The First Scientific Expedition of Charles Mason and Jeremiah Dixon

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The exact projection of Venus upon the face of the Sun and the exact time occupied in transit would depend upon the position of the observer upon the surface of the Earth. If with the aid of his telescope and a carefully regulated clock the observer could record the instants, first when the disk of Venus appeared just to "touch" the solar disk, then when it was just wholly inside, then when it just began to move off the disk, and finally the instant when the disk of Venus was last "touching" the limb of the Sun, he could report the time occupied in transit as observed from his station.

If in addition he could measure from time to time during the transit the least distance in minutes of arc between the edge of Venus and the limb of the Sun this information would locate the path of Venus upon the disk of the Sun as viewed from his station. And if clouds or accidents of any kind should prevent his seeing the entire transit, then such observations as he could make, combined with a careful determination of his latitude and longitude, would locate Venus on the face of the Sun as seen from his post.

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If observations of the kind just described could be reported from stations widely scattered over the Earth, then astronomers could attempt to answer a fundamental question still open in 1760—"How far is the Sun from the Earth?"

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Long years of patient observing and intensive study have brought an answer to the question "How far is the Earth from the

Sun?" The distance accepted today is 93,003,000 miles. It is the fundamental distance that must be known if the universe is to be measured. Astronomers express this distance in terms of the angle that the equatorial radius of the Earth would subtend if viewed broadside from the distance of the Sun. This angle is called the Solar Parallax. Its accepted value is eight and seven hundred and ninety thousandths (8.790) seconds. In 1761, and again later, Charles Mason and Jeremiah Dixon contributed materially towards finding the distance from Earth to Sun.

Early in 1760 the Royal Society of London began to organize expeditions to observe the transit of Venus due to occur one year later. In July, 1760, president, council and fellows petitioned the Lords of the Treasury for a grant of sixteen hundred pounds sterling to be used in observing the transit. One-half of this sum was to be expended in sending an expedition to St. Helena where the end of the transit would be visible in the early morning. The rest would send an expedition to Bencoolen in Sumatra where the entire transit could be seen with the Sun high in the heavens.

The request was granted and the Royal Society chose Nevil Maskelyne, a well known young astronomer, assisted by Robert Waddington, to go to St. Helena. Charles Mason, who had assisted Dr. James Bradley, the Astronomer Royal at Greenwich, for the past five years, was chosen to go to Sumatra. Jeremiah Dixon, a surveyor and amateur astronomer well known in the county of Durham, was selected to accompany Mason.[1]

At the request of the Royal Society transportation was provided for the expeditions. Maskelyne and Waddington proceeded to St. Helena on the East Indiaman "Prince Henry." They left England on January 17, 1761, and arrived at their destination on the sixth of the following April.[2] Mason and Dixon embarked on the ship-of-war "Seahorse," that the Admiralty had provided, during December 1760. They arrived at the Cape of Good Hope on the twenty-seventh of April. War between England and France had delayed their voyage. During the whole month of January the "Seahorse" had been at Plymouth for repairs following an en-

[1] C. R. Weld. *History of the Royal Society*, Vol. 2 (London, 1848), pp. 11-15. H. P. Hollis, "Jeremiah Dixon and his Brother," *Journal of British Astronomical Association*, June, 1934.
[2] *Philosophical Transactions*, Vol. 52, part 1, page 26; Vol. 52, part 2, page 573. Mrs. A. W. Lane Hall, "Nevil Maskelyne," *Journal of British Astronomical Association*, 432, pp. 67-77.

gagement in the Channel with the frigate "Le Grand." And in the Far East the French had taken Bencoolen. During their enforced delay at Plymouth a number of spirited letters passed between Mason and Dixon and officers of the Royal Society over a proposal made by the former that they proceed to a station in the Near East. Peremptory orders were soon issued that every effort be made to carry out the original plans.[3]

When the "Seahorse" brought Mason and Dixon into Sable Bay at the Cape of Good Hope on Sunday, April 27, 1761, the transit of Venus was only six weeks in the future. Bencoolen lay beyond the Indian Ocean, six thousand miles away—and the hostile French held it. Fortunes of war and of navigation had decided that the transit would be observed at the Cape. The scientific instruments were carried ashore and put under shelter and the erection of a temporary observatory was begun.[4]

The Royal Society had supplied Mason and Dixon with the following pieces of equipment:

a) Two reflecting telescopes made by James Short. Each was of two feet focal length, and magnified one hundred and twenty times. One of them was equipped with an "object-glass micrometer" of focal length 495.48 inches. Maskelyne describes it as "the curious object-glass micrometer adapted to the reflecting telescope according to Mr. Dollond's ingenious invention."[5]

b) An astronomical clock made by John Ellicott,

c) A quadrant of one foot radius made by John Bird. the personal property of the Earl of Macclesfield, president of the Royal Society.[6]

At the request of the Council of the Royal Society, Doctor James Bradley, Astronomer Royal, had drawn up instructions for the guidance of Mason at Bencoolen. Attached to the copy among Dr. Bradley's papers is the note:

> These were the instructions that Dr. Bradley drew up at the desire of the Council of the Royal Society, relating to my observing the transit of Venus in the East Indies.
> C. Mason.

[3] C. R. Weld, *History of the Royal Society*, Vol. 2, pp. 16-19. *Philosophical Transactions*, Vol. 52, part 1, page 380. R. H. Heindel. "An Early Episode in the Career of Mason and Dixon," *Pennsylvania History*, Vol. VI, No. 1, Jan. 1939.
[4] *Philosophical Transactions*, Vol. 52, part 1, pp. 378-380.
[5] *Philosophical Transactions*, Vol. 52, part 1, pp. 197, 378. A. Wolf. *A History of Science . . . in the 18th Century* (New York, 1939), pp. 143-145.
[6] *Philosophical Transactions*, Vol, 52, part 1, page 394.

The instructions in brief were as follows:

> Locate the observatory where there is a clear view toward the northeast, north, and northwest. Observe the first and second contacts of Venus with the limb of the Sun. Then measure the distance of Venus from the limb of the Sun to ascertain the nearest approach of Venus to the center of the Sun's disk. Measure the diameter of Venus.
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> Set up the clock so that the observers at the telescopes are immediately accessible to it. Observers must be careful not to prejudice one another in their judgments of events and times. Make a preliminary trial of the clock with its pendulum adjusted as it was at Greenwich to ascertain how much it loses in a sidereal day. Then adjust it to solar time. Keep a record of the temperature in the clock case. Record how much the pendulum must be changed in length to keep solar time at Bencoolen.[7]

When the sixth of June 1761 arrived the aged Doctor Bradley was so ill that he could not observe the transit at Greenwich. At his request Professor Nathaniel Bliss of Oxford University observed in his stead. John Bird and Charles Green assisted him. Doctor Bradley had trained Charles Mason in astronomy and had without doubt chosen him for the expedition to Bencoolen.[8]

From the day of their arrival, April 27, until the morning of June 6, when the Sun was due to rise at the Cape of Good Hope with the small black disk of Venus in front of it and near its southern limb, Mason and Dixon prepared to observe the event. On May 4th the astronomical clock made by John Ellicott "was set going, the pendulum having not been altered since it came from London." The quadrant was mounted, and on favorable nights observations were made on certain stars. Temperatures were recorded each morning, at mid-day, and in the evenings. The clock proved to be losing two minutes and seventeen seconds per day. On May 18th it was moved into the observatory, wound, and set "to nearly sidereal time." A total eclipse of the moon was observed on May 18th, and the times of "entrance into total darkness," "emersion," and "end of the eclipse" were recorded to the second by the clock.

[7] S. P. Rigaud, *Miscellaneous Works and Correspondence of The Rev. James Bradley* (Oxford, 1832), pp. 383-390.
[8] *Philosophical Transactions*, Vol. 52, part 1, pp. 173-177.

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From the 18th of May until the evening before the transit cloudy weather prevailed. Then the skies became clear and observing was carried on continuously until the transit ended. The bright stars Antares in the Scorpion and Altair in the Eagle were observed repeatedly during the night at equal altitudes above the horizon in the East and in the West and the times recorded. The means for each star were highly consistent. These means were the times when the stars crossed the meridian of the observatory and served as corrections to the indications of the clock.

On the morning of June 6 "the sun ascended in a thick haze, and immediately entered a dark cloud." The disk of Venus against the Sun was not seen until half an hour after sunrise. Seeing continued bad for an hour. Then observations began again. With the "object-glass micrometer" attached to one telescope the angular diameters of the Sun and of Venus were measured to tenths of seconds. The path of Venus across the disk of the Sun was followed by measuring repeatedly the angular distance between the northern limb of the Sun and the southern limb of Venus.

Two hours after sunrise the disk of Venus was approaching the western limb of the Sun and was about to begin to leave it. Seeing became excellent, and both the internal and the external contacts of the disks were recorded by both Mason and Dixon independently. Dixon recorded the internal contact four seconds before Mason judged it to occur, the external contact two seconds earlier. The disk of the Sun was scanned for signs of a possible small satellite of Venus but none was seen.

During favorable weather through June, July, August, and September the times of astronomical phenomena and the positions of familiar stars were recorded to establish the latitude and longitude of the temporary observatory. Observations of Antares, Spica, Arcturus, Fomalhaut, Altair, and four other stars in the Scorpion and the Archer established the latitude as 33 degrees, 55 minutes, and 40.5 seconds south.

The longitude of the observatory was determined by recording the local times of sharply defined events in the heavens that were also being observed at the Royal Observatory at Greenwich by Mr. Charles Green and at "Mr. James Short's house in Surry-street in the Strand" by Mr. Short and Dr. John Bevis. The same Dr. Bevis two years later joined Daniel Harris in drawing up in-

In June, 1769, Nevil Maskelyne observed the transit of Venus at Greenwich Observatory where for four years he had been serving as Astronomer Royal. Charles Mason, in the service of the Royal Society, observed the transit at Cavan, near Strabane, in the County of Donegal, Ireland, and Jeremiah Dixon, in the same service, observed it at Hammerfest, Norway. Five of the years that had intervened between 1761 and 1769 Mason and Dixon had spent in Maryland, Delaware, and Pennsylvania in the service of Lord Baltimore and the Penns, and also of the Royal Society. During those five years they wrote their names on the heart of America.[20]

The mills of the gods of science grind slowly. The observations made on June 6, 1761 and on June 3, 1769 continued to be studied and studied again. By 1835 the German astronomer Encke had reviewed all the data found on those two days and had concluded that the Earth is 95,370,000 miles from the Sun. This result was accepted until the middle of the nineteenth century. By 1854 long continued studies of the motion of the Moon had made it clear that the Sun is nearer to the Earth than Encke had concluded. And new opportunities were coming. Venus would again cross the disk of the Sun on December 9, 1874, and on December 6, 1882. World-wide preparations were begun to observe these rare phenomena.[21]

Preparations to observe the transits of 1874 and 1882 included exhaustive reviews of the records of earlier transits. In a study of the records Professor Simon Newcomb of the United States Naval Observatory became convinced of the great scientific value of the mass of data that had been accumulated in 1761 and 1769. Accordingly, he made a thorough restudy of the transits of 1761 and 1769 and published it in 1891, one hundred and thirty years after the expeditions to the Cape of Good Hope and to St. Helena. To the observations made by Mason and Dixon in 1761 Professor Newcomb assigned weights that were among the very highest that he allotted.[22]

[20] *Ibid.*, Vol. 58, pp. 270-355, 355-365; Vol. 60, pp. 454-496; Vol. 59, pp. 253-261.

[21] Simon Newcomb, *Popular Astronomy*, pp. 183-185.

[22] Simon Newcomb, "Discussion of Observations of the Transits of Venus in 1761 and 1769." *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac*, Vol. II (Washington, 1891), pp. 259-406.

This review of the careers of Mason and Dixon has reached the autumn of 1761, and it may prepare the mind for later events to make a concise summary of what took place during 1760 and 1761. On July 4, 1760, Lord Baltimore and the Penns signed an agreement in London to survey and to mark the boundaries between Maryland and the Three Lower Counties and Pennsylvania. During that same month the Royal Society of London applied to the Lords of the Treasury for funds to send expeditions to St. Helena and to Bencoolen. In November, 1760, the commissioners selected by Lord Baltimore and the Penns to carry out the agreement of July 4 held their first joint meeting at New Castle on the Delaware. A few weeks later Nevil Maskelyne and Robert Waddington, and Charles Mason and Jeremiah Dixon sailed from England on scientific missions. During the following April Maskelyne and Waddington landed on St. Helena and Mason and Dixon went ashore at the Cape of Good Hope. On the Maryland-Delaware peninsula during April, 1761, the surveyors, whom the Commissioners had chosen from Maryland and Pennsylvania, were beginning their attempt to run a meridian northward from the "Middle Point" of the peninsula. To this undertaking they were bringing the best in the way of science and skills and instruments of precision that the Colonies possessed.

All during the summer and autumn of 1761 Maskelyne and Waddington at St. Helena and Mason and Dixon at the Cape of Good Hope were applying the science and the skills of Greenwich Observatory and were using instruments made by the ablest craftsmen of the world.

genus *Diplodon*. Other material is unidentifiable. The Phoenixville specimens are from the Stockton formation of the Newark Series.

Diplodon is a freshwater genus and is best known from South America. The fact that the Phoenixville shells of this genus, particularly *Diplodon pennsylvanicus*, are quite different in appearance from the usual fresh water mussel *(Unio)* may explain why Lewis regarded them as marine.

As far as can be determined the only other Triassic mollusks from Eastern America are five from the Dockum Beds of Texas (Simpson, 1895, Reeside, 1927) and two from Massachusettes (Emerson, 1900, Troxell, 1914). All are freshwater. A few other unionid pelecypods are known from the Upper Triassic of New Mexico and Arizona (Reeside, 1927).

The mollusks, therefore, definitely favor a freshwater origin of the Newark Series. Detailed descriptions and figures of these Phoenixville fossils will be prepared in the near future and submitted to the Journal of Paleontology.

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ZENITH SECTORS, AND DISCOVERIES MADE WITH THEM, LINKED WITH MORE RECENT EVENTS IN PENNSYLVANIA

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The zenith sector was a fundamental instrument of astronomy and geodesy a few generations ago. It was used to measure the angle between the zenith and a star as it crossed the meridian. The instrument was mounted to rotate about both vertical and horilinked with places and events in this part of the world in a way of which few persons are aware. In 1742 James Bradley was chosen director of Greenwich Observatory, the third of England's Astronomers Royal. In 1749 he moved his zenith sector from Wansted to Greenwich Observatory. About 1755 two young men in their early twenties entered the Observatory as assistants. One of them, Nevil Maskelyne, was a volunteer. Ten years later he became the fifth Astronomer Royal and served in that post for forty-six years. The other assistant, Charles Mason, was employed by the Observatory. Together Maskelyne and Mason assisted James Bradley at Greenwich for five years.

In 1760 the Royal Society of London equipped two expeditions to go overseas to observe a transit of Venus across the face of the Sun which was to occur early in June, 1761. Maskelyne was selected to take one expedition to the island of St. Helena. Charles Mason, assisted by Jeremiah Dixon, was sent to Sumatra. Owing to war with France, Mason and Dixon were obliged to observe the Transit at the Cape of Good Hope instead.

Among the instruments that Maskelyne took to St. Helena was a ten foot zenith sector made for the Royal Society for this expedition. In using it Maskelyne discovered a fundamental fault in design to which all zenith sectors previously made had probably been subject. The manner of suspending the plumb-line introduced an error of many seconds of angle. Maskelyne proved his point to a committee of the Royal Society in an exhibition which he made before them at the British Museum on September 11, 1762.

On their return voyage from the Cape of Good Hope, Mason and Dixon had landed at St. Helena and had worked with Maskelyne on his scientific projects for several months during 1761 and 1762.

In 1762 the survey of the southern boundaries of Pennsylvania was under way and was not making progress owing to unskilled surveyors and inadequate equipment. Accordingly Thomas and Richard Penn, proprietors of Pennsylvania, with the best of advice engaged John Bird, pupil, former employe, and business successor of George Graham, to build for them the best zenith sector yet made, for use in the survey. Bird built for the Penns the first zenith sector to possess Nevil Maskelyne's proposed improvement of design. In the words of Nevil Maskelyne:—

TURTLES

Kinosternon subrubrum subrubrum (Lacepede), Mud Turtle. It is recorded from the county by Surface. No specimens have been seen.

Chelydra serpentina (Linnaeus), Snapping Turtle. Taken at Ligonier, New Alexandria, and Hood's Mill between 1,000 and 2,100 feet.

Clemmys guttata (Schneider), Spotted Turtle. Only one specimen, taken at Ligonier, is known from the county.

Clemmys insculpta (LeConte), Wood Turtle. It occurs between 900 and 1,200 feet and is known from St. Vincent and Rector.

Terrapene carolina carolina (Linnaeus), Box Turtle. It has been taken at Parnassus, Baggaley, St. Boniface Chapel, Hood's Mill, and St. Vincent from 1,100 to 2,200 feet.

Chrysemys picta marginata Agassiz, Eastern Painted Turtle. Taken at Rector and Idlewild between 1,400 and 1,600 feet.

The author is indebted to many persons for aid received during the course of this study and in collecting in the county. Especial thanks are due to Mr. M. Graham Netting for his guidance throughout this whole study.

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A FRAME OF REFERENCE FOR MASON AND DIXON

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"Mason" and "Dixon" are household words in Pennsylvania, but the men who bore the names remain "shadowy individuals" had appointed commissioners, had sought advice from authorities on surveying, and had supplied some instruments. The commissioners had met in joint sessions and had engaged surveyors of repute from the two colonies. During 1761 and 1762 these surveyors had attempted to establish the line that is now the western boundary of Delaware. Their success had been indifferent. Both Lord Baltimore and the Penn brothers, who were responsible for the survey and were paying for it, were dissatisfied.

During 1762 there returned to London the two expeditions that the Royal Society had sent to the Cape of Good Hope and to St. Helena to observe the transit of Venus of June 1761, and afterwards to carry out astronomical research on St. Helena. The scientists returning were Nevil Maskelyne and Robert Waddington, who had observed at St. Helena, and Charles Mason and Jeremiah Dixon, who had observed the transit at the Cape of Good Hope and then had joined Maskelyne and Waddington at St. Helena.

Among scientific men associated with the Royal Society and with Greenwich Observatory these four young men just returned from successful expeditions overseas had become favorably known. Now Baltimore and the Penns had been obtaining professional advice about sound procedures and necessary equipment from scientists in these circles. It was only natural that they should learn from them of highly competent personnel now available for engagements overseas.

To comprehend Mason and Dixon and their work in America one must attempt to see them as they appeared to James Bradley, third director of Greenwich Observatory, who trained Mason and who selected the two for the expedition to observe the transit of 1761. One must attempt to know them as Nevil Maskelyne knew them. Maskelyne had worked with Mason at Greenwich. Then the two men worked with him on St. Helena. In 1765 Maskelyne succeeded to the directorship at Greenwich. In this post he enjoyed a long association with both Mason and Dixon, in their work while they were in America, and afterwards until the ends of their lives.

One must know the two men as they were known by Dr. John Bevis and Daniel Harris. Bevis and Harris at the request of Lord Baltimore and Thomas Penn drew up instructions for the guidance of Mason and Dixon in the Colonies. Dr. Bevis was a distinguished in order directly for the ensuing transit of Venus over the Sun" (June, 1769).

Thereupon the clock was carried by four men to Wilmington, Delaware. From thence it was sent by water to Philadelphia where it arrived on May 28. On June 2 Mason sent an account of observations taken with the clock at Harlan's both to Maskelyne and to Doctor Morton, secretary of the Royal Society.[1] A full account of these observations is published in Philosophical Transactions for the year 1768.[2]

The clock is identified by Maskelyne in his instructions to Mason and Dixon, dated Greenwich, November 8, 1765, as —

> The Royal Society's "clock which I took to St. Helena and Barbados."

In the course of his instructions Maskelyne says

> "Adjust the pendulum to the upper scratch No. 3 standing against the index, which answered to sidereal time at St. Helena, and keep the clock going in the same place for some days in order to determine its rate of going. This experiment will show the force of gravity, where you set it up, compared with the force of gravity here (Greenwich), at St. Helena, the Cape of Good Hope, and Barbados."[1]

A review of reports published in Philosophical Transactions by Nevil Maskelyne has revealed more information about the clock. In a letter to Lord Charles Cavendish, Vice-President of the Royal Society, dated St. Helena, July 30, 1761, Maskelyne describes the clock as —

> "an excellent clock, with a gridiron-pendulum adapted to it, executed by that diligent and ingenious artist Mr. John Shelton."[3]

A record of the use of this clock from 1760 to 1767 appears to be as follows. During 1760 it was set up at Greenwich Observatory by James Bradley, Astronomer Royal, and was found to lose eleven seconds per day upon sidereal time.[4]

During 1761 and for a few weeks in 1762 the clock was used at St. Helena by Nevil Maskelyne and others in astronomical work and in a determination of gravity.[5] During the autumn of 1761, scientific publications with the outcomes that follow.

From May 25, 1768, to June 12, 1771, the clock accompanied Lieutenant James Cook of H.M.S. Endeavor on the first of his famous voyages round the world. Charles Green, who had succeeded Mason at Greenwich Observatory, was astronomer of the expedition. Green had accompanied Maskelyne to the Barbados. Cook and Green used the clock while observing the transit of Venus on June 3, 1769, from Fort Venus in Royal Bay on King George's Island (Tahiti). Their records state that —

> "The astronomical clock, made by Shelton and furnished with a gridiron pendulum" was first set up at Fort Venus on April 15, 1769.

They also set the pendulum at the length at which it had been swung at Greenwich and determined the rate at which the clock lost time, thus making a gravity determination. From its rates at Fort Venus and at Greenwich Maskelyne found that the force of gravity at the latter place is to that at the former as 1,000,000 is to 997,075.[9]

In 1772 Nevil Maskelyne read to the Royal Society "A Proposal for Measuring the Attraction of Some Hill in This Kingdom by Astronomical Observations."[10] The plan was approved and in 1773 Charles Mason was sent on a tour through northern England and the highlands of Scotland to select a suitable hill. He chose Schiehallien in Perthshire, Scotland. During 1774 Maskelyne made the observations. Among his instruments were Sisson's zenith sector that Maskelyne had used at St. Helena,

> "an astronomical clock by Shelton," and "a brass standard of five feet" . . . "The brass standard made by Mr. Bird, the same which was used in the measure of the degree at Pennsylvania."

Observations made north and south of the mountain showed that the plumb line was deflected by it. The mountain was surveyed, its dimensions and mass were estimated, and from the deflection of the plumb line a computation was made of the mean density of the Earth.[11]

Early in the nineteenth century the Royal Society was sending scientific expeditions to the Arctic. In May 1819 the Hecla sailed for the Northwest Passage under command of Lieutenant W. E.