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The Lewis and Clark expedition, "the most consequential and romantic peace-time achievement in American history," had its genesis in the mind of Thomas Jefferson fully two decades before the exploring party departed from Pittsburgh on 31 August 1803.[1] The need to determine the character and expanse of the western regions of the continent lingered in his mind, and during the intervening years he encouraged three unsuccessful attempts to explore them. After he assumed the presidency in 1801, he was finally able to bring his dream to realization. The venture not only achieved all that Jefferson had hoped, but also was the first and one of the most important applications of scientific practices and instrumentation attempted by the young republic.[2]

The third president was eminently suited to plan such a project, for he was better informed on national geography than anyone else in the United States. He had spent many years collecting and studying all that had been written and published about the subject, and he had had ample opportunity to meet Indians and others who had traveled in the West and to record all that he could learn from them. He was knowledgeable about scientific practices and instruments and was experienced in surveying, mapping, and making astronomical observations, all of which would be required to record the regions to be explored. As president of the American Philosophical Society, Jefferson could call upon the nation's most eminent men of science for advice on all the subjects that would concern the proposed expedition.[3]

Selecting his own secretary, Meriwether Lewis, to lead the exploring party, Jefferson set him the task of compiling lists of the needs and estimates of costs of such an undertaking, even before the president submitted the proposal to Congress. Lewis would prove an excellent leader: he was self-taught in the natural sciences, a lover of the outdoors, and, as a former army officer, experienced in the handling of men. He was also familiar with the lands beyond the Allegheny Mountains.[4]

Jefferson made his own instruments and

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scientific library available to Lewis and personally instructed him in the use of the instruments required for surveying and determining latitude. Lewis practiced particularly with the octant (fig. 1), an instrument designed primarily for use at sea but used also on land to observe altitudes of the sun or a star for determining latitude.[5]

Triangular in shape, the instrument was made of a closely grained tropical wood, the limbs blackened to eliminate glare. Ebony was preferred and most often used because it was already black. A movable arm or index pivoted from the apex. About 1750, brass replaced wood for the index arm. Two sets of colored glass shades were provided for use with the sun, and a sight (or later, a telescope) was attached to the right limb. Early octants had a second sight on the opposite limb, to be used when the horizon below the sun was poorly defined and the opposite horizon had to be used. A mirror fixed to the apex moved with the arm. A glass, half mirrored and half clear, was situated on the left limb, opposite the sight.

To use the octant, the observer sighted through the telescope to see simultaneously the horizon—visible through the unsilvered portion of the horizon glass—and the object, the sun or a star—reflected by a mirror at the apex of the index arm to the silvered portion of the horizon glass and then to the observer's eye. When sun or star and horizon coincided in the glass, the angle between the two mirrors was one-half the altitude of the object being observed. The angle through which the index mirror moved from a parallel position was determined by the movement of the index arm; double this angle was read on the arc, which was calibrated to ninety degrees.[6]

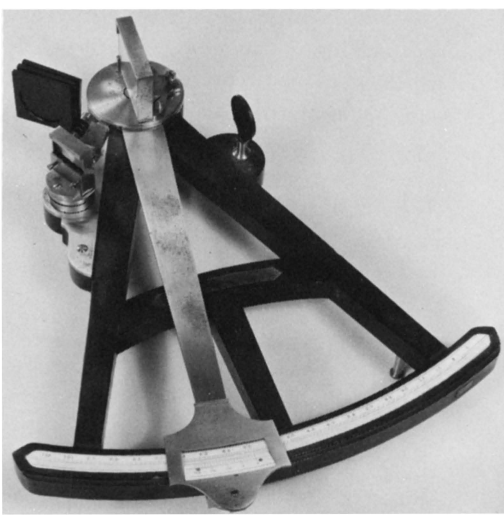

FIG. 1. *Octant, English, maker not known, late eighteenth or early nineteenth century. (The Franklin Institute, Philadelphia)*

The sextant (see fig. 5) closely resembled the octant in appearance and function and was based on the same principles of optics. It was made entirely of brass instead of wood, however, and included an arc calibrated to 120 degrees, which enabled it to measure lunar distances. A somewhat more modern instrument, it was used more frequently than the octant by the expedition.[7]

In order to take altitudes with the octant or sextant, a clear and distinct horizon was essential but was not always available in fog, mist, or inclement weather. An artificial horizon served as a substitute and enabled the observer using a sextant to dispense with the visible horizon when taking sights of the sun or a star. It featured a trough of mercury, the surface of which served as a reflector, with two sheets of glass attached gablewise over the trough to prevent motion of the mercury in the wind. The sextant measured the angle between the sun and its image on the mercury's surface, this angle being equal to twice the sun's apparent altitude.[8]

Although Lewis apparently became reasonably competent in the use of the octant and sextant, he needed more professional training. For advice on the scientific observations the expedition would be encouraged to make, Jefferson enlisted the cooperation of fellow members of the American Philosophical Society. To advise Lewis on scientific instrumentation, Jefferson chose Robert Patterson, professor of mathematics at the University of Pennsylvania, and Major Andrew Ellicott, secretary of the Pennsylvania Land Commission at Lancaster. Patterson was an authority on scientific principles and instruments, and Ellicott, the nation's foremost surveyor, had considerable field experience in their use.[9] For instruction on the scientific data to be collected by the exploring party, the president similarly sought out the botanist, Benjamin Smith Barton; Caspar Wistar, an anatomist also knowledgeable about zoology; and Dr. Benjamin Rush of the Pennsylvania Hospital to advise on medical practices and supplies.[10]

In anticipation of Lewis's visit, Patterson began to prepare astronomical formulas for the expedition's field use, including one for computing longitude from observations of lunar distances and another for computing time and altitudes. The equations were expressed by algebraic signs, which, he assured Jefferson, "renders it easy enough for boys or sailors to use."[11]

Major Ellicott stressed the need for Lewis to "acquire a facility, and dexterity, in making the observations, which can only be attained by practice." He also cautioned that the final calculations of latitude and longitude could not be made in the field but would have to be computed after the expedition's return, because of the number of astronomical tables and other references needed.[12] The instruments required by the exploring party, he explained, were identified in his published account of the survey of the southern boundary of the United States with Spanish territory, a copy of which he had given to the president. In this account, Ellicott specified that all that was required for determining both latitude and longitude was "a good sextant, a well made watch with seconds, and the artificial horizon, the whole of which may be packed up in a box 12 inches in length, 8 in width, and 4 in depth."[13] In practice, Lewis and Clark found that, although adequate for latitude, these instruments were not sufficient for determining longitude.

Ellicott provided specific instructions for determining the meridian altitude of the sun by a method of taking equal altitudes. He had used this successfully for years, although it was generally not practiced by other American surveyors of his time.[14] Ellicott also enclosed detailed instructions for making an artificial horizon of his own adaptation. He used water instead of other liquids commonly used, such as mercury, and separated the trough from the cover, to avoid possible disturbance of the liquid by the wind.

On 14 March 1803, Lewis began his journey of instruction to meet and work with his advisers. William Irvine and Israel Whelen, the Purveyor of Public Stores at Harper's Ferry, had been notified by the War Office that Lewis was to be provided with whatever he requested from military supplies. Whelen was instructed to purchase whatever Lewis needed that could not be obtained from the public stores, because all preparations for the expedition were to be vested in the War Office.[15] At Harper's Ferry, Lewis arranged to obtain weapons and supervised the construction of an iron-framed folding boat to be used on the upper Missouri River.[16]

These duties kept him for almost a month before he could move on to visit Major Ellicott in Lancaster, Pennsylvania. There he spent part of each day with Ellicott, who drew lessons from his own field experience, particularly of the difficulties and hazards to be anticipated in unknown country. During his many years of surveying the wilderness, Ellicott had coped with every type of privation and unexpected danger. His wise counsel would prove of immeasurable value to Lewis and his companions in the next several years. Lewis remained at Lancaster for two weeks using Ellicott's field instruments, including the octant and sextant. Although Lewis profited greatly from Ellicott's instruction and the experience with the instruments, in retrospect, the training period may have been too brief to achieve the competence required by the level of scientific responsibility imposed by President Jefferson.[17]

In Philadelphia, Lewis consulted with the other advisers and collected supplies for the expedition. Most of them were readily available from military stores or could be purchased, but acquisition of some of the instruments presented difficulties; thermometers, sextants, and chronometers, for example, were imported from England and were not always available in the quality desired.[18]

Jefferson had definite opinions about not only the scientific data to be collected but also the instruments to be used. Although Ellicott's account of the boundary survey published in 1803 had recommended "a good sextant, a well made watch, and an artificial horizon" to measure both latitude and longitude, Jefferson decided that longitude would be determined by the measurement of lunar distances using an equatorial theodolite. The establishment of latitude was relatively simple, requiring only an octant or sextant, but the determination of longitude was considerably more difficult.

At this time there were two common methods used for determining longitude. One required observing the times that one of Jupiter's major satellites entered or exited from the shadow of the planet. Because there were four major satellites, observations could be made with relative frequency, except when the planet was not favorably situated for observation. The second method required measuring lunar distances—determining the local time of the moon's transit and comparing it with the time of transit at a prime meridian. This method used the moon's movement around the earth as a clock, with the moon serving as the hand or index, and the sun, planets, and stars serving as the markers or indicators. The method using the Jovian satellites was easier to calculate, but the appearances of the satellites were still too infrequent and uncertain to be easily observed. On the other hand, the moon was visible each night, but its distances were more difficult to calculate. Considering the advantages and disadvantages of both methods of determining longitude, Jefferson selected the measurement of lunar distances for the expedition.[19]

In addition to a sextant or other astronomical instrument to observe lunar distances, a precise timekeeper was required to establish the times of observation. Jefferson opposed taking the usual timepiece into the field, noting that since he was "fearful that the loss or derangement of his watch on which these [lunar observations] were to depend, might lose us this great object of his journey, I endeavored to devise some method of ascertaining the longitude by the moon's motion without a timepiece."[20]

Instead, Jefferson proposed to substitute the equatorial theodolite (fig. 2). He owned such an instrument and was inordinately fond of it. The theodolite, like the octant and sextant, was used to measure angles, and was most accurate for horizontal angles such as those between a heavenly body and a fixed point on earth. The theodolite consists of a telescopic

FIG. 2. *Equatorial theodolite made by Jesse Ramsden, London, owned by Thomas Jefferson. (Thomas Jefferson Memorial Foundation)*

sight and two circles, each divided into degrees, minutes, and seconds, mounted at right angles to each other. The pedestal stand supporting the apparatus can be leveled and adjusted.

It was true, Jefferson admitted, that Jesse Ramsden, the maker of the theodolite, specified that a timekeeper be used with it, but the president believed that "this cannot be necessary, for the margin of the equatorial circle of this instrument being divided into time by hours, minutes, and seconds, supplies the main function of the time-keeper, and for measuring merely the interval of the observations, is such as not to be neglected. A portable pendulum for counting, by an assistant, would fully answer the purpose."[21] In Jefferson's opinion, the equatorial theodolite had distinct advantages over the sextant and the Borda reflecting circle because its telescope was more flexible and its apparatus for correcting optical distortion rendered the notations of altitude unnecessary, and even dispensed with the need for the timekeeper or portable pendulum.[22]

So convinced was Jefferson that the theodolite could satisfactorily replace a timekeeper for observing lunar distances, that he communicated his proposal not only to Ellicott and Patterson, but also to others. Among them were William Dunbar, John Garnett, William Lambert, Isaac Briggs, and possibly others to whom he had written concerning the expedition.[23] In response, Ellicott and Patterson suggested alternative methods, each requiring timekeepers, but diplomatically did not comment on the use of the equatorial theodolite, from which it may be inferred that they were not in agreement with the president's proposal.[24]

Jefferson now began to have some doubts of his own, and in a letter to Lewis he commented, "I would wish that nothing that passed between us here should prevent your following his [Ellicott's] advice, which is certainly the best. Should a time-piece be requisite, it is possible Mr. Arnold could furnish you one. Neither Ellicott nor Garnet [*sic*] have given me their opinion on the substituting the meridian at land instead of observations of time, for ascertaining longitude by lunar motions. I presume, therefore, it will not answer."[25]

Lewis reported that both Ellicott and Patterson disagreed with the use of the theodolite for measuring longitude by lunar distances. They believed it was too delicate an instrument for the rough use it would have in the field, difficult to transport and easily put out of order. In short, Lewis went on, "in its application to my observations for obtaining the longitude, it would be liable to many objections, and to much more inaccuracy than the sextant." Instead, both Patterson and Ellicott recommended that Lewis be equipped with two sextants, one or two artificial horizons, a good Arnold's watch or chronometer, a plain surveying compass with ball and socket joint, a two-pole chain, and a set of drafting instruments. "As a perfect knowledge of the time will be of the first importance in all my Astronomical Observations," Lewis went on to explain to the president, "it is necessary that the timekeeper intended for this expedition should be put in the best possible order, if therefore Sir, one has been procured for me and you are not perfectly assured of her being in good order, it would be best perhaps to send her to me by safe hand." He explained that Henry Voigt had offered to clean it and that Ellicott would regulate it.[26]

With all the advice that Jefferson sought from members of the American Philosophical Society and others, there was inevitably some overlap. John Vaughan, librarian of the society, had also been consulted by someone to whom Jefferson had written, and he in turn sought advice from Ellicott. The latter informed him that a brass sextant was infinitely superior to a wooden octant, and that one of the best quality might be purchased for between eighty and one hundred dollars. Ellicott himself planned to make an artificial horizon for the expedition, a project that required a slice of talc from a block in the society's museum.[27] Ellicott's use of talc for the reflecting surface of the instrument was an innovation evidently not used by others. Soon after his arrival in Philadelphia, Lewis visited Vaughan, bringing an artificial horizon made by Ellicott and a letter from him. Lewis also called upon Patterson with a letter from Ellicott asking him to provide Lewis with his own formulas for longitude.[28]

Lewis had done his homework well, for the list he had compiled with Jefferson's cooperation while he was still in Washington included most of the instruments later recommended by Ellicott and Patterson, as well as others they did not consider necessary. Each instrument listed would fulfill a particular aspect of the expedition's mission. On Lewis's earlier list but not included on the surviving list of instruments acquired for the expedition were a microscope for studying plant life and minerals; a theodolite, originally intended for making astronomical observations but useful also for surveying; hydrometers for determining the amount of water vapor in the atmosphere; and a brass rule, magnetic needles, and a measuring tape, all needed for surveying. Some of these items were probably deleted by Ellicott and Patterson as impractical, and others may have been eliminated simply because they could not be found. Or, some of them could have been purchased from other makers or dealers, from whom no records of purchase have survived.[29]

Additions made to Lewis's original list included a spirit level for surveying, one plated and three brass pocket compasses, a magnet for "touching" the compass needles when they lost their magnetism, a sextant, spare talc for the artificial horizon, a plain surveying compass for surveying through dense woodland and underbrush, a circular protractor with index arm for map making, a six-inch pocket telescope, a log line and reel, and a log-ship.

Particularly interesting on Lewis's original list is an

> Instrument for measuring made of tape with feet & inches marked on it, confined within a circular lethern [*sic*] box of sufficient thickness to admit the width of the tape which has one of its ends confined to an axis of metal passing through the center of the box, around which and within the box it is readily wound by means of a small crank on the other side of the box which forms a part of the axis, its tape when necessary is drawn out with the same facility & ease with which it is wound up.[30]

The instrument described in detail is the common surveyor's measuring tape. Such tapes, however, were not commercially produced until almost the mid-nineteenth century. The earliest commercial tape measure known was manufactured in England about 1846.[31] (See fig. 3.) Such a detailed description suggests that a commercial tape measure did not then exist. Jefferson may have proposed that such an item would be useful and should be ordered made by one of the Philadelphia instrument makers. Expedition records mention a "tape line" to measure the size of fishes, indicating that some form of the tape measure had been obtained.

In 1800 Philadelphia was a major American shipping center, with many makers and sellers of mathematical instruments. Some specialized in navigational and surveying instruments while others imported and sold optical and meteorological instruments from England and France.[32] With the assistance of Patterson and Whelen, Lewis was able to obtain most of the instruments he required, the majority coming from Thomas Whitney's shop on Water Street (fig. 4).

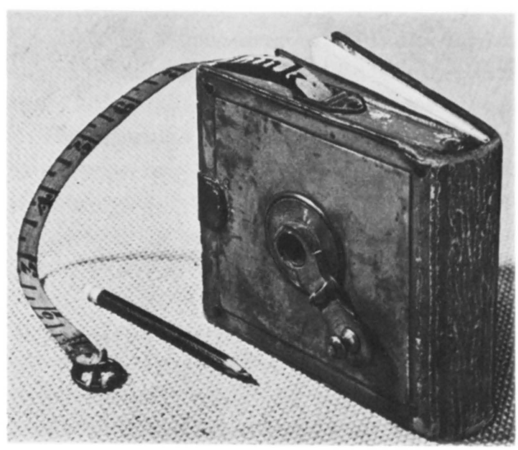

FIG. 3. *Cased measuring tape, English, 1846. (Science Museum, South Kensington, London)*

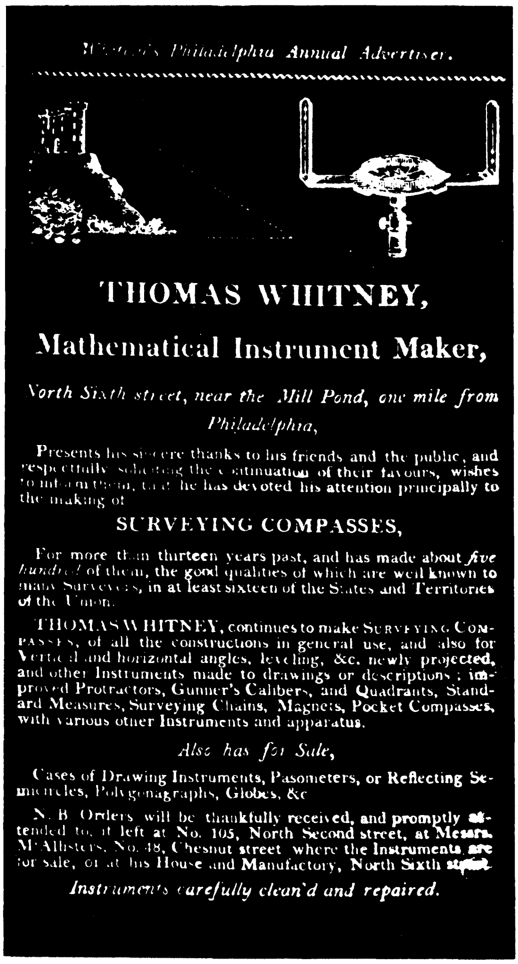

FIG. 4. *Advertisement of Thomas Whitney, mathematical instrument maker of Philadelphia. (From* Whitely's Philadelphia Annual Advertiser, *1820)*

In addition to making and selling instruments, Whitney also modified them as required by his clients. For example, he attached a small high-powered reading lens, which he called a "microscope," to the index arm of the sextant that Lewis purchased.[33] A user needed magnification to read the sextant's vernier scale, and at this time sextants were equipped with separate hand-held magnifiers that fitted into the field case. It was not until a decade or more later that a lens attached directly to the index arm of the sextant became a standard feature.

Whitney provided a total of fifteen instruments to the expedition, at a cost of $162.20. All were practical selections. From him Lewis purchased a late model octant with tangent screw, probably English, for $22. It had a fourteen-inch radius and a vernier scale, and was capable of back observations. For $90, he also obtained a sextant with a ten-inch radius and a vernier scale, equipped with three eyepieces—a hollow tube and two telescopes, one of which reversed the image. A cased set of plotting, or drafting, instruments was used for map making; the spirit level and two-pole chain were standard surveying equipment. The log line, reel, and log-ship were used with a timekeeper to determine the speed of a ship or boat, or the distance it had run in a given period of time. A brass boat or marine compass was a basic necessity for navigating. Lewis purchased one silver-plated pocket compass, probably for his own use, and three others of brass. Since a compass was an item that was frequently damaged or lost, he made certain that he would have replacements. From Whitney he also obtained a spare parallel glass and a slab of talc as replacements for the artificial horizon prepared for the expedition by Ellicott.[34]

One of Lewis's most important acquisitions was a gold-cased chronometer, which he purchased from the Philadelphia watch and clockmaker Thomas Parker.[35] The chronometer, or "Arnold's watch," cost $250, with an additional seventy-five cents for the winding key. As yet no chronometers were being manufactured in the United States, and the expedition's schedule did not allow time to order a chronometer from England, as Jefferson had suggested. The only alternative was to purchase an English-made timepiece that was already available in Philadelphia. As Lewis described it, this chronometer had a balance wheel and escapement of "the most improved construction."[36]

For cleaning and adjustment, Lewis brought the chronometer to the shop of Henry Voigt, the foremost clockmaker of the time. Voigt also constructed a protective mahogany case, in which he suspended the chronometer by means of "an universal joint," by which Lewis may have meant gimbals. Voigt also cleaned and adjusted Lewis's own silver pair-case watch with second hand, which he would take on the expedition. His total bill for the work was $7.37½.[37] Lewis sent the chronometer by Dr. Barton to Ellicott to regulate and rate it. Ellicott checked the chronometer's rate of going for two weeks until he felt assured that it was properly adjusted.

Meanwhile, Patterson had begun work on a "Statistical Table," on which Lewis was to record each astronomical observation as he made it. Patterson originally had planned to furnish Lewis with just a sketch from which he could develop such a table, but not having completed the sketch in time, Patterson compiled the table and sent it on to Lewis after his departure. As he assured Jefferson, it was "an expedient that would save a great deal of time, and be productive of many advantages."[38]

Jefferson's final instructions to Lewis, submitted on 30 June, specified, in addition to a multitude of other requirements, the instruments to be used "for ascertaining by celestial observations the geography of the country thro' which you will pass." Beginning at the mouth of the Missouri, Lewis was instructed to make observations of latitude and longitude at all notable points of the river, especially at distinguishable points such as mouths of tributaries, rapids, islands, and other natural landmarks that could be recognized again later. He was asked to determine the river's course between such points by means of the compass, the log line, and observations of time that were to be corrected by the celestial observations themselves. Variations of the compass at various places also were to be noted. Points of interest on the portage between the heads of the Missouri and water offering the best communication with the Pacific were also to be fixed by observations.

Jefferson was particularly insistent that all "observations are to be taken with great pains & accuracy" and that they were to be recorded distinctly and in such a manner that they would be comprehensible to others as well as to the observers, who would be able to establish the latitude and longitude for the locations at which they had been taken by using the requisite tables. These records were to be submitted to the War Office so that final calculations could be made later by several qualified individuals working at the same time. To ensure against possible loss of records, Jefferson directed the explorers to make several copies of their notes during their leisure and to give them into the safekeeping of their most trustworthy men. "A further guard," he wrote, "would be that one of these copies be on the paper of birch, as less liable to injury than common paper."[39] Jefferson also required the explorers to record climatological data similar to the records he personally had maintained daily since he was a law student at Williamsburg.[40]

Realizing the need for a second leader if an accident should befall Lewis, Jefferson left the selection to Lewis, who chose William Clark, one of his former army friends and a younger brother of George Rogers Clark, the explorer. Clark's considerable military experience and his familiarity with the region where the Ohio and Mississippi rivers meet later proved him an excellent choice. Clark had no role in planning the expedition for there was little time between his selection and Lewis's departure on 5 July for Pittsburgh. After further unexpected delays in procuring equipment, the exploring party finally departed from Pittsburgh at the end of August 1803. Clark would join the party later.[41]

The scientific entries in the surviving journals for the early part of the expedition proper, as it ascended the Missouri in 1804, were apparently kept only by Clark. He carefully compiled tables of the party's courses, times, and distances along the river, noting such landmarks as islands, sandbars, towns, river openings, unusual items observed along the banks, weather, and observations made with the octant.

Lewis began his scientific entries in the spring of 1805, after the party left the Mandan villages, and continued consistently for the remainder of the expedition. From the time that the exploring party wintered with the Mandans, the explorers adopted the procedure of having Clark make a copy of all of Lewis's scientific entries in his own journal. The decision to undertake this duplication may have resulted from the accident on 14 May when "some of the papers and nearly all of the books got wet, but not altogether spoiled" when their white pirogue capsized. Lewis's entries were copied by Clark, frequently without alteration but often dated earlier for no apparent reason.[42]

The earliest temperature records were kept by Lewis as the party progressed down the Ohio River in autumn 1803, and Clark continued the practice at the Wood River camp in early 1804. The last of their thermometers was accidentally struck against a tree and broken in September 1805, however, and no temperatures could be recorded after that. The thermometers were probably of a type similar to those described by Jefferson to Isaac Briggs. "The kind preferred," he wrote, "is that on a lackered plate slid into a mahogany case with a glass sliding cover, these being best weather."[43]

Although Lewis is usually considered the scientific specialist of the expedition, Clark made many more significant scientific contributions than are generally realized, particularly relating to natural history. Lewis may have been given more credit because his journal entries reflected superior qualities of writing and expression. Because Lewis had been trained to use the octant and Clark had not, Lewis probably instructed him in its use in the field, for Clark practiced with it constantly at the Wood River camp and may even have become more proficient in its use than Lewis. His previous experience as a surveyor served him well, and he kept a notebook in which he had written problems of celestial navigation with their solutions. Clark was responsible for recording navigational data, and he also prepared sketches and observational notes. His maps proved to be remarkable for their fine quality and accuracy.[44]

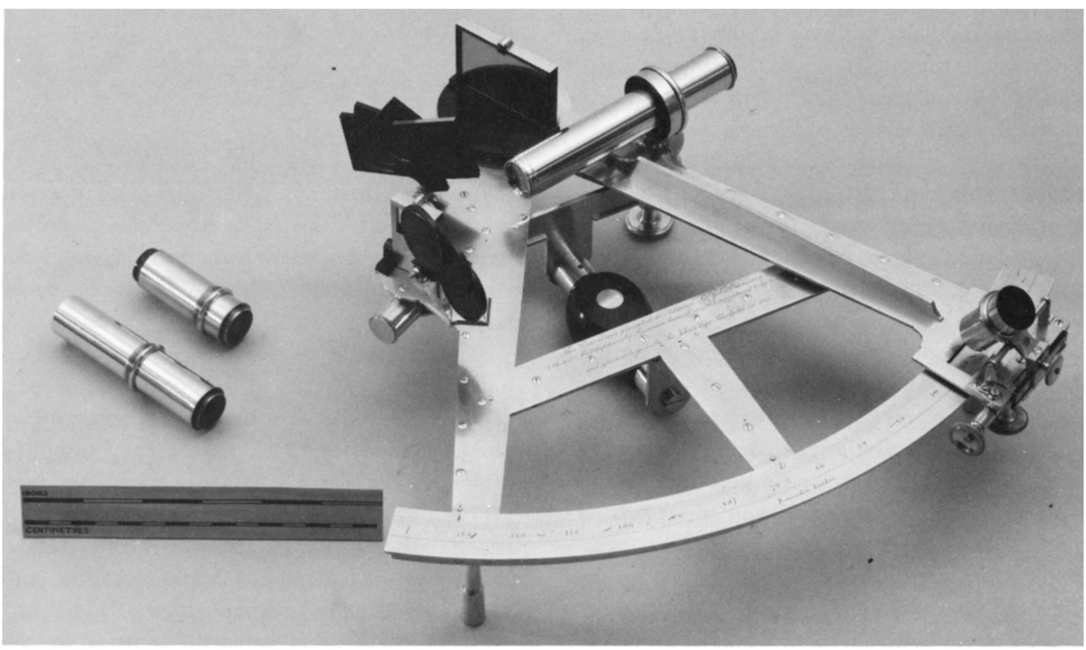

FIG. 5. *Sextant made by Jesse Ramsden, London, late eighteenth century. Brass with three telescopic sights. Note addition of a magnifier as standard part of the instrument. (National Maritime Museum, Greenwich)*

In an entry for 22 July 1804 in the journal recording astronomical observations, Lewis provided a detailed description of the instruments he used for this purpose: a sextant, an octant, three artificial horizons, a chronometer, and a surveying compass. Lewis preferred the reversing telescope for the eyepiece of the sextant (fig. 5) and used it in all his observations. He found the octant particularly useful for making back observations when the sun's altitude at noon proved too great to observe with the sextant.

Of the three artificial horizons with which the exploring party was equipped, the one prepared by Ellicott using water as the reflecting surface proved useful "when the object observed was sufficiently bright to reflect a distinct immage." The one provided by Patterson, consisting of a glass pane cemented to the side of a wooden ball and adjusted by a spirit level and platform, was more adaptable for taking altitudes of the moon and stars and of the sun under dull conditions. The third horizon, using the index mirror of a sextant attached to a flat board and also adjusted by a spirit level and platform, was particularly useful with bright objects such as the stars.

The chronometer, protected in the field case made for it by Voigt, was, according to Lewis's account, wound each day at noon and its "rate of going" confirmed by observations made by Lewis. He found it to be fifteen and five-tenths seconds too slow within a twenty-four-hour period on mean solar time, which was very close to the rate established for it by Ellicott. For taking the magnetic azimuth of the sun and the Pole Star, Lewis used the surveying compass (fig. 6), and he found it useful also for taking a traverse of the river. From these compass bearings, combined with the distances from point to point that he estimated, he was able to chart the Missouri River. From the onset of the expedition to the winter of 1805, Lewis made as many as seven or eight observations for each attempt to determine longitude, the number dependent on the degree of visibility of the object or objects observed.[45]

A careful study of the astronomical data in the expedition's journals suggests that any deficiencies in the observations made by Lewis and Clark were probably due as much to their lack of skill and experience as to the difficult conditions under which the observations had to be made. It is doubtful whether even an expert astronomer or surveyor such as Major Ellicott would have been able to make a set of lunar observations without the help of several assistants. Singlehandedly, an observer would have had to take several altitudes of the moon and of the planet or star in rapid succession, then proceed to observe several lunar distances and, finally, take several altitudes of the moon and planet or star once more.

A less experienced observer, however, such as Lewis or Clark, probably required as many as

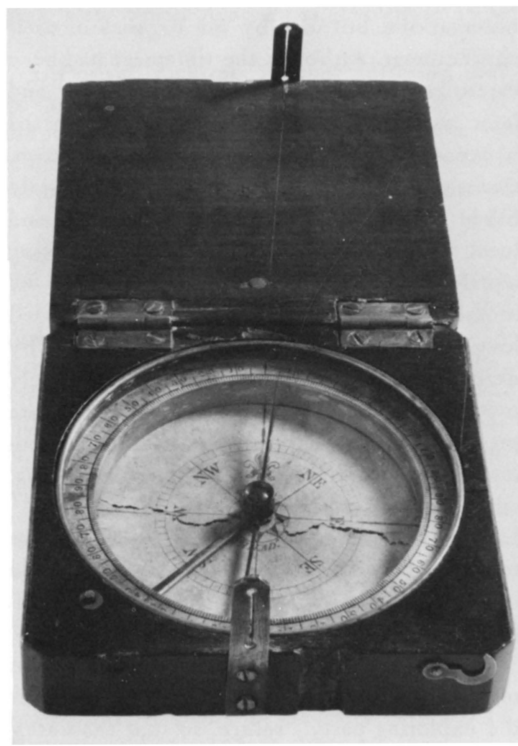

FIG. 6. *Pocket surveying compass probably carried on the Lewis and Clark Expedition. Made by Thomas Whitney, Philadelphia. (Division of Political History, National Museum of American History, Smithsonian Institution)*

three assistants. As the principal observer measured the angle between the moon's limb and a star or planet, one assistant measured the moon's altitude, another the altitude of the star or planet being observed, and the third assistant recorded the times of observations with the chronometer. The three required angles had to be measured simultaneously and the observations repeated four or five times; then the mean of each group of observations had to be calculated. Finally, the sums of the lunar distances, each of the two sets of altitudes, and the times were to be divided by the number of sets to eliminate or reduce minor errors of observation.[46]

The explorers' relative inexperience with sophisticated scientific instruments was compounded not only by the difficult field conditions under which they had to make their observations, but also by the vagaries of their chronometer. Although the timepiece had been carefully regulated first at Philadelphia and later at Lancaster, Lewis and Clark neglected it occasionally and permitted it to run down. Consequently, the original rate of going established in Pennsylvania no longer applied, and local time had to be obtained by observing equal altitudes of the sun to establish the moment of noon. Lewis faithfully recorded longitude by celestial observation as well as by dead reckoning, but the observations rarely proved to be correct, and the most useful data proved to be the records made by dead reckoning, especially those showing their westering, combined with the observations for latitude.[47] Lacking the time, convenience, and expertise to make the necessary calculations of longitude in the field, the task was left for later, as Ellicott had urged.

Lewis had been instructed to submit his records of observations to the War Office after the exploring party's return, so that the necessary calculations for longitude and latitude could be made from his data. Ferdinand Rudolph Hassler, instructor of mathematics at West Point, was selected for the task, and he attempted to correct the longitudes by making additional calculations. After considerable trial and error, he reported that he could make nothing of the observations. Errors made by the explorers may have been partly to blame, but it is also likely that Hassler did not have clear knowledge of the procedures that Lewis and Clark had used in the field. For example, he could not have known that although Lewis regulated the chronometer on mean solar time, he entered the observations on local time. Writing to Patterson in 1810 after receiving a chart of Lewis's calculations from Vaughan, Hassler stated that he had compared these with results he had obtained before, but he continued to find discrepancies. Although he had been promised all the journals to study, he complained that he had received "only one, in a fair copy, which I see has many faults in writing."[48]

More than a decade after the expedition's return, Jefferson commented on Lewis's observations for longitude and latitude in a letter to José Corrêa da Serra, newly appointed Spanish minister to the United States, with whom he shared scientific interests. He wrote, "Altho', having with him the Nautical almanacs [for the three years during which they were in the field], he could and did calculate some of his latitudes, yet the longitudes were taken merely from estimates by the log-line, time, and course. So that it is only as to latitudes that his map may be considered as tolerably correct; not as to its longitudes."[49]

The many kinds of observations of the country that the explorers were required to record, their camp duties, and the rigors of survival under difficult conditions, left Lewis and Clark too little time for difficult scientific observations. Despite the shortcomings of their astronomical records, the explorers returned with a remarkable corpus of information on the flora, fauna, ethnology, and geography of the regions they had traversed. Unfortunately, neither Jefferson nor Congress had made any special provisions to preserve the appurtenances of the expedition, the collections, or the records kept by the explorers on the nation's first scientific endeavor. Jefferson's lack of foresight is surprising in view of the considerable concern for the preservation of records he had always demonstrated since his student days at Williamsburg.[50]

When the exploring party returned to St. Louis, preserved specimens were stored temporarily, but some botanical specimens were shipped to Jefferson and some were permanently lost. No provision was made for the classification and preservation of the scientific collections, notes, and reports sent or brought back by Lewis and Clark; consequently, the materials were dispersed to various repositories, with inadequate record keeping and inevitable loss. Jefferson allowed Lewis and Clark to keep their original journals so that they could benefit financially from their publication. Many of the journals were subsequently dispersed and lost. It was not until 1904 that all the written records of the expedition were finally located and brought together for publication, a full century after Lewis and Clark arrived at their preliminary camp.[51]

Particularly regrettable is the dispersal of the scientific instruments used on the nation's first organized scientific exploration. All that survive are a handful of unimportant personally owned items, few of which can be documented as having been used on the expedition.[52] The appurtenances of the trip—knives, tomahawks, fishing gear, weapons, keelboat and canoes, handmade clothing, scientific instruments, and many other items used and collected by the exploring party—would have been of enormous interest and value to the public at that time and to future generations. In the absence of a request for Congress to appropriate money to preserve the items, they were sold at public auction at St. Louis in 1806 for $408.62.[53]

In retrospect, in addition to the important specific information the explorers brought back about the new lands in the West, the Lewis and Clark expedition had two important results. It provided Jefferson an opportunity to enlist government support of science for the first time, and it served as a precedent for future exploring expeditions to support the American position in the West. As Jefferson wrote to William Dunbar in 1805, while the expedition was still in progress, "The work we are now doing, is, I trust, done for posterity, in such a way that they need not repeat it. . . . We shall delineate with correctness the great arteries of this great country: those who come after us will extend the ramifications as they become acquainted with them, and fill up the canvas we begin."[54]

NOTES

1. Seymour Adelman, "Equipping the Lewis and Clark Expedition," *American Philosophical Society Bulletin for 1945* (1946): 39.

2. Paul Russell Cutright, *A History of the Lewis and Clark Expedition* (Norman: University of Oklahoma Press, n.d.), p. 3; Reuben Gold Thwaites, ed., *Original Journals of the Lewis and Clark Expedition, 1804–1806*, 8 vols. (New York: Dodd, Mead, 1904–1905; reprint, New York: Arno Press, 1969), 7: 193–205.

3. Donald Jackson, *Thomas Jefferson and the Stony Mountains* (Urbana: University of Illinois Press, 1981), pp. 86–97; Silvio A. Bedini, "Jefferson: Man of Science," *Frontiers* (Annual of the American Academy of Natural Sciences of Philadelphia) 3 (1981–1982): 10–23.

4. John E. Bakeless, "Lewis and Clark's Background for Exploration," *Journal of the Washington Academy of Sciences* 44, no. 11 (November 1954): 334–38; Dumas Malone, *Jefferson the President: First Term, 1801–1805* (Boston: Little, Brown, 1970), pp. 43–44, 275–76; Jackson, *Stony Mountains,* pp. 117–21.

5. Jefferson to Robert Patterson, 2 March 1803, Donald Jackson, *Letters of the Lewis and Clark Expedition with Related Documents, 1783–1854,* 2d ed., 2 vols. (Urbana: University of Illinois Press, 1978), 1: 21; Herman R. Friis, "Cartographic and Geographic Activities of the Lewis and Clark Expedition," *Journal of the Washington Academy of Sciences* 44, no. 11 (November 1954): 343–46.

6. The octant, or Hadley Reflecting Quadrant as it was originally known, was simultaneously invented about 1730 in Philadelphia by a plumber and self-taught man of science named Thomas Godfrey and in England by John Hadley, a mathematician and mechanic

employed by the admiralty. The instrument incorporated two principles of optics: first, that the angle of coincidence equaled the angle of reflection in a plane containing the perpendicular to the reflecting surface at the point of reflection, and second, that if a ray of light suffered two successive reflections in the same plane by two mirrors, the angle between the first and last direction of the ray was twice the angle between the mirrors. Because the angle of the mirrors was one-half the altitude of the object observed, double the angle would be read on the arc when the mirror on the index arm moved from parallel through the angle. In this manner the arc would read to ninety degrees although it was in itself one-eighth of a circle, or forty-five degrees.

Within a short period after its invention, the octant was improved by the addition of a small sliding scale for taking more accurate fractional readings, and a small telescope replaced the original sight, or was offered as an alternative. After 1750 the wooden arm, or index, was replaced with brass, and by 1775 the instrument had been substantially reduced in size so that it was easier to use. See H. O. Paget-Hill and E. W. Tomlinson, *Instruments of Navigation* (London: H.M.S.O., 1958), pp. 13–14; Silvio A. Bedini, *Thinkers and Tinkers: Early American Men of Science* (New York: Charles Scribner's Sons, 1975; reprint, Rancho Cordova, Calif.: Landmark Enterprises, 1983), pp. 118–23; "The Description of a new Instrument for taking Angles. By John Hadley, Esq., Vice-Pr. R. S. Communicated to the Society on May 13, 1731," *Philosophical Transactions of the Royal Society for August and September 1731* 37, no. 420 (1733–34): 147–57, pl. 13.

7. The invention of the sextant about 1757 is attributed to Captain John Campbell, a British naval officer, who experimented to find a more accurate means of measuring lunar distances. See E. G. R. Taylor, *The Mathematical Practitioners of Hanoverian England, 1714–1840* (Cambridge: Cambridge University Press, 1965), pp. 32, 45, 199; Charles H. Cotter, *A History of Nautical Astronomy* (New York: American Elsevier Publishing Company, 1968), pp. 87–91.

8. Cotter, *Nautical Astronomy,* pp. 91–96; E. G. R. Taylor and M. W. Richey, *The Geometrical Seaman* (London: Hollis and Carter, 1962), pp. 79–81.

9. Dumas Malone, ed., "Robert Patterson," *Dictionary of American Biography* (New York: Charles Scribner's Sons, 1934), 7: 305–06; Silvio A. Bedini, "Andrew Ellicott, Surveyor of the Wilderness," *Surveying and Mapping* 36, no. 2 (June 1976): 113–35; Catherine Van Cortlandt Mathews, *Andrew Ellicott, His Life and Letters* (New York: Grafton Press, 1908), pp. 50–79; Bedini, *Thinkers and Tinkers,* pp. 160–61.

10. Paul Russell Cutright, "Contributions of Philadelphia to Lewis and Clark History," *We Proceeded On,* Supplement no. 6 (July 1982): 1–18, previously published as "Meriwether Lewis Prepares for a Trip West," *Bulletin of the Missouri Historical Society* 23, no. 1 (October 1966): 3–20; Jackson, *Letters,* 1: 16–19.

11. Robert Patterson to Jefferson, 15 March 1803, Jackson, *Letters,* 1: 28–31.

12. Andrew Ellicott to Jefferson, 6 March 1803, Jackson, *Letters,* 1: 23–25. Jefferson's letter to Ellicott of 28 February 1803 has not survived.

13. [Andrew Ellicott], *The Journal of Andrew Ellicott Late Commissioner on Behalf of the United States . . . for Determining the Boundary Between the United States and the Possessions of his Catholic Majesty in America* (Philadelphia: 1803; reprint, Chicago: Quadrangle Books, 1962), appendix, p. 42.

14. Silvio A. Bedini, *The Life of Benjamin Banneker* (New York: Charles Scribner's Sons, 1972; reprint, Rancho Cordova, Calif.: Landmark Enterprises, 1984), pp. 113–14; Bedini, "Andrew Ellicott," pp. 121, 124.

15. Thwaites, *Original Journals,* 6: 231–37; Adelman, "Equipping the Expedition," pp. 40–41; Jackson, *Letters,* 1: 75–77.

16. Jackson, *Letters,* 1: 37–40, 75–76; Thwaites, *Original Journals,* 7: 217; Donald W. Rose, "Captain Lewis's Iron Boat: 'The Experiment,'" *We Proceeded On* 7, no. 2 (May 1981): 4–7.

17. Lewis to Jefferson, 9 April 1803, Jackson, *Letters,* 1: 48–49.

18. Jackson, *Letters,* 1: 48–55, 69–97.

19. Cotter, *Nautical Astronomy,* pp. 180–267; Bedini, *Thinkers and Tinkers,* pp. 346–52. Longitude is measured in an east-west direction from an arbitrary point. To calculate

the difference in time and of the meridian of longitude, the observer must know the time at the arbitrary point at the moment of the sun's meridian at his position. See A. Pannekoek, *A History of Astronomy* (New York: Interscience Publishers, 1961), pp. 276–81; Cotter, *Nautical Astronomy,* pp. 189–92.

20. Jefferson to Patterson, 16 November 1805, Jackson, *Letters,* 1: 270.

21. Jefferson to Robert Patterson, 29 December 1805, Thomas Jefferson Papers, Manuscripts Division, Library of Congress. The theodolite owned by Jefferson, and the sort that he proposed for field use for determining longitude, was made by Jesse Ramsden of London, who described it in *Description of the Universal Equatorial, and of the New Refraction Apparatus, Much Improved by Mr. Ramsden* (London: 1791).

22. The Borda Reflecting Circle was considered one of the most accurate instruments for measuring lunar distances as well as for taking altitudes. Invented in 1752 as a replacement for the octant by Tobias Mayer, a German astronomer, the reflecting circle was constructed on the same basic principle but was circular in shape with two mirrors that could be moved alternately so that altitudes could be taken successively. To establish a mean, the altitudes totaled by the instrument were divided by the number of observations made. The instrument was named for Chevalier de Borda, a French inventor who greatly improved the instrument and published a description of it in 1787. The instrument was produced by various English and French makers. Cotter, *Nautical Astronomy,* pp. 83–87.

23. All were Jefferson's correspondents on scientific matters over a period of years. William Dunbar (1749–1810) was a Scottish planter and man of science who settled near Natchez in 1792 and was surveyor of the district. He served as representative of the Spanish government in the establishment of the boundary between the United States and Spanish possessions. John Garnett (ca. 1751–1820) of New Brunswick, New Jersey, was a publisher of astronomical tables and nautical almanacs and also imported and sold navigational instruments. William Lambert (fl. 1790–1820) of Washington, D.C., was a clerk in the War Department and an amateur astronomer with his own observatory. He corresponded with Jefferson on astronomical subjects and later avidly supported the establishment of a national observatory in Washington. Isaac Briggs (1763–1825), a Quaker from Sandy Spring, Maryland, was one of Ellicott's assistant surveyors in the survey of the Federal Territory. In 1803 he undertook the survey of the Mississippi Territory for the federal government. See particularly Jefferson to Dunbar, 25 May 1805, Dunbar to Jefferson, 9 July 1805, Jefferson to William Lambert, 22 December 1804, and Jefferson to Dunbar, 12 January 1806, Jackson, *Letters,* 1: 55–56, 244–46, 250–51, 290.

24. Ellicott to Jefferson, 6 March 1803, and Patterson to Jefferson, 15 March 1803, Jackson, *Letters,* 1: 23–25, 28–31.

25. Jefferson to Lewis, 30 April 1803, Jackson, *Letters,* 1: 44–45.

26. Lewis to Jefferson, 14 May 1803, Jackson, *Letters,* 1: 48–49. An Arnold's watch was designed to keep time with considerable precision, with a compensated balance to overcome irregularity due to temperature changes. It was invented in the third quarter of the eighteenth century by John Harrison, an English carpenter turned clockmaker. It was modified and improved by several other clockmakers: Larcum Kendal, Thomas Earnshaw, and John Arnold. Arnold's improvements included a bimetallic compensation balance, an improved pivoted detent escapement, and a helical balance spring.

27. Ellicott to John Vaughan, 16 April 1803, Andrew Ellicott Papers, Manuscripts Division, Library of Congress; Ellicott to Jefferson, 18 April 1803, Jackson, *Letters,* 1: 36–37. John Vaughan (1756–1841), a Philadelphia merchant, was treasurer and librarian of the American Philosophical Society.

28. Ellicott to John Vaughan, 7 May 1803, and Ellicott to Robert Patterson, 7 May 1803, Jackson, *Letters,* 1: 45–46.

29. See Jackson, *Letters,* 1: 69–97 for records relating to the acquisition of supplies by Lewis.

30. Jackson, *Letters,* 1: 69.

31. Found in the collections of the Science Museum, South Kensington, London.

32. Silvio A. Bedini, *Early American Scientific Instruments and Their Makers* (Washington, D.C.: GPO, 1964), pp. 30–33, 58–64; Bedini, *Thinkers and Tinkers,* pp. 354–56.

33. Invoice of Thomas Whitney, 13 May 1803, Jackson, *Letters,* 1: 82. Thomas Whitney (?-1823) was an English-born maker of mathematical instruments who established himself in Philadelphia about 1797. He specialized in surveying instruments of all types; an 1819 advertisement claimed that he had made over five hundred surveying compasses. See Bedini, *Early Scientific Instruments,* p. 30.

34. Jackson, *Letters,* 1: 82; Cutright, "Contributions," pp. 14-16; Thwaites, pp. 231-46.

35. Invoice of Thomas Parker, 19 May 1803, Jackson, *Letters,* 1: 88. Thomas Parker (1761-1833), trained as a clockmaker by David Rittenhouse and John Wood, established his own shop in Philadelphia in 1783, and produced tallcase and shelf clocks.

36. Lewis to Jefferson, 14 May 1803, and Lewis to Ellicott, 27 May 1803, Jackson, *Letters,* 1: 48-49, 51.

37. Invoice from Henry Voigt, 19 June 1803, Jackson, *Letters,* 1: 91. Henry Voigt (1738-1814) was a German-born clockmaker and mechanic who operated a wire mill in Reading, Pennsylvania. From about 1780 he worked as a clockmaker and mathematical instrument maker. He was well known to Jefferson, for whom he repaired clocks and watches over a period of years. He moved to Philadelphia about 1791. Sebastian Voight, who was also a clockmaker in Philadelphia in the same period, may have been a brother. Henry Voigt's son, Thomas Voight, also worked as a clockmaker in Philadelphia from 1811 to about 1835. See Bedini, *Thinkers and Tinkers,* pp. 326-27.

38. Patterson to Jefferson, 15 March 1803 and 18 June 1803, Jackson, *Letters,* 1: 28-31, 51.

39. Jefferson's instructions to Lewis, 20 June 1803, Jackson, *Letters,* 1: 61-66; Paul Russell Cutright, "Jefferson's Instructions to Lewis and Clark," *Bulletin of the Missouri Historical Society* 22, no. 3 (April 1966): 302-20.

40. Fred. J. Randolph and Fred. L. Francis, "Thomas Jefferson as Meteorologist," *Monthly Weather Review,* December 1895, 456-58; Alexander McAdie, "A Colonial Weather Service," *Popular Science Monthly,* 7 July 1894, 39-45.

41. Lewis to William Clark, 19 June 1803, Jackson, *Letters,* 1: 57-58; John Louis Loos, "William Clark's Part in the Preparation of the Lewis and Clark Expedition," *Bulletin of the Missouri Historical Society* 10, no. 6 (July 1954): 490-511; Jerome O. Steffen, *William Clark, Jeffersonian Man on the Frontier* (Norman: University of Oklahoma Press, 1977), pp. 44-46.

42. Jackson, *Letters,* 1: 173-76; Friis, "Cartographic Activities," pp. 349-50; Reuben Gold Thwaites, "The Story of Lewis and Clark's Journals," *Annual Report of the American Historical Association for the Year 1903* 1 (1904): 107-29; Paul Russell Cutright, *A History of the Lewis and Clark Journals* (Norman: University of Oklahoma Press, 1976), pp. 8-15.

43. Jefferson to Isaac Briggs, 5 June 1804, Thomas Jefferson Papers, Manuscript Division, Library of Congress. Jefferson purchased some of his thermometers from a Philadelphia stationer named Sparhawk. An example of the type of thermometer he described to Briggs, and which he once owned, is in the collections of the Historical Society of Pennsylvania.

44. Cutright, *History of the Journals,* pp. 3-15; Friis, "Cartographic Activities," pp. 349-51; Thwaites, *Original Journals,* 2: 131-32.

45. Thwaites, *Original Journals,* 6: 230-65.

46. Cotter, *Nautical Astronomy,* pp. 189-92.

47. Jefferson to José Corrêa da Serra, 26 April 1816, Jackson, *Letters,* 2: 611-12.

48. Clark to Ferdinand Rudolph Hassler, 26 January 1810, and Hassler to Patterson, 12 August 1810, Jackson, *Letters,* 2: 491-92, 556-59.

49. Jefferson to José Corrêa da Serra, 26 April 1816, Jackson, *Letters,* 2: 611-12.

50. Jefferson to the Hon. St. George Tucker, 9 May 1798, and Jefferson to George Wythe, 16 January 1798, Thomas Jefferson Papers, Manuscripts Division, Library of Congress; Helen Bullock, "The Papers of Thomas Jefferson," *The American Archivist* 4 (January-October 1941): 243-44.

51. E. G. Chuinard, "Thomas Jefferson and the Corps of Discovery: Could He Have Done More?" *The American West* 12 (November-December 1975): 4-13; Dumas Malone, *Jefferson the President: Second Term 1805-1809* (Boston: Little, Brown, 1974), pp. 208-12.

52. Jan Snow, "Lewis and Clark in the Museum Collections of the Missouri Historical Society," *Gateway Heritage* 2, no. 2 (Fall

1981): 36–41. The watch does not bear a maker's signature or other identification but is believed to be the silver pair-case watch owned by Lewis and carried on the expedition. A pocket surveying compass made by Thomas Whitney with a leather case, documented as having been owned by Clark and carried on the expedition, is in the collections of the National Museum of American History, Smithsonian Institution. Accession no. 122,864. (See fig. 6.)

53. Roy E. Appleman, *Lewis and Clark: Historic Places Associated with Their Transcontinental Exploration (1804–06)* (Washington: U.S. Department of the Interior National Park Service, 1975), p. 235; p. 375, n. 150.

54. Jefferson to William Dunbar, 25 May 1805, Jackson, *Letters,* 1: 245.