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THE STARGAZERS' STONE

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IN THE autumn of 1763 Charles Mason and Jeremiah Dixon brought with them to Pennsylvania a background of achievement in astronomy [1] and a desire to use their opportunities while in America to render additional services to science.

"Opportunities come to prepared minds." Mason had worked In the Royal Observatory and recently both men had been in the service of the Royal Society of London[2]. Both knew well of the scientific campaign that had been carried on by learned bodies of Europe since the early days of Isaac Newton to obtain accurate data from many parts of the earth to be used in computing its size and shape and especially the amount of flattening at its poles. No data for these purposes had as yet been secured from the continent of North America. Mason and Dixon began to gather such data immediately after their arrival.

By January 6th, 1764 the latitude of the "South Point of the City of Philadelphia" had been established and on the following day says the Field Notes : '4Set out from Philadelphia with a Quadrant to find (nearly) a Place in the Forks of Brandiwine having the same Latitude as the South Point of the City of Philadelphia. Jan. & Fixed our Station by the House of Mr. John Harlands (being about 31 miles west of the City of Philadelphia).[3] At the Harlan homestead in Newlin township. Chester county, Pennsylvania, the expedition remained until the following April 2nd. An observatory was set up, its latitude was determined, and a monument was erected.

During the succeeding four and one-half years and until they finally said farewell to it on June 29, 1768, Mason and Dixon re-turned to the Harlan farm time and time again for long sojourns or for brief visits, but always for the securing of more data. They became familiar figures in the community and the monument they had erected came to be known as the "Stargazers' Stone." The major part of their scientific work in America links itself to this stone.

Starting on April 2, 1764 they measured an arc of meridian southward from the Stargazers' Stone for almost fifteen miles to a point “in Mr. Bryan's field" in New Castle county. Again the latitude of a marker was obtained. The party then repaired to the "Middle Point" between the Atlantic and the Chesapeake in the

latitude of Cape Henlopen and now the southwest corner of the state of Delaware. This point had been established and marked by earlier surveys. Mason and Dixon established its latitude later, during October 1766.

The summer and autumn of 1764 were spent in running an arc of a great circle almost eighty-two miles long slightly west of north from the Middle Point to establish the Tangent Line from the Middle Point to the circle of twelve miles radius already laid out by earlier surveys. This circle centers in the courthouse spire at New Castle, Delaware. The Tangent Point had been marked by these earlier surveys. Mason and Dixon found no error in this position. Through it they extended the radius from New Castle to cut the arc of the great circle just run from the Middle Point. On November 26 the season ended and Mason returned to Harlan's where he remained until January l0th, 1765. Whether Dixon accompanied him is not clear. The rest of the winter was spent in sightseeing excursions to Lancaster, Pennsylvania, to New York City and Long Island and to towns in New Jersey.[4]

Work was resumed on March 2nd, 1765 at the marker in Mr. Bryan's field in New Castle county and from it the famous parallel of latitude known everywhere as Mason and Dixon's Line was extended westward as far as the Susquehanna. On June 1, 1765 the party returned to the Tangent Point and the next three weeks were spent in extending and marking an arc of meridian north-ward to intersect the parallel.

The Stargazers' Stone and the Middle Point had now been joined by five successive lines on the earth's surface whose lengths and bearings had been measured viz.-an arc of meridian from Harlan's to the post in Mr. Bryan's field, thence an arc of parallel westward to what is now the northeast corner of Maryland, thence an arc of meridian southward to the Tangent Point, thence a short extension of a radius from New Castle to cut the arc of a great circle, thence for eighty-two miles an arc of great circle to the Middle Point. The latitude of the Stargazers' Stone had been determined and if that of the Middle Point should be found all the data needed would be at hand for finding the length of a degree of latitude "in the Neighborhood of Pennsylvania."

At some Period during 1764 or early 1765 the opportunities at hand to serve science took definite form in the minds of Mason and Dixon. They communicated their ideas to the Astronomer Royal, the Reverend Nevil Maskelyne. The writer has never seen their letter. It is said to be in the archives of the Royal Society. Its essential content may however be inferred from the replies it brought from the Astronomer Royal and from the secretary of the Royal Society, Dr. Charles Morton.[5]

The first replies were sent during October and November, 1765 and apparently never reached their destination owing to a wreck on the New Jersey coast, of the ship *Egdon* which carried them. On September l0th, 1766 the secretary of the Royal Society wrote again enclosing copies of the original communications. These reveal that Mason and Dixon had proposed to measure a degree of latitude and a degree of longitude and had asked for funds and instruments to carry out their plans.

The enclosures include a copy of the minutes of a meeting of the council of the Royal Society held on October 24th, 1765. At this meeting the proposal to measure a degree of latitude under the auspices of the Royal Society had been approved, the necessary funds appropriated, and the Astronomer Royal had been asked to draw up instructions for carrying out the work. The acquiescence of Lord Baltimore and of the Penns had been sought and the use of their instruments then in the possession of Mason and Dixon had been bespoken. Additional enclosures are copies of gracious letters of acquiescence from Lord Baltimore and Thomas Penn dated November 7, 1765.[6]

The following are quoted excerpts from the instructions of the Astronomer Royal:

Greenwich, November 8th. - 1765

Messrs. Mason and Dixon

I have the pleasure to acquaint you that the Council of the Royal Society, to whom I communicated your pro-posals for measuring a degree of latitude and a degree of longitude in North America, have resolved that you should carry the first into execution upon the terms you offered. But to prevent any mistake I must observe that the Council understand your proposals that you are to measure all the lines over again, or at least the two prin-cipal lines, namely the line A B, according to your scheme, which makes an angle of 4^0-with the meridian, and the line B C which is due north. This they direct should be done with four fir rods of ten foot each, tipt with brass at the end, with which you will he furnished by Mr. Bird, together with a brass standard of five foot to examine the rods by from time to time, and one or two thermometers to note the temperature of the air, whether the room or open air, where the rods are com-pared, at the time. Hence an allowance may be made hereafter for any change the rods may undergo. You are also desired to bring hack the rods and standard to England, as they may be hereafter compared with the French measures.

The Council have desired me to send you some Instructions about the method you should pursue in your operations. I rely a great deal upon your own judgment and attention, nevertheless I will point out to you those circumstances which seem to me most necessary you should attend to.

• • •

As I do not find that you have a clock with you, I shall make a proposal to the Council of the Royal Society, that their clock, which I took to St. Helena and Barbados, may be sent to you, with the help of which joined to your transit instrument you may determine the hearings of your signals many different ways, and make any other astronomical observations. Always fix the clock up firm and adjust the pendulum to the same length, and it will always keep the same rate of going very nearly. If the interval of the transits of the two stars is small, it is not necessary to be so very nice about the rate of the clocks going. Should this clock be sent to you, 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. Note the height of the thermometer at the time. This experiment will show the force of gravity, where you set it up, compared with the force of gravity here, at St. Helena, the Cape of Good Hope, and Barbados. Endeavor to estimate your elevation above and distance from the sea where you set the clock up, also note the latitude of the place.

You ought to determine the direction of your line within 5 minutes, and the whole length within the ten thousandth part of the whole or fifty feet.

Preserve all your measures and observations as they may be revised at leisure. I am yours etc. .

N. Maskelyne, Astr. Reg.

More than a year later the Astronomer Royal wrote in part:

Greenwich, Feb.24, 1767

Messrs. Mason and Dixon,

Herewith I send you, agreeable to your desire, the nautical almanac of 1767: also a table for facilitating the computation of the moon's distance from the sun. I am not a little surprised at never receiving a line from you in answer to my two letters of Oct. and Nov. 1765 (in which I gave you an account that the Council of Royal Society had agreed to employ you to measure a degree of latitude in Pennsylvania and sent you my instructions on that head) nor any acknowledgement of your having received the instruments I sent you out on account of the Royal Society; tho' Mr. Mason acquainted me you had received my letters and would write to me as Soon as you received the instruments, which surely must have been long ago. The Council of the Royal Society have ordered that you should send the clock home immediately as we hear it has received great damage, and must be put in order directly for the ensuing transit of Venus over the Sun.

I desire to hear from you directly and to know what you are doing, or have done about the measure of the degree. Be pleased also to send an account of your hav-ing received the instruments and what. I am your sincere friend and humble servant.

N. Maskelyne

The foregoing letter was received by Mason and Dixon at Harlan's farm on May 24, 1767, and immediately the clock of the Royal Society was sent to Philadelphia. The Journal reads: "June 2, 1767-Wrote to Mr. Maskelyne and Dr. Morton with an account of the clocks going etc., etc. [7]

Let us resume our narrative of the accumulation of scientific data. During the autumn of 1766, stones were set along the Tangent Line. At this opportunity, from October 8 to 18, observations were taken to find the latitude of the Middle Point and the bearing of the arc of a great circle run from that point during 1764.

The long awaited replies from London were at hand when work for the proprietors was closed for the season and the winter of 1766-67 set in. The previous winter had been spent in a sight-seeing tour through Maryland and Virginia. The coming winter was to be devoted to intensive work for the Royal Society.[8]

December 5, 1766 finds the expedition "at Brandiwine" and on "December 11, the Sector was set up at Mr. Harlands in the same parallel that it stood in, in the year 1764. Here we also set up the clock, sent us by the Royal Society of London: and also the Proprietors clock, to which I applied a Pendulum made with walnut that had lain dry for about 40 years."

Observations for latitude, of the rate of the Royal Society's clock, on eclipses of satellites of Jupiter, and thermometer readings continued through the winter and spring. As remarked before, Maskelyne's letter of February 24, 1767 arrived on the following May 24 and the clock was sent to Philadelphia immedi-ately thereafter. On June 2 came news from Sir William Johnson that the Six Nations had agreed to allow the westward extension of the Parallel.

On June 15 men and instruments were started westward towards Fort Cumberland. But scientific observations continued "at Brandiwine." Mr. Joel Bayley proceeded until late October to read Fahrenheit's thermometer-"the same thermometer as is taken account of for four months past by myself-hung (in the

shade) on the North Side of a house standing on a hill, about three miles Eastward of Mr. Harlands."[9]
On October 10, 1767, the westward extension of the Parallel was halted at an Indian warpath at Dunkards' Creek 233 miles westward from the "Post marked West in Mr. Bryan's field." On January 29, 1768 "Delivered to Rev. Rich'd Peters plans of the above mention'd Lines," and work for the Proprietors was ended.
February 1, 1768 found them "at Brandiwine." "Began at the point N, to remeasure the lines with two rectangular levels, 20 feet each in length." The lines referred to are the five successive lines from Harlan's to the Middle Point. The levels had been made by Mr. Joel Bailey to support the precision rods sent by the Royal Society. The point "N" is a point at Harlan's "10.5 seconds of latitude south of the Southernmost Point of the City of Philadelphia." "N" marks the site of the Observatory set up on the Harlan farm. The writer believes that the Stargazers' Stone marks point "N." J. Carroll Hayes a lifelong student of Mason and Dixon places the stone slightly north of "N."[10]
Remeasuring continued all winter. The Middle Point was reached on June 6. June 16,1768 finds us again "at Brandi-wine," where farewells were said on June 29. During August (25-27), accounts with the commissioners were settled and on September 11, 1768 Mason and Dixon sailed from New York for England. "Thus ends my restless progress in America," writes Mason.
The scientific reports of Mason and Dixon were read before the Royal Society on November 24 and on December 15, 1768. They are published in full in volume LVIII of *Philosophical Transactions* for the year 1768, in which they occupy sixty-five pages. To these reports the reader must be referred for detailed information.[11]
In his introduction to, the reports the Astronomer Royal ex-plains why the Royal Society had been led to sponsor the undertaking. It was because of their high esteem of the competence of Messrs. Mason and Dixon, because a well organized, admirably equipped party was already in the field, because the lines of the survey between Harlan's and the Middle Point lay almost north and south, for the reason that along these lines the longest and straightest vistas ever made had been cut, and because these lines ran over ground nearly level thus assuring little deflection of the plumb line by chains of hills. The last supposed advantage proved to be illusory, for the Honorable Henry Cavendish soon after pointed out that the Allegheny Plateau to the north and west conspired with the defect of matter in the Atlantic Ocean to the south and east in such a way as to affect the plumb line materially.[12]
The party was equipped with the best of instruments then made. They included besides those already named a zenith sector of novel design made by John Bird, instrument maker for the Royal Observatory, and a transit also by Bird, one of the first ever used.[13]
From the data the Astronomer Royal deduced that the difference in latitude between "Point N" at Harlan's and the Middle Point was 1 degree 28 minutes 45 seconds and that the length of an arc of meridian between the parallels through these two points was '538,067 feet. This made one degree of latitude equal to 363,763 feet at mean latitude 39 degrees 12 minutes north. The pendulum observations carried to naught owing to damage that the dock had suffered in transit.
Throughout his original notes Mason records observations of storms, of flashes of lightning and of eclipses of the sun and moon. On April 9, 1766 the position of a comet among the stars was sketched.
The Stargazers' Stone marks the second station occupied by Mason and Dixon in their survey of the boundaries between the lands of the Baltimores and those of the Penns. But it is far more than a reminder of disputed boundaries, for it stands as the only monument on the continent of North America to com-memorate

an era of endeavor by scientists and scientific groups that began about 1670 and lasted for more than a century until governments of western Europe and finally the United States began to establish geodetic surveys on a permanent basis.

Christian Huyghens was the first to conceive the idea that owing to the rotation of the earth, the weight of an object at sea level must decrease as it is carried toward the equator. In 1671 Isaac Newton tried to calculate the decrease and learned that 'to do this business right, is a thing of far greater difficulty than I was aware of."[14]

By a remarkable coincidence in the very same year, 1671, the French astronomer Richer discovered that a pendulum clock,, which he had regulated to keep time in Paris, lost time at a surprising rate when set up unchanged on the coast of Guiana in South America.[15]

In 1673 Christian Huyghens published his classic, *De Horologio Oscillatorio,* in which sound principles of centrifugal and centripetal forces were first set forth. And at the same era astronomers were first observing through their telescopes that the planet Jupiter rotates on an axis with a short day and is markedly flat-tened at its poles and bulged at its equator.[16]

During this era Newton was discovering the law of gravitation. He finally published it in the *Principia* in 1687. The law assumes that every particle of matter in the universe attracts every other with a force that varies inversely as the square of the distance between them.

The idea of a spherical earth is very old, hut the idea of an earth not quite spherical but flattened at its poles owing to the mutual attractions of its particles and its rotation dates from the late seventeenth century. Isaac Newton and Christian Huyghens attempted to calculate the figure of a section of the earth through its axis and came to divergent results. Newton dealt with an idealized earth nearly spherical but actually elliptical in section, homogeneous throughout, and of the same form as if fluid. He assumed the principles of centrifugal force and his law of gravi-tation in concluding that the polar and the equatorial diameters were in the ratio of 229 to 230.[17]

Three years later Huyghens published his *Discours de la Cause de la Pesanteur* in which he attacked the same problem. He re-jected Newton's ideas about the attraction of the earth for its particles, used an idea of his own, and concluded that the ratio of the diameters is as 577 to 578.[18] Here was a difference that could be settled only by appeal to measurements of the actual physical earth.

Newton did more. He returned to the problem that he had tried to solve in 1671 and found that on his ideal earth the weight of an object at sea level should increase as it is carried from the equator to either pole in proportion to the square of the sine of its latitude. An equivalent statement is that the length of a pendulum that beats seconds as it swings increases from equator to pole at sea4evel in the ratio stated.[19]

And Newton did still more. He calculated the length of a degree of latitude on his ideal earth at each fifth degree from zero of latitude at the equator to ninety at the pole. Taking the length of a "seconds" pendulum as known at Paris, he calculated the length of a "seconds" pendulum at any latitude. A table of his results was published in the *Principia.*[20]

On an earth flattened at its poles a degree of latitude must in-crease in length from equator to pole, for angles of latitude must be measured by the change in the vertical among the stars, while arcs are measured over ground in the usual ways. Newton found a degree of latitude equal to 56,637 French fathoms at the equator, and 57,382 at either pole on his ideal earth.

Fuel was soon added to the fires of scientific controversy. The French Academy, founded in 1666, had from

its infancy regarded a precise measure of the size of the earth as its particular responsibility and, under the patronage of Louis XIV, Jean Picard, selected by the Academy, had measured an arc of meridian in the south of France between 1669 and 1671. The earth that Picard measured had been assumed to be a true sphere.

To the problem of size Newton and Huyghens had now added that of exact shape and accordingly meridian measuring in France was resumed under the auspices of the Academy and under the direction of the Cassinis. Father, son, and grandson in succession played the leading roles. The arc of meridian was extended until it spanned France from the Pyrenees to the British Channel and the measures seemed to show that the degrees grew shorter from south to north.[21]

This was a direct challenge to the concept of an earth flattened at the poles. In fact there came into being a school that sup~ ported the concept of an earth prolate at its poles. This school continued active until in 1744 Cassini de Thury, the grandson, bowed gracefully before accumulated evidence.[22] On the other hand the pendulum of Richer's clock and other pendulum experiments conducted on the coast of Africa, and on islands of the Atlantic and the West Indies gave results in substantial agreement with Newton's theory.

It was dear that the measurement of arcs in France had covered a region too restricted to admit of conclusive results and accord-ingly the French Academy decided in the early 1730's to send two expeditions to measure arcs of meridian and to time the swings of pendulums, one to go to the Equator, the other to locate as near as practicable to the North Pole. Louis XV financed the undertakings.

The Expedition to the North, manned by the Academicians de Maupertuis, Clairaut, Camus, and Le Monnier, and by L'abbe Outhier, and Celsius, professor of astronomy at Upsala, chose to work in the valley of the river Tornea in Lapland. The Expedition to the Equator chose a valley in the Andes to the east of Quito, then in Peru, now the capital city of Ecuador. Chimborazo and Pambamarca rise from the borders of this valley. Thither went the Academicians Bouguer, De la Condamine and Godin accompanied by the Spanish naval officers Don Jorge Juan and Don Antonio de Ulloa.

The destinations chosen by these famous expeditions undoubtedly suggested to Oliver Goldsmith years later that in these distant regions so congenial to science, Poetry, "Dear charming nymph neglected and decried" in Britain, might try her voice "On Torno's cliffs, or Pambamarca's side."

Those who would follow these expeditions must read through the vast literature of science, travel and controversy that grew out of them. The Lapland party set out in May 1736 and returned in less than two years. Their report was given to the Academy on April 16, 1738. Its findings upheld the views of Isaac Newton and demolished the prolate earth of Cassini. In recognition Voltaire named de Maupertuis, "Aplatisseur du monde et de Cassini."

The Peruvian expedition sailed from France in May 1735. Its members returned, one at a time, nine years later with results that confirmed substantially what the Lapland expedition had already established. In the year of its return Cassini de Thury abandoned the prolate earth that his grandfather and father had created.

Theoretical problems created by investigations of the "Figure of the Earth" challenged the ablest mathematicians. Among contributors to this field during the first half of the eighteenth century after Newton were Stirling, Maclaurin, and Simpson from Great Britain and D'Alembert and Clairaut from France. The latter had been a member of the Lapland expedition. After his return to France he attacked the theoretical side and in 1743 published his *Theorie de la Figure de la Terre* which contains a theorem on the flattening of an idealized earth regarded as funda-mental to the present day.[23]

In 1750 two Jesuit mathematicians Boscovich and Le Maire began to measure an arc of meridian in the Papal States for Pope Benedict XIV. The arc ran from the tomb of Metella on the Appian Way northward over the Appenines to a mark near Rimini. The report of this survey was published in Latin in 1755. In 1770 there

appeared a French translation in which the claim is made by Boscovich that lie had suggested to the Royal Society of London the desirability of measuring a degree of latitude in America.[24]

Boscovich had been elected a fellow of the Royal Society, and had spent some time in London during 1760. Professor Gore thinks it likely that he and Mason and Dixon conferred at this time.[25] Le Maire was an Englishman, born Christopher Maire in the County of Durham. In his introduction to the report of Mason and Dixon the Astronomer Royal points out that Boscovich . and Le Maire had called attention to the deflection of the plumb line caused by "any mountain, or even elevated ground of more mod-crate height, continued for a great length."[26]

The state of knowledge of the "Figure of the Earth" in the year 1756 was summarized by D'Alembert in the *Encydopedie.*[27] All work to that date favored the views of Newton, but no simple ellipsoid would fit all the data. Such questions as "Are the meridians all equal?" "Are the parallels of latitude true circles?" "What is the exact amount of flattening at the poles?" "Is the earth homogeneous throughout or does its density vary from cen-ter to surface?" remained unanswered. There was need that arcs of meridians be measured in the same latitude but in widely different longitudes.

Seven years after the publication of D'Alembert's summary, Charles Mason and Jeremiah Dixon came to Pennsylvania. They were soon to have behind them the resources of the Royal Society and the counsel of the Astronomer Royal. In their hands were to be placed the finest instruments of precision that John Bird had ever made, a zenith sector for finding the position of the vertical among the stars, a transit for use in running true arcs over the earth's surface, and brass tipped fir rods and a brass, standard for the precise measurement of distances over ground.

There was to come an old familiar veteran of many expeditions, a clock of the Royal Society whose pendulum had already counted off the force of gravity at Greenwich, on St. Helena, at the Cape of Good Hope, and on the Barbados. All evidence indicates that this was the "excellent clock, with a gridiron-pendulum adapted to it, executed by that diligent and ingenious artist Mr. John Shelton.[28] It is still in the possession of the Royal Society.

Rev. James Bradley, a former Astronomer Royal, had rated this clock at Greenwich. Rev. Maskelyne took it with him to St. Helena in 1761 for use while observing the transit of Venus and for measuring the force of gravity. Mason and Dixon had at the same time taken John Ellicott's clock to the Cape of Good Hope.

On their homeward voyage Mason and Dixon landed on St. Helena and there Maskelyne and Mason worked together during the autumn of 1761 and in the early months of 1762. Shelton's clock and Ellicott's clock were set up and rated. The former was then placed on board ship on October 28, 1761, in the care of Mr. Dixon for a voyage to the Cape of Good Hope where its rate was to be determined.[29] Dixon returned with the clock to St. Helena on the following December 30.

During the autumn of 1763 and for eight months in 1764 Rev. Maskelyne made astronomical observations at the Island of Barbados. He took Shelton's clock with him.[30] He now proposed to link a station in Pennsylvania with those already established. Mason and Dixon chose Harlan's farm as its site.

The clock had been damaged by shipwreck and was not usable for gravity determinations. But the degree of latitude computed from the arc of meridian measured between the Stargazers' Stone and the Middle Point was announced by the Astronomer Royal as a major contribution to man's knowledge of the size and shape

of the earth. It continued to be so regarded by scholars for a century.[31] Today the degree of Mason and Dixon is regarded as about 500 feet too short.[32]

The writer has known the Stargazers' Stone from boyhood. Three generations ago many a farmer in its vicinity found recreation in mathematical and astronomical pursuits. Could it have been that the presence in the community of an expedition of the Royal Society a century before had left its impress?

If there be favored spots on earth where the Great Dead are wont to hold reunion surely the Stargazers' Stone marks one of them. Here perhaps may gather at times the shades of Isaac Newton, Christian Huyghens, Richer, Picard, the three Cassinis, the academicians of Lapland and those of Peru, the mathema-ticians whose theory gave meaning to the work, the Fathers Boscovich and La Maire, Charles Mason and Jeremiah Dixon, Nevil Maskelyne, John Bird and a host of others. Here they renew old campaigns and review great issues fought out on the battlefields of science. And perhaps they rejoice together that man still strives even as they strove, with transit and pendulum, in heat and frost, through swamp and forest, over mountain ranges and at peril of the seas better to know and to comprehend the earth on which he lives.

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