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Article Summary: Oliver N Chaffee and his crew endured hardships during the survey of the western boundary of Nebraska. Despite those difficulties and the limitations of the surveying equipment of their day, they achieved remarkably accurate readings of time and distance.

Cataloging Information:

Names: Oliver N Chaffee, Edwin Goodfellow, E P Austin

Nebraska Place Names: Omaha, Julesburg, Big Springs

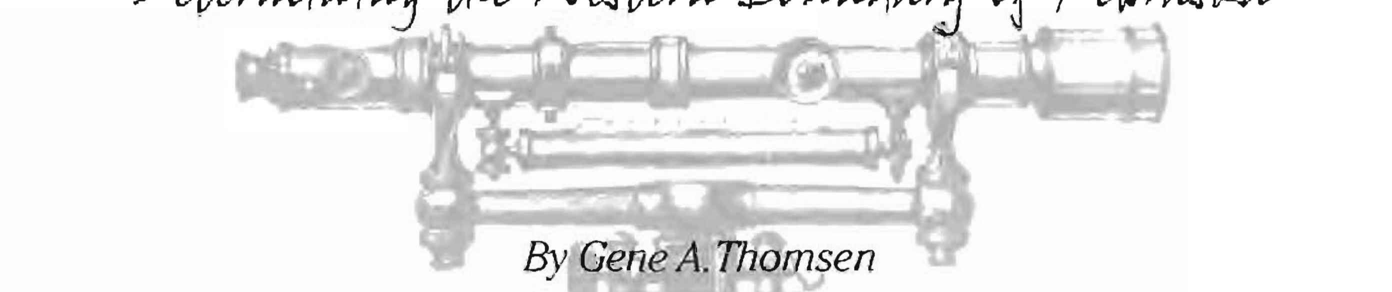
Surveying Equipment: meridian transit, astronomical clock, sidereal (star time) chronometer, chronographic register, Morse telegraph register

Keywords: Oliver N Chaffee, latitude, longitude, Washington Meridian, Bessel's ellipsoid, Omaha field observatory, Greenwich Prime Meridian

Photographs / Images: (Table 2) Correlations of time, longitude, and distance along the 40th parallel; (Fig 29) survey crews at Mount Callahan Station, Nevada, 1881; (Fig 30) the second territorial capitol on Capitol Hill, from Thirteenth and Farnam Streets, Omaha; (Fig 31) Omaha High School; (Fig 32) map showing the western observation stations and portions of Chaffee's western boundary survey; (Fig 33) stone monument set by Chaffee in 1869 at the intersection of the Nebraska-Wyoming-Colorado boundaries, southwest of Bushnell

# TIMING SPACE

## Determining the Western Boundary of Nebraska



By Gene A. Thomsen

In 1869 the United States surveyor general for Nebraska and Iowa, Robert R. Livingston, contracted with Oliver N. Chaffee of Detroit, Michigan, to survey the western boundary of Nebraska. Chaffee had worked with the United States Lake Survey for over ten years; many of his duties included determinations of latitude and longitude. Chaffee's survey was to determine and monument the two western longitudinal boundary lines of Nebraska, being the twenty-fifth and twenty-seventh degrees of longitude west from Washington, D.C., and the forty-first degree of latitude between them. His survey reveals how surveyors used time to determine location in space.

A longitudinal line—also called a meridian—is any line that runs along the Earth's surface from the North to the South Pole. One's own meridian is the north-south line through the particular place you happen to be at any given moment. An example of such a line is the Sixth Principal Meridian, which in Nebraska forms the dividing line between Thayer, Fillmore, York, Polk, Madison, and Pierce counties on the west, and Jefferson, Saline, Seward, Butler, Stanton, Wayne, and part of Cedar counties on the east; the line also runs through the western part of Columbus in Platte County and through western Cedar County. This meridian was used to survey lands in Nebraska and Kansas, most of Colorado and Wyoming, and part of South Dakota. It is still used to describe rural lands in these states. The Prime Meridian, which is 0 degrees of longitude and passes through Greenwich, England, is the global starting point for measurement of longitude and universal time.

The Washington Meridian, which passed through the center of the dome of the old Naval Observatory in Washington, D.C., was adopted and used as the American Meridian for territorial and state boundary purposes in the United States from 1850 to 1912. (The United States officially adopted the Greenwich Prime Meridian in 1912.) Besides Nebraska, the Washington Meridian was used to define the boundaries of the Territories of Arizona, Colorado, Dakota, Idaho, Montana, Nevada, and Wyoming; and the states of Kansas, New Mexico, and Utah. It has a longitudinal astronomic value of 77 03'02.3," or five hours, eight minutes, 12.15 seconds west of Greenwich.[1] This uneven differential from the Prime Meridian numbers is the main reason why Nebraska's western boundaries are not expressions of whole degree numbers today.

Two basic measurements are needed for calculating longitude. First one must know the circumference of the Earth. For Chaffee, the circumference at the equator was 24,898.52 miles, as determined from Bessel's "ellipsoid," a series of equations that he assembled in 1841.[2] Because there are 360 degrees in a circle, or the circumference of a sphere, dividing 360 into the circumference at the Earth's equator yields a figure of 69.16 miles for each degree of longitude. Similarly, dividing 360 degrees by twenty-four hours provides fifteen degrees of longitude for each hour, in other words, the Earth rotates through fifteen degrees of longitude each hour, and each hour at the equator equals 1037.4 miles.

Second, the surveyor must know the precise time at his location. This is accomplished by measuring the time it takes for a specific star to cross two meridians—one meridian at a known location in space and at a known time, the other at the location that needs to be determined. For example, if the time difference between the two locations was four minutes and both time measurements were made where each meridian crossed the fortieth degree of latitude, the two meridians would be 53.06 miles apart.

Table 2 gives the relationship of time to degrees of longitude and distance, using Bessel's "ellipsoid" at the fortieth degree of latitude, which is the Nebraska-Kansas boundary. This table emphasizes the need to be able to measure time very precisely in order to calculate longitude. A timing mistake of one second would cause a surveying error of 1,167 feet on the ground.

The invention of the telegraph in 1844 presaged a new era in the use of time to determine longitude, an era that began the abandonment of less-reliable portable clocks. On the night of October 10, 1846, the first successful exchange of time signals via the electromagnetic telegraph was conducted by Sears C. Walker of the U.S. Coast Survey.[3] The success of this test led to further experimentation. In 1869 the U.S.Coast Survey used the electromagnetic telegraph to record observations that involved a site in Nebraska. The intent was to use time to calculate the difference in longitude

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Table 2 Correlations of time, longitude, and distance along the 40th parallel.

| Time | Longitude | Distance |
|---|---|---|
| 24 hours | 360 degrees | 19100.11 miles |
| 1 hour | 15 degrees | 795.84 miles |
| 4 minutes | 1 degree | 53.06 miles |
| 1 minute | 15 minutes | 13.264 miles |
| 1 second | 15 seconds | 1167.386 feet |
| .067 seconds | 1 second | 77.815 feet |

between a known location and one that was not known—in this case, Harvard College Observatory in Cambridge, Massachusetts, and Washington Square in San Francisco. Two additional temporary observatories were used in this test, one in Salt Lake City and the other in Omaha.[1] Temporary observatories were easily erected and could be placed in remote areas where both latitude and longitude needed to be determined.

A typical field observatory (Fig. 29) included a meridian transit, an astronomical clock, a sidereal (star time) chronometer, and chronographic and Morse telegraph registers. The meridian transit was a specially designed telescope used to observe the stars. It had a forty-six-inch focal length, a clear aperture of 2 3/4 inches, and a magnifying power of 80 to 120.[5] The transit moved about an east-west axis to reveal objects as they crossed the meridian of the transit. The instrument had five to seven vertical lines in the focal plane. These were used to observe the time stars, or specific stars that were selected for a given timing operation. The transit used by the U.S. Coast Survey at the Omaha station was made by Troughton and Simms of London.[6]

The astronomical clock, an extremely accurate timekeeper, was also an essential piece of equipment. It contained a thirty-five- to thirty-six-inch long compensating pendulum whose end was fitted with tubes or vials of mercury. The pendulum rod, which was made of steel, was subject to expansion or contraction in overall length due to changes in temperature. These gradual changes would cause the clock to gain or lose time. To overcome this problem, mercury in glass or steel cylinders was placed at the bottom of the pendulum to keep the clock beating at a constant rate by maintaining the center of gravity of the pendulum in the same arc. These clocks, which were adjusted and regulated with great care, were used to determine the exact time a star passed a meridian.

Attached to the clock was a circuit breaker, which operated an electromagnet that recorded time to the second. The circuit breaker was attached to a chronographic register that recorded not only the beats of the clock on paper, but any arbitrary signal made by the operator as well. The chronographic register, invented by a Mr. Bond of Boston, had a cylinder eleven and one-half inches long and nineteen inches in circumference. It revolved once each minute and recorded the exact time a star passed the meridian. The operator pressed a lever to send an electrical current to the register to make a permanent mark on the paper. After the observations were complete, the astronomer could read the timing marks on the paper and use them for computing his location.[7]

Another vital piece of equipment was a sidereal chronometer. Unlike the astronomical clock, this instrument was the most accurate portable timekeeper available. Some of these timepieces looked like huge pocket watches others had the clock mounted on gimbals or movable rings encased in a wooden box. When the approximate difference in longitude between two points was not known, the observer determined his local time on a single, clear night by observing certain stars. He then set the chronometer, transported it to the telegraph office, and sent the time over the wire to the corresponding observation station. As soon as the approximate difference in longitude was obtained, a set of stars was selected for the timing observations needed to determine the precise longitude.[8]

A Morse telegraph register was used to send time over the telegraph to the other observatories. These transmissions were done after regular business hours; lines were usually made available between 10 P.M. and 2 A.M., with the operators connecting the main line to the

Fig. 29 Survey crews at Mount Callahan Station, Nevada, 1881. The tent at left has its meridian flaps open to provide an unobstructed view for the meridian transit. National Oceanic and Atmospheric Administration, National Geodetic Survey

Fig 30 **View of the second territorial capitol on capitol hill, from Thirteenth & Farnam Streets in Omaha. The telegraph office was just up the street.** NSHS RG2341-787

wires of the observation stations to create a galvanic circuit. Batteries supplied the electricity for the local circuit between the astronomical clock and the chronographic register.[9]

After the stations were ready for observations, and when the star being observed entered the field of view, the astronomer at the westernmost station would alert the others by rapidly breaking the circuit, producing a rattle. The instant the star bisected the first vertical line in the telescope, the observer at the western station tapped on the Morse register. This tap on the key was recorded on the chronographs at the other stations. As the star passed the remaining lines in the telescope's field of view the procedure was repeated. Astronomers at the other stations would repeat the process as the same stars passed their field of view. The difference in time, as recorded on the chronograph registers, could be calculated for conversion to longitude.

To eliminate transmission errors, the process was repeated starting from the easternmost observatory, sending signals to the western station. By averaging the recorded times of the two-way signals, a true time differential was obtained. On a typical night, twenty to twenty-five stars were observed, which usually required two to three hours. Gathering enough data for the final calculations generally took three to four nights.[10]

At the location where the new meridian had been established, a granite or marble block about five feet long, three feet wide, and one foot thick would be placed in a hole about two and one-half feet deep to establish a permanent point for future observations. Sand was tamped along its sides to keep it from moving, and a copper bolt was placed in its center to mark the block permanently. To make new observations from this point, a meridian transit would be placed over the bolt and adjusted upon the block. After the meridian had been found, the stand that supports the transit was fastened to the top of the stone block with plaster of paris to keep it from moving.[11] If a large stone was not available, a smaller stone with a copper bolt would mark the station. A wooden frame or table would be built above the stone for the transit to rest on. A similar "reference" stone with bolt would be placed due north or south to perpetuate the meridian line for future observations.

The astronomical clock was placed on or fastened to a granite or marble pier if one could conveniently be obtained. If not, hardwood or white pine, properly secured in the ground, would be used to keep the timepiece stable.[12] All of this equipment would be sheltered by a simple structure or awning for the greatest convenience and protection of the instruments. Temporary field observatories were often canvas tents like those used by the U.S. Army. The top of the tent could be opened to the heavens during observations, much like the dome of permanent observatories (cf. Figs. 13, 29).

At the time of Chaffee's survey of Nebraska's western boundary, the Omaha observatory was manned by Edwin Goodfellow, an employee and astronomer of the U.S. Coast Survey. Assisting him was E. P. Austin of the Nautical Almanac Office. Austin also helped determine the north boundary of Nebraska in 1874.

The location for the Omaha observations was at the southeastern edge of the old territorial capitol square in Omaha, now the site of Omaha Central High School. This locale was selected for its height and its unobstructed view of the sky from north to south. The main wires of the Western Union Telegraph Company, located at the corner of Fourteenth and Farnam, were connected to the observatory and preliminary testing began February 7, 1869 (Fig. 30).

Goodfellow began the project of determining the latitude and longitude of Omaha on February 9, and completed eleven nights of observations on February 28, remarking, "The intensely cold and stormy weather and the frozen state of the soil in January made the work of putting up an observatory, and the subsequent processes, matters of much hardship and exposure.[?]

To mark the astronomical station that had been occupied by his meridian transit, Goodfellow placed a limestone block into the ground. It was fourteen inches square, with a copper bolt secured in the top (see Fig. 31). A reference stone, also with a copper bolt, was placed 281.4 feet due north of the station to perpetuate a meridian line on the capitol grounds. The city of Omaha paid for the purchase and the setting of these monuments.[13]

Between April and July 1869, Goodfellow returned to the Omaha station to help determine the longitudes of Mattoon and Springfield, Illinois, as well as those of Burlington and Des Moines, Iowa.[14] Before Goodfellow left Omaha, surveyor and astronomer Oliver N. Chaffee used the Omaha station to determine the twenty-fifth and twenty-seventh American meridians (longitude) along the forty-first parallel (latitude), the western boundary lines of Nebraska.

With an assistant, Chaffee arrived at Bushnell Union Pacific Station on July 5, 1869. After attaching the telegraph line to his Morse register, he set up his meridian transit No. 126, made by William Wurdemann. Equipped with two Bond and Sons chronometers and a Troughton sextant, he began observations on the nights of July 8 and 9, 1869. According to Chaffee's field notes,

> The mode of sending time signals was as follows: Notice having been given that the preparatory arrangements were completed and the observers ready, the observer at Bushnell touched the telegraphic operating key at the beginning of a minute as indicated by the chronometer and at intervals of 10 seconds throughout that minute, giving the last signal at the beginning of the next minute, thus sending 7 signals which are comprised in one set, and the mean, or average time then of place in the record. They were recorded at the Omaha station by means of the Coast Survey clock & chronograph working in the electrical circuit. At intervals of one minute between them, two other sets

Fig. 31 **Omaha High School, built on the site of the second territorial capitol; the Geodetic Survey stone is barely visible at lower right.** Bostwick-Frohardt Collection owned by KMTV and on permanent loan to the Durham Western Heritage Museum, Omaha. #14-327

of signals were transmitted in like manner. The same operation was repeated by the observer at Omaha, but the times of the receipt of the signals at Bushnell were taken by ear from the chronometer by myself & assistant. Forty-two independent measurements of the difference of time were therefore made in one evening. On July 9 these operations were repeated. On July 10 the same method was pursued at Julesburg Station U.P.R.R., but exchanges were made on one night only as Mr. Goodfellow's official duties called him away from Omaha after that time.[15]

Chaffee returned to Omaha following his observations to await approval of his survey and monument contract for the western boundary of Nebraska. He probably spent the time working on the calculations for the latitude and longitude of the Bushnell and Julesburg Stations (Fig. 32).

After employing a survey party, Chaffee returned to Julesburg and commenced the boundary survey on July 23, 1869. The point where he set his instrument at Julesburg Station was approximately 140 feet east of the Union Pacific depot. From this station, he measured north 89.65 chains (5,916.90 feet) to the forty-first degree of latitude. He then proceeded due east to the intersection with the South Platte River, setting six-inch-square by eight-foot-long wooden posts at every mile.

Four days later the survey proceeded west from Julesburg to the intersection with the twenty-seventh degree of longitude west of Washington, determined by the timing calculations made earlier at Bushnell. On August 17, 1869, the surveyors set a six-foot-long by one-foot-square limestone monument with these inscriptions (Fig. 33): facing north, "27 W.L."; facing east, "104 miles 72 ch. 07 lks."; facing south, "Colorado"; and facing west, "41 N.L." The crew then proceeded north along the twenty-seventh degree of longitude, the western boundary of Nebraska, and arrived at the northwest corner of the state on September 6, 1869.

Returning to the Platte River east of Julesburg, the crew proceeded east along the forty-first degree of latitude. On September 24 they arrived at the intersection of the twenty-fifth degree of longitude west of Washington and set a six-foot-long limestone monument two feet into the ground. This point is approximately four miles south and one mile east of Big Springs, Nebraska. Four pits were dug toward the cardinal points, each two feet square and one foot deep. A mound of earth was raised around the stone three feet high and seven feet in diameter at the base. The monument is inscribed: north side, "25 W. L."; east side, "Nebraska"; west side, "41 N.L."; and south side, "Colorado."

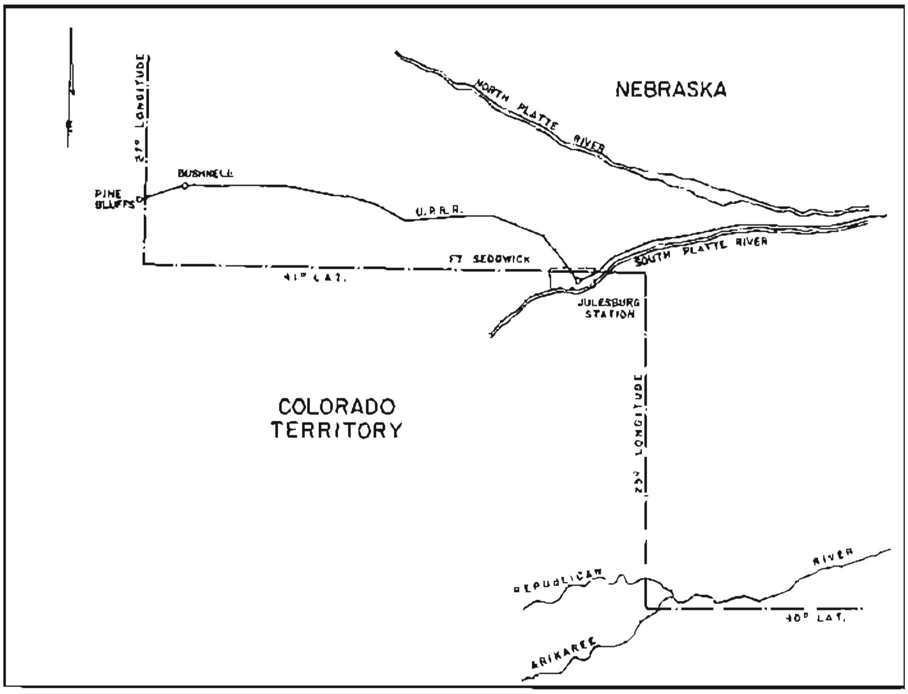


Fig. 32 **Map showing the western observation stations and portions of Chaffee's western boundary survey.** Courtesy of author

The surveyors then proceeded south along the twenty-fifth degree of longitude marking temporary locations for the mileposts. On September 28 the party arrived at the fortieth degree of latitude, the boundary between Kansas and Nebraska that had been established ten years earlier. They could find no section corner monuments on the boundary, so they made astronomical observations on October 1 to precisely determine the fortieth degree of latitude. After erecting a stone monument similar to those at the other state corners, Chaffee then proceeded north again to set permanent mileposts. On October 7, 1869, the crews arrived at the corner south of present Big Springs, and the survey of Nebraska's western boundary was complete (Fig. 32).[16]

During the past ten years, the four cornerstones of Nebraska set by Chaffee have been resurveyed using a Global Positioning System (GPS). The GPS receivers also use time to determine distances on Earth. An atomic clock on board the GPS satellite records time in nanoseconds (.000000001 sec) for the precise determination of latitude and longitude. By contrast, Chaffee's and Goodfellow's clocks could measure only to the nearest second.

The point with the most error along the western boundary of Nebraska is incorrect by approximately 3.5 seconds in longitude, or about 272 feet. This difference could be caused by a timing error of only 0.23 seconds. Other sources of error could be from hand calculations, chaining or measuring mistakes, transit


Fig 33 **The stone monument set by Chaffee in 1869 at the intersection of the Nebraska-Wyoming-Colorado boundaries, southwest of Bushnell.** Robert L. Brown photograph, 1988, courtesy of author

accuracy, or other variables in setting points to determine the true meridian. Another factor might be the adjustment of the telegraphic instruments and the conductivity of the telegraph line. Finally, the reflexes of the observer in tapping the Morse register at the precise second the star crossed the line in the transit's field of view could also be cause for error.

Modern-day surveyors owe their utmost respect to men like Chaffee, Goodfellow, and their survey crews for enduring personal sacrifices and hardships in the survey of the western boundary of Nebraska, and for the remarkable accuracy they gained with the surveying equipment of their day.

## Acknowledgment

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## Notes

[1] Franklin Van Zant, *Boundaries of the United States and the Several States* (Washington: GPO, 1976), 3–4.

[2] *A Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels*, sixth ed., U.S. Coast and Geodetic Survey, Special Publication No. 5 (Washington: GPO, 1946); Herbert W. Stoughton, "Research Notes Concerning Nebraska's Boundaries with Colorado and Wyoming," typescript, 1997, 5–7; copy in author's collection.

[3] Sarah Beall, *Astronomic Determinations by United States Coast and Geodetic Survey and Other Organizations* (Washington: GPO, 1925), 6.

[4] *Report of the Superintendent of the United States Coast Survey for the Year 1870* (Washington: GPO, 1873), 100 (hereafter cited as *Report of the Superintendent* and the specific year)

[5] *Report of the Superintendent . . . 1856* (1856), 168

[6] Beall, *Astronomic Determinations*, 11

[7] *Report of the Superintendent . . . 1856*, 170.

[8] Ibid., 171.

[9] Ibid., 173.

[10] Beall, *Astronomic Determinations*, 6.

[11] *Report of the Superintendent . . . 1856*, 167–68.

[12] Ibid., 167.

[13] The details concerning the Omaha observations are from *Report of the Superintendent . . . 1869* (1872), 44–45.

[14] Beall, *Astronomic Determinations*, 11.

[15] O. N. Chaffee to Robert Livingston, July 17, 1869, Letters Sent from Deputy Surveyors to the United States Surveyor General, Records of the U.S. Surveyor General's Office, Record Group 510, Roll 29, microfilmed by the Nebraska State Historical Society.

[16] The details of the survey are from Field Note Book number 2, Nebraska State Surveyor's Office, Lincoln.