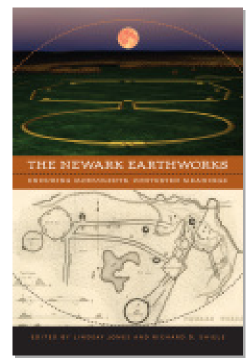
The Newark Earthworks

Jones, Lindsay, Shiels, Richard D.



Published by University of Virginia Press

Jones, Lindsay & Shiels, D..
The Newark Earthworks: Enduring Monuments, Contested Meanings.
Charlottesville: University of Virginia Press, 2016.
Project MUSE., https://muse.jhu.edu/.

RAY HIVELY & ROBERT HORN

The Newark Earthworks

A Grand Unification of Earth, Sky, and Mind

O, swear not by the moon, the inconstant moon
That monthly changes in her circled orb,
Lest that thy love prove likewise variable.
—*Romeo and Juliet*

Romeo invokes "yonder blessed moon" to seal his pledge of love for Juliet, and Juliet reminds him that the blessed moon is also fickle, a poor sponsor for a constant love. Today it is difficult to fathom either Romeo's awe or Juliet's doubt.

The famous NASA image of the Apollo 11 moon landing that depicts a half-Earth visible in the background as the lunar module lifts off from the moon to rendezvous with the Apollo command module on July 21, 1969, is an appropriate place to begin thinking about the blessed but inconstant moon and its place in the story of the Newark Earthworks. Even today the sight of the moon can inspire awe. But this image of the Apollo 11 lander lifting off from the moon as the blue earth rises on the horizon has another fascination. It calls attention to the remarkable human achievement of space exploration. These two—awe still inspired by the sight of the moon and fascination with the strange match between human wit and the perplexing cosmos—may bring us closer to Newark than we might imagine.

We cannot juxtapose Newark and NASA without reviving the valid criticism that there are vast differences between modern celestial mechanics and prehistoric observation of the heavens, however practiced and disciplined it may have been. Brad Lepper has suggested Newark is something like "a pre-Columbian Large Hadron Collider—a vast machine, or device, designed and built to unleash primordial forces."[1] The gap between CERN and Newark remains great. Yet they may share the grand assumption that there is a fundamental affinity between our human aspiration to comprehend the world and the world we try to comprehend. The Large Hadron Collider plays a fundamental role in the continuing effort at a Grand Unified Theory of the forces at work in the cosmos. It may not be folly to guess that the planners and builders of Newark supposed they had in one vast geometric design mirrored the fundamental forces of their world. They had mapped the annual travel of the sun and found constancy in the odyssey of the inconstant moon, a grand unification of earth, sky, and mind. They appear to have had an answer for Juliet. Romeo may, after all, "swear by the moon."

Hopewell Background

Over the past two centuries there has been a gradual accumulation of evidence showing that during the centuries between 100 bce and 500 ce the American Indian peoples of the eastern American Woodlands shaped a remarkable culture that archaeologists call Hopewell. Many believe that the core of this cultural explosion was in Central and South Central Ohio. Remnants are still visible on the ground in the form of massive geometrical earthworks and in museum displays of sophisticated textiles, ingenious artwork, pottery, and exotic raw materials. But analysis of the evidence, which traces the origins of Hopewell or Middle Woodland culture to Adena, or Early Woodland, culture, has not resolved the essential mystery of the geometric earthworks. Archaeologists have suggested variously that they were ceremonial centers; corporate centers encompassing periodic social, civic, and trade exchanges, burial rituals, sacred games; goals for pilgrimage. Still there has been no widespread consensus about the ultimate motivation for the spectacular geometric accuracy and scale of the earthworks. Nowhere is this puzzle more provocative, or answers more within reach, than at Newark.

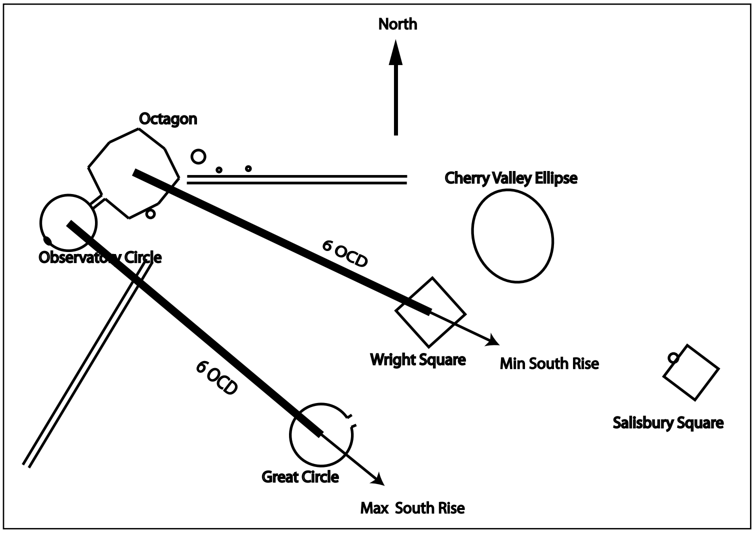
Our work at Newark began in 1975 as a field exercise in data collection and analysis for an undergraduate interdisciplinary course at Earlham College. The scope of the course included the cosmology and the astronomical knowledge of prehistoric and ancient cultures. Our aim at that point was to teach students the rudiments of surveying by mapping the remnants of the Newark Earthworks. We did not expect to find any particular geometrical or astronomical pattern. Indeed, given the difficulty of showing that any such pattern was intentional rather than fortuitous, we doubted any persuasive hypothesis regarding design of the earthworks could be formed.

Much to our surprise, our continued analysis of the Newark Earthworks over the past thirty years has revealed repetitive patterns of earthwork and topographical features oriented or aligned to the extreme rise and set points of both the sun and the moon on the horizon. These alignments combined with the massive scale, geometrical symmetry, and regularity of the earthen enclosures suggest that the Newark Earthworks were built to record, celebrate, and connect with the celestial actors or large-scale forces that appear to govern relations among earth, sky, and the human mind.

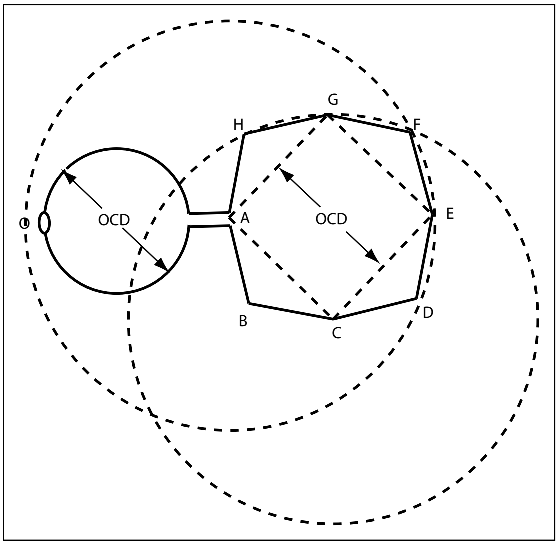
Geometry and Scale of the Site

The major geometric enclosures associated with the Newark Earthworks are shown in figure 1. These figures include a Circle-Octagon joined by an avenue, a second larger circle known as the Great Circle, two squares (the Wright Square and the Salisbury Square), and an oval earthwork enclosing some forty-nine acres that we refer to as the Cherry Valley Ellipse. The first notable feature of the Circle-Octagon combination is the geometrical precision and plan involved in their design and construction. The scale of both Observatory Circle and the Octagon is based on a common unit of length (which we call the Observatory Circle diameter, or OCD) of 1,054 feet. The shape of the Octagon conforms to a simple geometrical construction involving circles (centered on the corners of a square) with radius equal to the diagonal of the length of the associated square. The square has a side equal (to within the errors of measurement) to the OCD. This plan is illustrated in figure 2. The intentional nature of this design is supported by the fact that a similar design was employed in the only other circle-octagon earthwork constructed by the Hopewell, the so-called High Bank Works located at Chillicothe, Ohio.2

The importance of the OCD as a geometrical length in Hopewell earthwork design is revealed by the fact that the High Bank Circle has (within the errors of measurement) the same diameter as the Newark Observatory Circle. The same multiple of this distance (6 OCDs) separates the centers of the Observatory Circle and Great Circle and also the centers of the Octagon and Wright Square. Other geometrical regularities can be found as well. The Observatory Circle encloses an area equal to that of the Wright Square within ~0.6 percent. The perimeters of the Wright Square and the Great Circle correspond within less than .02 percent. These together with repetitive and accurate, though often not equally precise, geometrical figures in the valleys of Paint Creek and the Scioto River (near Chillicothe) show that the Hopewell were experimenting on a monumental scale with geometrically regular shapes and dimensions.



Figur e 1. Schematic map of the Newark Earthworks. The only surviving major components are the Observatory Circle, the Octagon, the Great Circle, and a small part of the corner of the Wright Square. The scale of the map is established by noting that the Observatory Circle diameter (OCD) is 1,054 ft. It should be noted that the distances between the two sets of major figures is the same (6 OCDs). Lines between the figure centers align with the southern extreme moonsets at major and minor standstills.



Figur e 2. The geometrical plan that relates the Octagon to the Observatory Circle. The plan suggests that the Octagon was laid out and constructed using a simple but elegant construction. The Octagon begins with a square ACEG with a side equal to the Observatory Circle diameter. Then circles (or arcs) are drawn around each square vertex with a radius of the diagonal of the square. The intersection of these vertex-centered circles then determines the Octagon vertices B, D, F, and H.

Any assessment of the intentionality of a geometrical or astronomical design for the earthworks must consider objective quantitative measures of the accuracy and precision with which the earthworks embody such a plan. Accuracy here refers to a measure of how closely the earthwork structure conforms to the proposed plan. Precision refers to a measure of how well the earthwork structure can actually be determined from measurements at the site.

The accuracy and precision of the Newark Earthworks and other comparable geometrical sites were first demonstrated by meticulous surveys undertaken by the Smithsonian Institution. As reported in the *Twelfth Annual Report of the Smithsonian Bureau of Ethnology,* "In the summer of 1887 a resurvey of some of the more important ancient works described and figured by Squier and Davis was made in order to determine the accuracy of the measurements and figures of these authors."3 The accurate and precise geometry of the Newark Earthworks came as a major surprise to James Middleton and Gerard Fowke, the surveyors who did the Bureau of Ethnology resurvey. Fowke described the care with which the measurements were made and their astonishment at the result: "Greater care was taken in getting bearings and distances than is usually employed in railway or canal surveys. Middleton and I, who did the work, stand by our figures, and with all the more reason too, that in some cases they completely upset our antecedent ideas and opinions."4

For example, the Observatory Circle wall is constructed so accurately that its surveyed circumference of 3,309 feet is within 2 feet of the ideal circumference of a perfect circle with the measured diameter of 1,054 feet (the OCD). The angles formed by the diagonals through the Octagon vertices BF and DH (shown in fig. 2) differ by only 10 minutes of arc from a right angle; similarly, the Octagon diagonals AD and EG show a comparable accuracy.

The monumental scale of the Newark Earthworks is certainly one of its most remarkable features and suggests a purpose larger than that of an enclosure whose symmetry and structure could be utilized or even appreciated on the ground. The main features of the site covered four square miles, and their construction required the placement of seven million cubic feet of earth. The amount of labor required to construct this complex would have been comparable to the several hundred thousand person-days estimated for structures such as Stonehenge and Avebury.5

The precise symmetry and construction of the Newark Earthworks become even more remarkable when one considers that neither of these features can be seen or appreciated by casual observation from the ground. The scale of the figures is so grand that no observer from ground level or even on the surrounding hills can see the geometric enclosures in a manner that makes their accuracy and precision readily apparent. Only an observer situated high above in the sky can see this, a notable fact in formulating a probable interpretation of the site.6

Archaeoastronomy at Newark

A possible and plausible answer for the design, location, and scale of the Newark Earthworks comes from the field of archaeoastronomy, the study of the artifacts of prehistoric and more recent societies for evidence of astronomical knowledge. Typically such an analysis involves a search for the systematic alignment of linear architectural features to important periodic celestial rise and set events on the local horizon. In the absence of ethnographic evidence indicating a society's interest in and knowledge of specific astronomical events, the primary challenge in such studies is to demonstrate that astronomical alignments found in the architecture were deliberate and not simply fortuitous.

At present the only methodology for establishing intentionality in the astronomical alignments of Hopewell earthworks involves an attempt to find repetitive patterns of alignments to the same astronomical phenomena. If such consistent patterns can be found, statistical methods (such as Monte Carlo simulations of earthwork shapes) can be utilized to determine whether such patterns are likely by chance alone. Unfortunately, there is no established consensus about the procedures to be used in establishing repetitive patterns or determining an unambiguous way of computing the probability that such patterns are the result of chance. However, the Newark Earthworks present an almost unique opportunity among prehistoric sites for developing a methodology to lead to confident conclusions. Specifically, meaningful statistical analyses require a significant number of intentional linear structures that define azimuthal alignments to specific points on the horizon to within a fraction of a degree. No other prehistoric site meets these criteria more impressively than the Newark Earthworks.

It has been evident since the Smithsonian resurveys of Newark in 1887 that the geometrical features at Newark were designed with careful attention to their accuracy. Until our surveys, beginning in 1975, there had been no comparable attention to their orientation.7 In fact, it was the remarkable geometric accuracy of the Circle-Octagon that forced us to think more seriously about orientation. The level of accuracy of the Octagon design is so high that it is possible both to discover departures from the achievable accuracy and to suspect they are not accidental. Might these departures from exact symmetry be explained by an attempt to orient the walls in question? What structures or properties of the natural world could have been used to provide such reference directions? There would seem to be only two possibilities: (1) directions defined by topographical features in the local terrain and (2) directions defined by astronomical phenomena, most likely the locations of the rise and set points of the sun and moon on the local horizon. Studies of the monumental architecture of ancient and prehistoric societies around the globe indicate that both earth and sky were frequently used to orient and locate major constructions. Our study of the geometry of the earthwork figures and their relationship to the surrounding terrain has revealed substantial evidence that the Newark site was designed and located to achieve an integrated harmony with the features of the local terrain and directions established by extreme rise and set points of the moon.

Analysis of the relation between the internal geometry of the site and the surrounding terrain suggests that for many generations astronomical observations were made from specific identifiable hilltops surrounding Cherry Valley. The hilltops would have been chosen in part because they were connected by sightlines that marked the sunsets and sunrises that occurred at the winter and summer solstices. The earthen geometric figures constructed in the valley below these prominent observation points were then apparently located so that lines between the designated hilltops and the centers of major figures marked the extreme north and south moonsets and moonrises. If the case for deliberate design and planning can be firmly established, the result will offer insight into the mentality and worldview of the Hopewell not accessible in any other fashion. An advance in understanding how the builders sought to bring together their experiments in geometry, their grasp of their terrain, and periodic events at the margin of earth and sky would undoubtedly help us infer more reliably some of the social, political, and ceremonial practices that structured and gave meaning to daily life.8

Astronomical Events Marked at the Newark Earthworks

Among the wide variety of celestial phenomena that prehistoric observers recorded, the most vivid were the cycles of the sun and moon. Few if any societies until recently have lacked a sense of reverence, awe, and curiosity about the periodic movements of the sun, the moon, the stars, and the "wandering stars" we call planets. Observers at the latitude of Newark would have noticed that the regular annual movements of the sun were related roughly to the cyclic passage of the seasons. The most widely recorded aspect of the sun's motion is the oscillation of the rise and set points of the sun between a northern extreme in summer and a southern extreme in winter. At Newark the northern extreme rise and set points occur about 30° north of east and west, respectively, at the summer solstice. The southern extremes occur about 30° south of east and west at the winter solstice.

Even casual observers would note that the rise and set points of the moon undergo a similar periodic movement between northern and southern extremes. The primary difference with the moon, however, is that the period of the movement between northern and southern extremes is much more rapid than that of the sun. The moon completes its north-to-south-and-back excursion in only 27.3 days. A more careful and persistent observer would note over time that the precise location of the lunar extreme rise and set points oscillates much more slowly between maximum extremes and minimum extremes, spanning a period of 18.6 years. The directions to the extreme rise and set points of the sun and moon are illustrated in figure 3.

The rate of movement of the moon's rise and set points varies dramatically near the northern and southern extremes. When near a monthly extreme point, the moon's rise point will vary by no more than 0.5° over three days. Near the midpoint of the monthly cycle the moon's rise point can change by as much as 7.0° per day. In a similar fashion the location of the extreme north and south rise and set points changes much more rapidly during the middle of the 18.6-year cycle than it does when the cycle is at the maximum and minimum extremes. During the middle of the cycle, when the lunar extremes are near the solstice rise and set points, the position of the extreme lunar rise and set points changes by about 3.0° per year. In contrast, when the lunar extreme rise and set points are near a maximum or minimum value (as shown in fig. 4), the extreme rise and set points remain fixed in position within 0.5° for a period of some three years. During this three-year period the rise and set points of the moon appear to linger at the extreme points with little change. Hence when the moon is at the maximum of this cycle, it is said to be at a major standstill. When the moon is at a minimum of the cycle, it is said to be at a minor standstill.

There is some evidence for the alignment of prehistoric structures to the

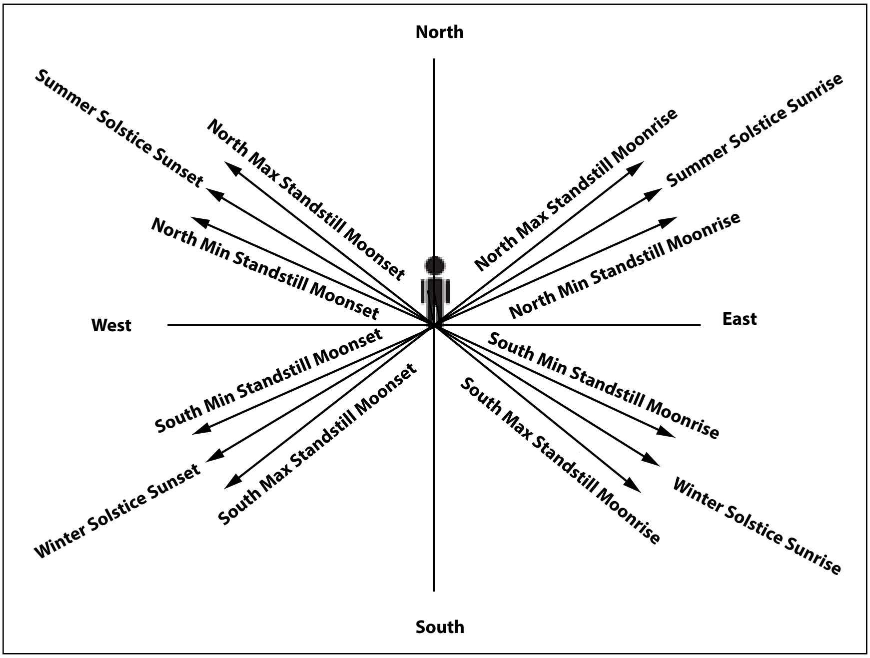
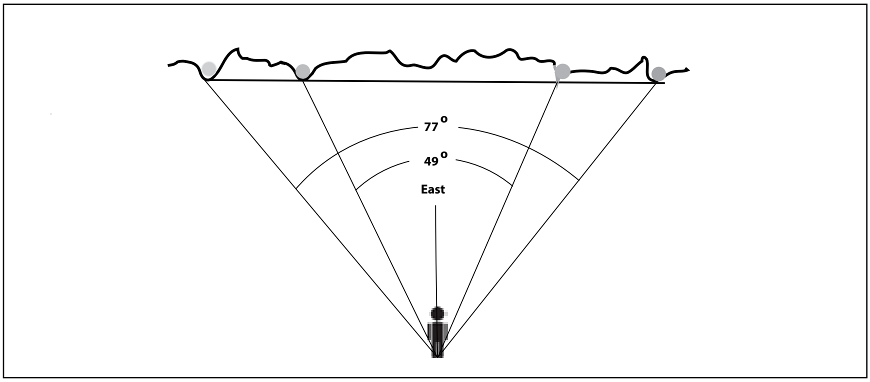


Figure 3. This diagram shows the directions (relative to true north at the top) of the northern and southern extreme rise and set points for both the sun and the moon. The solar extreme rise and set points are attained on the days of the summer and winter solstices. The lunar extremes vary between a maximum value at major standstill and minimum value at the minor standstill. The major standstill is achieved every 18.6 years.

lunar standstills in ancient Britain and Ireland, Mesoamerica, and the American Southwest.[9] However, no clear ethnographic evidence indicating that these cultures observed the 18.6-year cycle has survived. As a result the issue of the existence and importance of an ethnographic precedent for such knowledge remains a topic of continuing conjecture, debate, and controversy. Nevertheless, it should be noted that the 18.6-year motion of lunar extreme rise and set points is not a trivial or subtle effect if one is concerned with following and understanding the moon. The swing between maximum and minimum extremes at Newark is 14°, some twenty-eight lunar diameters. This shift would be highlighted in dramatic fashion viewed against a horizon background punctuated with hills and valleys. Such a punctuated horizon would invite and facilitate both observing and recording this motion of extreme lunar rise and set points. This is the case at Newark, and even more



Figur e 4. This diagram shows a hypothetical observer looking toward the east at the latitude of Newark to observe the northern and southern extreme moonrises at the major and minor standstills. The full moon is seen rising relative to prominent hills and valley on the local horizon. Notice the large difference in the monthly angular motion of the moonset: a swing of 77° at major standstill compared to only 49° at the minor standstill.

remarkably so among the many related Hopewell geometric sites in the valleys of the Scioto River and Paint Creek, as we have shown in recent work.10

Observing and recording the 18.6-year lunar cycle would perhaps be much more difficult if the motions occurred against a background of distant, relatively featureless horizons. The situation at Newark is quite different. Many local hills, streams, valleys, and distinct topographical features that make the motion of the moon from major to minor standstill quite conspicuous would have been well known to the inhabitants. Indeed we believe that evidence supports the notion that the location and orientation of the Newark Earthworks were chosen in part to record and celebrate the correspondences to be seen between the local topography and the motions of the moon. Skeptics concerning prehistoric knowledge of lunar standstills generally make two points: (1) observation of the lunar standstills has no pragmatic or survival value, since it is not correlated with agricultural seasons, the prediction of tides, or other phenomena of immediate importance; and (2) establishing and recording the lunar extreme rise and set points require a long period of multigenerational observation and persistence. Many lunar events would not be visible because they occur in daylight, when the moon is near new phase, or when the weather is unfavorable.

With respect to practical reasons for observing the lunar standstills, the most practical "reason" we can imagine is a response rather than a reason: reverence, awe, recognition of mystery, and fear of the cosmic power represented by the moon. Something of this survives, if only as a literary trope, in Romeo's appeal to the "blessed moon" and in Juliet's wariness of the moon's caprice.

If we need a reminder of why prescientific societies might have had a passionate concern for observing the moon, consider the *Natural History* of the Roman polymath Pliny the Elder (29–79 ce), an Old World contemporary of the Hopewell:

> But the moon, which is the last of the stars, and the one most connected with the earth, the remedy provided by nature for darkness, excels all the others [celestial bodies] in its admirable qualities. By the variety of appearances which it assumes, it puzzles the observers, mortified that they should be the most ignorant concerning that star which is the nearest to them. She is always either waxing or waning; sometimes her disc is curved into horns, sometimes it is divided into two equal portions, and at other times it is swelled out into a full orb; sometimes she appears spotted and suddenly becomes very bright; she appears very large with her full orb and suddenly becomes invisible; now continuing during all the night, now rising late, and now aiding the light of the sun during a part of the day; becoming eclipsed and yet being visible while she is eclipsed; concealing herself at the end of the month and yet not supposed to be eclipsed.
>
> Sometimes she is low down, sometimes she is high up, and that not according to one uniform course, being at one time raised up to the heavens, at other times almost contiguous to the mountains; now elevated in the north now depressed in the south; all which circumstances having been noticed by Endymion, a report was spread about that he was in love with the moon.
>
> We are not indeed sufficiently grateful to those, who, with so much labor and care, have enlightened us with this light; while, so diseased is the human mind, that we take pleasure in writing the annals of blood and slaughter, in order that the crimes of men may be made known to those who are ignorant to the constitution of the world itself.[11]

Here we find ample "reasons" for attending to the moon. Pliny does more. He alludes to the ancestors, like the legendary Endymion, who brought these lunar phenomena to light. And he shames his contemporaries for ignoring them. This is not to say that Pliny's text or any other text we know unambiguously records the long lunar cycle. What Pliny does report are lunar phenomena that in the right circumstances could engender awe, wonder, and the attentive observation that could lead to discovery of the long lunar cycle. Indeed one would have to establish the nature of the lunar cycles in order to determine whether such knowledge had practical predictive power.

With respect to the difficulty of measuring the standstill cycle, it is undoubtedly the case that marking the extreme points with a typical accuracy of 0.5° would require strong motivation. It would demand the persistence to make regular and disciplined observations and to average the results of observations extending over many human generations. It would also require some way of transmitting the knowledge from one generation to the next. This would require a certain minimum of social, political, and ritual stability. However, these requirements of curiosity, intelligence, persistence, and the ability to transmit information from one generation to the next are precisely the traits suggested by the construction of the earthworks themselves. That was not a feat likely to be confined to a single generation.

Analysis of Internal Geometry for Astronomical Alignment

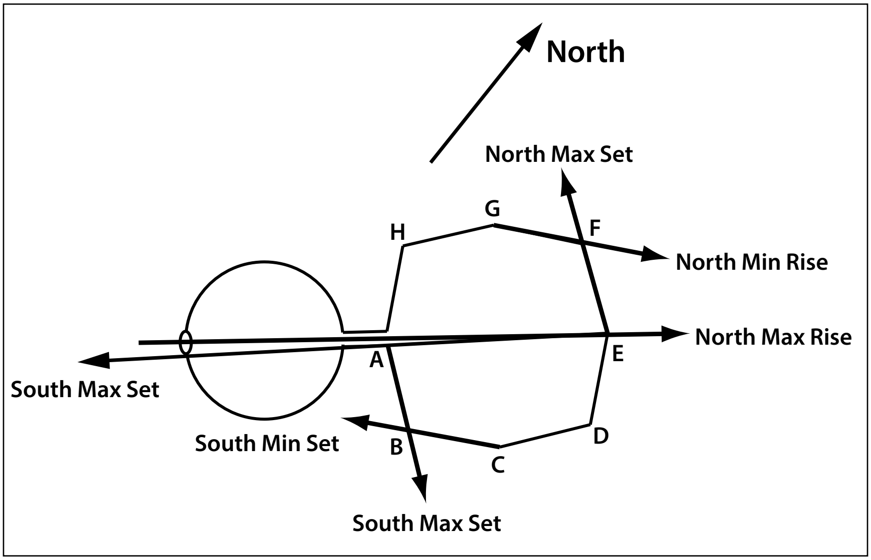
An investigation into the possibility of astronomical alignments within the Newark Earthworks has two major prerequisites: (1) an accurate survey of the azimuths (directions relative to true north) of major linear features in the earthworks before the structure was significantly altered by agriculture and by undocumented or poorly documented construction at the site and (2) an accurate representation of the physical relation of each of these elements of the site to the others. Our previous archival work and surveys of the site have established that only the aforementioned survey by James Middleton and Gerard Fowke for the Smithsonian Institution's Bureau of Ethnology in 1887 meets these prerequisites. The 1887 survey, published in the *Twelfth Annual Report of the Bureau of Ethnology,* includes detailed drawings and data tables for surveys of the Circle-Octagon, the Great Circle, and the Wright Square.[12] It also maps the ensemble formed by these figures, including the parallels that connect the Octagon and the Great Circle. Other surveys and maps, including the celebrated map of Charles Whittlesey, published in Squier and Davis's pioneering *Ancient Monuments of the Mississippi Valley,* give valuable information about the Newark site but do not satisfy these criteria. Consequently our study of the orientation and internal geometry of the Newark

Earthworks relies solely on the Middleton survey, on our confirmation of that survey through archival study, and our own surveys and work at the site.13

The first and most important fact emerging from a survey of the Circle-Octagon combination is that the 2,839-foot symmetry axis through the two figures and the connecting avenue points with subdegree accuracy (less than 1.0°) toward the northern extreme rise point of the moon at the major standstill. This alignment is shown in figures 14 and 15 and in plate 1. Taken by itself, there is no reason to believe that this alignment is anything but a random accident. It would take a pattern of repeated alignments to lunar standstills to give the intentionality of this alignment any credibility. Remarkably, we do find as many repetitive alignments to lunar standstills within the Octagon geometry as would be allowed by the constraints of a symmetrical equilateral structure.

If we are to believe that the Hopewell designers went to great effort to align the axis of the structure to the northern extreme moonrise at the major standstill, then we must think it probable that they would give some attention to its southern counterpart. Our expectations in this regard are met when we find that a sightline along the Octagon wall AB (see fig. 5), some 570 feet in length and 5.5 feet high, points directly (again with subdegree accuracy) to the southern extreme moonrise at the major standstill. It is also notable that this structure achieves another standstill alignment of comparable accuracy along the Octagon wall CB to the southern lunar extreme set point at the minor standstill.

If the Octagon had been constructed perfectly in conformity with the geometrical plan shown in figure 2, an alignment along Octagon wall FE would duplicate the alignment along wall AB, and an alignment along wall FG would parallel the alignment along wall CB. Here we encounter a most significant property of the Octagon: its largest deviation from its nearly perfect symmetry. The most notable "error" in the construction of the Octagon is in the placement of vertex F. This vertex alone has been built in a location some 20 feet closer to the center of the figure than its ideal position. The result of this "distortion" of vertex F is to create two additional standstill alignments to rise and set events when the walls are used as sightlines in the reverse directions EF and GF. By pushing vertex F inward by a significant amount, sightlines have been produced to the northern extreme moonset at major standstill along wall EF and to the northern extreme moonrise at minor standstill along wall GF.



Figur e 5. The five major lunar standstill alignments found in the internal geometry of the Newark Circle-Octagon. The six alignments have an impressive average accuracy of about 0.5°. No possible octagon of significantly different orientation or shape could align with more standstills than we find here.

The immediate question that presents itself, then, is this: does the position of vertex F constitute a random construction error, or is it evidence of a deliberate distortion of the geometry to achieve intentional alignments to additional standstill events? We can evaluate the likely standard of accuracy for the construction of parallel walls by looking at all the pairs of walls that would be parallel in ideal geometrical figures at the site. There are six such pairs of parallel walls, four pairs in the Octagon and two pairs in the Wright Square. When we look at the four wall pairs that are not astronomically aligned, their average deviation from true parallelism is 0.4°. In contrast, the pairs of Octagon walls aligned to the lunar standstills (BC-FG and EF-AB) differ from true parallelism by 1.4° and 1.8°, respectively. Thus the four nonastronomical pairs have an angular divergence that is three to four times smaller than the astronomically aligned pairs. This difference amounts to three lunar diameters, and we believe that, given the entire context, the hypothesis of deliberate distortion is more probable than that of random error.

Altogether, then, the Octagon incorporates five accurate alignments to five of the eight lunar standstill events. The pressing question that cannot be answered reliably through intuition alone is, What is the likelihood that a randomly constructed octagon would produce five or more alignments with comparable or greater accuracy? A randomly constructed octagon is one with a randomly chosen orientation and a single randomly chosen vertex angle between 90° and 180°. With one vertex angle chosen, octagonal symmetry determines the remaining angles. A randomly chosen octagon has only these two degrees of freedom: orientation and vertex angle. This makes it much more difficult to encode more than two alignments without distortion of symmetry.

The only means of determining the probability of five alignments (to either sun or moon) of comparable accuracy in a randomly constructed octagon is to perform a Monte Carlo analysis, in which a computer algorithm actually counts the number of accurate alignments on sides or symmetry axes produced by large numbers of randomly constructed octagons. We have conducted such a Monte Carlo analysis of some one hundred billion randomly chosen octagons.[14] A variety of plausible models and assumptions were considered. The analysis firmly yielded the conclusion that the probability of accidental alignments producing these data was on the order of one in a million. The study also showed that no symmetrical, equilateral octagon with a significantly different shape or orientation could possibly have captured as many standstill alignments as the Newark Octagon. The Newark Octagon appears to have been optimally designed for that purpose.

We have argued earlier that the general shape of the Octagon was determined by geometrical experimentation that resulted in the elegant plan shown in figure 2. Given that geometrical plan, some distortion was necessary to achieve the five standstill alignments. We believe the Hopewell planners were energized and fascinated by the discovery that a single structure of their own design could simultaneously encode important geometrical and astronomical regularities. This result could only have been achieved after a long period of careful experimentation with geometrical figures and observations of astronomical events.

This is not the place to discuss the sociopolitical aspects of this disciplined observation and experimentation. Martin Byers has argued recently that this was the work of dispersed nonkinship groups who actively sought, used, and maintained this kind of esoteric knowledge.[15] At the same time, it seems to us reasonable to suppose that such an elite effort could only have succeeded if a significant portion of the population shared enchantment with the moon and fascination with the power of those who could reliably anticipate it. To encode that schedule in an earthen symbol with unprecedented scale and accuracy would have been a stunning achievement.

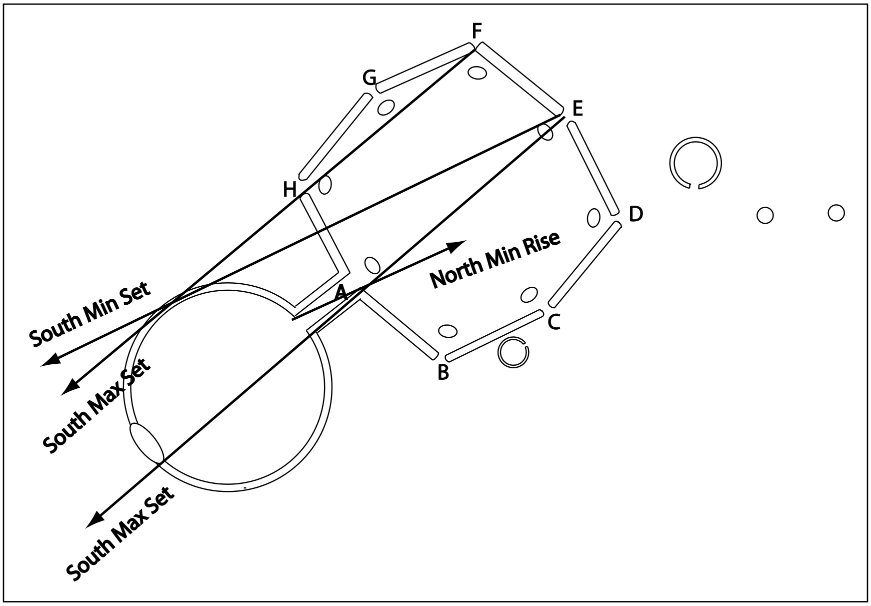
Evidence of Lunar Astronomy beyond the Octagon

If the Hopewell deliberately conceived the Octagon structure as a simultaneous encoding of geometrical and astronomical regularity, we should expect the priority of this interest to appear as well in the additional degrees of freedom afforded by other enclosures in the earthwork complex at Newark. These added alignments are shown in figure 6 and figure 7.16

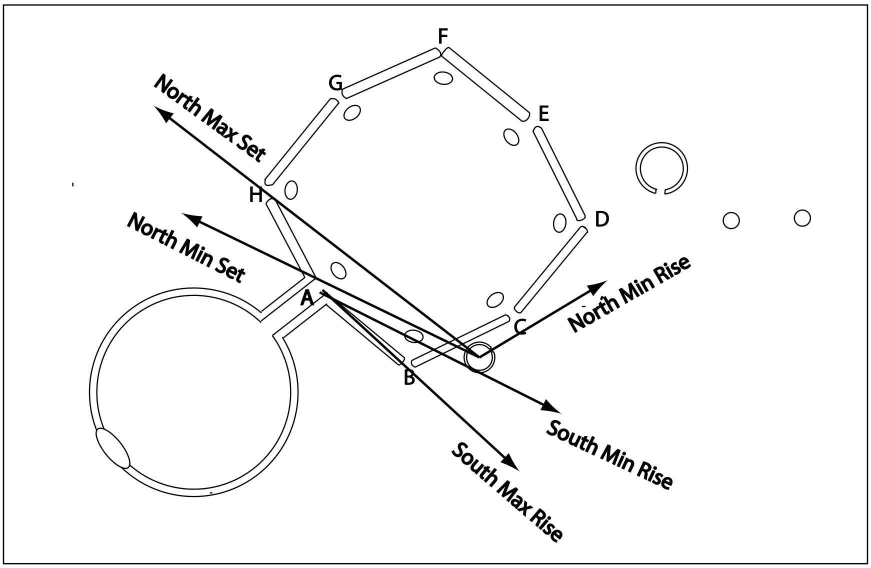
Evidence of Hilltop Observing Stations

Observing and recording the location of the lunar standstill directions with subdegree accuracy would require accumulating astronomical information extending over many human generations. How could such observations be most effectively carried out? A consideration of that question is involved in a resolution of a problematic aspect of our account of the Octagon "alignments." One of the most puzzling and troubling features of our original interpretation was the relative inaccuracy of the alignment along wall EF.17 This alignment to the northern extreme moonset at the major standstill would have an impressive accuracy of 0.2° if viewed against a zero-altitude or plane horizon. However, the actual moonset at the standstill as seen from vertex E is displaced by 1.7° from the wall line. The accuracy of the other four standstill alignments within the Octagon geometry averages 0.25° when viewed against the local (and small) horizon altitudes. Why should the builders have tolerated this "error" in the alignment of wall EF, especially when the "error" is created by a local hill located only 5,905 feet (1.8 km) to the northwest of wall EF? This local hill creates a horizon altitude of 1.7°, which shifts the direction of moonset by 1.7° away from the wall alignment. The anomalously large "error" is some six times greater than the average error of the remaining four alignments.

This "error" is troublesome for our initial interpretation because it might have been avoided by moving the Octagon. The whole array of the enclosures as we have described it thus far could be preserved unchanged by moving the entire ensemble about a mile to the southwest along the northern



Figur e 6. This diagram shows additional accurate alignments to the lunar standstills (major and minor) in the Circle-Octagon. If intended as part of the design, these alignments "explain" the length and width of the Circle-Octagon avenue, the shortening of wall HA, and the width of the Observatory Mound on the Observatory Circle. Otherwise these features remain unexplained.



Figur e 7. This diagram shows the lunar standstill alignments (major and minor) that can be achieved from the placement, size, and orientation of the circle BC. The hypothesis of deliberate alignment to the standstills provides a consistent explanation for these features.

maximum rise line. That would reduce the EF error to about 0.4°. As we were to discover later, probable constraints on the overall design made this option unavailable.18

It finally occurred to us that there would be no anomalous error in the bearing of wall EF if the enclosure walls were built to align with directions established by horizon rise and set observations made from backsights on elevated hilltops toward foresights on hilltops across Cherry Valley. In that case the altitude of distant horizons would be negligible. On further reflection we believe this is by far the best interpretation of the alignments.

The repetitive and long-term observations required for establishing and marking the lunar 18.6-year cycle would have been most easily made in places with distant clear horizons in all directions and where there would be little interference from other human activity or seasonal changes in horizon visibility—specifically, high elevations such as hilltops or ridges.19Thus we came to believe that the most probable scenario for establishing Octagon alignments to the lunar standstills was a two-step procedure involving (1) long-term observations from elevated points in the local topography that had small and distant horizons and (2) the projection of these alignments into Cherry Valley to establish the standstill directions, which would then be encoded by the Octagon.

This scenario requires that the Hopewell builders had the capacity to project parallel lines over distances of several miles. We know in fact from the archaeological record at Newark that they had this capability. One of the best-known features associated with the Newark Earthworks is a set of parallel walls (separated by about 190 ft.), which are known to extend at least six miles from the site along a very straight course through terrain of varying slope and altitude at an azimuth of ~211° (fig. 1).20There is some evidence that these walls extended in an undeviating course for at least 12 miles from the Octagon. Brad Lepper has suggested that this road may have extended some 55 miles all the way to the "core" region of Ohio Hopewell earthworks, on the Scioto River and Paint Creek near Chillicothe, Ohio.21This hypothetical passage has become known as the Great Hopewell Road. Whether the road extends all the way to Chillicothe is currently a matter for continued research. What is certain is that the Hopewell had the ability to extend straight lines (for the planning and construction of earthen walls) for distances of several miles.

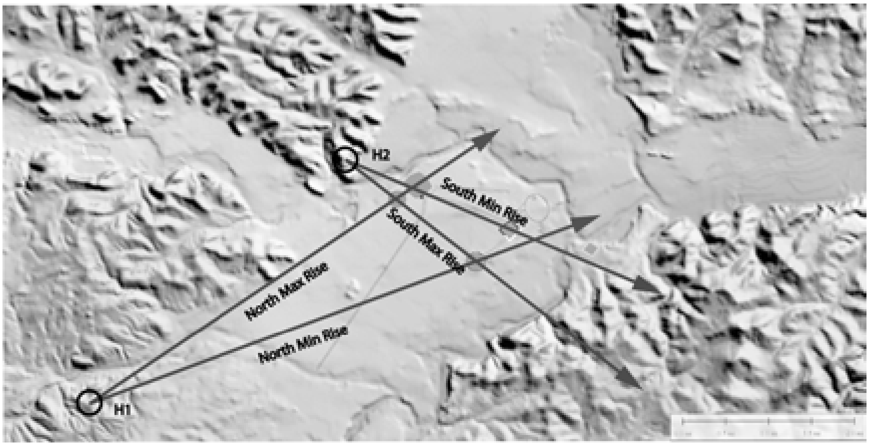
Tests of the Hilltop Hypothesis

We will refer to our hypothesis that the Hopewell observed and recorded lunar standstills from elevated positions with negligible horizon altitude as the zero-altitude hypothesis and call it H_Z. One clear testable consequence of H_Z is this: if any Octagon standstill alignment is extended in the reverse direction, the line will pass over a prominent elevation where the critical astronomical observations were made.[22] At first glance this prediction would appear to have little significance. One would expect that any line drawn from the earthworks in the valley back toward the surrounding hills would pass over some high point that could be claimed as the sought observing position.[23] Consequently our initial enthusiasm for even testing the hypothesis was very small. When we did test the hypothesis, we were astonished at the result.

The most obvious test of H_Z is to extrapolate the standstill alignment on the symmetry axis of the Circle-Octagon back along a line to the southwest and determine whether this line passes over a prominent overlook that could have been used for establishing the alignment. As we have said, we expected any such line drawn from Cherry Valley to the surrounding hills to pass over some hill or ridge. But we were impressed to find that the line through the Octagon and the Observatory Circle passes over one of the most prominent overlooks on the valley to the southwest, an elevated plateau some five miles from the center of the Octagon and more than 200 feet above the valley floor. This position is designated H1 in figure 8.

After locating H1 as the optimum site for establishing the standstill alignment through the Circle-Octagon, we were surprised to discover that a line from H1 through the center of the Great Circle passes through the gateway opening of that circle and points accurately to the extreme northern moonrise at the minor standstill. An observer at H1 would see the northern extreme moonrise move from a line through the Circle-Octagon at major standstill to a line through the center of the Great Circle at minor standstill. H1 thus serves as common backsight for complementary extreme northern moonrises occurring over the centers of the two major circular earthworks at major and minor standstills. Still a skeptical reader might reasonably assume this is accidental.

The strongest evidence that this was intentional would be finding that the six remaining standstill alignments are marked in a similar fashion. We did not expect such a confirmation. Indeed we were quite surprised to find that this is the case. Consider the alignment shown in figure 1 (to the extreme



Figur e 8. The locations of the prominent elevated observing stations H1 and H2 (some 200 ft bove the valley floor) are shown in this map. Both H1 and H2 serve as common backsights for accurate (subdegree) alignments to major and minor standstill extreme moonrises passing through the centers of the major geometrical figures in the earthworks. This suggests that these figures were intentionally located with respect to H1 and H2 to achieve those alignments.

southern moonset at major standstill) that passes through the centers of the Observatory and Great Circles. Extending this alignment in the reverse direction to the northwest shows that it passes directly over the top of a very well-defined hill (designated H2), offering a splendid view of both circles in the valley below.

H2 is located about 0.8 miles from the center of the Observatory Circle and is about 200 feet above the valley below. The most remarkable fact about H2 is that the line from H2 through the center of the Wright Square marks the southern extreme moonrise and the minor standstill. Thus H2 plays the same role as H1: it provides the backsight for subdegree alignments (through the centers of major earthen figures) to complementary extreme southern moonrises at both standstills. If the major geometric figures were placed deliberately to mark all four of the standstill moonrises as seen from H1 and H2, we would expect that the Hopewell designers would have situated other earthwork features to mark the corresponding standstill set points from other prominent observation points.

Next we look at the northern moonset alignment along wall EF. If we extend this alignment backward toward the southeast, it passes over an elevated ridge top that is well positioned to view the valley below. This point is

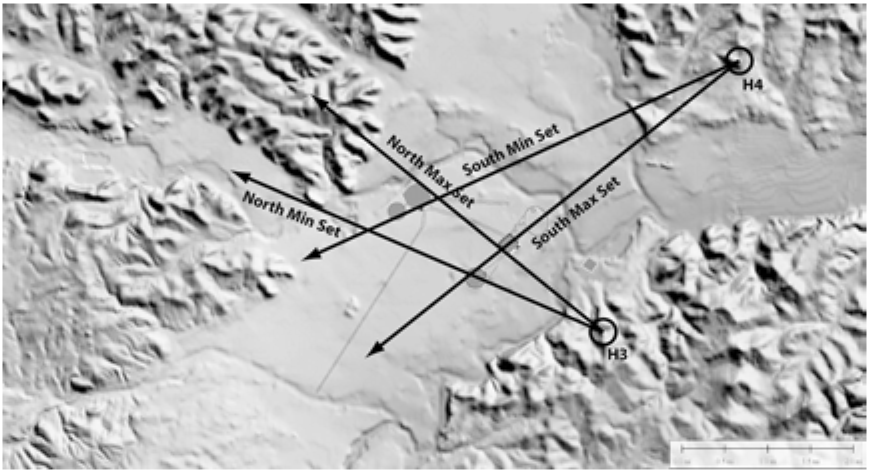


Figure 9. The elevated high points H3 and H4 were located by backward extrapolation of standstill alignments along the Octagon walls EF and CB. These overlooks (some 150 ft bove the valley floor) provide common backsights for both major and minor standstill extreme moonsets as seen through the centers of major geometric figures in the earthworks. They play a role similar but complementary to H1 and H2.

designated H3 in figure 9. It is located about 2.9 miles east of vertex E and is elevated some 150 feet above valley below. As predicted by our hypothesis of standstill alignment, H3 also serves as a backsight for a subdegree alignment to the complementary extreme northern moonset at the minor standstill that passes through the center of the Great Circle. Thus H3 plays the same role in the alignment scheme as H1 and H2.

The final test for the standstill alignment hypothesis would be a convincing location for an elevation H4 that would provide alignments to the remaining two southern moonsets (fig. 9). The prediction of H4 can be verified by taking the Octagon alignment to the southern extreme at minor standstill along wall CB and extending it back to the northeast until it passes over a well-defined high point on a 150-foot ridge some 4.5 miles from vertex C. Remarkably, the location of H4 conforms to the pattern established by H1–H3. A line from H4 through the center of the Wright Square marks the complementary southern extreme moonset at the major standstill with subdegree accuracy. Thus, from H4 as the 18.6-year cycle unfolds, the southern extreme moonset moves from Octagon wall CB at minor standstill to a line through the center of the Wright Square at major standstill.

The four overlooks H1–H4 were all located in the same fashion: finding the first prominent overlook along the reversed directions of the standstill alignments previously established in the Octagon or between the centers of two major figures (the Observatory Circle and Great Circle). The overlooks were located without any reference to one another or to any other geometrical earthworks at the site. In each case, however, we find that each overlook serves as a backsight for observing extreme lunar events at both standstills over the centers of major earthwork figures. Moreover, taken together the alignments mark all eight standstill events with no duplication.

Readers who imagine that it is possible to read into the earthworks any comparable pattern can test this hypothesis very simply. Try the exercise for constructing a similar set of alignments to the solstice rise and set points and cardinal directions. We have tried, and we know it cannot be done. Our own remaining doubts about the use of H1–H4 as key observations points were further reduced when we discovered an unexpected relation among the four overlooks.

Solar Astronomy at the Newark Earthworks

From the beginning of our work at Newark, one of the puzzling aspects of our analysis of the site was the complete absence of any credible alignment to solar rise and set events at the solstices. This raises the question of why the Hopewell would invest such effort and give such priority to marking lunar standstills and ignore the comparable solar solstices completely. Historical and archaeological evidence from the study of ancient and prehistoric cultures across the world shows that most societies with an interest in observing the moon also closely follow the sun. The absence of solar alignments within the earthworks was hard to explain. We looked for credible solar alignments, and they were not there. Why not? We had no explanation.

Now the mere act of inquisitively drawing lines between H2 and H3 and between H1 and H4 revealed the long-missing solstices. Lines connecting pairs of these high points chosen by the Hopewell builders picked out the solstice events quite accurately. The geometric earthworks in Cherry Valley were drawn on a template formed by solstice stations on the surrounding hills. We had found the sun. Or better, the American Indian planners already had found it.

If a line is extended from H2 through H3 (a distance of 3.7 miles), the line marks with subdegree accuracy the winter solstice sunrise (when viewed

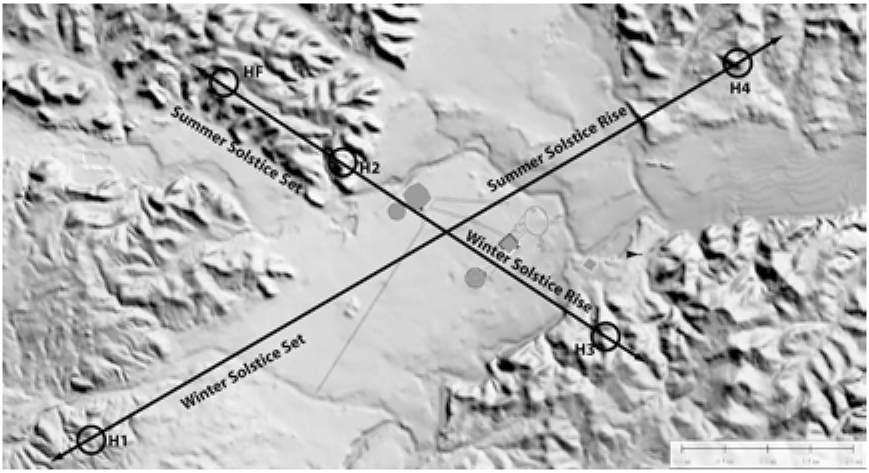


Figure 10. This map shows the surprising solstice alignments connecting H1 with H4 and H2 with H3. This set of alignments suggests the reason that H1–H4 were chosen as observation sites for establishing lunar alignments. The circle labeled HF shows the hilltop fort on the summer solstice sunset alignment.

from H2 across H3) and the summer solstice sunset (when viewed from H3 across H2). The obvious test of the likelihood of the intentional use of high points related in this way is to check H1 and H4 for a similar relation. Indeed, we find that the elevations H1 and H4 have a precisely similar but complementary relation, as one would expect if solstice alignments were deliberately sought out for high points in the local topography. A line from H1 to H4 (a distance of 8.6 miles) provides subdegree accuracy in marking alignments to the winter solstice sunset and summer solstice sunrise. These solstice alignments are shown in figure 10.

Further supporting evidence for the significance of the H3–H2 alignment to the summer solstice sunset comes from the presence of a hilltop earthwork along that line. This hilltop earthwork (shown in fig. 10) described by Squier and Davis forms the natural horizon as viewed from H3.[24] The major earthwork enclosure on this hill was known to have a smaller earthen circle of some 100 feet in diameter at the very highest point, near the center of the enclosing earthwork. According to Squier and Davis, this smaller circle contained two earthen mounds that upon excavation contain what appeared to be altars, which showed evidence of fire. Fire or smoke from this location would have made it easily visible as an astronomical foresight as viewed from H3.

These relations and alignments suggest two reasons why the four points H1–H4 would have been singled out as astronomical observing stations: (1) they all provide a commanding view of the valley in which the earthworks were constructed, and (2) lines between the stations accurately record the positions of the sunrises and sunsets associated with the solstices. This scenario, then, makes it plausible that the Hopewell did indeed make observations of solar events as well as lunar events.

Integration of Topography with Standstill Alignments

Our analysis thus far suggests that the Hopewell attempted to integrate individual geometric enclosures with standstill alignments passing through significant topographical features. This idea offers a plausible explanation for the general location of the earthworks in Cherry Valley. In fact it now appeared that the entire earthwork ensemble was a coherent structure that could not be moved from its present position. Our earlier guess that the anomaly at Octagon wall EF could be resolved by moving the whole ensemble to the southwest now appeared untenable in the light of tight azimuthal relations we had found between the array of earthworks in the valley and the hilltop solstice stations.

Once it seemed plausible that local topographical features had played a role in observing and marking astronomical events, we examined what could be seen from the highest point near the Newark Earthworks, Coffman Knob, some 3.2 miles southeast of the center of the Great Circle and 320 feet above the valley (fig. 11). As viewed from Coffman Knob, the northern extreme moonset at the standstills has a vivid and impressive alignment with two major topographical features across the valley to the northwest. A line from the top of Coffman Knob along the west edge of the linear Sharon Valley aligns with the northern extreme moonset at major standstill. Similarly, a line from the peak of Coffman Knob along the eastern edge of the valley of Raccoon Creek aligns with the northern extreme moonset at minor standstill.

As viewed from the highest elevation in the locality, the extreme northern moonset moves (during the standstill cycle) back and forth between two prominent valleys in quite dramatic fashion. This correspondence between major topographical features and lunar standstill events would certainly draw the attention of those interested in understanding or connecting terrestrial and celestial phenomena. So we conjecture that exactly this location

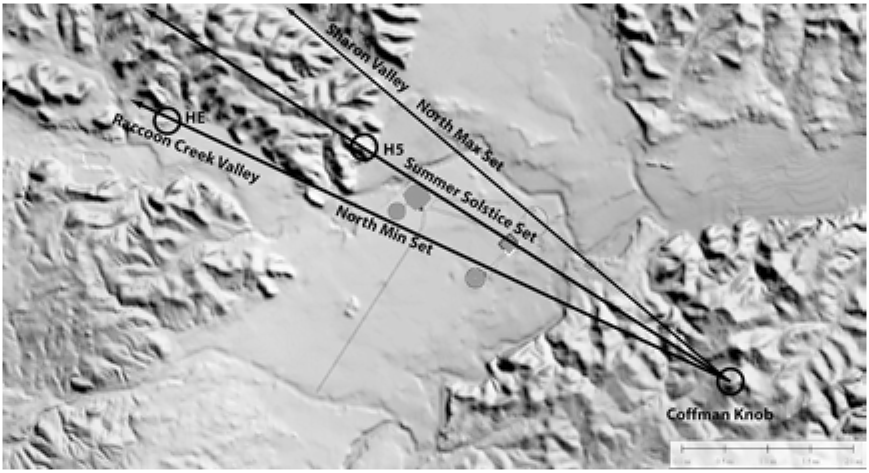
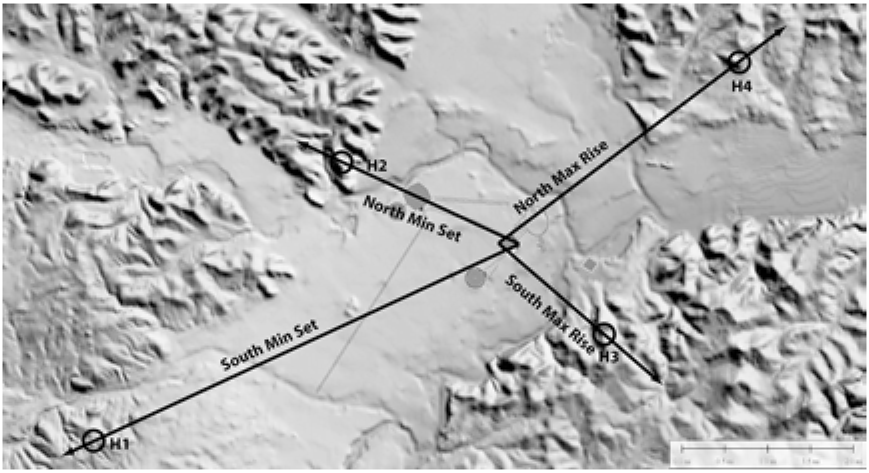


Figure 11. This map shows the fortuitous but striking topographical alignment of the northern extreme moonsets at major and minor standstills along major valleys as seen from the highest point in the area (the top of Coffman Knob some 320 ft bove the valley). The north maximum moonset alignment passes through the centers of the Salisbury Square and the Cherry Valley Ellipse. The northern minimum moonset passes through the Hill Earthwork shown as circle HE.

of the major geometric earthworks in the valley was chosen to highlight the correspondence. There is independent evidence in support of this suggestion. The line from Coffman Knob along the northern extreme moonset at major standstill also passes through the centers of two significant earthwork figures, the Salisbury Square and the Cherry Valley Ellipse, known to contain the "main focus" of burials found at the Newark Earthworks.[25] A line along the northern moonset at minor standstill passes along the length of the Raccoon Creek valley, and close to the center of the Hill Earthwork, a large, perhaps incomplete, circular earthwork, now visible only on aerial photographs.[26]

Finally, we ask whether our hypothesis can account for the size and orientation of perhaps the most puzzling of the major geometric figures at Newark: the Wright Square, shown in figure 12. In the present context the orientation of the Wright Square is puzzling because it bears no obvious relation to astronomical events or other geometrical figures. But when the Wright Square is placed in the context of the observation points H1–H4, there is a plausible and consistent explanation for its orientation. An observer standing at the western vertex of the square (denoted as V_W) sees the moon rise above H4 when it is at the northern extreme of the major standstill. About two weeks



Figur e 12. This map shows the alignments to four lunar standstills from corners of the Wright Square through the high points H1–H4. Given the abundant additional evidence for intentional alignment to the lunar standstills, these alignments support the possibility that the Wright Square orientation was chosen to achieve this effect.

later the same observer sees the moon rise over H3 at the southern extreme of the major standstill. So as seen from V_W the moon's rise point swings back and forth at the extremes between H4 and H3.

Perhaps the best evidence in support of intentional design in the V_W sightlines would be to find a similar pattern at another vertex. Consider the easternmost vertex of the square (denoted by V_E). An observer at V_E will see the moon set at the northern extreme at the minor standstill along a line passing over H2. Similarly, the V_E observer sees the moon set at the southern extreme at minor standstill along a line passing over H1. These four alignments over H1–H4 have an average accuracy of about 0.3°. The alignments are shown in figure 12. It is noteworthy that the east–west diagonal of the ~931-foot Wright Square is oriented at precisely the angle that minimizes the errors in the aforementioned alignments. If the builders had intended to orient the east–west diagonal for this purpose, they could not have done it more accurately.

Conclusions

After examining the accuracy and precision of the earthworks, the geometrical accuracy of their orientation to lunar standstill alignments, and the encoding of this information into a solar template on the local terrain, we conclude that the Hopewell were engaged in an effort to unify their understanding of the three fundamental cosmological components: earth, sky, and mind. The large number of geometric Hopewell earthworks found in Ohio and nearby shows that the culture invested many generations of effort in experimentation with rudimentary geometric shapes, their perimeters, and their areas. This experimentation culminated in the production of the geometrically exacting earthworks at Newark and near Chillicothe, Ohio. These provide evidence of an understanding and concern with geometrical form, symmetry, and patterned relationships among different figures. The intellectual vitality, effort, persistence, and cultural continuity of the Hopewell planners and builders are well documented by these earthworks on the ground. These are also precisely the qualities that would be inferred from the accurate marking of lunar standstills.

We will attempt to reconstruct what we believe to be the simplest and most straightforward scenario for explaining the geometry and astronomy of the Newark Earthworks and their integration with the local topography. Notice that in many respects this process occurs in exactly the reverse order from our findings at Newark.

The American Indian people occupying the region near present-day Newark and in southern and central Ohio engaged in systematic observation of the surrounding terrain and astronomical events occurring on the local horizon, and they experimented with the symmetries and regularities to be found in geometrical figures. This activity accumulated and recorded knowledge extending over several centuries, most likely reaching back into the Archaic period.[27] At some point after 100 ce or so, two significant discoveries were made at the present site of the Newark Earthworks.

First, local observers noticed that there was a striking correspondence between the motion of the northern extreme moonset between the major and minor standstills and features of the local topography. They saw that this moonset moved back and forth in dramatic fashion between two major valleys, as viewed from the highest elevation in the Newark area (shown in fig. 11). We suppose that the recognition of this relation between the local topography, with its water boundaries,[28] and the motion of the moon, was accorded great importance. These fortuitous correspondences between geometry, topography, and the moon provided the motivation for the Hopewell to launch their great experiment of integrating all three phenomena in the Newark Earthworks in Cherry Valley, at the confluence of Raccoon Creek and the south fork of the Licking River.

Second, planners found that the geometrical octagon construction shown in figure 2 could be approximately aligned with directions to five of the eight lunar standstills as they were seen at Newark. After considerable experimentation they noticed that this alignment could be made even more precise with slight distortions of the figure from the ideal octagonal design. This correspondence between the discoveries of geometrical symmetry and the behavior of the moon, an awe-inspiring and mysterious, perhaps capricious, cosmic actor, was a moment of great significance. It galvanized and sustained interest in geometry and astronomy. The sense of reverence and awe evoked by this discovery was enhanced by the recognition that this correspondence was limited to the Newark area. In modern terms we would say that the fortuitous relation between the octagonal design shown in figure 2 and the lunar standstills was latitude dependent. This close correspondence indeed only exists for a strip of latitudes about twenty-eight miles wide near 40° N. This latitude dependence explains in part why the only other octagon built by the Hopewell near Chillicothe, at a latitude of 39.3°, has a different shape.29

This project was ultimately carried out in the following fashion: (1) astronomical observations from local hilltops revealed four prominent elevations (H1–H4) that were connected by solar rise and set lines marking the winter and summer solstices; (2) the directions to the lunar standstills were established by observations conducted from H1–H4 and Coffman Knob; (3) lines along the lunar standstill extreme directions were projected from Coffman Knob and H1–H4 into the valley below; (4) the shapes, locations, and orientations of the large geometric figures in the earthworks were designed to fall along these lunar standstill directions as projected into the valley; (5) the vertices of the Wright Square were then positioned so as to achieve the standstill alignments shown in figure 12.

The accuracy, precision, and intentionality of Hopewell knowledge of large-scale geometric construction and the priority they gave to geometry cannot be disputed. The documented evidence on the ground objectively establishes that fact. The evidence of astronomical knowledge, while similar in accuracy and precision to Hopewell knowledge of geometry, involves an element of inference and abstraction that puts its interpretation in a different methodological category.

While the exacting alignments described can be clearly demonstrated and documented, the evidence that they were intended remains a matter of subjective judgment. Two choices present themselves in the interpretation of the astronomical evidence: (1) the Newark Earthworks were designed to incorporate lunar standstill alignments with a number and accuracy that make the site the most accurate prehistoric lunar observatory known, or (2) the astronomical alignments are fortuitous and random, their supposed intentionality "read into" the site by credulous investigators.

While the possibility that the astronomy at the site is entirely fortuitous can never be absolutely eliminated, we believe it clearly has been eliminated as the preferred interpretation. The hypothesis of a deliberate intent to understand natural regularities by integrating them with geometrical rules discerned by the human mind, we believe, not only is plausible but has no serious competitor. No other hypothesis has been advanced that accounts for so much of the geometrical and architectural design that we find in the earthworks.

Skepticism about the astronomy of the site is generally based on two contentions: (1) there is no precedent in the prehistoric world for disciplined and accurate observation and recording of the lunar standstills, and (2) there is no utilitarian or survival value to motivate an interest in the lunar standstills. These contentions then are used to invoke the axiom that extraordinary claims require extraordinary evidence. Hence the astronomical hypothesis is accorded extraordinary skepticism.

The lunar-oriented Newark Earthworks in the context of the Cherry Valley hilltop solstice stations do constitute extraordinary evidence. No other site offers the same ensemble of geometric constraints on proposed alignments that is found at Newark. No other site encodes with the same accuracy all of the solstice stations and all of the stations of the lunar extreme standstills. No other site so tightly integrates the exacting geometry of its architecture with the local terrain.

There is no precedent for prehistoric earthworks with the combination of scale, geometric accuracy, and precision we find at Newark. The Newark Earthworks are nonetheless there on the ground. They are undisputable proof of unprecedented achievement by their American Indian builders.

Utility is hard to define. The reasons humans inquire are not transparent. Before observers could judge the practical worth of knowing the pattern and period of the lunar standstills, they had to spend substantial effort to discover it. Was it practical to want to decode the moon's baffling behavior and possibly to communicate with the moon? The moon is cryptic and elusive, awesome and mysterious. What would ensue if the builders at Newark offered to the moon their vision of its journey? Did the tradition of standstill observation that Newark epitomizes eventually disappear from memory and record because it was found impractical? This is one of the many things we do not know.

The subject of archaeoastronomy as applied to the Hopewell cultural tradition is still young. We currently believe we have found significant evidence in support of our astronomical hypothesis from our study of the geometry and placement of Hopewell earthworks near Chillicothe. Archaeoastronomical research at the Newark site and at related sites in the Chillicothe region and beyond began in the 1970s and continues today.30New survey work combining geophysics with the remote sensing capabilities of LiDAR has already given archaeologists better data about aspects of Adena and Hopewell sites than nineteenth-century surveys.31While the evidence continues to be accumulated and analyzed, we believe the question of intentional astronomical alignment is likely to remain a subject of debate and conjecture rather than consensus for some time.32However, our best effort to balance appropriate skepticism with three decades of experience in working with the available data and Monte Carlo simulations of randomly constructed geometric figures leads us to conclude that the Newark Earthworks were built to encode simultaneously a knowledge of geometry and regularities perceived in the sky and on the earth below.

An even more important conclusion will enjoy a wide consensus. The construction of the Newark Earthworks stands as a striking example of what human beings can achieve when motivated by ideas with the power to inspire their imagination, discipline, and effort. In that sense the message of the earthworks speaks to us clearly from prehistoric Ohio. Not unlike CERN's Large Hadron Collider, it shows what we can achieve when we seek with determination to comprehend our place between heaven and earth. Pliny would have been impressed. Even Juliet would have been relieved to discover the constant inconstancy of Romeo's blessed moon.

Notes

1. See Lepper's contribution to the present volume.

2. See Hively and Horn, "A New and Extended Case for Lunar (and Solar) Astronomy at the Newark Earthworks"; and Greber et al., "Astronomy and Archaeology at High Bank Works."

3. C. Thomas, *Report on the Mound Explorations of the Bureau of Ethnology,* 440.

4. Fowke, *Archaeological History of Ohio,* 171.

5. See Bernardini, "Hopewell Geometric Earthworks," for detailed labor estimates for the construction of some Hopewell earthworks.

6. This striking view of the symmetry and precision of the Circle-Octagon Earthworks, one never seen by any Hopewell architect or builder, is illustrated in an aerial photo taken by Dache Reeves in 1934. Dache M. Reeves, collection of aerial photographs (Washington, DC: National Anthropological Archives, 1934).

7. The late John Eddy (1931–2009) did a transit survey of the site in 1978 confirming his earlier conjecture, based on the Squier and Davis map, that the Circle-Octagon symmetry axis aligned with the north maximum moonrise extreme (personal communication, 1980).

8. Sims, "Which Way Forward for Archaeoastronomy?," points to the importance of each of these elements in assessing the likelihood that alignments are intended and not fortuitous.

9. See, for example, Ruggles, *Astronomy in Prehistoric Britain and Ireland;* Aveni, *Foundations of New World Cultural Astronomy;* Powell, "The Shapes of Sacred Space: A Proposed System of Geometry Used to Lay Out and Design Maya Art and Architecture and Some Implication Concerning Maya Cosmology"; Sofaer, "The Primary Architecture of the Chacoan Culture" 88–132; Malville, *Chimney Rock*; and Sutcliffe, *Moon Tracks.*

10. See Hively and Horn, "Hopewell Cosmography at Newark and Chillicothe, Ohio."

11. Pliny the Elder, *The Natural History,* II.6.

12. C. Thomas, *Report on the Mound Explorations of the Bureau of Ethnology.*

13. See Hively and Horn, "Geometry and Astronomy in Prehistoric Ohio."

14. See Hively and Horn, "A Statistical Analysis of Lunar Alignments at the Newark Earthworks."

15. See Byers, *The Ohio Hopewell Episode;* and Byers, *Sacred Games, Death, and Renewal in the Ancient Eastern Woodlands.*

16. For detailed discussion, see Hively and Horn, "A New and Extended Case for Lunar (and Solar) Astronomy at the Newark Earthworks."

17. See Hively and Horn, "Geometry and Astronomy in Prehistoric Ohio"; and Hively and Horn, "A Statistical Analysis of Lunar Alignments at the Newark Earthworks."

18. Byers, *Sacred Games, Death, and Renewal in the Ancient Eastern Woodlands,* 435–68, proposes a scenario for the placement of the Circle-Octagon in Cherry Valley that follows our earlier suggestion that the enclosures could be moved in order to avoid the anomaly at wall EF. Among salient questions that should be considered is whether the Great Circle is an Adena-period construction later incorporated in the Hopewell plan for Newark. We will address this issue more closely in forthcoming work. Also see Lepper's contribution to the present volume.

19. See Hively and Horn, "Hopewell Cosmography at Newark and Chillicothe, Ohio."

20. See Hively and Horn, "A Statistical Analysis of Lunar Alignments at the Newark Earthworks"; and Romain and Burks, "LiDAR Imaging of the Great Hopewell Road."

21. See Lepper, "Tracking Ohio's Great Hopewell Road"; and Lepper, "The Great Hopewell Road and the Role of Pilgrimage in the Hopewell Interaction Sphere."

22. See Hively and Horn, "A Statistical Analysis of Lunar Alignments at the Newark Earthworks"; Hively and Horn, "Hopewell Cosmography at Newark and Chillicothe, Ohio"; and Hively and Horn, "A New and Extended Case for Lunar (and Solar) Astronomy at the Newark Earthworks."

23. See Park, *Notes of the Early History of Union Township, Licking County, Ohio.*

24. Squier and Davis, *Ancient Monuments of the Mississippi Valley,* 24, plate 9, no. 1.

25. Lepper, personal communication and his contribution to this volume.

26. See Hooge, "Preserving the Ancient Past in Licking County, Ohio," 179–88.

27. See Brian Hayden and Suzanne Villenueve, "Astronomy in the Upper Paleolithic?," *Cambridge Archaeological Journal* 21, no. 3 (2011): 331–55.

28. See Lepper, "The Newark Earthworks: Monumental Geometry and Astronomy at a Hopewellian Pilgrimage Center," 76.

29. See Hively and Horn, "Hopewellian Geometry and Astronomy at High Bank"; Hively and Horn, "Hopewell Cosmography at Newark and Chillicothe, Ohio"; and Greber et al., "Astronomy and Archaeology at High Bank Works."

30. In addition to numerous articles by Hively and Horn, see, for instance, Greber and Jargiello, "Possible Astronomical Orientations Used in Constructing Some Scioto Hopewell Earthwork Walls"; Greber, "Astronomy and the Patterns of Five Geometric Earthworks in Ross County, Ohio"; Essenpreis and Moseley, "Fort Ancient"; Essenpreis and Duszynski, "Possible Astronomical Alignment at the Fort Ancient Monument"; C. Turner, "A Report on Archaeoastronomical Research at the Hopeton Earthworks, Ross County, Ohio"; Romain, "Hopewell Geometric Enclosures"; Romain, "Summary Report on the Orientations and Alignments of the Ohio Hopewell Geometric Enclosures"; and Mickelson and Lepper, "Archaeoastronomy at the Newark Earthworks."

31. See Romain and Burks, "LiDAR Assessment of the Newark Earthworks"; Romain and Burks, "LiDAR Imaging of the Great Hopewell Road"; and Romain and Burks, "LiDAR Analyses of Prehistoric Earthworks in Ross County, Ohio."

32. See, for instance, Sims, "Which Way Forward for Archaeoastronomy?"