The Mason Dixon Line: An Engineering Achievement

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In 1761 when first approached to perform the survey, Charles Mason and Jeremiah Dixon did not envision the task that was before them or the legacy their line would leave behind. After encounters with rebels, hostile Indians, weather and politicians, their surveyed line stands today as a remarkable engineering achievement.

The Border Dispute and the Need for the Survey

The origin of the boundary dispute and the need for the survey starts near the beginnings of colonial America. Sir George Calvert, Secretary of State for King James I was able to successfully petition the king for a grant of land in the new world. This colony would be one of religious tolerance, perfect for the Calverts and their persecuted Catholic families and friends who were living in a Protestant England. On June 20, 1632, King Charles I granted Cecilius (Cecil) Calvert title to a plot of land extending west and bound by the southern border of the Potomac River and that "which lieth under the Fortieth degree of north latitude." Since there was no Pennsylvania or Delaware yet, no conflict yet existed. But not for long.

In March of 1638, four years after the settlement at St. Clement's Island in St. Mary's County Maryland was settled, Swedish colonists staked a claim at Fort Christinahamm, now Wilmington, Delaware. The Dutch also had a settlement in America, on the tip of Manhattan Island, called New Amsterdam. European politics being what they were in the seventeenth century, only a few years could pass without some sort of war breaking out on the continent. The war in Europe, this time with the Dutch, spread to the New World as well. By 1674 when the third Dutch war came to a close with the Treaty of Westminster, the Dutch were overwhelmed by the cost of the war. As a condition of the treaty, they ceded all of their colonial possessions in the New World to the English.

The English were not without their war debts, either. In order to help England win the war, Admiral William Penn had lent the king £16,000, a huge sum of money at the time. His son, also named William Penn, inherited the debt after the Admiral's death in 1670. Penn, and his fellow Quakers, felt the same religious intolerance in England that the catholic Calverts had. Penn felt that if he could start a colony in the New World, the Quakers would be able to practice their religion freely. After petitioning the king, Penn was provided a grant of land on January 5, 1681. In exchange for the land grant, Penn released the king from his debt. Penn's woods or Pennsylvania had a northern border at the forty-third parallel and extended west five degrees of longitude from the Delaware River. The southern border of Pennsylvania was to be tied to a twelve-mile circle drawn from the center of New Castle, Delaware, "to the beginning of the fortieth degree." A review of a map of the United States will immediately alert

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the reader to the border conflict created by this charter. The twelve mile arc is the current northern border of Delaware and the fortieth parallel runs though downtown Philadelphia. A twelve-mile arc from New Castle does not reach the fortieth parallel, as the fortieth parallel is almost nineteen miles from New Castle.

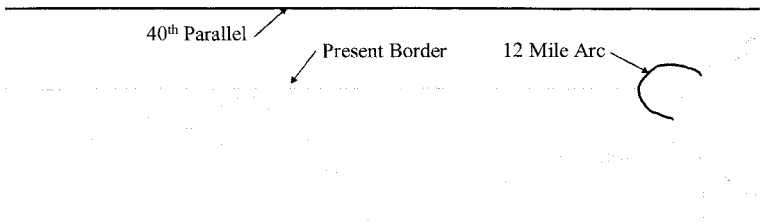

Figure 1. Overlap of land grants creating the border dispute

Since the King was the one to create the border dispute, Penn and Calvert eventually agreed that the King should be the one to settle the dispute. The king's decree in 1685 stated that the Delaware peninsula should be divided in half, set at a line north of Cape Henlopen. The border between Maryland and Pennsylvania was to be a line nineteen miles south of the fortieth parallel. This should have settled the dispute, but unfortunately it didn't. As the colonies grew, the need to ensure which land owners paid taxed to which colonial governor became more important. The King's commissioners of the Board of Trade and Plantations stated in 1732 that the southern border of Pennsylvania was to be set fifteen miles south of Philadelphia. But this was still not enough to resolve the dispute. By 1735, the dispute was referred to the English courts in what became known as the Great Chancery Suit. In the fifteen years it took to settle the suit, border skirmishes broke out on both sides, including attacks in 1743 on a survey party funded by the Calverts.

In 1750, the courts rendered the decision on the Great Chancery Suit. The southern border of Delaware was to be set as a line of latitude extending west from Fenwick Island to the Chesapeake Bay. The mid point of this line would determine the starting point of a north south line connecting to an arc of twelve-mile radius with a center in New Castle. The center of New Castle was later defined as the belfry of the courthouse. The northern border of Maryland was to be set fifteen miles from the southern most point of Philadelphia. After more negotiations, the point of beginning in Philadelphia was set as "the north wall of a house on the south side of Cedar Street." With the limits of the boundary set, Thomas Penn and Cecilius set out to find someone to survey and mark the border between the two states.

The Surveyors

As proprietors of colonies in the English sphere of influence, Penn and Calvert went to the Royal Observatory in Greenwich to seek professional help. Charles Mason had been an employee of the Royal Observatory since 1756, becoming a competent mathematician and astronomer. By the time of the survey, Mason was the assistant to top astronomer at the Royal Observatory, Dr. James Bradley. Jeremiah Dixon had

excelled in mathematics in school and his family connections enabled him to be recommended to Dr. Bradley as a promising assistant for the observatory. It was only logical that when Penn and Calvert approached Bradley looking for a surveyor that he recommended his own assistant, Charles Mason to lead the survey and Bradley also suggested the young and promising Jeremiah Dixon as Mason's assistant.

Prior to the border survey, the pair had been engaged by the Royal Observatory for the observation of the transit of Venus in 1761. Fortunately for Penn and Calvert, the Seven Years War (French and Indian War in America) intervened and Mason and Dixon never made it to India to make their observations. By the spring of 1763, Mason and Dixon had returned to London and were available to be introduced to the proprietors of Maryland and Pennsylvania. Both Calvert and Penn who explained the need for the survey and found Mason and Dixon to be "persons intirely accomplished and of good character." Thomas Penn and Cecilius Calvert contracted with Charles Mason and Jeremiah Dixon on August 4, 1763 to survey and mark the border between the two states.

The Instruments

While in London looking for surveyors, Penn and Calvert were also busy acquiring surveying equipment. Two of the most important pieces of equipment were a transit and equal altitude instrument and a six-foot zenith sector. Both of these instruments purchased for the survey were made by John Bird, a renowned English instrument maker. The transit and equal altitude instrument was predominately a telescope, but on a frame that could be leveled. In the telescope lens were both a horizontal and vertical crosshairs. The transit was used to determine true north. A rising star in the sky was viewed as it first crossed the horizontal crosshair in the telescope and the time was noted. When the star reached the top of its rise, the telescope was clamped into a fixed position and the time was again noted. As the star "set" a third time was recorded. The mean of the rising and setting time was the actual time the star reached the top altitude. A comparison of the mean time to the recorded time allowed the instrument to be adjusted until the true north meridian was set. Usually several stars were viewed as a means of checking the setting of the instrument. Additionally, by using the catalog of known stars, Mason and Dixon could use the time a star crossed the meridian as a means of establishing the local sidereal time.

Using the same principal as that used for a sextant or quadrant, the zenith sector was device primarily used to determine latitude. Although Mason could have used his quadrant to get the latitude, the zenith sector was far more accurate. Stars near the zenith (straight overhead) are freer from the refractive effects of the Earth's atmosphere. With a similar technique to that used for the equal altitude instrument, a star was observed using the zenith sector. The angular distance (zenith distance) was measured from when the star first passed the horizontal crosshair to the meridian. By observing known stars and using a set of star charts, the observer could add or subtract this zenith distance to the star's declination, or angle above the celestial equator, to determine the latitude of location of the observation. While the transit

allowed one to determine a line of longitude, the zenith sector was used to determine the latitude. Of course, a major disadvantage or both instruments is they could not be used when clouds obscured the sky.

The zenith sector contained a six-foot telescope mounted on an eight-foot tripod. The telescope was pointed straight up and set in this position using a plumb line. To view the star, the observer needed to lie on his back under the telescope. The zenith sector was placed in a tent and observations were made through a hole in the top of the tent. Often, a candle was held near the top of the instrument to help illuminate the crosshairs. The instrument could be turned 180 degrees in both the horizontal and vertical axes. Under the instrument was a graduated scale, used to measure the angular distance. A set of brass thumbscrews allowed for refined measurements, up to one hundredth of a second of arc (1/360,000 of a degree). On this instrument, the radius of the scale was six feet, thus the reason the instrument was referred to as a six-foot zenith sector.

In addition, the survey party had a number of more common instruments. They had a pair of telescopes, useful for observing the "posts in the line for ten or twelve miles." They had at least one Gunter's chain, the standard surveyor's measurement tool of the time. A Gunter's chain was a chain of 100 links each exactly 0.66 feet long, for a total length of 66 feet. Sixty-six feet is four rods (16.5 feet each) thus 80 chains was a mile. Additionally, for the land surveyor (like Dixon) a parcel of ground one chain wide by 10 chains long was an acre. Mason also had with him a Hadley Pattern Quadrant, a device used by mariners for quickly checking the latitude. The quadrant could also be used to measure the angular slope of the Gunter's chain and calculate the corrected horizontal distance. Also included in their equipment was a set of sixteen and a half foot softwood levels, useful for determining horizontal distance on steeply sloped terrain where the Gunter's chain was not effective.

The Work Begins

Upon arriving in Philadelphia and receiving their instructions, Mason and Dixon went to work. Their survey was to include establishing the latitude of the southern point of Philadelphia; establishing a point fifteen miles south of the point of Philadelphia to be the starting point of the north border of Maryland and extending this line west; and determining the east border of Maryland, the north-south line separating Maryland from Delaware. Mason and Dixon began at the south edge of Philadelphia on December 19, 1763. As a first order of the work, an observatory was constructed and the transit and the zenith sector were calibrated against each other. By checking the zenith sector against the transit, they were able to confirm that both instruments yielded identical results. By using the zenith sector, they were able to determine the latitude of the southernmost point of Philadelphia, the starting point for the survey.

Figure 2. The Plumstead-Huddle House marked the southern point of Philadelphia. Currently at the corner of South and Front Streets

Figure 3. The Stargazer's Stone. Near Embryville Pennsylvania, this point marks the location on the Harlan farm where Mason and Dixon worked in 1764

Figure 4. Monument at the site of the Post Mark'd West, in White Clay Creek State Park, Delaware

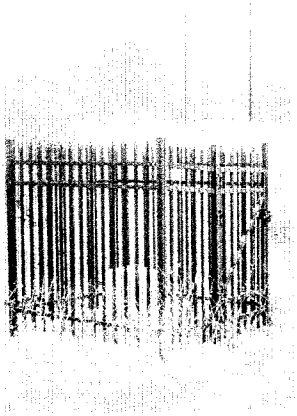

Figure 5. Tangent Point Monument near Newark Delaware

With the southernmost point of Philadelphia established, the next task was to find a point fifteen miles to the south, which marked the northern border of Maryland. Fifteen miles due south of Philadelphia was in New Jersey, on the other side of the Delaware River, so the surveyors first carried the line of latitude thirty-one miles west to a point where they could head south over land. This point was on John Harlan's farm and a point from a previous survey attempt on the farm could be used as a reference. After further observations with the zenith sector they determined the latitude and tied it into the southernmost point of Philadelphia. At this point they set a monument, known as the stargazer's stone. From here the survey party headed south.

Several reports place the size of the survey party at thirty-nine men and several make it to be as large as 115 men. Either way the party including tent carriers, wagon masters, cooks, chainmen and axmen, two to three wagons and eight draught horses. The camp boss, Moses McClean was an experienced hand and ensured that the instruments were cared for, meals ready and the laborers did not drink too much. Included in this group were three American surveyors, Joel Bailey, Jonathan Cope and William Darby. They were each competent surveyors and capable of working unsupervised, useful since Mason and Dixon could not have made every measurement themselves.

The axmen went first. They cut an eight to ten yard wide path through the countryside and allowed the surveyors to see the line. In eastern Pennsylvania and Delaware at this time, the terrain was still quite wooded and cutting the line was a major undertaking. When surveying the western parts of the border, the cut line was the only visible man-made object that could be seen for miles. By May of 1764, Mason and Dixon had set marker they called "post mark'd west" at a point fifteen miles south of Philadelphia. This post would later be the starting point for the survey of the border between Maryland and Pennsylvania.

The Tangent Line

With the "post mark'd west" set, Mason and Dixon turned their attention to the survey of the line on the east of Maryland, that between Maryland and Delaware. The line was not a true north-south meridian, but rather a line starting at the mid point on the peninsula and continuing to a point tangent to the circle of the arc, twelve miles from the center in New Castle. Prior to Mason and Dixon, John Watson, William Parsons, John Emory and Thomas Jones had been retained by the Penns and the Calverts in 1750 to survey across the peninsula and to determine the distance from the Atlantic Ocean to the Chesapeake Bay. The middle point of this trans-peninsular line was to be used as the starting point for the line dividing Maryland and Delaware. Although the survey was completed within six months, the final location of the middle point was not established until a compromise was reached between the Penns and the Calverts in 1760. The following year, Richard Peters and John Lukens lead a team of surveyors to set the marker on the middle point, survey the twelve-mile radius around New Castle and survey the tangent line. Although their tangent line survey was not as

accurate as it needed to be, the work of Peters and Lukens was immensely useful to Mason and Dixon in the summer of 1764.

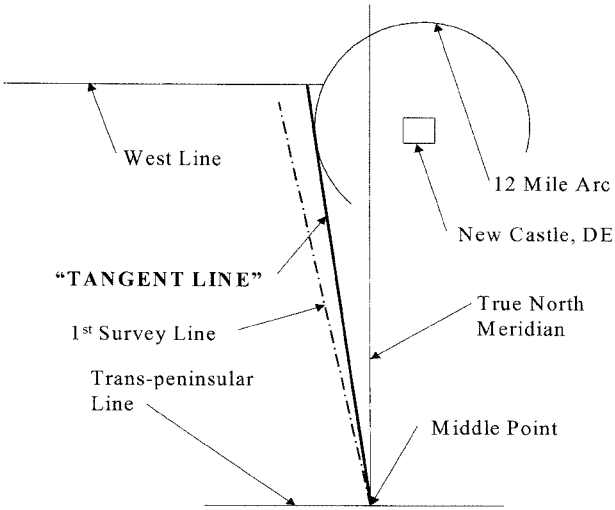

Figure 6. Layout of the Tangent Line.

From the previously set middle point, Mason and Dixon began their work establishing the Delaware Maryland border. Mason wanted to set the north line as a great circle and used Peters's and Lukens's previously surveyed line as a guide. First, starting at night, a candle was placed about a mile away in the direction of the previously surveyed line. By observing equal altitudes of a star using the transit, Mason could determine the meridian (true north). The angle between the meridian and the survey line (marked with the candle) could be checked with the transit to verify that the survey was proceeding in the correct direction and that the line remained a true great circle. After establishing the great circle line, a table of linear offsets could be calculated to reset the markers from Peters and Lukens onto the real tangent line. The genius of this solution is it allowed them to set a remarkably straight line. Mason did not need to actually survey the tangent line, just set a straight line to use to set the tangent line. Once the first line was set, Mason then established a second line as a check. Knowing the alignment of the tangent line, Mason established a line as parallel as possible passing through milepost ten of the tangent line. Using newly reset mileposts as a guide he carried this line to the south and found the offset from the middle point to be 2'-2". When the line was carried to the north to the tangent point, the error was 16'-9", a deviation of 0.004%. Mason then adjusted the offsets once again to further refine the line. As a final review, he checked the angle from the courthouse belfry to the tangent line. For a true tangent, this angle should be exactly 90° and determined that "it was so near a right angle that the post was the true tangent post."

The West Line

After a break for the winter, the work on the northern border of Maryland, known as the West Line, began. By their instructions and writ of the king, the line was to be a line of latitude, so the first order of business was to determine the latitude. After several nights work with the zenith sector, the latitude of the "post mark'd west" was reconfirmed as 39 degrees 43 minutes 18.2 seconds north latitude. This latitude was used as the check to determine that the West Line was set in the correct location as the survey proceeded. Setting the line in the correct position was important as a deviation of only one foot north or south would result in an error of almost 24 acres over the length of the line.

Although the West Line was to be a line of latitude, a great circle was easier to construct using the instruments on hand. To lay out a line of latitude also required a greater knowledge of the earth's true shape than Mason or any 18th century astronomer had. Although Mason knew the earth was an oblate spheroid, the actual degree of flatness at the pole or bulge at the equator was not precisely defined. Mason's proposed to survey the line in segments, each ten minutes of longitude long, or approximately 11 miles. By knowing the latitude and being an accomplished 18th century astronomer with an up to date 18th century knowledge of the shape of the earth, Mason could determine the length of a degree of longitude in the northern hemisphere. During the winter break, Mason had done a set of calculations using spherical trigonometry to determine that the offset from a great circle and a line of latitude would be a maximum of 17.14 feet at the midpoint of the ten minute segment as the lines intersected at the ends of the segment. He had also determined the angle from the great circle to the meridian at each end of the segment to be 89 degrees 55 minutes 51 seconds or that this was the angle between the great circle and true north. Using a star low in the sky at the start of the evening, they determined by equal altitudes the sidereal time and calculated the time when the star would travel up in the sky the required angle. The angle between the meridian observed at the beginning of the night and the position of the star later in the night yielded the correct angle for the survey to proceed. After observing the star in the calculated position, the transit was locked to prevent it from turning horizontally and tilted vertically to view the horizon. As with the Delaware survey, a lantern or candle at a distance of a mile or so was used to mark the line and then it was more permanently marked with a stake. Multiple stars were observed over a period of nights until a cluster of stakes was set, usually with an accuracy of less than six inches. With a line established by two points, the transit and chain were used to extend it west.

At the end of each ten-minute segment, the plan was to use the zenith sector to check the latitude. The distance from the end of one segment to the correct starting position for the next segment would be calculated, as were adjustments to the line as surveyed. This process of stellar observations to determine latitude and direction followed by chaining west would be repeated until the limits of the survey were reached.

The process was later adjusted. After crossing the wide Susquehanna River, Mason found that they were almost 60 chains too far north of the desired latitude. Rather than measure south and set the correct starting point for the next segment, he calculated the angular change from their current position to the end of the next 10-minute segment. This angular change was used to set the survey in the correct direction and they proceeded westward. At the end of each segment, a set of observations with the zenith sector was used to determine the latitude at the end point and then the angular difference that would place the survey back on the correct line. Although this meant that the survey zigzagged slightly, it probably save considerable time cutting the path through the woods and thus setting the line. Surveying each segment took about one to two months. This time included five to ten days to check the latitude at each end, depending on how many cloudless nights were available for observations.

At wide river crossings, like the Susquehanna, Mason used the Hadley Quadrant on its side to measure a horizontal angle. First, the West Line was continued across the river using the transit. Then they established a long, straight baseline on one side of the river with one end point on the West Line. With the quadrant, the angles between the baseline and the West Line were measured. Knowing the length of the baseline and the angles at the two ends of the baseline allowed the length across the river to be calculated using plane trigonometry.

By October of 1765, the survey had reached the end of the eleventh segment and Mason marked the limit of the work for the year so that it could be recovered in the spring. It also was at this point that he climbed to the top of North Mountain to view the path west to see what lay ahead of them. Mason was relieved to see that the line of survey would not cross the Potomac River near Hancock, Maryland. He had been apprehensive about the political issues surrounding the potential for Maryland being cut into two pieces, but being a surveyor, his immediate concern were about how to measure across the wide river on a skewed angle.

After storing their instruments with the local magistrate, the surveyors headed home back along the line. As they went, they reset the border monuments using the offsets calculated at the end of each of each ten-minute segment to get the monuments onto the true line of latitude. Within a month they had returned to their starting point for that year near the Susquehanna River.

On April 1, 1766, the surveyors returned to the limit of the previous years work and headed west once more. After setting the direction from the previous ending point, the line cutters advanced followed by the chaining crews. They missed the Potomac River at Hancock by a little over a mile and a half, as Mason had seen the earlier year. Before reaching the limit of their commission, they crossed Sidling Hill, Town Hill, Evitt's Creek Mountain and Savage Mountain. Savage Mountain marked the eastern watershed divide and the end of the survey since King George III had ceded land on the west of the divide to the Indians in his proclamation of 1763. On June 18, they set a wooden post to mark the end of the line, 165 miles, 54.88 chains from the

"post mark'd west," and headed east. On the way back, as they did the year before, they set markers on the line based on the tables of offsets that Mason had calculated at the end of each 10-minute segment.

At the western end of the 1766 survey, Mason had wondered if the line would ever be continued to the end of the full five degrees of arc included in the original land grant. He calculated the remaining survey to be almost 87 miles, meaning that only two-thirds of the total line was completed. By reaching the watershed divide, however, they had surveyed all that had been requested of them to date.

In June of 1767, Mason received word that the Tribes of the Six Nations had come to terms and would allow the survey to continue to its completion. By July, the survey party had reassembled in Fort Cumberland and was ready to go. To be included with the survey party for this part of the work was Captain Hugh Crawford, a typical American frontiersman, three Onondagas and eleven Mohawk guides. Mason told the men that any disrespect toward the Indian guides would not be tolerated. Since the Seneca (part of the Six Nations) and the Cherokee were close to open hostilities, keeping the guides happy was essential to the success of their work. The work proceeded quickly, crossing the Youghiogheny, Cheat and Monongahela rivers. As they went further west, the men grew more uneasy about being in the wilderness surrounded by potential hostile Indians. Several times, members of the survey party deserted and returned east. The Indians themselves were unsure of the limit of the survey and when they reached Dunkard Creek, the chief of the guides told Mason and Crawford that he "would not proceed one step further westwards." Mason marked this point as 233 miles, 13 chains and 68 links from the "post mark'd west" and thirty miles short of the end. As before, on the way back east they set markers on the line, including large cairns of stones at the top of each summit in the Appalachian Mountains.

While Mason and Dixon were completing the survey in the west, a second crew was setting carved limestone "crownstones" along the surveyed border. These stones replaced the temporary wooden posts the survey crews had set. Every five miles, a stone was placed with the Calvert's coat-of-arms on the southern side and that of the Penn's on the northern side. In between these were placed stones with a carved "M" on the south toward Maryland and a "P" toward Pennsylvania. The only exception was that no stone was placed at the mile marker that landed in the middle of the Susquehanna River. No milestones were set west of Sidling Hill.

Upon return east, Mason and Dixon met with the commissioners and gave a full accounting of their efforts. The commissioners asked that Mason and Dixon to prepare a map of all of the lines of their survey. Dixon, the land surveyor prepared the map and it was delivered in January 1768.