FINDING LATITUDE AND LONGITUDE: CELESTIAL NAVIGATION OF THE LEWIS AND CLARK EXPEDITION

by
Eileen M. Starr

Thomas Jefferson's orders to Captain Meriwether Lewis were straightforward:

> Beginning at the mouth of the Missouri, you will take observations of latitude and longitude, at all remarkable points on the river & especially at the mouths of rivers, at rapids, at islands & other places & objects distinguished by such natural marks & characters of a durable kind, as that they may with certainty be recognized hereafter.[1]

Lewis and Clark's methods for calculating latitude and longitude depended on their having three accurate items: a chronometer (timepiece) which kept Greenwich, England time; a set of astronomical tables (*Nautical Almanac*) that predicted the location of celestial objects as viewed from Greenwich; and an instrument, either a sextant or quadrant, for measuring the angular distance between celestial objects, or the horizon and the object. This paper will discuss the astronomical instruments of Lewis and Clark, how these instruments, in conjunction with the astronomical tables, were used to find latitude and longitude, and some of the reasons for the errors in their measurements.

Latitude and longitude, and how they were determined

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Latitude is the distance, in degrees, north or south of the earth's equator. The number is expressed as parallels running from zero degrees at the equator to ninety degrees at the poles. Longitude is the distance, in degrees, east or west of a designated meridian, an imaginary line that runs directly between the earth's North and South Poles. The current Prime Meridian runs through Greenwich, England, and was the Prime Meridian used by the English-speaking world at the time of the Lewis and Clark expedition. By knowing a place's latitude and longitude, the location of the place can be specified exactly.

Lewis's instruments for calculating latitude and longitude consisted of a sextant, octant or Hadley's Quadrant, artificial horizons, circumferentor, and chronometer. Lewis gives a description of each of these instruments in his June 22, 1804 entry.[2]

Sextant

A sextant consists of two arms of equal length, plus a third arm, which is calibrated in chords to measure altitude. The arm containing the axis of the telescope and the arm carrying a mirror were connected to form a plane perpendicular to that of the mirror. The instrument was held vertically, with the horizon just visible at the tip of the mirror. The user, looking through an eyepiece, moved the telescope arm until the image of the observed object was also at the tip of the mirror. The angle was determined using a table of chords, and was doubled to give the altitude.[3]

According to Lewis' writings, the sextant was purchased from Thomas Whitney of Philadelphia. It was made of brass and had a ten-inch radius. It was graduated into fifteen minutes, which, by using a device called a nonius, was divisible to fifteen seconds, and half that amount by using a micrometer. A nonius, according to Moulton, was a method of dividing the arc of a circle into a given number of parts.[4]

The sextant, as described by Lewis, had three eyepieces. One eyepiece was a hollow tube. The other two eyepieces were telescopes, one of which reversed the image of the observed object. Lewis used the reversing telescope eyepiece most often because it gave a fuller and better image than the others. The error of the reversing telescope was 8' 45",

and was considered the standard error of the instrument.

Octant

The octant, also known as a Hadley's Quadrant, was fourteen inches in radius, and graduated to 20 minutes of arc. See Figure 1.

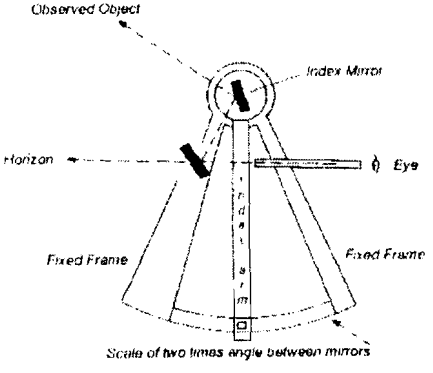

Fig. 1. Drawing of a Hadley's Quadrant or Octant

By means of a nonius it was divisible to one second, and to a half-second by the use of the micrometer. The instrument could be used for both forward and back observations. The error in the fore observation was 2 degrees plus, and the error in the back observation was 2 degrees 11 minutes and 40.3 seconds.[5] The octant was used when the sun's altitude at noon was greater than could be read using the sextant. The angle recorded was subtracted from 180 degrees, and the remainder was twice the actual altitude. Lewis' description of Hadley's Quadrant mentions that it came with a tangent screw, which acted as a nonius.

A problem with the octant is mentioned when the Corps was spending the winter of 1805-06 at Fort Clatsop. On February 16, 1806, Lewis implies that the octant had been broken. He writes:

> By several trials made today in order to adjust my Octant and ascertain her error in the direct observation, I found that it was

> 2 degrees one minute 45 seconds+ or additive beyond the fracture; this error was ascertained by a comparison with my sextant the error of which had been previously ascertained. The error of Octant in the direct observation on the broken limb next to 0 or below 55 degrees 20 minutes inclusive is 2 degrees additive only.[6]

Artificial Horizons

The sextant and octant used an artificial horizon as the point for measuring the altitude of celestial bodies. Lewis carried three artificial horizons. He described them while wintering at Ft. Mandan in 1805-05.

> An Artificial Horizon on the construction recommended and practiced by Mr. Andrw.(sic) Ellicott of Lancaster, Pensyla., in which water is used as the reflecting surface; believing this artificial Horizon liable to less error than any other in my possession. I have uniformly used it when the object observed was sufficiently bright to reflect a distinct immage (sic); but as much light is lost by reflection from water, I found it inconvenient in most cases to take the altitude of the moon with this horizon, and that of a star impracticable with any degree of accuracy.[7]

While wintering at Fort Mandan, Lewis writes: "Observed Equal altitudes [of the sun] with Sextant and artificial Horizon on the construction recommended by Mr. Andrew Elliott, in which sperits (sic) were substituted for water it being to (sic) cold to use the latter."[8]

Lewis gives this information about the second artificial horizon:

> An Artificial Horizon constructed in the manner recommended by Mr. Patterson of Philadelphia; glass is here used as the reflecting surface. This horizon consists of a glass plane with a single reflecting face, cemented to the flat side of the larger segment of a wooden ball; adjusted by means of a sperit-level

> (sie) and a triangular stand with a triangular mortice (sic) eut through it's (sic) center sufficiently large to admit of the wooden ball partially; the stand rests on three screws inserted near it's (sic) angles, whieh serve as feet for it to rest on while they assist also in the adjustment. This horizon I have employed in taking the altitude of the sun when his image he has been reather (sic) too dull for a perfect reflection from water; I have used it generally in taking the altitude of the moon, and in some cases of the stars also; it gives the moon's image very perfectly, and when carefully adjusted I consider it as liable to but little error.[9]

Lewis describes the third artificial horizon, part of the sextant:

> An Artificial Horizon formed of the index specula [the mirror] of a Sextant cemented to a flat board; adjusted by means of a sperit (sic) level and the triangular stand as before diseribed (sie). As this glass reflects from both surfaces it gives the image of all objects much more bright than either of the other horizon; I have therefore most generally employed it in observing the altitudes of stars.[10]

Circumferentor

The cireumferentor was a six-inch surveying compass that was used for determining their bearing and course. When it was leveled, it was used to find the magnetie azimuth of the sun and the pole star.[11]

The cireumferentor was temporarily lost on June 29, 1805, when during a great rainstorm, Lewis, Charboneau and Sakakawea took shelter in a ravine about a quarter of a mile above the Great Falls of the Missouri. They put their guns, compass and other items under a "shelving rock" on the upper side of the ravine where they would be out of the rain. However during the ensuing flood the water became a "rolling torrent with irrisistable (sic) force collected in the rivene (sic) and came down in a roling (sic) torrent and driving rocks, mud, and everything before it...."[12]

Head Spring of the Missouri (Lehmi Pass, MT/ID)	Latitude: 44°33'22"N	Latitude: 44°58'N	-0° 25' error: 29 miles
Travelers Rest MT	Latitude: 46°48'26"N	Latitude: 46°45'N	+0°3' error: 3.5 miles
Lewis' (Snake) River entering Columbia	Latitude: 46°19'11" N	Latitude: 46°12'N	+0° 7' error: 8 miles
Mouth of Columbia WA/OR	Latitude: 46°19'11"N Longitude: 124°57'W	It is not known from which site Lewis obtained his values.* Latitude of Cape Disappointment WA: 46°17'N Longitude of Cape Disappointment WA: 124°4'W Latitude of Clatsop Spit OR: 46°14' N Longitude of Clatsop Spit OR: 124°01'W *Values are given for the farthest west land point in Washington (N bank) and Oregon (S bank).	+0°2' error: 2.5 miles +0°53' error: 42 miles +0°5' error: 6 miles +0°56' error: 45 miles

Reasons for errors in the latitude and longitude measurements of the Lewis and Clark Expedition

Table Error of the Moon's position: According to Williams[30] there was considerable error in the published lunar distance tables. At the time of the Lewis and Clark expedition, the mean error in the tables for celestial latitude was 13 seconds, with a maximum of 80 seconds. The mean error for celestial longitude was 27 seconds, with a maximum of 87 seconds.

Equation of Time: In the figures that Clark used to determine the latitude of Kashaskias and Camp Dubois, he does not include an adjustment for the equation of time. Local noon is not the same as 12 o'clock because the earth's orbit is an ellipse. Sometimes the earth travels faster, and sometimes slower around the sun. The correction is given in the *Nautical Almanac* for each day.

Mathematical Accuracy: The determination of longitude using the distance of the moon from another celestial object required solving a number of equations using spherical trigonometry. It was easy to miscalculate.

Instrument Error: Although the standard error of each instrument was known, each was affected by the expansion or contraction of metals due to changes in temperature. Lewis included instrument error in his calculations but not error caused by the temperature.

Weather: Clouds interfered with observations. Lewis writes on November 24, 1803:

> "I am not confident with respect to the accuracy of the observation of this day, in consequence of some flying clouds which frequently interveened (sic) and obscured his [sun's] disk about noon and obliged me frequently to change the coloured (sic) glasses of the Sextant in order to make the observation as complete as possible.[31]

Results:

The Journals report many astronomical observations to determine latitude and longitude. However, in a short final report to Jefferson, written upon their return to St. Louis, Lewis gives the latitude of seven significant locations on the journey:[32]

Ft. Mandan: 47 degrees, 21 minutes, 47 seconds
Falls of the Missouri: 47 degrees, 84 minutes
Three Forks: 45 degrees, 22 minutes, 34 seconds
Head spring of the Missouri (Lemhi Pass): 44 degrees, 33 minutes, 22 seconds
Travelers Rest: 46 degrees, 48 minutes, 26 seconds
Mouth of Lewis' (Snake) River entering the Columbia: 46 degrees, 15 minutes, 13 seconds
Mouth of the Columbia: 46 degrees, 19 minutes, 11 seconds.

Significantly, the only longitude mentioned is that of the mouth of the Columbia (124 Degrees, 57 minutes, West), no doubt reflecting Lewis' lack of confidence in his other longitude measurements. At these seven locations, Lewis' latitude readings were either too far north or south meaning that a systematic error was not present. The one longitude reading (mouth of the Columbia) was too far west by at least 42 miles. See Table 1.

Conclusions:

The Corps of Discovery, following Jefferson's orders, did make latitude and longitude measurements at all remarkable points of the river. Considering the instruments and tables that they had to work with, the latitude and longitude measurements were remarkably accurate, and provided the approximate locations of the durable "natural marks & characters" found in the lands secured by the Louisiana Purchase, and of the lands located farther west. The information has made it possible to recognize most of the places and objects they discovered.

NOTES

1. Bernard DeVoto, editor, "Appendix I: Jefferson's Instructions to Lewis, *The Journals of Lewis and Clark* (Cambridge, MA: The Riverside Press, 1953). 482.
2. Gary E. Moulton, Editor, 1983-1998. *The Journals of the Lewis & Clark Expedition.* 12 volumes (Lincoln: University of Nebraska Press, 1984-1999). Volume 2, 410-413.
3. J.E.D.Williams. *From Sails to Satellites* (New York: Oxford University Press, 1992) 97.
4. Gary E. Moulton, Editor, 1982-1998. *The Journals of the Lewis & Clark Expedition.* 12 volumes (Lincoln: University of Nebraska Press, 1984-1999) Volume 2, 414.
5. Ibid., Volume 2, 411.
6. Ibid, Volume 6, 317.
7. Ibid., Volume 2, 411.
8. Ibid., Volume 3, 279.
9. Ibid., Volume 2, 412
10. Ibid., Volume 2, 412.
11. Ibid., Volume 2, 413.
12. Ibid., Volume 4, 341.
13. Ibid., Volume 4, 345.

14. Ibid., Volume 2, 92.
15. Ibid., Volume 2, 412.
16. Ibid., Volume 2, 269.
17. *The Astronomical Almanac*, (Washington: U.S. Government Printing office, 1998) C2.
18. Moulton., Volume 2, 121.
19. Ibid., Volume 2, 412.
20. Ibid., Volume 2, 382.
21. Ibid., Volume 2, 506.
22. Ibid., Volume 2, 113.
23. Ibid., Volume 2, 87.
24. E.G.R. Taylor and M.W. Richey, *The Geometrical Seaman: A Book of Early Nautical Instruments* (Cambridge: Hollis & Carter for the Institute of Navigation, 1962) 257-267.
25. Moulton, Volume 2, 87.
26. Charles Cotter, *A History of Nautical Astronomy* (New York: American Elsevier Publishing Company, Inc., 1968) 239.
27. Ibid., 205-206.
28. Moulton, Volume 3, 289.
29. Ibid., Volume 3, 273.
30. Williams, 96.
31. Moulton, Volume 2, 110.
32. Ibid., Volume 8, 413.

MY LEWIS AND CLARK – DISCOVERY IS AT THE CORE

by
Julianne Couch

Mrs. Eolah Lewis Couch, 93, descendant of both leaders of the Lewis and Clark Expedition of 1804-06, died yesterday of infirmities at her home, 738 Ethel Ave., Richmond Heights. She had lived in Richmond Heights since 1903. Born at Ashland, Kentucky, Mrs. Couch was the daughter of Mehlon Lewis, descendant of Capt. Meriwether Lewis, one of the expedition's leaders, and Mrs. Isabella Clark Lewis, descendant of Capt. William Clark, the other leader. She came to St. Louis with her parents during the Civil War.

The St. Louis newspaper confirmed the myth of our family heritage, back in the 1960s when newspapers did not lie. No wonder I've spent 40 years believing it. The only trouble is I no longer think the story is true.

About 10 years ago I started looking into the connection I was raised to believe existed between my father's family and those famous two men who carried the baton of westward expansion under President Thomas Jefferson. Political philosophy did not enter in to my research: whether one views the opening of the West as an unforgivable decimation of indigenous cultures, or as the natural next step in the development of the greatest nation in the world, the fact remains that an enormous feat took place. Captains Clark and Lewis were brave, intelligent, disciplined, ingenious, and adventurous, and by golly their blood surges in my veins. I could have gone on believing that myth had I not used my own bravery, intelligence, and so on to do my own discovering. I set out to read scholarly editions of the published journals. I read books. I joined the Lewis and Clark societies. I spoke with experts and worked the genealogy knot. I learned about William Clark's extraordinary skills as a mapmaker

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and riverman, his ability to lead the several dozen members of the Corps of Discovery and get along well with Native Americans along the trail. I learned about Meriwether Lewis' knowledge of medicine, his education, and his careful preparation under Thomas Jefferson to record all he observed about the people, the plants and animals, and of course, the trading routes to the Northwest.

I also learned two important facts about Meriwether Lewis: he was reputed by contemporaries and by present scholars to be of a dark and brooding disposition, prone to spells of depression. Tragically, his death in 1809 was quite possibly a suicide, committed because he was depressed over finances and general business miseries. The circumstances still provoke debate, but his slow, messy death by gunshot and knife wounds at a cabin along the Natchez Trace was certainly not part of the story my family ever told.

The other key fact I learned but that my family never talked of was that Lewis never married. Of course, that fact doesn't eliminate the possibility of his having fathered children, but experts I've consulted concur that in spite of rumors of Lewis having left some Native women along the trail in the family way, there is no convincing evidence that he had done so. That would make it tough to be his direct descendant.

So how did the family story begin? Did my great-grandmother Eolah Lewis Couch know the real details? It seems to me that my family has taken the anti-intellectual approach to ancestor worship so common in a country where people have immigrated, emigrated, and often become lost from one another over the vast stretches of prairie and time. Most of us have only a hazy knowledge of where our ancestors came from, what ghastly battle claimed our great uncle, or how our grandparents managed during the Depression. My family, with our sundry long-lost cousins, is typical of many American families who do their best to connect with relations over the haze of the past, and when stories exist at all, tend to take them on faith.

So far, I've not been able to verify that Lewis and Clark were related to each other, as family lore has held, merely that Lewis had served under Clark in the military, and that they had developed a friendship and mutual respect. Nor have I been able to discover any linking of their genes down

through the generations, as the obituary of my great-grandmother might suggest. In spite of my lack of evidence, I believe that a member of Lewis's family at some point linked up with a Clark, and that is how my great-grandmother came to descend from both men. It is true that Clark named his first child Meriwether Lewis Clark; perhaps the mix-up started there.

Frankly, I've become less interested in the pursuit of genealogy as I've thought about this question and more interested in what my findings mean to how identity is shaped. Of the two explorers, I somehow allied myself more closely with Lewis. I 'm sure the association started for me as a young child because he was the more famous of the two (after all, his name comes first when you say Lewis and Clark). Looking into the doubting faces of teachers and the admiring faces of peers, I bragged about my ancestry. As I began to grow up, I could attribute my adolescent dark side and rebellious behavior to the blood that flowed in my veins. Of course, I never disciplined myself to be a mapmaker or navigator or naturalist or leader of men. But possessing their legendary wanderlust was enough; for in my suburban community where few ever left the 'burb, let alone the city or state, a call to adventure was tantamount to a loaded canoe and an airgun from the hands of President Jefferson.

Wanderlust finally tightened its metaphorical shoelaces when I realized at around age 30 that the West sang to me, and that Wyoming felt like home, and that the college town of Laramie held the perfect combination of convenience, culture, and roughness. (That was an important time of life for Lewis, too, who celebrated his 31st birthday along the trail after reaching a milestone of the journey. To mark the occasion he jotted down in his journal that he hadn't done much in his life but waste time, and that from that moment on he hoped to live more for others and less for himself.) Lewis and Clark became the patron saints of my wanderlust, leading me to rally my husband, quit my job, rent out our house, say goodbye to family and lifelong friends, and strike out in a U-Haul for the West.

Predictably the trouble came when my husband realized he wasn't related to expansionist explorers, but to Missouri homesteaders. After a year or two he went back to Kansas City, and I stayed put, divorced, but

somehow content to be a person to whom a sense of place meant more than the security of family. After all, Lewis and Clark said goodbye to all they knew for several years, never sure if they'd see home again: that's how committed they were to their cause and how deeply the desire for discovery ran in them. If they could face malaria, mosquitoes, unnavigable rivers, fearsome winters, uncertain relations with Natives, and dwindling food, I could face, and would face, this new place in unlooked for circumstances. As I thought then, I was their great-great-great (at least) grandchild. An oft-repeated phrase from Lewis and Clark's journals became my mantra, and I "proceeded on."

The time for me to become a skilled navigator arrived. Not because Laramie was uncharted, but because I was and still am. I'm not the product of inescapable genealogical urgings that I thought I was. I miss being the product of the explorers' fabulous alchemy. I didn't come West because of psychological manifest destiny, as it turned out, but because I was sick of the heat and the crowds. I didn't end my marriage because I wanted to document animal species unknown to science. The marriage started to shake before the move West, I now see. Lastly, I'm not the brooding genius I'd fancied myself to be, though never really have been, in the fashion of Meriwether Lewis. Instead I'm descended most likely from William Clark, one of the most noteworthy men in our nation's history, which provides plenty of rations for my self-identity quest.

It turns out I'm just an average woman living in a place she loves, who grew up in a family connected enough to tell some stories, with sufficient personal confidence and independence to try new things. I got lucky when I picked Laramie. I didn't know I'd land in a town of other expatriates, so many adventurers just like me here from Missouri, and Kansas, and Illinois, and Iowa, looking for a place they can call home. I got even luckier when one such expatriate turned out to be a man who wanted the same thing.

As it happens, I'm no more an adventurer than my next door neighbor, or the mailman. I've not done anything worthy of marking the occasion of this insight by carving my name and date on a tree, as did William Clark when the Corps of Discovery finally reached the Pacific Ocean. I'm not sure whose blood runs in my veins, besides my own, or

if that even really makes a difference. But I do owe a debt of gratitude to Lewis and Clark for kindling in me a love of discovery and a willingness to examine what it is I've found.