	15
4	....	....	....	....	....	....	....	....	....	16
5	....	....	....	....	....	....	....	....	....	17
6	....	....	....	....	....	....	....	....	....	18
7	....	....	....	....	....	....	....	....	....	19
8	....	....	....	....	....	....	....	....	....	20
9	....	....	....	....	....	....	....	....	....	21
10	....	....	....	....	....	....	....	....	....	22
11	....	....	....	....	....	....	....	....	....	23
12	....	....	....	....	....	....	....	....	....	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Wn 70, transit circle.(h)	Wn 71 and Wn 72, transit circle.(h)	Wn 73, transit circle.(h)	Wn 74, transit circle.(h)	Wn 66 to Wn 71, mural.	Wn 72 and Wn 73, mural.	Ro 62.	Ro 63.	Ro 64.	δ
°	″	″	″	″	″	″	″	″	″	°
+ 90	00	00	00	+ .07	00	+ .45	00	00	+ .40	+ 90
+ 85	00	00	00	— .04	00	+ .45	— .26	— .17	+ .26	+ 85
+ 80	00	00	00	— .14	00	+ .45	— .48	— .34	+ .13	+ 80
+ 75	00	00	+ .02	— .24	00	+ .45	— .66	— .50	00	+ 75
+ 70	00	00	+ .04	— .33	— .14	+ .31	— .86	— .63	— .13	+ 70
+ 65	00	00	+ .07	— .41	— .25	+ .20	—1.03	— .73	— .26	+ 65
+ 60	.00	.00	+ .10	— .49	— .37	+ .08	—1.21	— .81	— .40	+ 60
+ 55	— .03	— .05	+ .14	— .56	— .43	+ .02	—1.36	— .87	— .55	+ 55
+ 50	— .06	— .10	+ .18	— .62	— .50	— .05	—1.49	— .90	— .70	+ 50
+ 45	— .09	— .16	+ .24	— .68	— .57	— .12	—1.56	— .90	— .75	+ 45
+ 40	— .23	— .22	+ .46	— .40	— .62	— .17	—1.60	— .90	— .80	+ 40
+ 35	— .41	— .26	+ .75	— .03	— .66	— .21	—1.60	— .85	— .74	+ 35
+ 30	— .45	— .30	+ .88	00	— .70	— .25	—1.52	— .85	— .62	+ 30
+ 25	— .46	— .33	+ .93	00	— .73	— .28	—1.51	—1.00	— .55	+ 25
+ 20	— .47	— .34	+ .96	00	— .75	— .30	—1.60	—1.20	— .50	+ 20
+ 15	— .47	— .33	+ .98	00	— .75	— .30	—1.68	—1.23	— .50	+ 15
+ 10	— .47	— .32	+ .99	00	— .75	— .30	—1.67	—1.20	— .42	+ 10
+ 5	— .46	— .31	+1.00	00	— .70	— .25	—1.54	— .87	— .20	+ 5
0	— .41	— .30	+1.03	00	— .59	— .14	—1.14	— .38	+ .25	0
— 5	— .36	— .29	+1.11	00	— .44	+ .01	— .78	— .10	+ .48	— 5
— 10	— .31	— .27	+1.19	00	— .25	+ .20	— .59	+ .02	+ .56	— 10
— 15	— .31	— .25	+1.28	+ .04	....	....	— .43	+ .09	+ .56	— 15
— 20	— .31	— .23	+1.36	+ .16	....	....	— .30	+ .13	+ .58	— 20
— 25	— .31	— .21	+1.45	+ .29	....	....	— .20	+ .16	+ .65	— 25
— 30	— .31	— .19	+1.53	+ .42	....	....	— .10	+ .18	+ .72	— 30
— 35	— .31	— .17	....	+ .53	....	....	....	....	....	— 35
— 40	— .31	— .15	....	....	....	....	....	....	....	— 40
— 50	....	....	....	....	....	....	....	....	....	— 50
— 60	....	....	....	....	....	....	....	....	....	— 60
— 70	....	....	....	....	....	....	....	....	....	— 70
— 80	....	....	....	....	....	....	....	....	....	— 80
— 90	....	....	....	....	....	....	....	....	....	— 90

A. R.	Wn 70.	Wn 71 and Wn 72.	Wn 73.	Wn 74.	Wn 66 to Wn 71.	Wn 72 and Wn 73.	Ro 62.	Ro 63.	Ro 64.	A. R.
h.	″	″	″	″	″	″	″	″	″	h.
0	....	....	....	....	....	....	....	....	....	12
1	....	....	....	....	....	....	....	....	....	13
2	....	....	....	....	....	....	....	....	....	14
3	....	....	....	....	....	....	....	....	....	15
4	....	....	....	....	....	....	....	....	....	16
5	....	....	....	....	....	....	....	....	....	17
6	....	....	....	....	....	....	....	....	....	18
7	....	....	....	....	....	....	....	....	....	19
8	....	....	....	....	....	....	....	....	....	20
9	....	....	....	....	....	....	....	....	....	21
10	....	....	....	....	....	....	....	....	....	22
11	....	....	....	....	....	....	....	....	....	23
12	....	....	....	....	....	....	....	....	....	24

When the argument is 12^h to 24^h the signs are to be reversed.

Recapitulation of systematic corrections—Continued.

δ	Re 65.	Re 66.	Re 67.	Re 68.	Re 69.	Re 70.	Re 71.	Re 72.	Re 73.	δ
°	″	″	″	″	″	″	″	″	″	°
+ 90	+ .10	+ .74	00	+ .10	00	+ .10	+ .23	+ .17	00	+ 90
+ 85	+ .27	+1.00	00	+ .15	00	+ .13	+ .27	+ .24	+ .21	+ 85
+ 80	+ .38	+1.26	00	+ .18	00	+ .17	+ .31	+ .32	+ .39	+ 80
+ 75	+ .41	+1.43	00	+ .19	— .03	+ .19	+ .36	+ .40	+ .52	+ 75
+ 70	+ .40	+1.50	00	+ .20	— .06	+ .20	+ .40	+ .48	+ .67	+ 70
+ 65	+ .31	+1.41	00	+ .18	— .12	+ .19	+ .42	+ .50	+ .80	+ 65
+ 60	+ .20	+1.21	00	+ .13	— .23	+ .17	+ .44	+ .51	+ .86	+ 60
+ 55	+ .08	+ .96	— .10	+ .08	— .30	+ .12	+ .41	+ .49	+ .82	+ 55
+ 50	— .03	+ .60	— .22	00	— .34	+ .11	+ .35	+ .42	+ .70	+ 50
+ 45	— .10	+ .47	— .37	— .06	— .32	— .01	+ .23	+ .33	+ .47	+ 45
+ 40	— .14	+ .20	— .46	— .10	— .27	— .22	+ .10	+ .15	+ .21	+ 40
+ 35	— .18	— .02	— .48	— .09	— .28	— .50	— .10	— .07	— .02	+ 35
+ 30	— .18	— .14	— .47	+ .03	— .28	— .63	— .27	— .21	— .13	+ 30
+ 25	— .18	— .30	— .49	+ .12	— .33	— .65	— .25	— .17	— .06	+ 25
+ 20	— .21	— .51	— .58	+ .07	— .48	— .40	— .10	+ .08	+ .10	+ 20
+ 15	— .33	— .88	— .73	— .06	— .62	00	+ .20	+ .32	+ .21	+ 10
+ 10	— .42	—1.06	— .88	— .10	— .66	+ .26	+ .40	+ .44	+ .23	+ 15
+ 5	— .26	—1.11	—1.00	— .10	— .56	+ .20	+ .36	+ .40	+ .11	+ 5
0	+ .13	— .93	— .88	— .10	— .47	00	+ .18	+ .30	— .09	0
— 5	+ .40	— .91	— .74	— .20	— .40	— .25	+ .02	+ .18	— .26	— 5
— 10	+ .53	—1.06	— .79	— .35	— .40	— .50	— .11	+ .07	— .34	— 10
— 15	+ .62	—1.30	— .89	— .51	— .40	— .65	— .24	— .02	— .35	— 15
— 20	+ .80	—1.57	—1.05	— .67	— .40	— .80	— .34	— .11	— .30	— 20
— 25	+ .90	—1.83	—1.22	— .83	— .35	— .90	— .42	— .20	— .25	— 25
— 30	+1.00	—2.10	—1.40	—1.00	— .30	—1.00	— .50	— .28	— .20	— 30
— 35	....	....	....	....	....	....	....	....	....	— 35
— 40	....	....	....	....	....	....	....	....	....	— 40
— 50	....	....	....	....	....	....	....	....	....	— 50
— 60	....	....	....	....	....	....	....	....	....	— 60
— 70	....	....	....	....	....	....	....	....	....	— 70
— 80	....	....	....	....	....	....	....	....	....	— 80
— 90	....	....	....	....	....	....	....	....	....	— 90

A. R.	Re 65.	Re 66.	Re 67.	Re 68.	Re 69.	Re 70.	Re 71.	Re 72.	Re 73.	A. R.
h.	″	″	″	″	″	″	″	″	″	h.
0	....	....	....	....	....	....	....	....	....	12
1	....	....	....	....	....	....	....	....	....	13
2	....	....	....	....	....	....	....	....	....	14
3	....	....	....	....	....	....	....	....	....	15
4	....	....	....	....	....	....	....	....	....	16
5	....	....	....	....	....	....	....	....	....	17
6	....	....	....	....	....	....	....	....	....	18
7	....	....	....	....	....	....	....	....	....	19
8	....	....	....	....	....	....	....	....	....	20
9	....	....	....	....	....	....	....	....	....	21
10	....	....	....	....	....	....	....	....	....	22
11	....	....	....	....	....	....	....	....	....	23
12	....	....	....	....	....	....	....	....	....	24

When the argument is 12^h to 24^h the signs are to be reversed.

For general explanation see Sections VIII. and X.

Notes.—In a few cases the corrections of the table are only applicable to declinations by direct observations above the pole. For these, where it is thought to be worth while, the corrections to declinations, as they result from observations below the pole, are given in the following table.

For observations below the pole.

δ	Ce 36 and Ce 37.	Eh 41.	Eh 42.	Eh 43.	Eh 44.	Wn 45.	Ce 45 to Ce 51.	Wn 61 and Wn 62.	δ
°	″	″	″	″	″	″	″	″	°
+ 90	+ .09	− .23	+ .94	−1.29	+ .36	+ .35	+ .43	+ .76	+ 90
+ 85	+ .09	− .17	+1.06	−1.36	+ .37	+ .39	+ .43	+ .79	+ 85
+ 80	+ .09	+ .01	+1.16	−1.39	+ .37	+ .40	+ .43	+ .80	+ 80
+ 75	+ .09	+ .13	+1.24	−1.37	+ .34	+ .39	....	....	+ 75
+ 70	+ .02	....	....	....	....	+ .35	....	....	+ 70
+ 65	− .09	....	....	....	....	....	....	....	+ 65
+ 60	− .23	....	....	....	....	....	....	....	+ 60

δ	Wn 63 to Wn 65.	Washington transit circle.						δ
		Wn 66.	Wn 67 (before June 1).	Wn 67 (after June 1.)	Wn 68.	Wn 69.	Wn 74.	
°	″	″	″	″	″	″	″	°
+ 90	+ .55	+ .29	− .20	− .54	+ .14	+ .15	− .07	+ 90
+ 85	+ .58	+ .36	− .16	− .50	+ .10	+ .19	− .17	+ 85
+ 80	+ .59	+ .44	− .11	− .45	+ .07	+ .25	− .28	+ 80
+ 75	+ .58	+ .53	− .03	− .37	+ .06	+ .33	− .38	+ 75
+ 70	+ .55	+ .62	+ .06	− .28	+ .05	+ .41	− .48	+ 70

These corrections are in the cases of Ce 36 to Ce 37, Wn 45, Ce 45 to Ce 51, Wn 61 and Wn 62, and Wn 63 to Wn 65, derived merely by the addition of a constant to the correction for declinations above the pole.

(*a*) *Correctiones ultimæ*, pp. 351 to 371 of Struve's Pos. Med. (1830) must be added for each star to the correction of Dt 21, in order to make it applicable to Dt 30.

(*b*) Re 45. The corrections, with reversed signs, pp. viii to xi Int. to Radcliffe catalogue for 1845 must be added.

(*c*) The curve southward from — 10° is probably very near Ms 35 — 0″.4.

(*d*) Re 58. The correction, pp. xviii and xix Int. to second Radcliffe catalogue, must be added, with reversed signs.

(*e*) Me 62. The important effect of the correction given in the table, pp. xxii to xxiv, introduction to the catalogue, varies too rapidly to be included here. The two corrections must therefore be added.

(*f*) Observations taken from Bonn Beob. Bd. vi require the further correction given in Int., p. xiv.

(*g*) The corrections to Wn 66–69 (transit circle) are applicable to the mean declinations of the detailed observations after these have been corrected for division error only. The effect of the latter might have been included; but greater accuracy, in interpolating, results from the above course.

(*h*) Applicable to declinations of the catalogues.

CATALOGUE OF 500 STARS

FOR

THE EPOCH 1875.0,

CONTAINING DECLINATIONS WITH THEIR ANNUAL VARIATIONS AND OTHER TERMS OF PRECESSION.

COMPILED FROM ORIGINAL AUTHORITIES.

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	Δδ	Δμ′
				h. m. s.	s.	s.	″	″
1	4	α Andromedæ	1	0 01 55.8	+ 3.089	+ 18	— .43	— .99
2	7	β Cassiopeæ	2.5	02 31.1	+ 3.162	+ 54	— .07	+ .81
3	26	γ Pegasi	2	06 48.0	+ 3.082	+ 10	— .41	— .45
*4	46	....	6	10 15.1	+ 3.183	+ 60	+ .35	+2.24
*5	67	ρ Andromedæ	5.5	14 32.4	+ 3.141	+ 26	— .36	—1.60
6	88	β Hydri	3	19 09.1	+ 3.266	— 154	— .11	—1.30
*7	120	....	6	24 47.6	+ 3.116	+ 24	—1.15	—8.30
8	126	κ Cassiopeæ	4	25 54.5	+ 3.358	+ 70	+ .78	+ .23
9	153	ζ Cassiopeæ	4	30 01.0	+ 3.309	+ 49	— .10	— .14
10	155	π Andromedæ	4.5	30 12.5	+ 3.188	+ 24	+ .98	+ .30
11	166	δ Andromedæ	3	32 38.8	+ 3.192	+ 22	+ .35	+1.45
12	169	α Cassiopeæ	3	33 25.5	+ 3.366	+ 55	— .01	— .17
*13	175	....	6	34 37.5	+ 3.510	+ 87	+ .51	+1.72
14	196	β Ceti.....	2.5	37 18.8	+ 3.012	— 6	— .03	+ .49
15	194	21 Cassiopeæ	5.5	37 25.6	+ 3.834	+ 160	+1.11	+2.43
*16	198	ο Cassiopeæ	5.5	37 45.9	+ 3.314	+ 41	— .22	— .47
17	215	ζ Andromedæ	4	40 43.0	+ 3.169	+ 18	+ .79	+2.72
18	218	η Cassiopeæ	4	41 32.8	+ 3.581	+ 64	+ .43	+1.35
*19	219	ν Cassiopeæ	5	41 45.5	+ 3.367	+ 46	+ .97	+1.34
*20	239	....	5.5	45 37.5	+ 3.530	+ 71	+ .50	+1.44
21	253	γ Cassiopeæ	3	49 10.7	+ 3.566	+ 71	+ .26	+1.57
*22	259	μ Andromedæ	4	49 49.2	+ 3.304	+ 30	— .35	— .86
23	288	ε Piscium	4	56 27.4	+ 3.109	+ 09	— .44	— .37
*24	......	(LL. 1985)	......	1 02 25.9	+ 3.966	+ 113	+ .60	+1.70
25	334	β Andromedæ	2	02 44.3	+ 3.340	+ 29	— .51	—2.63
*26	345	82 Piscium	5.5	04 13.4	+ 3.291	+ 25	+ .47	+1.36
27	395	υ Piscium	5.5	12 36.0	+ 3.283	+ 22	— .37	—1.15
28	360	α Ursæ Minoris	2	13 00.2	+20.868	+15068	+ .02	— .26
*29	401	91 Piscium	6	14 12.9	+ 3.301	+ 23	— .46	— .71
30	416	δ Cassiopeæ	3	17 39.3	+ 3.870	+ 79	+ .02	+ .34
31	420	θ¹ Ceti	3	17 46.5	+ 2.998	+ 02	+ .01	— .53
*32	438	38 Cassiopeæ	5	21 57.4	+ 4.357	+ 144	— .87	—2.86
33	447	γ Phenicis	3	22 56.1	+ 2.612	— 13	— .48	—3.58
34	453	η Piscium	4	24 47.7	+ 3.199	+ 14	—1.15	—2.54
*35	474	....	6	28 49.2	+ 3.630	+ 48	— .25	+ .20
*36	487	51 Andromedæ	3.5	30 19.6	+ 3.618	+ 48	— .17	+ .61
37	507	α Eridani	1	33 03.3	+ 2.240	— 13	— .00	—1.74
*38	522	54 Andromedæ	4	35 50.2	+ 3.726	+ 53	— .58	—2.49
39	537	ο Piscium	5	38 47.7	+ 3.162	+ 11	— .57	—1.17
*40	560	2 Persei	6	44 13.1	+ 3.781	+ 54	+ .61	+ .61
41	564	ε Cassiopeæ	3	45 25.4	+ 4.215	+ 99	+ .09	— .47
42	569	α Trianguli	3.5	45 57.6	+ 3.403	+ 25	+ .23	+ .53
43	577	β Arietis	3	47 44.2	+ 3.301	+ 18	— .53	—1.40
44	600	50 Cassiopeæ	4	52 47.9	+ 4.984	+ 186	+1.06	+2.35
*45	611	53 Cassiopeæ	6	53 46.4	+ 4.365	+ 11	+ .45	+ .95

for the epoch 1875.0.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
1	+ 28 24 00.79	.06	26	+ 19.8866	.0021	− 124	− 102	− .1669
2	+ 58 27 36.63	.12	6	+ 19.8601	.0036	− 140	− 109	− .1929
3	+ 14 29 18.67	.06	24	+ 20.0269	.0022	− 220	− 101	− .0185
*4	+ 60 50 18.60	.35	1	+ 20.0365	.0102	− 294	− 111	+ .0024
*5	+ 37 16 33.11	.10	8	+ 19.9469	.0050	− 376	− 109	− .0670
6	− 77 57 30.11	.26	1	+ 20.2912	.0099	− 456	− 114	+ .3070
*7	+ 32 53 28.25	.29	1	+ 19.8780	.015	− 584	− 107	− .059
8	+ 62 14 29.68	.21	2	+ 19.9227	.0057	− 638	− 130	− .0077
9	+ 53 12 30.94	.13	5	+ 19.8621	.0041	− 716	− 124	− .0204
10	+ 33 01 50.98	.22	2	+ 19.8723	.0057	− 697	− 111	− .0080
11	+ 30 10 35.27	.19	3	+ 19.7476	.0055	− 748	− 111	− .1035
12	+ 55 51 05.12	.07	20	+ 19.8006	.0022	− 800	− 130	− .0407
*13	+ 65 27 41.66	.24	2	+ 19.8050	.0111	− 038	− 856	− .0208
14	− 18 40 23.23	.07	16	+ 19.8139	.0033	− 800	− 93	+ .0249
15	+ 74 18 15.68	.12	6	+ 19.7667	.0048	− 991	− 191	− .0207
*16	+ 47 35 59.48	.12	6	+ 19.7748	.0048	− 877	− 124	− .0077
17	+ 23 35 12.69	.17	3	+ 19.6648	.0058	− 900	− 108	− .0738
18	+ 57 09 08.23	.11	7	+ 19.2481	.0037	− 1071	− 155	− .4775
*19	+ 50 17 09.37	.27	1	+ 19.6957	.0070	− 974	− 129	− .0266
*20	+ 60 26 17.35	.26	1	+ 19.8186	.0081	− 1100	− 149	+ .1604
21	+ 60 02 21.50	.10	9	+ 19.5780	.0041	− 1191	− 153	− .0163
*22	+ 37 49 14.69	.12	7	+ 19.5897	.0048	− 1121	− 122	+ .0074
23	+ 7 12 59.93	.07	17	+ 19.4721	.0035	− 1188	− 101	+ .0233
*24	+ 67 06 43.88	......	......	+ 19.3167	....	− 1655	− 205	+ .002
25	+ 34 57 26.09	.10	10	+ 19.1852	.0031	− 1406	− 125	− .1223
*26	+ 30 45 33.94	.33	1	+ 19.2696	.0124	− 1411	− 119	− .0024
27	+ 26 36 22.53	.16	3	+ 19.0389	.0054	− 1574	− 117	− .0175
28	+ 88 38 33.86	.03	93	+ 19.0458	.0010	− 9670	−11308	+ .0004
*29	+ 28 05 03.38	.24	1	+ 18.9158	.0060	− 1613	− 119	− .0961
30	+ 59 35 04.92	.13	5	+ 18.8594	.0039	− 1978	− 188	− .0546
31	− 8 49 44.31	.07	17	+ 18.6902	.0033	− 1534	− 90	− .2203
*32	+ 69 37 12.89	.17	3	+ 18.7100	.0057	− 2318	− 261	− .0756
33	− 43 57 32.48	.30	1	+ 18.5496	.0105	− 1427	− 60	+ .1342
34	+ 14 42 02.65	.08	16	+ 18.6898	.0035	− 1768	− 107	− .0074
*35	+ 48 05 00.32	.36	1	+ 18.5480	.0098	− 2083	− 155	− .0190
*36	+ 47 59 38.47	.11	7	+ 18.3978	.0036	− 2125	− 156	− .1189
37	− 57 52 20.30	.22	2	+ 18.3763	.0086	− 1375	− 40	− .0474
*38	+ 50 03 28.61	.10	9	+ 18.2954	.0040	− 2282	− 164	− .0309
39	+ 8 31 39.81	.09	12	+ 18.2459	.0037	− 2009	− 102	+ .0263
*40	+ 50 10 25.57	.33	1	+ 17.9714	.0068	− 2496	− 168	− .0449
41	+ 63 03 11.63	.11	8	+ 17.9450	.0034	− 2828	− 234	− .0247
42	+ 28 58 08.16	.20	2	+ 17.7131	.0058	− 2291	− 125	− .2557
43	+ 20 11 45.94	.07	19	+ 17.7609	.0035	− 2262	− 113	− .1180
44	+ 71 48 53.84	.10	10	+ 17.6975	.0036	− 3503	− 357	+ .0235
*45	+ 63 47 06.78	.32	1	+ 17.6469	.0079	− 3108	− 248	+ .0135

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	s.	s.	"	"
46	628	γ Andromedæ	3	1 56 13.9	+ 3.652	+ 39	+ .31	+ .46
47	648	α Arietis	2	2 00 07.8	+ 3.368	+ 21	— .35	— .75
*48	656	β Trianguli	4	02 06.7	+ 3.550	+ 30	— .32	— .16
49	684	ξ^1 Ceti	5	06 22.5	+ 3.170	+ 12	— .20	— .43
*50	744	ι Cassiopeæ	4	18 47.5	+ 4.844	+ 131	— .03	+ .77
*51	752	11 Trianguli	6.5	20 03.8	+ 3.535	+ 27	— .42	+ .07
52	760	ξ^2 Ceti	4	21 30.9	+ 3.181	+ 12	— .16	+ .28
53	777	....	5.5	26 11.4	+ 5.553	+ 200	+ .36	+1.57
*54	825	μ Arietis	6	35 19.3	+ 3.370	+ 18	— .26	— .22
55	827	θ Persei	4	35 40.2	+ 4.061	+ 51	+1.14	+1.29
56	837	γ^2 Ceti	3	36 49.5	+ 3.103	+ 9	— .56	— .45
57	863	η Persei	4	41 35.5	+ 4.333	+ 68	+ .66	+3.10
58	872	41 Arietis	3	42 37.8	+ 3.514	+ 23	— .69	+ .15
59	885	τ Persei	5	45 24.3	+ 4.212	+ 58	— .08	+ .46
*60	896	....	6	49 33.8	+ 7.668	+ 457	+ .55	+2.19
61	937	θ^1 Eridani	3.5	53 31.2	+ 2.274	+ 7	— .43	—1.35
62	919	α Ceti	2.5	55 44.8	+ 3.129	+ 10	— .17	+ .21
63	947	γ Persei	3.5	55 45.3	+ 4.307	+ 59	+ .49	+1.17
64	953	ρ Persei	4	57 10.3	+ 3.821	+ 33	— .41	—1.27
65	963	β Persei	2.5	3 00 02.4	+ 3.878	+ 35	— .07	—1.62
66	962	ι Persei	4	00 03.3	+ 4.294	+ 52	+ .23	—1.18
*67	979	....	5.5	04 32.1	+ 7.360	+ 353	+ .48	+1.41
*68	999	ζ Arietis	5	07 43.1	+ 3.436	+ 18	— .23	— .32
*69	1029	60 Arietis	7	13 01.2	+ 3.542	+ 20	— .24	+ .34
70	1043	α Persei	2.5	15 24.4	+ 4.249	+ 48	— .04	+ .56
71	1057	ο Tauri	4.5	18 05.3	+ 3.221	+ 11	— .22	— .55
72	1068	ξ Tauri	4	20 23.8	+ 3.244	+ 12	+1.52	+ .77
*73	1067	....	6	21 33.3	+ 6.430	+ 204	+ .68	+2.78
*74	1101	....	6.5	27 51.4	+ 3.708	+ 24	+ .12	+ .90
75	1129	δ Persei	3	34 01.8	+ 4.241	+ 41	— .30	— .08
*76	1127	....	6	34 12.7	+ 5.600	+ 116	— .13	+ .30
77	1166	η Tauri	3	40 03.4	+ 3.555	+ 18	— .37	— .78
78	1207	ζ Persei	3.5	46 16.6	+ 3.757	+ 22	— .29	— .73
*79	1203	....	5	46 24.7	+ 5.242	+ 84	— .21	— .26
*80	1228	ξ Persei	5	50 51.5	+ 3.873	+ 25	— .84	— .71
81	1234	γ^1 Eridani	2.5	52 11.8	+ 2.791	+ 4	— .34	+ .40
*82	1254	λ Persei	4.5	57 16.7	+ 4.440	+ 42	— .15	— .37
83	1235	....	6	57 58.1	+16.853	+1811	+ .86	+3.28
84	1266	48 Persei	5	59 35.5	+ 4.331	+ 37	— .87	— .90
*85	1287	μ Persei	4.5	4 05 43.5	+ 4.380	+ 37	+ .13	+ .58
86	1328	γ Tauri	3.5	12 40.9	+ 3.408	+ 11	— .88	—2.55
87	1376	ε Tauri	3.5	21 19.1	+ 3.496	+ 12	— .13	—1.67
88	1420	α Tauri	1	28 45.0	+ 3.436	+ 10	— .25	—1.08
89	1456	4 Camelopardi	5	37 35.9	+ 4.969	+ 40	+ .28	+ .60
90	1474	α Camelopardi	4	41 38.0	+ 5.915	+ 69	— .24	—2.14

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.			Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	°	′	″	″		″	″	″	″	″
46	+ 41	43	43.50	.13	5	+ 17.4676	.0036	— 2663	— 149	— .0624
47	+ 22	52	13.17	.06	25	+ 17.2103	.0021	— 2543	— 116	— .1515
*48	+ 34	23	41.73	.11	7	+ 17.2248	.0037	— 2714	— 136	— .0496
49	+ 8	15	33.55	.11	8	+ 17.0666	.0040	— 2492	— 97	— .0153
*50	+ 66	50	19.27	.11	7	+ 16.4926	.0043	— 4097	— 310	+ .0047
*51	+ 31	14	19.64	.25	1	+ 16.3870	.0075	— 3031	— 129	— .0373
52	+ 7	53	55.03	.08	14	+ 16.3369	.0036	— 2758	— 95	— .0142
53	+ 72	16	09.56	.19	3	+ 16.1156	.0063	— 4883	— 432	+ .0017
*54	+ 19	28	38.91	.22	2	+ 15.5662	.0073	— 3148	— 107	— .0562
55	+ 48	41	53.24	.20	2	+ 15.5050	.0051	— 3819	— 181	— .0981
56	+ 2	42	28.16	.08	16	+ 15.3820	.0029	— 2919	— 85	— .1575
57	+ 55	22	29.46	.23	2	+ 15.2466	.0065	— 4166	— 213	— .0260
58	+ 26	44	37.79	.11	7	+ 15.0941	.0042	— 3407	— 118	— .1195
59	+ 52	14	56.91	.13	5	+ 15.0427	.0048	— 4122	— 194	— .0114
*60	+ 78	55	16.59	.16	4	+ 14.8183	.0053	— 7610	— 904	+ .0069
61	— 40	48	22.63	.29	1	+ 14.6222	.0101	— 2336	— 45	+ .0465
62	+ 3	35	52.89	.06	22	+ 14.3553	.0023	— 3226	— 82	— .0859
63	+ 53	00	54.54	.23	2	+ 14.4384	.0068	— 4424	— 198	— .0023
64	+ 38	21	15.39	.20	2	+ 14.2417	.0061	— 3963	— 141	— .1127
65	+ 40	28	20.48	.09	12	+ 14.1657	.0029	— 4058	— 146	— .0122
66	+ 49	08	01.33	.21	2	+ 14.0853	.0061	— 4631	— 193	— .0918
*67	+ 77	16	19.19	.11	7	+ 13.8452	.0051	— 7819	— 763	— .0519
*68	+ 20	34	46.86	.11	7	+ 13.6107	.0042	— 3716	— 101	— .0842
*69	+ 25	12	38.65	.24	2	+ 13.2529	.0089	— 3912	— 107	— .0996
70	+ 49	24	51.43	.08	13	+ 13.1625	.0030	— 4725	— 175	— .0334
71	+ 8	35	14.68	.14	5	+ 12.9299	.0048	— 3624	— 81	— .0885
72	+ 9	17	43.17	.12	6	+ 12.8077	.0044	— 3688	— 82	— .0563
*73	+ 72	55	12.89	.29	1	+ 12.7748	.0121	— 7273	— 502	— .0112
*74	+ 31	15	38.51	.27	1	+ 12.3255	.015	— 4316	— 114	— .031
75	+ 47	23	08.49	.08	13	+ 11.8828	.0029	— 5024	— 158	— .0438
*76	+ 66	48	24.09	.21	2	+ 11.8228	.0079	— 6642	— 329	— .0910
77	+ 23	43	00.57	.07	18	+ 11.4429	.0029	— 4298	— 94	— .0558
78	+ 31	30	37.56	.09	11	+ 11.0171	.0036	— 4621	— 106	— .0313
*79	+ 62	42	10.78	.26	1	+ 11.0480	.0094	— 6422	— 257	+ .0094
*80	+ 35	25	46.51	.20	2	+ 10.6936	.0056	— 4825	— 112	— .0181
81	— 13	51	56.04	.08	16	+ 10.4965	.0033	— 3507	— 46	— .1160
*82	+ 50	00	34.57	.12	6	+ 10.1890	.0043	— 5617	— 154	— .0437
83	+ 85	13	20.27	.19	3	+ 10.2135	.0066	—21219	— 3786	+ .0328
84	+ 47	22	34.67	.23	2	+ 10.0150	.0060	— 5510	— 142	— .0430
*85	+ 48	05	21.69	.22	2	+ 9.5579	.0057	— 5652	— 139	— .0322
86	+ 15	19	26.23	.09	11	+ 9.0238	.0040	— 4486	— 67	— .0275
67	+ 18	54	04.44	.08	16	+ 8.3258	.0039	— 4679	— 66	— .0447
88	+ 16	15	21.78	.06	26	+ 7.5836	.0021	— 4658	— 58	— .1918
89	+ 56	31	56.13	.11	7	+ 6.9050	.0042	— 6819	— 141	— .1510
90	+ 66	07	36.73	.10	8	+ 6.7231	.0037	— 8151	— 213	— .0014

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	*s.*	"	"	"
91	1520	ι Aurigæ	4	4 48 51.3	+ 3.897	+ 14	— .81	— .95
92	1536	β Camelopardi	4.5	52 18.3	+ 5.309	+ 42	+ .12	— .34
93	1540	ε Aurigæ	4	53 00.0	+ 4.292	+ 20	— .23	—1.29
94	1541	ζ Aurigæ	4	53 44.5	+ 4.181	+ 18	+ .31	+ .48
95	1557	11 Orionis	5	57 25.7	+ 3.425	+ 8	—1.07	—2.75
96	1558	η Aurigæ	4	57 45.1	+ 4.196	+ 17	— .23	—1.18
97	1613	α Aurigæ	1	5 07 27.4	+ 4.422	+ 16	— .16	— .74
98	1623	β Orionis	1	08 31.9	+ 2.881	+ 4	+ .10	— .11
99	1681	β Tauri	2	18 23.5	+ 3.788	+ 8	— .36	— .47
100	1706		5	23 01.6	+ 7.990	+ 77	+ .83	+2.11
101	1730	δ Orionis	2	25 37.3	+ 3.064	+ 4	+ .09	+2.00
102	1741	α Leporis	3.5	27 13.1	+ 2.645	+ 3	— .36	— .06
103	1765	ε Orionis	2.5	29 52.3	+ 3.042	+ 4	— .46	— .36
104	1802	α Columbæ	2	35 07.4	+ 2.173	+ 3	— .62	— .51
105	1845	ν Aurigæ	5	42 49.6	+ 4.155	+ 6	+ .10	— .31
106	1878	β Columbæ	3	46 33.2	+ 2.113	+ 3	— .12	— .11
107	1883	α Orionis	1	48 24.3	+ 3.247	+ 3	— .01	— .02
108	1885	δ Aurigæ	3.5	49 14.1	+ 4.936	+ 6	— .02	— .52
109	1895	β Aurigæ	2	50 21.5	+ 4.395	+ 4	— .11	— .25
110	1900	θ Aurigæ	4	51 11.8	+ 4.090	+ 3	+ .22	+2.30
111	1980		5	6 05 03.9	+ 6.619	— 7	— .40	—1.13
112	2002	η Geminorum	4	07 20.0	+ 3.622	+ 1	+ .08	+ .19
113	2047	μ Geminorum	3	15 23.9	+ 3.633	— 1	— .86	—1.46
114	2096	α Argus	1	21 10.5	+ 1.330	+ 1	— .13	+ .87
115	2163	γ Geminorum	2.5	30 29.4	+ 3.469	— 1	— .25	—1.36
116	2194	ε Geminorum	3	36 14.5	+ 3.694	— 3	+ .23	— .12
117	2157		5	41 14.7	+30.234	—2101	+ .03	— .11
118	2237	θ Geminorum	5	44 32.9	+ 3.960	— 7	— .29	—1.02
119	2293	ε Canis Majoris	2.5	53 42.8	+ 2.357	+ 2	— .43	+ .72
120	2305	ζ Geminorum	4	56 41.7	+ 3.563	— 5	+ .37	—1.14
121	2345	δ Canis Majoris	3.5	7 03 18.5	+ 2.439	+ 1	— .81	+ .93
122	2398	λ Geminorum	4.5	10 54.5	+ 3.453	— 5	+ .62	— .99
123	2410	δ Geminorum	3	12 39.4	+ 3.591	— 7	— .96	—2.53
124	2439		5	17 51.4	+ 6.311	— 84	+1.38	+3.55
125	2442	ι Geminorum	4	17 57.7	+ 3.736	— 10	— .08	— .08
126	2462	β Canis Majoris	3	20 22.3	+ 3.257	— 4	— .13	— .58
127	2485	α^2 Geminorum	1.5	26 37.0	+ 3.839	— 13	+ .03	— .13
128	2551	κ Geminorum	4	36 54.0	+ 3.629	— 11	+ .57	—1.13
129	2555	β Geminorum	2	37 39.9	+ 3.681	— 13	— .33	— .35
130	2617	φ Geminorum	5	45 50.8	+ 3.684	— 13	— .33	—1.06
131	2710	ζ Argus	2.5	59 11.5	+ 2.108	+ 1	+ .08	— .03
132	2707	55 Camelopardi	5	8 00 20.9	+ 6.066	— 119	+ .57	+1.30
133	2728	ρ Argus	3.5	02 13.3	+ 2.554	+ 1	— .51	—1.46
134	2778	β Cancri	4	09 44.1	+ 3.257	— 7	— .27	— .10
135	2819	o Ursæ Majoris	4	19 51.9	+ 5.043	— 76	+ .22	+ .34

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
91	+ 32 57 57.28	.08	15	+ 6.1044	.0033	— 5437	— 65	— .0215
92	+ 60 15 22.90	.11	6	+ 5.8243	.0041	— 7431	— 139	— .0134
93	+ 43 38 09.00	.11	8	+ 5.7606	.0031	— 6017	— 79	— .0189
94	+ 40 53 27.31	.20	2	+ 5.6922	.0051	— 5868	— 72	— .0252
95	+ 15 13 40.70	.12	7	+ 5.3090	.0044	— 4837	— 40	— .0385
96	+ 41 03 46.64	.11	7	+ 5.3065	.0033	— 5921	— 69	— .0738
97	+ 45 52 05.56	.06	23	+ 4.1231	.0020	— 6312	— 64	— .4344
98	— 8 20 51.96	.06	24	+ 4.4598	.0022	— 4114	— 22	— .0061
99	+ 28 29 58.49	.06	25	+ 3.4402	.0021	— 5452	— 34	— .1807
100	+ 74 57 22.41	.16	4	+ 3.2404	.0061	—11526	— 210	+ .0191
101	— 0 23 36.71	.07	18	+ 2.9920	.0029	— 4433	— 17	— .0050
102	— 17 54 48.06	.09	10	+ 2.8581	.0038	— 3832	— 11	— .0006
103	— 1 17 00.94	.08	15	+ 2.6292	.0033	— 4409	— 14	+ .0004
104	— 34 8 31.22	.16	4	+ 2.1273	.0066	— 3163	— 7	— .0451
105	+ 39 06 33.53	.21	2	+ 1.5192	.0060	— 6047	— 17	+ .0179
106	— 35 48 59.72	.27	1	+ 1.5648	.0086	— 3087	— 5	+ .3889
107	+ 7 22 54.34	.06	26	+ 1.0210	.0021	— 4735	— 5	+ .0068
108	+ 54 16 19.12	.11	7	+ 0.8114	.0044	— 7206	— 14	— .1302
109	+ 44 55 55.62	.09	12	+ 0.8399	.0028	— 6392	— 10	— .0035
110	+ 37 12 04.92	.17	3	+ 0.6751	.0060	— 5968	— 6	— .0950
111	+ 69 21 35.08	.13	5	— 0.5615	.0055	— 9645	+ 28	— .1183
112	+ 22 32 27.18	.10	10	— 0.6576	.0041	— 5270	+ 8	— .0161
113	+ 22 34 31.93	.08	16	— 1.4680	.0030	— 5289	+ 15	— .1216
114	— 52 37 40.83	.23	2	— 1.8416	.0085	— 1925	+ 2	+ .0087
115	+ 16 30 14.10	.07	19	— 2.7078	.0033	— 5009	+ 23	— .0476
116	+ 25 15 09.76	.14	4	— 3.1732	.0051	— 5306	+ 32	— .0152
117	+ 87 14 04.35	.07	19	— 3.6289	.0033	—43267	+ 4794	— .0391
118	+ 34 06 34.48	.11	8	— 3.9229	.0047	— 5648	+ 48	— .0492
119	— 28 48 12.13	.11	7	— 4.6700	.0059	— 3324	+ 14	— .0128
120	+ 20 45 05.75	.11	8	— 4.9219	.0040	— 5017	+ 44	— .0114
121	— 26 11 45.81	.12	6	— 5.4602	.0055	— 3393	+ 18	+ .0093
122	+ 16 45 50.12	.16	4	— 6.1521	.0047	— 4767	+ 50	— .0459
123	+ 22 12 37.60	.07	18	— 6.2680	.0029	— 4948	+ 57	— .0163
124	+ 68 43 03.10	.16	4	— 6.7199	.0058	— 8652	+ 264	— .0375
125	+ 28 02 39.96	.14	4	— 6.7729	.0048	— 5097	+ 68	— .0818
126	+ 8 32 21.67	.10	10	— 6.9393	.0041	— 4426	+ 48	— .0498
127	+ 32 09 37.90	.07	19	— 7.4784	.0024	— 5152	+ 80	— .0783
128	+ 24 41 44.66	.15	4	— 8.2919	.0051	— 4787	+ 76	— .0633
129	+ 28 19 34.20	.06	26	— 8.3472	.0020	— 4790	+ 79	— .0575
130	+ 27 05 14.74	.11	8	— 8.9607	.0041	— 4771	+ 85	— .0246
131	— 39 39 06.72	.30	1	— 9.9360	.0096	— 2621	+ 24	+ .0297
132	+ 68 50 20.20	.14	4	— 10.0515	.0053	— 7619	+ 353	+ .0020
133	— 23 56 42.71	.10	9	— 10.1495	.0043	— 3155	+ 37	+ .0454
134	+ 9 34 09.08	.09	10	— 10.8076	.0039	— 3956	+ 73	— .0520
135	+ 61 08 00.80	.12	6	— 11.6155	.0037	— 5957	+ 251	— .1226

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Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	s.	s.	"	"
136	2953	δ Cancri	4.5	8 37 34.8	+ 3.419	− 13	+ .00	− .18
137	2965	ι Cancri	5	39 07.8	+ 3.614	− 20	− .22	−1.15
138	2971	ε Hydræ	4	40 09.4	+ 3.184	− 7	−1.17	−3.17
139	3048	ι Ursæ Majoris	3.5	50 38.4	+ 4.139	− 44	− .20	+ .02
140	3075	κ Ursæ Majoris	4	55 05.0	+ 4.125	− 44	+ .91	+2.79
141	3099	σ² Ursæ Majoris	5	59 22.0	+ 5.374	− 134	+1.95	+3.92
142	3111	κ Cancri	5	9 00 58.5	+ 3.255	− 9	− .87	−2.47
143	3126	λ Argus	3	03 23.9	+ 2.202	+ 4	− .04	−1.74
144	3178	α Lyncis	4	13 26.1	+ 3.672	− 27	− .08	− .18
145	3186	ι Argus	2	13 44.6	+ 1.606	− 2	+ .22	+2.82
146	3199	....	5	19 05.9	+ 9.113	− 795	−1.06	−2.34
147	3223	α Hydræ	2	21 26.7	+ 2.949	− 2	− .03	− .48
148	3232	24 Ursæ Majoris	5	23 23.5	+ 5.425	− 169	− .32	− .01
149	3242	θ Ursæ Majoris	3	24 29.1	+ 4.050	− 55	− .13	+ .85
150	3312	ο Leonis	4	34 28.6	+ 3.207	− 9	+ .38	− .03
151	3331	ε Leonis	3	38 45.2	+ 3.419	− 18	− .43	−1.46
152	3346	υ Ursæ Majoris	4	42 05.1	+ 4.330	− 82	+ .17	− .42
153	3371	μ Leonis	3	45 39.0	+ 3.424	− 20	− .54	− .66
154	3453	η Leonis	3.5	10 00 31.0	+ 3.278	− 13	− .56	−1.84
155	3459	α Leonis	1	01 42.8	+ 3.202	− 10	− .32	−1.30
156	3496	32 Ursæ Majoris	5	08 56.0	+ 4.437	− 115	+ .61	+ .95
157	3505	λ Ursæ Majoris	3.5	09 33.1	+ 3.646	− 38	− .27	+ .41
158	3523	γ¹ Ursæ Majoris	2	13 04.7	+ 3.317	− 15	−1.24	−2.65
159	3533	μ Ursæ Majoris	3	14 52.6	+ 3.602	− 36	− .18	−1.36
160	3593	....	5.5	24 25.0	+ 5.303	− 280	− .51	−1.11
161	3609	ρ Leonis	4	26 13.7	+ 3.166	− 8	− .51	− .98
162	3695	η Argus	2	40 12.9	+ 2.310	+ 22	− .06	− .38
163	3708	53 Leonis	6	42 41.1	+ 3.159	− 8	−1.10	−2.78
164	3767	β Ursæ Majoris	2	54 17.3	+ 3.367	− 63	− .64	−2.70
165	3777	α Ursæ Majoris	1.5	55 59.8	+ 3.758	− 81	+ .09	+ .04
166	3812	ψ Ursæ Majoris	3.5	11 02 37.7	+ 3.398	− 37	− .27	− .18
167	3834	δ Leonis	2.5	07 27.5	+ 3.202	− 13	− .54	−2.31
168	3838	θ Leonis	3	07 40.8	+ 3.155	− 10	+ .34	−1.22
169	3852	ν Ursæ Majoris	4	11 43.4	+ 3.258	− 23	− .01	−1.28
170	3859	δ Crateris	3.5	13 05.5	+ 2.995	+ 6	− .53	+ .35
171	3900	τ Leonis	4	21 30.5	− 3.088	− 2	− .57	−1.20
172	3914	λ Draconis	3.5	23 57.5	+ 3.637	− 111	+1.59	+3.84
173	3946	υ Leonis	4.5	30 32.9	+ 3.072	0	− .86	−1.80
174	3981	χ Ursæ Majoris	4	39 26.7	+ 3.197	− 36	− .13	− .52
175	3995	β Leonis	2.5	42 41.0	+ 3.065	− 7	− .47	−2.51
176	4002	β Virginis	3.5	44 11.0	+ 3.125	0	− .43	−1.05
177	4017	γ Ursæ Majoris	2	47 14.8	+ 3.188	− 44	+ .28	− .05
178	4072	ο Virginis	4.5	58 50.5	+ 3.058	− 3	− .76	−1.22
179	4112	....	5	12 06 19.4	+ 2.904	− 126	+1.67	+2.93
180	4123	δ Ursæ Majoris	3	09 13.9	+ 3.003	− 43	+ .08	+ .92

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
136	+ 18 36 44.17	.12	6	− 12.9634	.0039	− 3797	+ 96	− .2358
137	+ 29 12 55.56	.20	2	− 12.8937	.0060	− 4025	+ 115	− .0615
138	+ 6 52 34.59	.07	17	− 12.9548	.0030	− 3486	+ 80	− .0537
139	+ 48 31 50.87	.08	15	− 13.8425	.0020	− 4333	+ 173	− .2528
140	+ 47 38 57.05	.17	3	− 13.9401	.0047	− 4279	+ 174	− .0671
141	+ 67 38 23.33	.12	6	− 14.1971	.0041	− 5494	+ 359	− .0558
142	+ 11 10 11.92	.08	14	− 14.2444	.0040	− 3278	+ 92	− .0037
143	− 42 55 43.04	.30	1	− 14.3765	.0102	− 2171	+ 31	+ .0126
144	+ 34 55 11.02	.10	9	− 14.9717	.0039	− 3474	+ 135	+ .0152
145	− 58 45 03.78	.25	1	− 14.9766	.0098	− 1486	+ 21	+ .0282
146	+ 81 52 32.83	.12	7	− 15.3300	.0046	− 8510	+ 1428	− .0184
147	− 8 07 04.31	.07	22	− 15.4132	.0023	− 2676	+ 75	+ .0302
148	+ 70 22 40.25	.18	3	− 15.4916	.0061	− 4915	+ 401	+ .0599
149	+ 52 14 44.25	.08	13	− 16.1682	.0028	− 3548	+ 185	− .5565
150	+ 10 27 35.91	.10	8	− 16.1789	.0037	− 2694	+ 98	− .0333
151	+ 24 20 55.41	.07	19	− 16.3863	.0020	− 2810	+ 119	− .0216
152	+ 59 37 31.17	.11	8	− 16.6917	.0033	− 3176	+ 203	− .1602
153	+ 26 35 40.61	.08	13	− 16.7587	.0031	− 2676	+ 121	− .0526
154	+ 17 22 16.68	.18	3	− 17.3984	.0053	− 2304	+ 110	− .0084
155	+ 12 34 38.26	.06	27	− 17.4430	.0020	− 2217	+ 103	− .0010
156	+ 65 43 50.60	.14	5	− 17.7705	.0060	− 2927	+ 265	− .0255
157	+ 43 32 15.64	.10	9	− 17.8131	.0032	− 2378	+ 152	− .0429
158	+ 20 28 22.85	.07	19	− 18.0565	.0028	− 2112	+ 117	− .1455
159	+ 42 07 38.22	.12	6	− 17.9619	.0040	− 2245	+ 148	+ .0194
160	+ 76 21 20.73	.11	7	− 18.3514	.0044	− 3054	+ 441	− .0161
161	+ 9 56 56.87	.08	14	− 18.4077	.0035	− 1758	+ 101	− .0088
162	− 59 01 39.76	.22	2	− 18.8551	.0088	− 1067	+ 43	− .0038
163	+ 11 12 21.88	.08	13	− 18.9527	.0043	− 1443	+ 105	− .0288
164	+ 57 03 06.52	.09	11	− 19.2275	.0036	− 1435	+ 165	+ .0080
165	+ 62 25 31.31	.06	24	− 19.3439	.0021	− 1420	+ 177	− .0666
166	+ 45 10 34.53	.09	12	− 19.4710	.0031	− 1141	+ 133	− .0418
167	+ 21 12 29.60	.07	21	− 19.6719	.0026	− 981	+ 112	− .1424
168	+ 16 06 45.03	.18	3	− 19.6111	.0055	− 956	+ 107	− .0772
169	+ 33 46 33.99	.24	2	− 19.5798	.0062	− 909	+ 118	+ .0312
170	− 14 06 08.73	.08	15	− 19.4521	.0034	− 801	+ 92	+ .1835
171	+ 3 32 39.95	.10	9	− 19.7930	.0039	− 668	+ 101	− .0210
172	+ 70 01 14.63	.09	12	− 19.8274	.0030	− 743	+ 164	− .0206
173	− 0 08 01.73	.08	15	− 19.8539	.0035	− 489	+ 100	+ .0350
174	+ 48 28 20.68	.11	8	− 19.9549	.0034	− 330	+ 115	+ .0188
175	+ 15 16 14.62	.06	25	− 20.1161	.0021	− 248	+ 99	− .1191
176	+ 2 28 08.39	.09	12	− 20.2890	.0028	− 233	+ 105	− .2825
177	+ 54 23 22.85	.07	20	− 20.0247	.0022	− 173	+ 112	− .0915
178	+ 9 25 38.37	.09	12	− 20.0162	.0036	+ 61	+ 99	+ .0378
179	+ 78 18 39.34	.10	9	− 20.0253	.0043	+ 203	+ 85	+ .0213
180	+ 57 43 38.28	.11	8	− 20.0288	.0035	+ 263	+ 93	+ .0092

Catalogue of 500 *stars*

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in a.	$\frac{d^2a}{dt^2}$	Δa	$\Delta\mu'$
				h. m. s.	s.	s.	"	"
181	4131	β Chameleontis........	5	12 11 03.5	+ 3.380	+ 180	+ .21	— .68
182	4145	η Virginis..............	3.5	13 30.7	+ 3.068	+ 3	— .87	—1.58
183	4187	α¹ Crucis	1	19 39.5	+ 3.282	+ 68	— .76	—2.17
*184	4191	14 Comæ...............	5	20 08.9	+ 3.009	— 12	— .02	— .80
*185	4222	4 Draconis	5.5	24 37.5	+ 2.677	— 58	— .14	—1.02
186	4234	β Corvi	2.5	27 49.3	+ 3.132	+ 16	— .25	+ .41
187	4239	κ Draconis	3.5	28 08.3	+ 2.600	— 54	+1.41	+2.93
*188	4258	9 Canum Venaticorum .	6.5	32 45.2	+ 2.904	— 19	— .93	—1.42
189	4342	....	5.5	48 13.8	+ 0.361	+ 221	+1.72	+3.38
*190	4335	ε Ursæ Majoris	3	48 31.5	+ 2.661	— 273	+1.44	+3.96
191	4346	α Canum Venaticorum .	2.5	50 10.7	+ 2.817	— 15	— .34	—1.09
*192	4366	78 Ursæ Majoris	5	55 21.7	+ 2.592	— 25	— .65	—2.46
193	4401	θ Virginis	4.5	13 03 28.8	+ 3.101	+ 8	— .86	—2.12
194	4421	β Comæ...............	4.5	06 02.3	+ 2.807	— 8	— .27	—1.64
*195	4433	....	5	08 02.7	+ 2.730	— 14	— .13	—1.79
196	4480	α Virginis.............	1	18 36.6	+ 3.152	+ 11	— .14	— .68
197	4484	ζ¹ Ursæ Majoris	3	18 53.4	+ 2.421	— 17	— .07	— .07
*198	4506	....	6	22 56.7	+ 1.518	+ 7	— .01	— .67
*199	4513	....	6	24 56.6	+ 2.848	— 5	+ .22	+2.20
200	4532	ζ Virginis..............	4	28 19.5	+ 3.053	+ 6	—1.22	—2.79
*201	4540	81 Ursæ Majoris	5.5	29 18.9	+ 2.320	— 14	— .15	+1.02
*202	4596	....	6	40 55.1	+ 2.555	— 9	— .18	— .35
203	4607	η Ursæ Majoris	2.5	42 36.8	+ 2.374	— 10	— .20	— .75
204	4618	6 Bootis................	6	43 48.2	+ 2.840	— 2	— .08	—1.37
*205	4637	7 Bootis	6	47 14.6	+ 2.867	— 6	— .72	—2.67
206	4648	η Bootis................	3	48 41.0	+ 2.859	0	— .67	—1.59
*207	4659	....	6	50 29.3	— 0.011	+ 182	+ .06	+ .08
208	4669	β Centauri	1	51 01.1	+ 4.170	+ 84	— .14	—4.71
*209	4675	11 Bootis................	6	55 30.4	+ 2.724	— 3	— .08	— .53
210	4696	α Draconis	3.5	14 01 00.4	+ 1.623	+ 5	+ .21	— .11
211	4706	12 Bootis................	5.5	04 42.0	+ 2.739	— 2	— .40	—1.26
*212	4732	....	5	09 45.0	+ 1.098	+ 29	+ .34	+ .02
213	4729	α Bootis................	1	09 57.6	+ 2.735	+ 2	— .86	—2.04
214	4741	λ Bootis................	4	11 37.8	+ 2.284	— 5	— .26	— .68
215	4789	θ Bootis................	4	20 56.5	+ 2.043	— 1	— .18	— .32
*216	4801	24 Bootis................	6	24 16.9	+ 2.088	— 3	— .13	— .68
217	4808	ρ Bootis................	4	26 26.6	+ 2.587	— 2	— .33	—1.58
218	4812	γ Bootis................	3.5	27 02.6	+ 2.418	— 3	+ .30	—1.74
219	4822	5 Ursæ Minoris........	4	27 48.8	— 0.208	+ 121	+1.61	+3.59
*220	4827	....	6.5	29 31.8	+ 2.186	— 2	— .16	— .53
221	4832	α² Centauri	1	31 07.2	+ 4.029	+ 74	—1.13	—6.43
222	4864	34 Bootis................	4.5	37 55.7	+ 2.639	0	+ .21	— .31
223	4876	ε¹ Bootis................	3	39 31.7	+ 2.621	0	+ .30	+1.42
224	4895	α² Libræ	3	43 57.9	+ 3.309	+ 15	— .47	—1.86
*225	4897	....	6.5	44 12.3	+ 2.357	— 1	—1.16	—1.52

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
181	− 78 37 04.29	.22	2	− 19.9878	.0094	+ 323	+ 133	+ .0432
182	+ 0 01 40.75	.07	18	− 20.0472	.0032	+ 349	+ 100	− .0278
183	− 62 24 21.76	.25	1	− 20.0219	.0090	+ 495	+ 121	− .0417
*184	+ 27 57 38.99	.20	2	− 20.0038	.0056	+ 471	+ 94	− .0270
*185	+ 69 53 38.16	.14	4	− 20.0038	.0061	+ 505	+ 66	− .0652
186	− 22 42 18.75	.09	12	− 19.9725	.0039	+ 637	+ 105	− .0659
187	+ 70 28 38.85	.10	9	− 19.8980	.0031	+ 548	+ 61	+ .0053
*188	+ 41 33 45.55	.28	1	− 19.8729	.0066	+ 688	+ 84	− .0232
189	+ 84 05 32.73	.11	8	− 19.5990	.0042	+ 191	+ 69	+ .0128
*190	+ 56 38 18.77	.12	6	− 19.6318	.0042	+ 895	+ 64	− .0254
191	+ 38 59 37.72	.07	20	− 19.5274	.0027	+ 970	+ 76	+ .0481
*192	+ 57 02 25.55	.30	1	− 19.4966	.0098	+ 993	+ 60	− .0246
193	− 4 52 16.10	.07	16	− 19.3311	.0034	+ 1319	+ 100	− .0412
194	+ 28 30 44.08	.13	5	− 18.3458	.0044	+ 1220	+ 74	+ .8816
*195	+ 40 48 55.48	.37	1	− 19.1607	.0114	+ 1.49	+ 69	+ .0161
196	− 10 30 29.68	.06	26	− 18.9239	.0021	+ 1625	+ 103	− .0378
197	+ 55 34 43.01	.10	16	− 18.9095	.0031	+ 1281	+ 49	− .0317
*198	+ 73 02 27.83	.22	2	− 18.7748	.0083	+ 866	+ 20	− .0197
*199	+ 24 52 56.68	......	......	− 18.6925	....	+ 1585	+ 76	....
200	+ 0 02 38.03	.07	18	− 18.5432	.0031	+ 1743	+ 93	+ .0101
*201	+ 55 59 22.25	.24	2	− 18.5713	.0084	+ 1365	+ 41	− .0208
*202	+ 41 42 58.88	.34	1	− 18.1897	.0110	+ 1672	+ 56	− .0485
203	+ 49 56 15.80	.06	21	− 18.1020	.0021	+ 1570	+ 46	− .0245
204	+ 21 53 07.12	.24	2	− 18.0229	.0076	+ 1892	+ 74	+ .0093
*205	+ 18 32 58.49	.27	1	− 17.9231	.0062	+ 1965	+ 76	− .0247
206	+ 19 01 30.42	.07	21	− 18.2001	.0028	+ 1979	+ 75	− .3609
*207	+ 79 36 44.94	.23	2	− 17.7777	.0093	− 133	+ 124	− .0092
208	− 59 46 07.14	.23	2	− 17.6344	.0091	+ 2997	+ 218	− .0531
*209	+ 27 59 28.11	.16	4	− 17.5600	.0047	+ 1998	+ 65	+ .0007
210	+ 61 58 25.33	.07	17	− 17.3174	.0028	+ 1262	+ 27	+ .0059
211	+ 25 41 01.84	.25	1	− 17.2238	.0116	+ 2112	+ 6[illegible]	− .0656
*212	+ 70 01 10.40	.19	3	− 16.9961	.0081	+ 933	+ 33	− .0708
213	+ 19 50 02.58	.06	27	− 18.9148	.0020	+ 2151	+ 66	− 1.9994
214	+ 46 39 47.01	.13	6	− 16.6817	.0043	+ 1868	+ 41	+ .1548
215	+ 52 25 45.12	.09	11	− 16.7873	.0032	+ 1767	+ 34	− .4072
*216	+ 50 24 18.17	.24	2	− 16.2565	.0060	+ 1833	+ 33	− .0468
217	+ 30 55 15.53	.09	11	− 15.9845	.0040	+ 2313	+ 53	+ .1132
218	+ 38 51 21.11	.15	4	− 15.9247	.0041	+ 2170	+ 45	+ .1416
219	+ 76 15 06.01	.09	10	− 16.0100	.0031	− 108	+ 106	+ .0159
*220	+ 47 20 04.78	.36	1	− 15.9744	.0109	+ 2009	+ 37	− .0393
221	− 60 19 11.63	.23	2	− 15.4245	.0090	+ 3347	+ 176	+ .4257
222	+ 27 03 36.91	.25	1	− 15.4811	.0069	+ 2515	+ 55	− .0031
223	+ 27 36 07.83	.07	20	− 15.3787	.0028	+ 2515	+ 51	+ .0102
224	− 15 31 15.67	.07	21	− 15.2156	.0024	+ 3221	+ 100	− .0786
*225	+ 38 19 37.78	.25	1	− 15.0076	.0094	+ 2302	+ 41	+ .1158

Catalogue of 500 *stars*

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in c.	$\frac{d^2c}{dt^2}$	Δδ	Δμ'
				h. m. s.	s.	s.	″	″
*226	4918	....	5.5	14 48 16.1	+ 1.517	+ 9	− .69	−2.51
227	4936	β Ursæ Minoris	3	51 05.4	− 0.246	+ 103	+ .39	+1.54
*228	4937	....	6	52 14.1	+ 1.984	+ 1	− .05	−1.48
229	4958	β Bootis...............	3	57 14.2	+ 2.260	0	− .27	− .73
*230	4974	44² Bootis..............	5	59 40.3	+ 1.979	+ 1	− .05	− .64
*231	5026	....	6	15 08 50.0	+ 2.284	+ 1	− .47	−1.13
232	5024	3 Serpentis............	6	08 58.7	+ 2.979	+ 7	− .18	− .46
233	5031	β Libræ................	2.5	10 16.9	+ 3.220	+ 12	− .24	− .49
234	5 71	....	6	16 24.7	+ 1.759	+ 5	− .51	−2.10
235	5084	μ¹ Bootis..............	4	19 46.2	+ 2.268	+ 1	− .56	−1.06
236	5094	γ² Ursæ Minoris........	3.5	20 56.5	− 0.144	+ 75	− .51	−1.03
*237	5097	ι Draconis	3	22 09.1	+ 1.325	+ 14	+ 00	− .53
238	5098	β Coronæ Borealis	4	22 40.6	+ 2.476	+ 2	+ .34	− .65
*239	5115	....	6	25 2[illegible].9	+ 1.179	+ 17	+ .38	+1.51
240	5122	ν¹ Bootis..............	5.5	26 26.4	+ 2.153	+ 2	+ .03	− .20
241	5130	ν² Bootis..............	5.5	27 18.6	+ 2.145	+ 2	+ .58	− .03
242	5131	θ Coronæ Borealis	4.5	27 53.4	+ 2.411	+ 2	− .22	−2.17
243	5143	α Coronæ Borealis	2.5	29 23.8	+ 2.539	+ 2	− .37	− .77
244	5157	....	6	30 52.9	+ 2.056	+ 3	− .21	− .59
245	5168	φ Bootis...............	5.5	33 20.3	+ 2.154	+ 2	−1.08	−2.50
*246	5178	ζ Coronæ Borealis	5	15 34 40.3	+ 2.257	+ 2	− .19	− .18
247	5192	γ Coronæ Borealis	5	37 29.7	+ 2.518	+ 3	+ .26	−3.96
248	5196	α Serpentis............	2.5	38 06.7	+ 2.951	+ 6	− .20	− .71
249	5216	β Serpentis............	3.5	40 21.9	+ 2.765	+ 4	+1.01	−1.77
250	5245	ε Serpentis............	3	44 35.2	+ 2.987	+ 7	− .66	−1.19
*251	5271	γ Herculis.............	6	48 21.2	+ 2.071	+ 2	+1.06	+2.99
252	5285	ζ Ursæ Minoris	4	48 33.9	− 2.281	+ 203	− .11	+ .14
253	5298	4 Herculis	6	51 18.2	+ 2.019	+ 4	− .21	−1.07
254	5302	ε Coronæ Borealis	4.5	52 24.9	+ 2.485	+ 3	−1.59	−2.75
255	5303	δ Scorpii	3	52 56.6	+ 3.537	+ 16	− .24	−2.65
*256	5313	....	5.5	54 49.4	+ 1.410	+ 10	+ .28	+1.32
257	5329	β¹ Scorpii	2	58 10.2	+ 3.477	+ 14	− .16	−5.80
258	5341	....	5.5	58 54.2	+ 1.525	+ 9	+ .72	+1.60
259	5348	θ Draconis	3	59 33.0	+ 1.119	+ 14	+ .27	+ .68
260	5388	φ Herculis	5	16 04 49.9	+ 1.884	+ 5	+ .07	− .40
261	5406	....	5	05 59.1	+ 0.134	+ 40	+ .18	− .10
*262	5415	....	6	06 36.1	+ 1.170	+ 14	− .32	−2.70
263	5414	δ Ophiuchi.............	3	07 47.8	+ 3.138	+ 8	− .25	+ .16
264	5426	16 Herculis	6.5	09 56.3	+ 2.655	+ 4	+ .07	−2.11
*265	5460	....	6	15 38.1	+ 2.048	+ 4	+ .69	+1.90
266	5463	τ Herculis.............	4	15 58.9	+ 1.798	+ 5	− .35	− .34
267	5466	γ² Herculis............	3.5	16 21.4	+ 2.644	+ 4	− .08	− .80
268	5473	ξ Coronæ	5	17 13.7	+ 2.343	+ 3	− .28	−1.64
269	5484	23 Herculis............	6	18 08.6	+ 2.302	+ 3	+ .12	−1.32
*270	5502	....	5	21 41.5	+ 1.309	+ 10	+1.15	+3.46

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
*226	+ 59 48 09.67	.25	1	— 14.7446	.0082	+ 1531	+ 25	+ .1429
227	+ 74 39 58.82	.06	23	— 14.7165	.0021	— 187	+ 103	+ .0044
*228	+ 50 08 25.11	.25	1	— 14.8935	.0083	+ 2043	+ 30	— .2408
229	+ 40 53 04.27	.08	14	— 14.3957	.0035	+ 2359	+ 37	— .0453
*230	+ 48 08 30.91	.23	2	— 14.1601	.0065	+ 2057	+ 28	+ .0406
*231	+ 38 44 02.28	.27	1	— 13.6428	.0114	+ 2504	+ 36	— .0193
232	+ 5 24 17.12	.23	2	— 13.6369	.0075	+ 3249	+ 68	— .0226
233	— 8 55 13.00	.07	20	— 13.5611	.0029	+ 3518	+ 84	— .0309
234	+ 52 24 33.59	.33	1	— 13.1505	.017	+ 1996	+ 25	— .021
235	+ 37 48 59.73	.10	9	— 12.8177	.0033	+ 2575	+ 34	+ .0884
236	+ 72 16 43.62	.08	14	— 12.8097	.0021	— 107	+ 84	+ .0177
*237	+ 59 24 16.68	.09	13	— 12.7252	.0042	+ 1547	+ 26	+ .0207
238	+ 29 32 15.34	.19	3	— 12.6428	.0057	+ 2836	+ 41	+ .0675
*239	+ 61 06 07.12	.31	1	— 12.5392	.0103	+ 1397	+ 28	— .0129
240	+ 41 15 36.63	.24	2	— 12.4559	.0081	+ 2515	+ 31	— .0020
241	+ 41 19 28.32	.24	2	— 12.4035	.0070	+ 2509	+ 30	— .0093
242	+ 31 46 55.88	.26	1	— 12.3759	.0090	+ 2820	+ 39	— .0217
243	+ 27 08 11.55	.06	25	— 12.3498	.0021	+ 2995	+ 42	— .0997
244	+ 43 34 56.59	.23	2	— 12.1038	.0095	+ 2433	+ 28	+ .0431
245	+ 40 45 41.21	.23	2	— 11.9172	.0065	+ 2577	+ 30	+ .0580
*246	+ 37 02 33.81	.20	2	— 11.8762	.0067	+ 2700	+ 32	+ .0052
247	+ 26 41 33.66	.19	3	— 11.6641	.0054	+ 3027	+ 40	+ .0174
248	+ 6 49 12.87	.06	24	— 11.6037	.0022	+ 3565	+ 58	+ .0339
249	+ 15 48 52.01	.19	3	— 11.5206	.0052	+ 3360	+ 49	— .0177
250	+ 4 51 19.62	.10	10	— 11.1035	.0039	+ 3677	+ 58	+ .0681
*251	+ 42 48 08.07	.26	1	— 10.2901	.0063	+ 2629	+ 24	+ .6159
252	+ 78 10 40.77	.07	18	— 10.8824	.0024	— 2731	+ 280	— .0016
253	+ 42 55 49.89	.34	1	— 10.6895	.0099	+ 2539	+ 25	— .0107
254	+ 27 14 27.75	.15	4	— 10.6578	.0053	+ 3120	+ 36	— .0615
255	— 22 15 50.64	.10	9	— 10.5934	.0046	+ 4429	+ 82	— .0365
*256	+ 55 06 13.04	.22	2	— 10.3006	.0089	+ 1772	+ 21	— .1162
257	— 19 27 41.36	.08	16	— 10.2034	.0032	+ 4413	+ 75	— .0380
258	+ 53 15 49.12	.59	......	— 10.0441	.016	+ 1961	+ 21	— .034
259	+ 58 53 58.60	.11	8	— 9.7203	.0030	+ 1408	+ 22	— .3108
260	+ 45 15 48.77	.16	3	— 9.6258	.0051	+ 2443	+ 22	— .0330
261	+ 68 08 22.63	.16	3	— 9.5012	.0065	+ 204	+ 52	+ .0690
*262	+ 58 15 50.87	.35	1	— 9.4827	.023	+ 1542	+ 23	+ .040
263	— 3 22 14.98	.07	17	— 9.5740	.0032	+ 4075	+ 56	— .1434
264	+ 19 07 29.87	.23	2	— 9.3579	.0113	+ 3466	+ 37	— .0931
*265	+ 40 00 31.66	.49	......	— 8.8149	.014	+ 2699	+ 22	+ .005
266	+ 46 36 42.79	.10	9	— 8.7700	.0037	+ 2391	+ 20	+ .0226
267	+ 19 26 53.32	.13	6	— 8.7062	.0043	+ 3502	+ 31	+ .0530
268	+ 31 10 59.72	.20	2	— 8.5928	.0065	+ 3116	+ 26	+ .1016
269	+ 32 37 33.02	.22	2	— 8.6424	.0076	+ 3072	+ 26	+ .0032
*270	+ 55 29 24.26	.25	1	— 8.3192	.0090	+ 1765	+ 20	+ .0216

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	Δδ	Δμ′
				h. m. s.	s.	s.	″	″
271	5498	α Scorpii	1	15 21 44.7	+ 3.668	+ 15	— .18	— .67
272	5512	η Draconis	3	22 18.2	+ 0.805	+ 18	+ .06	— .54
*273	5523	30 Herculis	5	24 32.3	+ 1.968	+ 4	—1.35	—3.74
274	5520	λ Ophiuchi	4	24 36.6	+ 3.024	+ 6	— .07	—1.42
275	5535	34 Herculis	6.5	26 40.2	+ 1.644	+ 6	+ .75	+1.28
*276	5545	15 Draconis	4.5	28 14.3	— 0.141	+ 41	.00	— .41
277	5541	32 Herculis	6	28 37.0	+ 2.332	+ 3	+ .65	— .47
278	5552	σ Herculis	4	30 04.5	+ 1.932	+ 4	— .05	+ .40
279	5548	ζ Ophiuchi	3.5	30 16.6	+ 3.298	+ 9	—1.65	—2.58
280	5568	....	6	32 32.4	+ 1.741	+ 5	+ .93	+1.16
281	5596	42 Herculis	5	16 35 21.4	+ 1.625	+ 6	+ .27	— .41
282	5578	α Trianguli Aust.	2	35 26.9	+ 6.287	+ 91	— .09	—1.63
283	5604	ζ Herculis	3	36 34.5	+ 2.263	+ 3	— .14	— .10
284	5617	η Herculis	3	38 36.7	+ 2.055	+ 4	—1.44	—2.63
*285	5624	46 Herculis	7	40 06.7	+ 2.385	+ 3	+ .20	+1.11
286	5643	....	5	42 55.7	+ 1.134	+ 10	— .21	—1.85
*287	5644	....	6	43 19.8	+ 1.914	+ 4	— .23	— .60
*288	5658	....	6	44 17.8	+ 1.237	+ 10	+ .09	+ .84
*289	5693	53 Herculis	5	48 13.6	+ 2.269	+ 3	.00	—1.00
290	5706	....	6	50 43.9	+ 1.721	+ 5	—1.38	—4.12
291	5708	κ Ophiuchi	4	51 45.1	+ 2.835	+ 4	— .21	— .86
292	5731	ε Herculis	3	55 30.5	+ 2.293	+ 3	— .34	—2.15
293	5747	59 Herculis	5	56 59.3	+ 2.209	+ 3	—1.49	—2.89
294	5780	ε Ursæ Minoris	4	58 50.9	— 6.376	+ 307	+ .02	— .59
295	5776	....	6	17 01 31.0	+ 1.594	+ 6	— .01	+2.89
296	5778	η Scorpii	3.5	03 12.1	+ 4.286	+ 17	— .25	+ .57
297	5801	....	6	05 23.9	+ 1.151	+ 8	+ .90	+3.90
*298	5823	ζ Draconis	3	08 25.7	+ 0.162	+ 19	— .02	+ .28
299	5821	α¹ Herculis	3.5	08 56.9	+ 2.733	+ 3	+ .13	— .26
300	5834	π Herculis	3.5	10 41.6	+ 2.087	+ 3	— .06	— .87
301	5847	69 Herculis	4.5	13 21.6	+ 2.036	+ 3	— .68	—3.69
*302	5853	....	6	13 37.8	+ 1.527	+ 5	— .56	—4.18
303	5874	....	6	17 37.6	+ 1.968	+ 4	— .29	+ .93
304	5876	41 Ophiuchi	5	18 44.2	+ 3.657	+ 7	— .55	—1.11
305	5886	ρ² Herculis	4	19 22.2	+ 2.070	+ 3	— .10	—1.02
*306	5911	77 Herculis	5.5	23 25.4	+ 1.586	+ 4	— .30	+ .01
307	5918	....	6	24 12.5	+ 0.895	+ 8	+ .50	+1.99
308	5937	β Draconis	2.5	27 36.5	+ 1.351	+ 5	+ .05	— .06
309	5941	α Ophiuchi	2	29 08.0	+ 2.782	+ 3	— .22	—1.11
310	5997	....	6	36 50.6	+ 1.815	+ 3	+ .57	.00
311	6006	ω Draconis	4	37 41.1	— 0.355	+ 11	+ .46	+1.97
312	6021	μ Herculis	4	41 34.0	+ 2.315	+ 4	— .40	—1.49
313	6033	87 Herculis	6	43 45.0	+ 2.430	+ 3	— .13	—1.17
314	6036	....	7	43 46.7	+ 1.613	+ 3	+ .19	+1.30
*315	6047	ψ¹ Draconis	4.5	44 09.9	— 1.082	+ 2	+ .08	— .41

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
271	− 26 09 09.18	.09	11	− 8.3734	.0041	+ 4900	+ 71	− .0367
272	+ 61 47 51.11	.07	17	− 8.2376	.0026	+ 1107	+ 26	+ .0546
*273	+ 42 09 28.15	.27	1	− 8.1111	.0083	+ 2656	+ 20	+ .0026
274	+ 2 15 32.64	.11	8	− 8.2062	.0043	+ 4068	+ 44	− .0982
275	+ 49 14 02.15	.43	......	− 8.0040	.0109	+ 2230	+ 18	− .0612
*276	+ 69 02 18.29	.13	6	− 7.7958	.0047	− 157	+ 55	+ .0209
277	+ 30 45 45.25	.20	2	− 7.7908	.0106	+ 3158	+ 24	− .0047
278	+ 42 41 45.08	.12	6	− 7.6334	.0041	+ 2637	+ 19	+ .0350
279	− 10 11 43.56	.11	8	− 7.6308	.0047	+ 4480	+ 52	+ .0212
280	+ 46 52 01.93	.40	1	− 7.4570	.0116	+ 2379	+ 17	+ .0116
281	+ 49 10 25.01	.19	2	− 7.2184	.0052	+ 2335	+ 17	+ .0209
282	− 68 47 39.59	.22	2	− 7.2882	.0094	+ 8585	+ 268	− .0563
283	+ 31 49 49.47	.08	15	− 6.7387	.0032	+ 3068	+ 20	+ .4010
284	+ 39 09 39.91	.10	9	− 7.0633	.0030	+ 2844	+ 19	− .0903
*285	+ 28 35 15.28	.30	1	− 6.8077	.0087	+ 3302	+ 22	+ .0421
286	+ 57 00 20.98	.16	4	− 6.5672	.0103	+ 1596	+ 17	+ .0505
*287	+ 42 27 45.06	.29	1	− 6.6194	.0104	+ 2668	+ 16	− .0350
*288	+ 55 37 54.61	.29	1	− 6.5260	.0122	+ 1751	+ 17	− .0216
*289	+ 31 54 35.34	.19	2	− 6.2002	.0056	+ 3159	+ 19	− .0220
290	+ 46 44 31.22	.34	1	− 6.0105	.0131	+ 2428	+ 14	− .0412
291	+ 9 34 15.45	.07	19	− 5.8897	.0032	+ 3947	+ 27	− .0056
292	+ 31 06 42.18	.10	9	− 5.5476	.0042	+ 3230	+ 17	+ .0215
293	+ 33 45 01.75	.15	4	− 5.4424	.0058	+ 3120	+ 16	+ .0021
294	+ 82 14 22.49	.07	18	− 5.2906	.0028	− 8926	+ 552	− .0029
295	+ 48 58 37.19	.30	1	− 5.1532	.0113	+ 2285	+ 13	− .0911
296	− 43 04 17.25	.29	1	− 5.1936	.0109	+ 6083	+ 63	− .2743
297	+ 55 55 38.90	.48	......	− 4.6937	.014	+ 1652	+ 14	+ .039
*298	+ 65 52 06.96	.11	7	− 4.4578	.0039	+ 251	+ 27	+ .0168
299	+ 14 32 03.76	.06	23	− 4.4039	.0022	+ 3905	+ 19	+ .0264
300	+ 36 57 03.65	.11	7	− 4.2959	.0050	+ 2987	+ 12	− .0147
301	+ 37 25 24.62	.18	3	− 4.0069	.0049	+ 2920	+ 11	+ .0461
*302	+ 49 49 33.75	.30	1	− 4.0157	.0123	+ 2190	+ 10	+ .0142
303	+ 40 05 54.51	.26	1	− 3.7564	.0100	+ 2840	+ 10	− .0697
304	− 24 03 29.05	.13	6	− 3.7222	.0060	+ 5260	+ 27	− .1311
305	+ 37 15 43.15	.11	7	− 3.5458	.0042	+ 2985	+ 10	− .0092
*306	+ 48 21 56.68	.18	3	− 3.2029	.0058	+ 2299	+ 9	− .0159
307	+ 58 45 24.50	.25	1	− 3.0992	.0110	+ 1303	+ 12	+ .0199
308	+ 52 23 40.57	.07	17	− 2.8255	.0025	+ 1959	+ 8	− .0006
309	+ 12 39 09.44	.06	24	− 2.9299	.0022	+ 4041	+ 12	− .2371
310	+ 43 31 58.67	......	......	− 1.9728	....	+ 2650	+ 6	+ .050
311	+ 68 48 55.74	.11	7	− 1.6258	.0041	− 499	+ 14	+ .3237
312	+ 27 47 42.17	.07	20	− 2.3701	.0031	+ 3380	+ 8	− .7589
313	+ 25 39 56.97	.18	3	− 1.4703	.0057	+ 3538	+ 5	− .0497
314	+ 47 39 22.19	.41	1	− 1.4053	.014	+ 2358	+ 5	+ .013
*315	+ 72 12 34.25	.11	7	− 1.6576	.0040	− 1565	+ 30	− .2731

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	Δδ	Δμ′
				h. m. s.	s.	s.	″	″
316	6056	88 Herculis	6	17 46 47.1	+ 1.567	+ 3	− .05	−1.39
*317	6073	89 Herculis	5.5	50 22.7	+ 2.420	+ 2	− .20	− .96
318	6079	ξ Draconis	3.5	51 22.1	+ 1.036	+ 4	+1.05	+1.02
319	6082	θ Herculis	4	51 57.9	+ 2.053	+ 2	− .47	−1.83
320	6091	γ Draconis	2	55 42.4	+ 1.394	+ 3	+ .04	+ .28
*321	6114	35 Draconis	5	55 02.6	− 2.696	+ 6	+ .24	+ .84
322	6115	γ² Sagittarii	4	57 46.7	+ 3.852	+ 2	+ .07	+ .15
323	6150	o Herculis	4	02 40.0	+ 2.338	+ 2	+ .43	− .86
*324	6157	102 Herculis	5.5	03 24.7	+ 2.560	+ 2	− .41	−1.69
325	6168	μ Sagittarii	3.5	06 17.2	+ 3.584	+ 1	− .38	− .18
*326	6206	40 Draconis	5	18 09 23.4	− 4.470	− 26	+ .59	+3.24
327	6216	....	6	12 30.0	+ 1.062	+ 1	+ .46	+1.50
328	6281	δ Ursæ Minoris	3	12 39.3	− 19.420	− 385	+ .17	+ .66
329	6229	η Serpentis	4	14 50.5	+ 3.100	+ 2	+ .12	− .22
330	5959	σ Octantis	6	15 28.5	+109.058	−11035	+ .08	− .76
*331	6245	....	6	17 17.6	+ 2.645	+ 2	+ .55	+1.70
*332	6268	μ Lyræ	5.5	20 06.8	+ 1.974	+ 2	− .65	−1.22
*333	6289	39 Draconis	5	22 04.9	+ 0.874	0	− .18	+ .22
334	6302	χ Draconis	4.5	23 18.6	− 1.075	− 9	− .15	−1.56
*335	6318	....	6	25 58.8	+ 0.820	− 1	+ .38	+1.61
336	6325	1 Aquilæ	5.5	28 24.3	+ 3.272	0	+ .05	− .82
337	6355	α Lyræ	1	32 42.4	+ 2.031	+ 1	00	−1.16
*338	6365	....	6	35 58.1	+ 2.036	+ 2	− .12	− .48
339	6390	ε¹ Lyræ	5	40 11.9	+ 1.986	+ 1	− .76	− .64
340	6387	110 Herculis	5	40 17.0	+ 2.582	+ 2	+ .08	+ .65
341	6397	111 Herculis	5.5	41 30.1	+ 2.649	+ 1	+ .03	−1.29
*342	6421	....	6	44 16.0	+ 1.547	0	+ .35	+2.08
343	6429	β Lyræ	3	45 27.9	+ 2.214	+ 1	− .53	−2.51
344	6440	σ Sagittarii	3	47 30.8	+ 3.723	− 5	− .03	+ .28
345	6463	o Draconis	5	49 21.4	+ 0.887	− 4	00	− .62
346	6478	50 Draconis	5	50 23.6	− 1.901	− 55	+1.18	+1.65
*347	6476	....	6	51 29.3	+ 1.580	0	+1.45	+1.54
348	6487	ε Aquilæ	3.5	53 57.0	+ 2.721	+ 1	− .05	+ .74
349	6491	γ Lyræ	3	54 16.0	+ 2.242	+ 1	− .50	−1.38
350	6526	λ Aquilæ	3	59 36.9	+ 3.184	− 2	− .16	− .57
351	6528	ζ Aquilæ	3	18 59 39.8	+ 2.755	0	− .08	−1.03
*352	6553	17 Lyræ	6	19 02 42.0	+ 2.266	+ 4	− .12	− .42
*353	6586	55 Draconis	6	09 17.7	+ 0.238	− 17	+ .24	+ .56
354	6584	43 Sagittarii	5	10 19.2	+ 3.514	− 6	−3.50	−5.74
355	6585	22 Aquilæ	6	10 19.9	+ 2.969	− 1	− .73	−1.78
356	6612	δ Draconis	3	12 31.3	+ 0.033	− 23	+ .25	+ .74
357	6623	κ Cygni	4	11 12.8	+ 1.388	− 3	− .14	+ .40
*358	6624	....	6	11 47.4	+ 2.005	− 1	− .04	+ .60
359	6650	τ Draconis	4.5	17 56.7	− 1.108	− 58	+ .70	+1.06
360	6646	δ Aquilæ	3.5	19 11.7	+ 3.024	− 2	+ .11	+ .03

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
316	+ 48 25 43.42	.22	2	— 1.1526	.0063	+ 2287	+ 4	+ .0031
*317	+ 26 04 16.59	.14	5	— 0.8413	.0065	+ 3528	+ 3	+ .0004
318	+ 56 53 34.27	.16	4	— 0.6840	.0048	+ 1530	+ 4	+ .0712
319	+ 37 16 05.73	.23	2	— 0.6902	.0060	+ 2992	+ 3	+ .0127
320	+ 51 30 15.44	.07	20	— 0.5808	.0023	+ 2037	+ 4	— .0302
*321	+ 76 58 40.25	.18	3	— 0.1901	.0052	— 3913	+ 14	+ .2431
322	— 30 25 23.53	.18	3	— 0.4128	.0086	+ 5612	0	— .2185
323	+ 28 44 47.53	.21	2	+ 0.2247	.0064	+ 3408	0	— .0086
*324	+ 20 47 45.96	.25	1	+ 0.2617	.0076	+ 3738	— 1	— .0369
325	— 21 05 21.58	.08	14	+ 0.5383	.0036	+ 5216	— 7	— .0118
*326	+ 79 58 54.77	.21	2	+ 0.9408	.0062	— 6486	— 44	+ .1194
327	+ 56 32 47.26	.54	......	+ 1.1722	.015	+ 1556	0	+ .079
328	+ 86 36 27.58	.06	24	+ 1.1574	.0020	— 28244	— 768	+ .0506
329	— 2 55 45.52	.10	9	+ 0.6245	.0012	+ 4448	— 7	— .6732
330	— 89 16 38.77	.15	4	+ 1.3297	.0067	+159005	—24722	— .0236
*331	+ 17 45 53.82	.39	1	+ 1.4948	.022	+ 3840	— 7	— .017
*332	+ 39 26 24.24	.22	2	+ 1.7474	.0054	+ 2864	— 3	— .0102
*333	+ 58 43 43.56	.23	2	+ 1.9835	.0064	+ 1250	— 2	+ .0542
334	+ 72 40 40.95	.12	6	+ 1.6566	.0037	— 1401	— 9	— .3796
*335	+ 59 27 58.88	.21	2	+ 2.3026	.0089	+ 1179	— 4	+ .0341
336	— 8 19 46.61	.11	8	+ 2.1489	.0040	+ 4733	— 18	— .3302
337	+ 38 40 06.16	.06	26	+ 3.1246	.0020	+ 2946	— 8	+ .2721
*338	+ 38 15 07.25	.25	1	+ 3.1376	.0094	+ 2912	— 7	+ .0032
339	+ 39 32 24.90	.12	6	+ 3.5520	.0039	+ 2836	— 8	+ .0526
340	+ 20 25 41.18	.18	3	+ 3.1592	.0054	+ 3692	— 13	— .3475
341	+ 18 02 37.70	.21	2	+ 3.7118	.0060	+ 3791	— 15	+ .1001
*342	+ 49 17 39.20	.30	1	+ 3.8772	.0109	+ 2198	— 6	+ .0278
343	+ 33 13 07.21	.06	22	+ 3.9352	.0025	+ 3150	— 11	— .0171
344	— 26 26 59.03	.12	7	+ 4.0506	.0049	+ 5296	— 42	— .0772
345	+ 59 14 09.28	.12	7	+ 4.2994	.0036	+ 1257	— 9	+ .0138
346	+ 75 17 07.67	.12	6	+ 4.4487	.0059	— 2730	— 86	+ .0745
*347	+ 48 42 14.32	.56	......	+ 4.3480	.0131	+ 2216	— 8	— .1196
348	+ 14 54 00.16	.13	5	+ 4.5926	.0045	+ 3831	— 21	— .0846
349	+ 32 31 09.33	.11	7	+ 4.6905	.0041	+ 3157	— 13	— .0138
350	— 5 04 05.79	.10	9	+ 5.0622	.0041	+ 4462	— 34	— .0957
351	+ 13 40 45.01	.07	20	+ 5.0587	.0030	+ 3856	— 23	— .1033
*352	+ 32 18 21.38	.23	2	+ 5.4360	.0064	+ 3170	— 16	+ .0178
*353	+ 65 46 10.12	.19	2	+ 5.9941	.0072	+ 303	— 24	+ .0226
354	— 19 10 24.10	.12	6	+ 6.0397	.0045	+ 4855	— 52	— .0174
355	+ 4 36 57.77	.41	1	+ 6.0443	.0079	+ 4102	— 33	— .0138
356	+ 67 26 30.05	.08	16	+ 6.3259	.0025	+ 45	— 32	+ .0854
357	+ 53 08 18.45	.11	8	+ 6.4911	.0035	+ 1901	— 12	+ .1100
*358	+ 40 07 51.59	......	......	+ 6.4379	....	+ 2742	— 17	+ .009
359	+ 73 07 22.06	.14	5	+ 6.7984	.0051	— 1589	— 82	+ .1086
360	+ 2 52 01.79	.07	19	+ 6.8691	.0028	+ 4142	— 39	+ .0763

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in a.	$\frac{d^2a}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	s.	s.	"	"
361	6657	....	5.5	19 20 15.4	+ 2.480	+ 2	— .33	—1.65
362	6661	5 Vulpeculæ...........	6.5	20 45.9	+ 2.619	+ 1	+ .03	—2.04
*363	6681	....	6.5	23 31.2	+ 1.090	— 6	— .07	+ .75
364	6690	β Cygni................	3	25 40.8	+ 2.417	+ 1	+ .06	— .04
365	6697	ι^2 Cygni................	5	26 33.3	+ 1.514	— 2	+ .08	+ .55
396	6698	8 Cygni	6	27 08.3	+ 2.234	+ 1	— .10	—1.33
367	6713	κ Aquilæ...............	4	30 10.0	+ 3.230	— 4	—1.92	—2.12
*368	6728	....	5.5	32 33.9	+ 1.910	0	+ .62	+1.70
369	6734	θ Cygni................	4	33 05.4	+ 1.609	— 2	— .08	+1.15
*370	6748	....	5	35 52.7	+ 1.356	— 4	+ .17	+1.90
371	6758	10 Vulpeculæ...........	6	38 31.1	+ 2.493	+ 1	— .13	—1.45
372	6772	γ Aquilæ...............	3	40 19.0	+ 2.852	— 1	— .08	— .34
*373	6780	....	5	40 48.6	+ 1.178	— 7	— .48	— .57
374	6779	δ Cygni	3.5	41 04.1	+ 1.876	0	— .10	—1.12
375	6802	α Aquilæ	1.5	44 41.1	+ 2.928	— 2	+ .14	+ .31
*376	6817	....	5	46 20.0	+ 2.062	+ 1	— .10	+ .05
*377	6830	....	6	48 26.2	+ 1.763	0	— .56	— .68
378	6836	ε Draconis	5.5	48 35.1	— 0.173	— 44	+1.40	+3.11
379	6833	β Aquilæ...............	3.5	49 10.4	+ 2.947	— 1	— .34	— .89
380	6999	λ Ursæ Minoris	(5)	49 17.8	—60.647	—29716	+ .57	+1.46
381	6856	ψ Cygni................	5.5	52 23.9	+ 1.554	— 2	+ .20	+3.19
*382	6865	....	6	53 19.9	+ 1.639	— 2	+ .40	+1.50
383	6879	15 Vulpeculæ...........	5	55 57.2	+ 2.468	+ 1	—2.01	—5.04
384	6893	τ Aquilæ...............	5.5	58 02.0	+ 2.933	— 2	—1.33	—1.14
*385	6937	28 Cygni	5	20 04 47.2	+ 2.226	+ 2	—1.14	—2.53
*386	6970	68 Draconis	6	09 31.9	+ 0.992	— 14	+ .51	+2.09
387	6965	o^2 Cygni................	4	09 41.8	+ 1.889	0	— .17	+ .17
388	6974	α^2 Capricorni...........	3	11 07.0	+ 3.331	— 8	— .23	+ .03
389	7005	κ Cephei	4.5	13 03.7	— 1.899	— 165	+1.28	+2.93
390	7004	α Pavonis	2	15 44.7	+ 4.787	— 59	— .33	—4.02
*391	7024	71 Draconis	6.5	17 31.3	+ 1.014	— 14	+ .36	+ .61
392	7022	γ Cygni	3	17 44.5	+ 2.152	+ 2	— .16	—1.89
393	7031	π Capricorni	5	20 09.9	+ 3.411	— 11	—1.25	+1.27
394	7061	40 Cygni	6	22 56.4	+ 2.221	+ 2	— .67	—2.41
*395	7073	42 Cygni	6	24 34.4	+ 2.287	+ 2	— .13	+1.04
396	7088	ε Delphini	4	27 14.4	+ 2.866	— 1	— .43	— .19
397	7098	θ Cephei	5	27 28.8	+ 1.016	— 15	+ .20	+ .29
*398	7100	....	6	28 31.3	+ 2.086	+ 2	— .06	.00
399	7124	....	5.5	30 31.9	— 0.210	— 67	— .33	+ .21
400	7121	β Delphini	4	31 41.2	+ 2.811	0	— .23	—1.41
401	7140	29 Vulpeculæ...........	5.5	32 56.3	+ 2.676	+ 1	+ .44	— .88
402	7149	α Delphini	3.5	33 50.0	+ 2.789	0	— .05	— .18
*403	7166	....	6	35 46.3	+ 1.560	— 3	— .17	+ .07
404	7171	α Cygni................	1	37 10.3	+ 2.041	+ 2	— .25	— .94
405	7173	δ Delphini	4	37 37.4	+ 2.800	0	— .33	—1.81

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
361	+ 24 41 17.62	.21	2	+ 6.9286	.0057	+ 3348	— 22	— .6515
362	+ 19 51 03.13	.25	1	+ 6.8874	.0061	+ 3555	— 27	— .0341
*363	+ 57 46 32.43	.40	1	+ 7.1371	.0103	+ 1455	— 15	— .0105
364	+ 27 41 54.06	.09	11	+ 7.3094	.0038	+ 3247	— 24	— .0144
365	+ 51 27 51.12	.12	7	+ 7.5195	.0033	+ 2024	— 14	+ .1245
366	+ 34 11 17.40	.17	3	+ 7.4381	.0068	+ 3001	— 21	— .0043
367	— 7 18 13.08	.10	9	+ 7.6886	.0044	+ 4317	— 52	+ .0008
*368	+ 43 25 38.73	......	......	+ 7.9023	....	+ 2526	— 17	+ .021
369	+ 49 55 56.67	.11	8	+ 8.1709	.0034	+ 2122	— 16	+ .2475
*370	+ 54 40 52.85	.35	1	+ 8.3070	.017	+ 1783	— 15	+ .169
371	+ 25 28 26.27	.19	2	+ 8.3641	.0057	+ 3269	— 29	+ .0965
372	+ 10 18 36.31	.06	25	+ 8.4920	.0021	+ 3732	— 41	— .0084
*373	+ 57 43 08.02	.28	1	+ 8.4776	.0 06	+ 1545	— 17	— .0617
374	+ 44 49 35.66	.12	6	+ 8.5908	.0044	+ 2444	— 18	+ .0308
375	+ 8 32 22.75	.06	27	+ 9.2151	.0020	+ 3841	— 46	+ .3704
*376	+ 40 16 56.92	.41	1	+ 8.9377	.0132	+ 2647	— 21	— .0365
*377	+ 47 36 34.95	.24	2	+ 9.1196	.0095	+ 2256	— 18	— .0188
378	+ 69 56 58.38	.12	7	+ 9.1772	.0041	— 245	— 56	+ .0271
379	+ 6 05 45.45	.06	24	+ 8.7049	.0021	+ 3783	— 46	— .4909
380	+ 88 55 51.48	.06	22	+ 9.2170	.0026	—78715	—56385	+ 0116
381	+ 52 06 28.04	.13	5	+ 9.4175	.0047	+ 1955	— 17	— .0281
*382	+ 50 34 02.65	.56	......	+ 9.5436	.015	+ 2066	— 18	+ .026
383	+ 27 24 32.89	.24	2	+ 9.7185	.0067	+ 3110	— 33	— .0004
384	+ 6 55 35.57	.15	4	+ 9.8854	.0064	+ 3681	— 51	+ .0076
*385	+ 36 28 21.23	.22	2	+ 10.3933	.0067	+ 2733	— 28	+ .0057
*386	+ 61 42 01.60	.26	1	+ 10.8185	.0076	+ 1196	— 24	+ .0779
387	+ 46 21 46.84	.12	7	+ 10.7551	.0042	+ 2279	— 22	+ .0027
388	— 12 55 50.43	.07	19	+ 10.8577	.0025	+ 4039	— 77	+ .0003
389	+ 77 20 02.43	.10	9	+ 11.0284	.0038	— 2360	— 220	+ .0283
390	— 57 07 59.13	.24	2	+ 11.1055	.0100	+ 5741	— 212	— .0902
*391	+ 61 51 39.15	.37	1	+ 11.3494	.0094	+ 1166	— 24	+ .0251
392	+ 39 51 26.82	.09	12	+ 11.3333	.0026	+ 2539	— 28	— .0069
393	— 18 37 11.65	.11	7	+ 11.4971	.0041	+ 4060	— 89	— .0173
394	+ 38 01 50.23	.18	3	+ 11.6783	.0070	+ 2576	— 30	— .0541
*395	+ 36 02 18.19	.19	2	+ 11.8195	.0072	+ 2612	— 32	— .0086
396	+ 10 52 47.17	.08	15	+ 11.9939	.0024	+ 3294	— 56	— .0219
397	+ 62 31 27.40	.12	6	+ 12.0075	.0038	+ 1138	— 25	— .0251
*398	+ 42 46 00.62	......	......	+ 12.1784	....	+ 2374	— 28	+ .073
399	+ 72 06 28.99	.15	4	+ 12.2255	.0060	— 299	— 77	— .0196
400	+ 14 09 41.07	.22	2	+ 12.2709	.0064	+ 3187	— 55	— .0541
401	+ 20 45 48.44	.27	1	+ 12.3925	.0078	+ 3015	— 49	— .0188
402	+ 15 28 20.30	.10	8	+ 12.4808	.0042	+ 3138	— 54	+ .0082
*403	+ 55 33 52.71	......	......	+ 12.5450	....	+ 1711	— 22	— .060
404	+ 44 50 03.97	.06	24	+ 12.6916	.0020	+ 2253	— 28	— .0084
405	+ 14 37 37.87	.22	2	+ 12.6675	.0060	+ 3098	— 54	— .0631

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	*s.*	*s.*	"	"
406	7200	γ^2 Delphini	4	20 40 51.6	+ 2.783	0	— .30	—1.40
407	7204	ε Cygni	3	41 09.2	+ 2.426	+ 3	+1.32	—2.09
408	7206	13 Delphini	5.5	41 37.0	+ 2.975	— 3	— .02	— .84
*409	7215		5	42 14.8	+ 1.489	— 4	+ .06	+1.39
410	7220	η Cephei	3.5	42 44.7	+ 1.230	— 14	+ .02	+1.29
411	7239	μ Aquarii	4.5	45 54.6	+ 3.240	— 8	—1.56	—2.33
*412	7277	υ Cygni	4	52 30.8	+ 2.234	+ 4	+ .09	+ .77
413	7299		5	53 11.6	— 2.504	— 309	+ .22	+1.35
*414	7320		6.5	58 13.9	+ 2.323	+ 4	— .39	— .93
415	7333	ξ Cygni	4	21 00 23.1	+ 2.180	+ 4	— .10	— .93
416	7336	61[1] Cygni	5.5	01 17.8	+ 2.688	+ 15	+ .53	— .54
*417	......	(Fed. 3689)	......	01 33.6	+ 1.462	— 6	+ .29	+2.10
*418	7345	63 Cygni	5	02 17.9	+ 2.054	+ 4	— .15	—2.44
419	7368	ζ Cygni	3	07 37.0	+ 2.550	+ 4	— .77	—1.13
*420	7377		5	08 37.2	+ 1.530	— 4	+ .09	+ .82
421	7380	α Equulei	4.5	21 09 34.5	+ 3.001	— 3	+ .07	— .02
422	7385	τ Cygni	5	09 48.1	+ 2.391	+ 4	— .52	—2.68
*423	7398	σ Cygni	4.5	12 30.4	+ 2.353	+ 5	+ .60	+2.13
424	7399	υ Cygni	4.5	12 46.7	+ 2.463	+ 5	— .07	— .88
*425	7416	α Cephei	3	15 35.7	+ 1.437	— 7	+ .40	+1.58
426	7418	1 Pegasi	4	16 18.4	+ 2.774	+ 2	+ .02	— .39
*427	7418		6	19 46.9	+ 2.006	+ 5	—1.24	—3.37
*428	7453	69 Cygni	6.5	20 40.6	+ 2.145	+ 6	+ .28	+ .04
429	7484		7	23 30.0	— 4.602	— 811	+ .17	+ .17
*430	7480	71 Cygni	5	24 50.2	+ 2.209	+ 6	+ .04	— .36
431	7478	β Aquarii	3	24 58.7	+ 3.164	— 7	+ .01	— .45
432	7493	β Cephei	3	27 02.4	+ 0.799	— 34	+ .30	+1.23
*433	7489		6	27 15.5	+ 2.017	+ 5	+1.57	+6.10
*434	7505	72 Cygni	5.5	29 40.3	+ 2.446	+ 7	— .39	— .06
435	7514	ξ Aquarii	5	31 05.8	+ 3.198	— 8	— .92	—1.83
436	7521	74 Cygni	6	31 56.4	+ 2.400	+ 7	— .51	—1.02
437	6554	76 Cygni	6	36 32.7	+ 2.408	+ 8	— .18	—3.88
438	7561	ε Pegasi	2.5	38 02.8	+ 2.948	— 1	— .13	— .58
*439	7566	79 Cygni	6	38 15.4	+ 2.473	+ 4	—1.07	—3.50
440	7571	κ Pegasi	4	38 59.1	+ 2.711	+ 5	— .63	—2.87
441	7588	11 Cephei	4.5	40 05.1	+ 0.903	— 33	+ .43	+1.65
*442	7595	ν Cephei	4.5	41 50.6	+ 1.730	+ 2	+ .09	+ .85
*443	7605	12 Cephei	6	43 44.0	+ 1.766	+ 3	+ .52	+1.10
444	7618	μ Capricorni	5	46 28.7	+ 3.279	— 11	—1.03	—3.33
*445	7627	16 Pegasi	5.5	47 22.5	+ 2.727	+ 5	— .21	— .51
*446	7636		6	48 51.4	+ 2.014	+ 8	+ .61	+2.17
447	7654	79 Draconis	6	51 18.7	+ 0.736	— 46	+ .69	+1.02
*448	7686	16 Cephei	5	57 27.5	+ 0.882	— 37	— .21	— .95
*449	7679		6	57 36.6	+ 2.158	+ 10	+1.16	+3.60
450	7688	α Aquarii	3	59 21.8	+ 3.083	— 4	— .04	+ .01

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
406	+ 15 40 29.78	.12	7	+ 12.7372	.0044	+ 3040	— 55	— .2110
407	+ 33 30 10.44	.09	10	+ 13.2739	.0035	+ 2674	— 43	+ .3061
408	+ 5 33 00.58	.33	1	+ 12.9902	.0085	+ 3250	— 67	— .0084
*409	+ 57 07 54.11	.30	1	+ 12.8095	.0087	+ 1581	— 21	— .2311
410	+ 61 21 13.39	.12	7	+ 13.8896	.0033	+ 1319	— 29	+ .8159
411	— 9 27 03.64	.10	10	+ 13.2392	.0040	+ 3484	— 86	— .0433
*412	+ 40 41 12.20	.12	6	+ 13.6915	.0040	+ 2318	— 34	— .0183
413	+ 80 04 56.31	.14	4	+ 13.7227	.0048	— 2729	— 371	— .0305
*414	+ 38 09 50.69	.24	2	+ 14.0641	.0092	+ 2354	— 38	— .0066
415	+ 43 25 47.90	.14	5	+ 14.2037	.0041	+ 2184	— 33	— .0006
416	+ 39 08 08.47	.07	17	+ 17.4880	.0028	+ 2991	— 37	+ 3.2276
*417	+ 59 45 31.97	......	......	+ 14.2617	....	+ 1436	— 23	— .015
*418	+ 47 08 48.05	.23	2	+ 14.3066	.0057	+ 2045	— 30	— .0154
419	+ 29 42 54.22	.07	18	+ 14.5765	.0032	+ 2477	— 49	— .0673
*420	+ 59 28 22.71	.29	1	+ 14.6950	.0079	+ 1454	— 23	— .0088
421	+ 4 43 55.81	.14	4	+ 14.6732	.0048	+ 2902	— 76	— .0872
422	+ 37 30 45.48	.14	4	+ 15.2070	.0044	+ 2508	— 43	+ .4332
*423	+ 38 52 17.47	.13	5	+ 14.9311	.0043	+ 2226	— 41	— .0017
424	+ 34 22 22.33	.28	1	+ 14.9299	.0066	+ 2330	— 45	— .0188
*425	+ 62 03 23.00	.07	21	+ 15.1537	.0022	+ 1334	— 24	+ .0118
426	+ 19 16 14.37	.12	6	+ 15.2039	.0040	+ 2593	— 62	+ .0511
*427	+ 51 07 11.76	.28	1	+ 15.3164	.0101	+ 1816	— 30	— .0337
*428	+ 36 07 41.23	.25	1	+ 15.3758	.0067	+ 2220	— 45	— .0246
429	+ 83 43 44.24	.30	1	+ 15.5592	.0111	— 4299	— 947	+ .0017
*430	+ 45 59 24.26	.19	3	+ 15.7294	.0052	+ 1953	— 36	+ .0981
431	— 6 07 12.05	.06	24	+ 15.6223	.0028	+ 2823	— 92	— .0165
432	+ 70 00 43.81	.07	21	+ 15.7464	.0022	+ 655	— 37	— .0047
*433	+ 52 04 09.69	......	......	+ 15.8139	....	+ 1746	— 30	+ .051
*434	+ 37 58 27.35	.14	5	+ 15.9769	.0044	+ 2116	— 46	+ .0841
435	— 8 24 49.39	.10	9	+ 15.9330	.0041	+ 2758	— 96	— .0353
436	+ 39 51 09.77	.24	2	+ 16.0117	.0059	+ 2039	— 44	— .0002
437	+ 40 14 16.92	.33	1	+ 16.1694	.0084	+ 1987	— 45	— .0828
438	+ 9 18 10.14	.07	19	+ 16.3231	.0031	+ 2428	— 78	— .0058
*439	+ 37 42 42.66	.55	......	+ 16.3075	.019	+ 2024	— 51	— .032
440	+ 25 04 16.37	.19	3	+ 16.3657	.0054	+ 2212	— 62	— .0107
441	+ 70 44 10.05	.12	6	+ 16.5283	.0052	+ 709	— 35	+ .0965
*442	+ 60 32 39.77	.11	8	+ 16.5080	.0034	+ 1359	— 26	— .0115
*443	+ 60 06 46.94	.30	1	+ 16.6117	.0079	+ 1374	— 26	— .0010
444	— 14 08 21.03	.11	8	+ 16.7437	.0040	+ 2576	— 107	— .0023
*445	+ 25 20 15.72	.08	13	+ 16.7769	.0049	+ 2102	— 64	— .0121
*446	+ 55 37 25.52	.24	2	+ 16.8636	.0063	+ 1518	— 31	+ .0017
447	+ 73 06 39.91	.12	6	+ 17.0064	.0061	+ 505	— 41	+ .0312
*448	+ 72 35 06.16	.16	4	+ 17.0786	.0050	+ 568	— 35	— .1765
*449	+ 42 12 42.76	......	......	+ 17.2950	....	+ 1748	— 49	+ .033
450	— 0 55 31.69	.06	28	+ 17.3257	.0020	+ 2185	— 92	— .0139

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2 \alpha}{dt^2}$	Δδ	Δμ'
				h. m. s.	*s.*	*s.*	″	″
451	7689	ν Pegasi	5	21 59 22.5	+ 3.028	— 2	— .43	— .82
452	7692	α Gruis	2	22 00 20.7	+ 3.810	— 46	— .37	—1.22
453	7706	ι Pegasi	4	01 11.6	+ 2.789	+ 6	+ .11	—1.41
454	7733	28 Pegasi	6	04 35.8	+ 2.832	+ 5	+ .36	—1.59
455	7749	ζ Cephei	4	06 51.2	+ 2.073	+ 11	+ .01	— .63
*456	7755	λ Cephei	5.5	07 16.3	+ 2.036	+ 11	— .11	00
*457	7765	....	5	08 30.9	+ 2.568	+ 11	+ .40	+1.48
458	7773	θ Aquarii	4.5	10 14.2	+ 3.170	— 8	— .74	—1.38
*459	7787	....	6	13 48.4	+ 2.310	+ 14	+ .78	+2.80
460	7795	γ Aquarii	3	15 12.0	+ 3.102	— 4	— .02	+ .68
*461	7800	2 Lacertæ	5	15 52.0	+ 2.468	+ 14	— .38	— .92
462	7814	π Aquarii	5	18 53.6	+ 3.065	— 3	— .47	— .76
*463	7820	4 Lacertæ	5	19 27.0	+ 2.419	+ 15	— .54	— .74
464	7843	38 Pegasi	6	24 18.9	+ 2.738	+ 11	— .22	— .89
465	7848	δ² Cephei	4.5	24 31.9	+ 2.215	+ 17	+ .56	+2.61
466	7855	ε Lacertæ	4	26 08.6	+ 2.459	+ 17	+ .05	+ .55
467	7868	η Aquarii	4	28 56.0	+ 3.084	— 3	— .17	+1.28
468	7881	....	5.5	30 04.4	+ 1.082	— 33	+ .59	+ .11
*469	7882	....	6	30 42.0	+ 2.479	+ 17	— .07	+1.40
*470	7907	....	6	34 31.9	+ 1.301	— 18	+ .76	+3.80
471	7908	ζ Pegasi	3	35 13.6	+ 2.988	+ 2	00	+1.63
472	7923	η Pegasi	3	37 08.7	+ 2.804	+ 11	— .30	—1.18
*473	7945	λ Pegasi	4.5	40 30.6	+ 2.883	+ 8	— .11	— .08
474	7958	μ Pegasi	4	43 58.3	+ 2.888	+ 9	— .03	+ .07
*475	7962	14 Lacertæ	6	44 43.7	+ 2.694	+ 17	+ .18	— .52
476	7967	ι Cephei	4	45 14.0	+ 2.119	+ 22	+ .26	+ .80
477	7970	λ Aquarii	4	46 05.5	+ 3.131	— 6	— .99	—1.73
478	7992	α Piscis Australis	1	50 44.3	+ 3.327	— 21	— .28	+ .92
479	8023	ο Andromedæ	4	56 10.4	+ 2.747	+ 19	— .64	—2.64
*480	8024	....	6.5	56 14.0	+ 2.519	+ 26	— .10	—1.31
481	8022	β Pegasi	2	57 43.1	+ 2.904	+ 12	— .58	—1.47
482	8031	α Pegasi	2	58 32.1	+ 2.984	+ 6	— .23	—1.81
*483	8036	3 Andromedæ	5.5	58 34.5	+ 2.676	+ 23	— .22	+ .13
*484	8059	5 Andromedæ	6	23 02 01.9	+ 2.708	+ 24	+ .01	+ .01
*485	8083	....	6	07 16.2	+ 2.861	+ 37	00	+ .09
486	8124	ο Cephei	5.5	13 30.1	+ 2.438	+ 41	+1.61	+3.62
*487	8128	10 Andromedæ	6	13 55.7	+ 2.842	+ 21	— .45	—1.05
488	8177	θ Piscium	5	21 37.6	+ 3.041	+ 3	—1.61	—3.03
*489	8206	72 Pegasi	5.5	27 45.1	+ 2.963	+ 16	— .21	— .53
490	8224	λ Andromedæ	4.5	31 27.1	+ 2.917	+ 28	+ .92	00
491	8229	ι Andromedæ	4	23 32 00.6	+ 2.923	+ 25	+ .26	—1.70
492	8233	ι Piscium	4.5	33 31.4	+ 3.085	— 3	— .19	+1.18
493	8238	γ Cephei	3	34 13.8	+ 2.405	+ 73	+ .42	+1.15
494	8237	κ Andromedæ	4.5	34 15.4	+ 2.937	+ 26	+ .47	— .41
*495	8273	....	5	41 56.6	+ 2.823	+ 60	— .23	—1.38

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
451	+ 4 26 54.27	.24	2	+ 17.4299	.0070	+ 2150	— 87	+ .0898
452	— 47 33 54.17	.22	2	+ 17.2104	.0094	+ 2703	— 169	— .0282
453	+ 24 44 06.85	.13	6	+ 17.4253	.0043	+ 1955	— 69	+ .0059
454	+ 20 21 51.76	.25	1	+ 17.5392	.0070	+ 1916	— 73	— .0259
455	+ 57 35 07.92	.10	9	+ 17.6493	.0032	+ 1361	— 34	+ .0037
*456	+ 58 47 53.44	.25	1	+ 17.6458	.0072	+ 1330	— 33	— .0310
*457	+ 39 05 43.24	.20	2	+ 17.7168	.0059	+ 1672	— 56	— .0112
458	— 8 24 17.80	.08	15	+ 17.7731	.0035	+ 2059	— 102	— .0248
*459	+ 52 01 49.94	......	......	+ 17.9577	....	+ 1426	— 43	+ .018
460	— 2 00 59.24	.09	12	+ 18.0066	.0036	+ 1925	— 96	+ .0128
*461	+ 45 54 26.93	.26	1	+ 18.0002	.0071	+ 1501	— 51	— .0192
462	+ 0 44 37.64	.12	6	+ 18.1296	.0046	+ 1831	— 93	— .0046
*463	+ 48 50 34.36	.26	1	+ 18.1255	.0059	+ 1423	— 48	— .0294
464	+ 31 56 00.28	.18	3	+ 18.3128	.0069	+ 1542	— 69	— .0189
465	+ 57 46 33.16	.15	4	+ 18.3424	.0040	+ 1229	— 39	+ .0031
466	+ 49 38 25.05	.11	8	+ 18.4025	.0035	+ 1357	— 51	+ .0065
467	— 00 45 40.21	.07	17	+ 18.4345	.0036	+ 1663	— 95	— .0572
468	+ 75 34 56.49	.16	4	+ 18.5212	.0031	+ 523	— 31	— .0089
*469	+ 49 25 26.62	......	......	+ 18.5690	....	+ 1294	— 52	+ .018
*470	+ 74 43 19.24	.33	1	+ 18.7168	.0111	+ 592	— 26	+ .041
471	+ 10 10 45.77	.07	18	+ 18.6852	.0031	+ 1497	— 89	— .0127
472	+ 29 34 04.43	.11	7	+ 18.7101	.0042	+ 1366	— 74	— .0478
*473	+ 22 54 29.73	.12	6	+ 18.8352	.0040	+ 1347	— 80	— .0248
474	+ 23 56 31.11	.12	6	+ 18.9105	.0043	+ 1294	— 81	— .0503
*475	+ 41 17 31.12	.30	1	+ 18.9721	.0076	+ 1185	— 66	— .0102
476	+ 65 32 35.59	.10	9	+ 18.8635	.0031	+ 903	— 35	— .1330
477	— 8 14 39.10	.09	11	+ 19.0561	.0037	+ 1364	— 103	+ .0357
478	— 30 17 03.08	.12	7	+ 18.9746	.0057	+ 1371	— 123	— .1708
479	+ 41 39 15.78	.12	6	+ 19.2431	.0043	+ 1019	— 70	— .0381
*480	+ 56 26 02.61	.33	1	+ 19.2638	.0134	+ 926	— 55	— .0191
481	+ 27 24 18.34	.12	7	+ 19.4466	.0038	+ 1061	— 83	— .1283
482	+ 14 31 59.01	.06	24	+ 19.2872	.0022	+ 1071	— 90	— .0501
*483	+ 49 22 22.11	.18	3	+ 19.4886	.0053	+ 959	— 66	+ .1503
*484	+ 48 36 54.62	.25	1	+ 19.5354	.0062	+ 909	— 68	+ .1181
*485	+ 56 28 41.74	.22	2	+ 19.7947	.0076	+ 919	— 79	+ .2689
486	+ 67 25 40.26	.12	6	+ 19.6601	.0044	+ 636	— 51	+ .0172
*487	+ 41 23 38.04	.25	1	+ 19.6509	.0067	+ 742	— 78	+ .0005
488	+ 5 41 33.03	.12	6	+ 19.7175	.0039	+ 652	— 96	— .0563
*489	+ 30 38 07.66	.25	1	+ 19.8347	.0060	+ 520	— 89	— .0213
490	+ 45 45 51.87	.19	3	+ 19.4689	.0047	+ 446	— 85	— .4300
491	+ 42 34 34.26	.13	6	+ 19.8999	.0050	+ 434	— 86	— .0050
492	+ 4 56 56.19	.07	19	+ 19.4773	.0029	+ 437	— 102	— .4132
493	+ 76 56 01.87	.07	21	+ 20.0711	.0022	+ 304	— 49	+ .1135
494	+ 43 38 31.17	.25	2	+ 19.9077	.0060	+ 395	— 87	— .0201
*495	+ 67 06 44.16	.16	4	+ 19.9722	.0051	+ 238	— 78	— .0198

Catalogue of 500 stars

Number.	B. A. C. number.	Name.	Magnitude.	Approximate right ascension, 1875.0.	Annual variation in α.	$\frac{d^2\alpha}{dt^2}$	$\Delta\delta$	$\Delta\mu'$
				h. m. s.	s.	s.	"	"
*496	8314	....	5	23 48 46.3	+ 2.850	+ 88	— .25	— .70
*497	8324	ψ Pegasi	5.5	51 23.5	+ 3.047	+ 15	— .06	— .10
498	8331	ω Piscium	4.5	52 53.6	+ 3.078	+ 5	— .87	—1.26
*499	8341	....	5	55 15.0	+ 3.026	+ 52	+ .37	+1.59
*500	8366	....	5	58 39.4	+ 3.061	+ 54	— .16	+ .90

for the epoch 1875.0—Continued.

Number.	Declination, 1875.0.	Probable error of δ, 1875.	Weight.	Annual variation, 1875.0.	Probable error of annual variation.	$\frac{d^2\delta}{dt^2}$	$\frac{d^3\delta}{dt^3}$	Proper motion in δ.
	° ′ ″	″		″	″	″	″	″
*496	+ 73 42 53.04	.13	5	+ 20.0211	.0066	+ 117	− 80	− .0090
*497	+ 24 26 47.71	.15	4	+ 19.9960	.0054	+ 81	− 98	− .0440
498	+ 6 10 16.47	.08	16	+ 19.9300	.0032	+ 53	− 101	− .1146
*499	+ 60 31 35.85	.25	1	+ 20.0299	.0077	+ 5	− 95	− .0201
*500	+ 60 37 04.34	.47	......	+ 20.0599	.016	− 60	− 99	+ .006

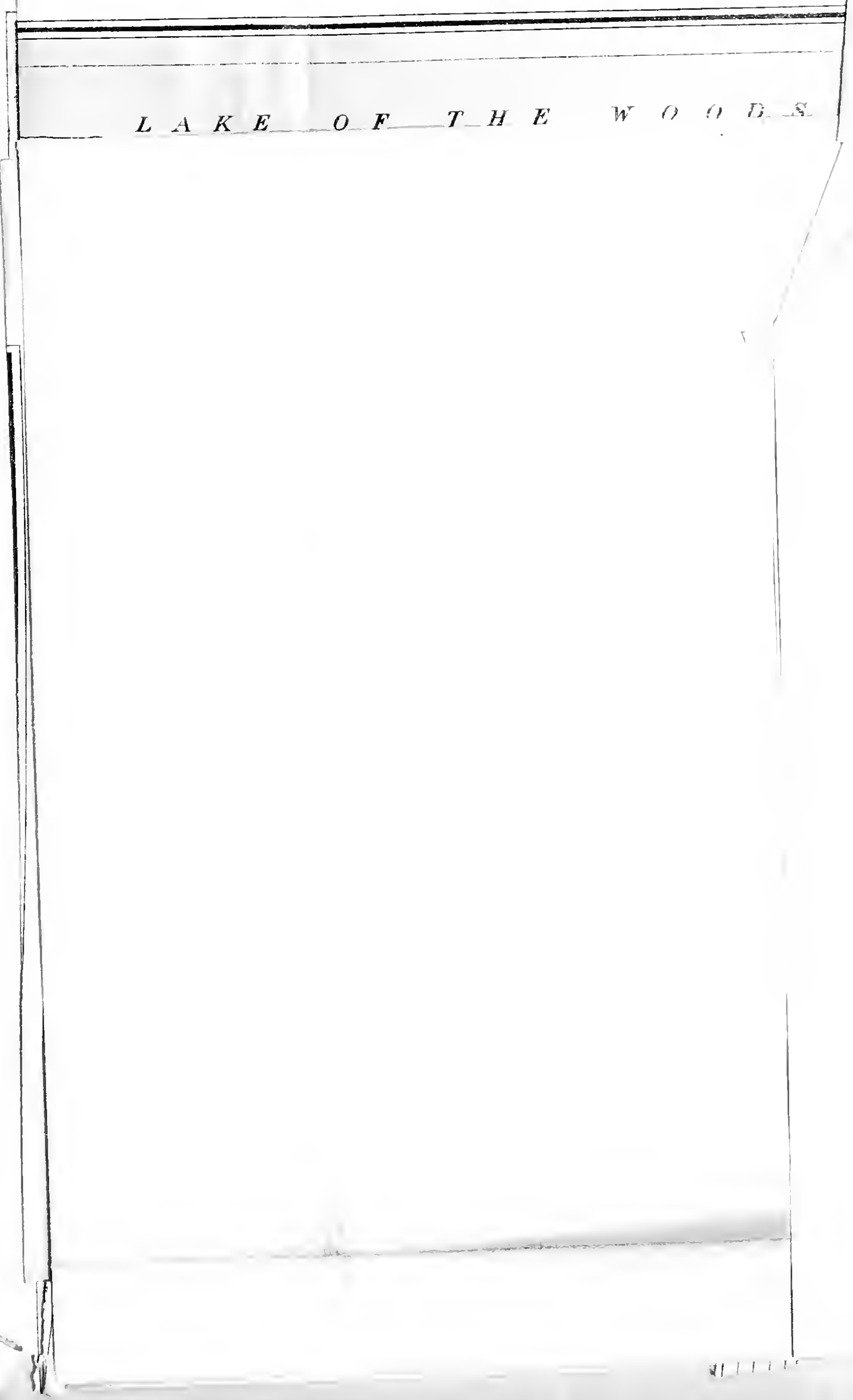
SPECIAL INDEX TO APPENDIX H.

EXPLANATION.—It has been found necessary to omit Part 2 of Appendix H, containing the details of corrections to assumed places.

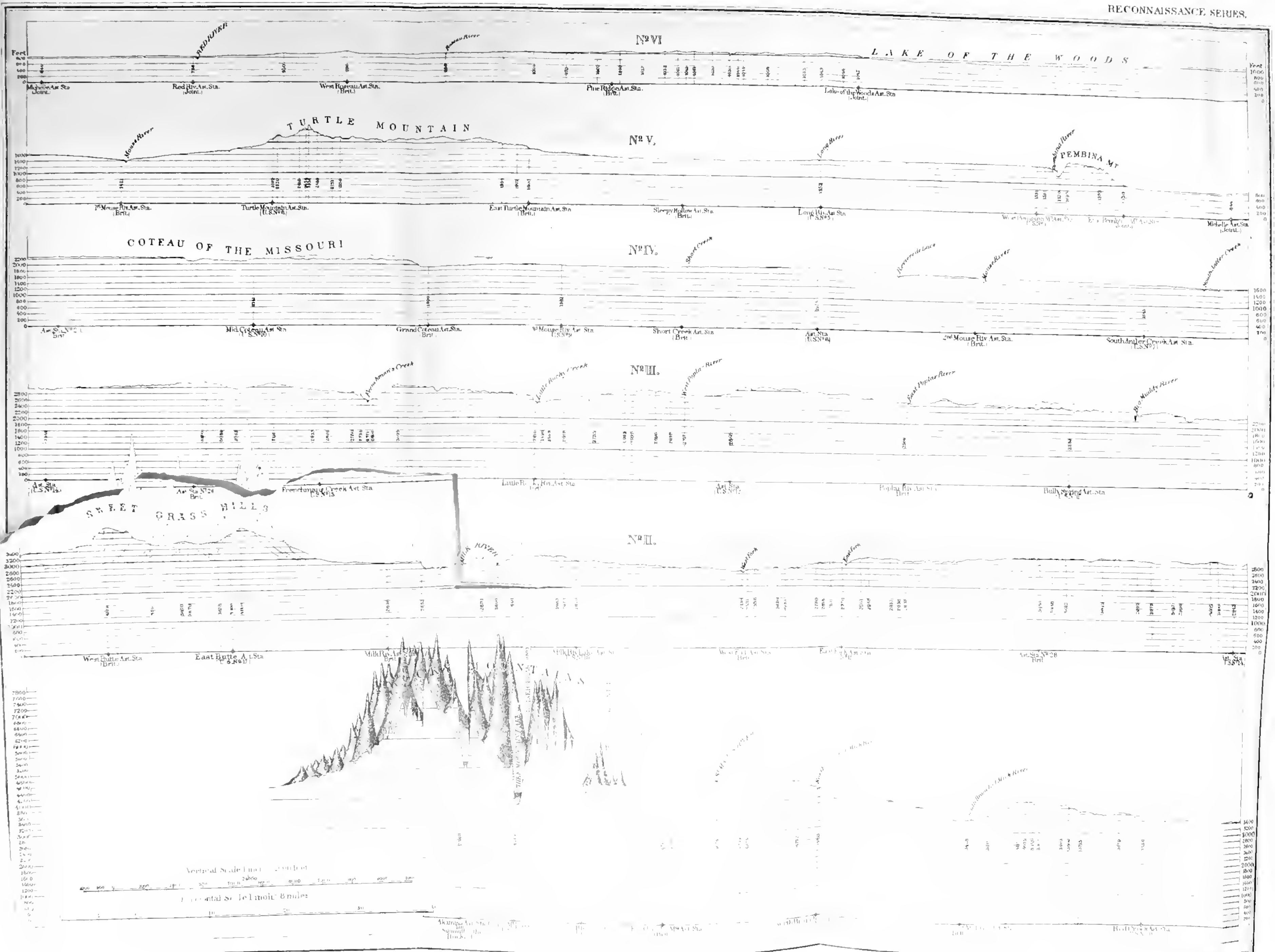
INDEX TO SUBJECTS.

GENERAL INDEX.

RECON



PROFILE.



Nº VI
LAKE OF THE WOODS
Red River
Roseau River
Michelle Ast. Sta. (Joint.)
Red Riv. Ast. Sta. (Joint.)
West Roseau Ast. Sta. (Brit.)
Pine Ridge Ast. Sta. (Brit.)
Lake of the Woods Ast. Sta. (Joint.)
Nº V.
TURTLE MOUNTAIN
Mouse River
Long River
Pembina River
PEMBINA MT
1st Mouse Riv. Ast. Sta. (Brit.)
Turtle Mountain Ast. Sta. (U.S. Nº 4)
East Turtle Mountain Ast. Sta. (Brit.)
Sleepy Hollow Ast. Sta. (Brit.)
Long Riv. Ast. Sta. (U.S. Nº 5)
Michelle Ast. Sta. (Joint.)
Nº IV.
COTEAU OF THE MISSOURI
Short Creek
Riviere de Lance
Mouse River
South Antler Creek
Mid Coteau Ast. Sta. (U.S. Nº 10)
Grand Coteau Ast. Sta. (Brit.)
3rd Mouse Riv. Ast. Sta. (U.S. Nº 9)
Short Creek Ast. Sta. (Brit.)
Ast. Sta. (U.S. Nº 8)
2nd Mouse Riv. Ast. Sta. (Brit.)
South Antler Creek Ast. Sta. (U.S. Nº 7)
Nº III.
Frenchman's Creek
Little Rocky Creek
West Poplar River
East Poplar River
Big Muddy River
Ast. Sta. Nº 26 Brit.
Frenchman's Creek Ast. Sta. (U.S. Nº 13)
Bully Spring Ast. Sta.
SWEET GRASS HILLS
Nº II.
MILK RIVER
West Fork
East Fork
West Butte Ast. Sta. (Brit.)
East Butte Ast. Sta.
Milk Riv. Ast. Sta. Brit.
Ast. Sta. Nº 28 Brit.
Feet
Vertical Scale
Horizontal Scale