Archaeoastronomical Evidence for *Wuism* at the Hongshan Site of Niuheliang

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Introduction

The Neolithic Hongshan Culture flourished between 4500 and 3000 BCE in what is today northeastern China and Inner Mongolia (Figure 1). Village sites are found in the northern part of the region, while the two ceremonial sites of Dongshanzui and Niuheliang are located in the south, where villages are fewer (Guo 1995, Li 2003). The Hongshan inhabitants included agriculturalists who cultivated millet and pigs for subsistence, and accomplished artisans who carved finely crafted jades and made thin black-on-red pottery. Organized labor of a large number of workers is suggested by several impressive constructions, including an artificial hill containing three rings of marble-like stone, several high cairns with elaborate interiors and a 22 meter long building which contained fragments of life-sized statues. One fragment was a face with inset green jade eyes (Figure 2). A ranked society is implied by the burials, which include decorative jades made in specific, possibly iconographic, shapes. It has been argued previously that the sizes and locations of the mounded tombs imply at least three elite ranks (Nelson 1996).

The Nature of Leadership

Hongshan scholars agree that the elite burials are those of leaders, but the nature of that leadership still needs to be elucidated. We propose that the Chinese word *wu* is appropriate to apply to the Hongshan leaders, and, following Tong (2002), we use the term *wuism* to describe their activities, arguing that this designation is appropriate for the Hongshan culture (Pak, et al. 2004).

Shamanism, ritual and magic are just beginning to be identified in archaeological sites (Insoll 2004). Ralph Merrifield defines ritual and magic as “practices intended to gain advantage or avert disaster by the manipulation of supernatural power” (1987:xii). Neil Price is particularly helpful in describing the kinds of material culture found in shamanistic contexts (2001:3). Notably, figurines found on the chests of shamans in Siberia (Devlet 2001:52) are similar to some finds in Hongshan burials.

Julia Ching (1997), in advancing her thesis that high leadership is related to mysticism, begins her exploration in the Chinese Neolithic. K. C. Chang (e.g. 1983, 1994) has been a strong advocate of the interpretation of shamanistic leadership in China. Likely shamanistic connections with specific artifacts have also been proposed (Childs-Johnson 1988). In addition, several archaeologists at a recent Chinese conference argued specifically that the Hongshan leaders were *wu* (Pak, et al. 2004; Yang 2004).

While there are no written documents from this period in Chinese history, the presence and influence of *wu* in the Hongshan culture may be inferred from the activities of wu as documented in later China. China’s earliest extant writing comes from the Shang dynasty, created by carving characters into bone with a sharp instrument. The character for *wu* (meaning a person who can reach the Powers) first appears in these

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Shang oracle bones, but it is not until the early Zhou dynasty (ca. 1050-221 BCE) that the activities of the *wu* were recorded. As described in the *Zhou Li*, the *wu* were responsible for divination, medicine and healing, music, dancing and star-gazing (Falkenhausen 1995). By engaging in rhythmic drumming and dancing, *wu* could trance and transcend the earthly realm in order to communicate with the celestial spirit world (Tong 2002:35).

Archaeoastronomy

Archaeoastronomy provides a useful interdisciplinary framework for examining the connection between *wuism* and astronomy in Neolithic China. By combining knowledge of the Hongshan culture with new research on the night sky of the region more than 5000 years ago, archaeoastronomy reflects the terrestrial-celestial ideology we wish to examine. Thus, by presenting both archaeological and astronomical lines of evidence, we propose that the *wu* were actively creating a connection between heaven and earth at the Hongshan site of Niuheliang (Figure 3).

We focus here on astronomical observations in particular because "the main purpose of Chinese astronomy was to study the correlation between [humanity] and [the] universe" (Sun 2000:425). Chinese astronomy is known to date back to the Neolithic. It has continuously involved relationships between human beings, especially leaders, and phenomena in the skies (Pankenier 2000). By creating calendars and observing the apparent movements of the heavenly bodies, leaders such as *wu* correlated occurrences in the sky with events on earth.

Archaeological Evidence

Shamanistic activity is implied by much of the archaeological evidence at Niuheliang. Similarly, archaeological continuities between the Hongshan and later cultures point to the presence of *wu* in Neolithic northeast China. Oracle bones without writing were used by cultures contemporaneous with the Hongshan suggesting that they may have practiced a similar form of divination long before the Shang (Keightley 1978). In the first century BCE, the *Zhou Bi Suan Jing* outlined the *gai tian* cosmography in which the earth was square, covered by a round heaven (Cullen 1996). The presence of both round and square structures at Hongshan ceremonial centers suggests that this cosmological model was present in Chinese society long before it was written down (Guo 1997).

Jade

While jade is found even in the earliest Neolithic sites in northeast China, it is only with the appearance of the Hongshan culture that jade is clearly used in ritual activities (Teng 1997). The relationship between jade and both royalty and religion is well established in China (Laufer 1974). For example, a burial at Locality 5 contained a large cloud-shaped pendant, several squared rings and two Jade turtles (Figure 4). The number and quality of the jade ornaments probably reflected the elite status of the individual, but in addition they suggest *wuist* activities. *Wu* often acted as healers and physicians (Tong 2002:48-49) and the *qi* (spirit or power) that jade was believed to possess made it a potent medicinal substance. The *wu* also used their skills as dancers and musicians to perform rain ceremonies during periods of drought (Ching 1997). The cloud-shaped jade that was found with the individual at Locality 5 may imply rainmaking rituals, and indeed many of the shapes of Hongshan jades could be interpreted as being associated with water (Nelson 1991). The turtle and ring-shaped jades excavated at the site may reflect Chinese cosmology (Allan 1991), another area of specialization for the *wu*: the two "square" rings with circular holes reflect the *gai tian* cosmography while the turtles may represent the cosmic tortoise which was believed to hold up the sky (Allan 1991).

A recently discovered jade in an elite burial at Locality 16 of Niuheliang also suggests connections with the later *wu* (Guo 1997, 2004). A large jade bird was found under the skull of a burial (Figure 5), suggesting a connection between the deceased and sacred birds as messengers of Powers (Keightley 2000). Birds were prominent in Shang dynasty (ca. 1500-1050 BCE) mythology (Allan 1991), and those beliefs are likely to have been of considerable age by the time of the Shang.

Statues

Several fragments of large, unbaked clay statues were excavated at Locality 1 (commonly referred to as the Goddess Temple) including a face with jade eyes (Figure 2), as well as a shoulder and breast that imply the statue is female. Small female figurines were excavated from Dongshanzui, as well as a seated statue wearing a knotted rope around the waist. Some fragments imply that statues at Niuheliang were larger than life-sized (Guo 2003). Certainly the ceremonial nature of the Goddess Temple and the size of the figures suggest that these statues served a ritual function, a function that was most likely realized by religious specialists such as *wu*.

As the name of the site suggests, the statues unearthed at the Goddess Temple were interpreted by the excavators as representations of female deities (Sun and Guo 1984). However, an alternate interpretation may be explored. While the term *wu* often refers to all early Chinese shamans regardless of gender, it was originally used to describe female shamans exclusively (Ching 1997:15, Tong 2002:34). Also, because of the belief of the great medicinal potency of jade, some scholars have proposed that "jade-working was monopolized by shamans" (Teng 1997:10). Thus, it is possible that the clay face with jade eyes from the Goddess Temple is a portrait of a *wu* rather than a "goddess."

Painted Pottery

Most of the Niuheliang tombs are surrounded by broken pottery cylinders (Figure 6), which once stood next to each other in rows near the outer edges of the tombs. Guo Dashun (1995) estimated that if all the mounded burials known at Niuheliang were surrounded by rows of these jars, 10,000 of them must have been made. Because these cylinders were open at both ends they were clearly not used as containers. Hongshan painted pottery has been found in ritual contexts, suggesting that painted pottery was produced primarily for ceremonial purposes. Therefore we may infer that there was a productive ceramics industry dedicated to the creation of ceremonial pottery, as well as sculpting the fragile statues of unbaked clay.

Architecture

Some of the most intriguing archaeological evidence for *wuism* at Niuheliang comes from the site's architectural structures, including the Goddess Temple (Locality 1).

The distinctive outline of the Temple (Figure 7) may be interpreted as the Chinee character *ya*, a cruciform shape which has significance in Chinese cosmography. The *ya* was a representation of the five cardinal directions: north, south, east, west and center. Similarly, according to Chinese mythology, the sky was supported above the earth by a cosmic turtle whose lower shell, or plastron, was *ya*-shaped (Allan 1991). If the Goddess Temple was indeed an early representation of a *ya*-shaped cosmos, then its architecture may have been an attempt to create a representation of heaven on earth, or to symbolize the connection between earth and heaven. Because one of the primary duties of *wu* was to connect the terrestrial and the celestial, this cosmic architecture may be evidence for the powerful influence of the *wu* at Niuheliang.

The placement of tombs at Niuheliang also suggests the influence of *wu*. All but one of the tomb groups at the site are positioned on top of prominent hills with line-of-sight views of the Goddess Temple. These vantage points offer views of the night sky which would make them prime spots for observations. Perhaps by placing the tombs on hills, the deceased also enjoyed this vantage point closer to the heavens and, thus, in proximity to the realm of the ancestors. Hence, the influence of *wu* as facilitators of a terrestrial-celestial association may have shaped architecture and tomb construction at Niuheliang.

Potential architectural evidence for *wuism* at Niuheliang includes the round and square structures found throughout the site. Because ancient Chinese lore described a round heaven which enveloped a square earth, these structures may have been representations of the celestial and terrestrial realms. While circular rings of white stones are found within mounds in several localities, the most compelling evidence for the architectural representation of the *gai tian* cosmography is found at Locality 2. Here, tombs that are both square and circular in ground plan lie side by side with other structures without burials that have been interpreted as altars.

As a representation of both the celestial and the terrestrial, Locality 13 is an artificial hill which must have served a ritual function. The data presented below suggest that the hill was constructed precisely in this spot for viewing the full moon at its farthest points north and south.

Astronomical Evidence

Data Analysis

As has been argued for other Neolithic sites, data from Niuheliang reveals possible astronomical alignments between localities which may be indicative of a connection between the celestial and the terrestrial landscape during the Hongshan period. To further examine these potential alignments, distances and angles between localities were determined from latitude, longitude and elevation values. In 2000, Chris Rock used a handheld global positioning system (GPS) device to obtain these values for all but two of the sixteen localities at Niuheliang including the Goddess Temple (Locality 1a) and the Platform (Locality 1b). Table 1 displays these values with the following exceptions:

In order to compensate for several outlying data points, the elevation for the Goddess Temple (1a) was obtained by examining the nine data points collected with the GPS device and averaging those with errors of less than 16 meters. Further exceptions include the elevation values for Localities 8 and 9, as no GPS data was acquired at these locations. To approximate the elevations, the old contour map and newer satellite image of Niuheliang (Figure 8) were examined and compared to the elevation values of the other localities. Locality 8 was determined to have an approximate elevation of 660 meters with an error of approximately ±30 meters, as it appears to be lower than the Platform (1b) but similar in elevation to the Goddess Temple (1a). It is also similar to but lower in elevation than Localities 6 and 7. The elevation for Locality 9 was approximated as being higher than Localities 11, 12 and 13 since it is in the northeastern most part of the valley and because elevation decreases to the west. Also, Locality 9 appears to be similar to Locality 2 in relation to the valley as well as elevation. Thus its elevation is approximated as 647 ±20 meters. To obtain elevation as well as latitude and longitude values for Locality 15 (which were absent from the data collected by Rock), measurements made by Hungjen Niu and Yangjin Pak at the same time as Rock but using a newer GPS unit were examined. Niu and Pak acquired two values for Locality 15 that when averaged together resulted in coordinates of N41° 18.87, E119 ° 30.34 and an elevation of 619±16 meters. Data for Locality 14 was absent from Rock's GPS readings as well as those of Niu and Pak and was therefore estimated from the satellite map and the data from nearby Locality 15. The latitude (N41°18.97), longitude (E119°29.97) and elevation (616±25 meters) for Locality 14 were approximated in this way.

The next steps in determining possible astronomical alignments are to determine the differences in elevation between the localities and distances between localities. By calculating the distances between the localities, a triangle can be formed between two specific localities such that the base of the triangle is the distance between the localities and the height of the triangle is the relative elevation between the localities. The first step in calculating the distances between localities was to convert the latitude and longitude values into their decimal form by dividing the minutes of latitude or longitude by 60 and adding them to the degree value. The values were then converted to degrees by dividing the decimal latitude or longitude by the ratio of 180 degrees for every pi radians. However, in order to account for the curvature of the Earth, we must apply the Haversine Approximation to these values:

```
dlon = lon2 - lon1
dlat = lat2 - lat1
a = (sin(dlat/2))^2 + cos(lat1) * cos(lat2) * sin(dlon/2))^2
d = R*  2 * atan2(sqrt(1-a), sqrt(a))
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First, the decimal radian values for latitude and longitude were used to determine the difference in latitude (dlat) and longitude (dlon) between localities. Second, these dlat and dlon values were used to solve for the variable "a" using the formula above. Finally, these resulting "a" values were used to solve for the variable "d" using the second formula in the Haversine approximation in which R is the radius of the Earth (6,367,000 meters). The corrected distance (d) and elevation can then be used as the base and height, respectively, of the aforementioned triangle in order to determine the azimuth angles between the localities by applying the formula: azimuth = atan2 (dlat, dlon). The resulting azimuth angles were converted into degrees and subtracted from ninety so that zero degrees corresponds to north rather than the x-axis in a Cartesian plane.

To determine the declination angles used to verify astronomical alignments, both the azimuth and altitude angles are needed. Just as the azimuth angles were calculated above, the next set of computations involved finding altitude angles. The altitude angles between localities (Table 2) were determined by calculating the arctangent of the difference in elevation and the distance between the localities. The angles were then multiplied by the conversion factor of 57.3 degrees per radian, giving the angles in degrees.

The final calculations performed were to determine the sight lines corresponding to declination angles in the sky. The declination angles were determined using the formula: sin(DEC)= sin(LAT)sin(ALT)+cos(LAT)cos(ALT)cos(AZ), in which LAT corresponds to the decimal latitude of each locality, ALT corresponds to the altitude angles and AZ corresponds to the azimuth angles. Because this formula gives the sine of the declination angles, the arcsine of the values was then calculated to obtain the declination angles. The results were then multiplied by 57.3 so that the final angles were given in degrees. Table 3 displays the resulting declination sight line angles.

Interpretation

To determine possible astronomical alignments between localities, the declination angles were inspected for angles that correspond to significant points in the orbits of the sun and moon because of their prominence in the sky as well as their usefulness in time keeping. Significant solar angles occur when the sun is at its farthest point north (+23.5°) or south (-23.5°), corresponding to the summer and winter solstices, and when the sun is at the midpoint of its motion (0°), occurring at the spring and autumn equinoxes. Because the moon's motion varies from the sun's, significant lunar angles are those five degrees to either side of the aforementioned solar angles: 28.5°, 18.5°, 5°, -5°, -18.5° and -28.5°. To account for the error within the calculations and variations in viewing locations due to the size of the localities, declination angles within ±1.5 degrees of the actual solar or lunar angles were considered for alignments. Table 4 highlights the significant angles considered for further analysis.

Of the interesting angles, one set occurs between Locality 13 and Localities 8, 9 and 10. The angles between Locality 13 and Localities 8 and 9 are within our range of lunar alignment angles, with Locality 8 having an angle of -19.63° and Locality 9 having an angle of -28.53°. Besides yielding possible lunar alignments, these angles are also potentially significant because of the prominence of Locality 13 which is an artificial hill characterized as an earthen "pyramid." Localities 8 and 9 are also considered likely for alignment because although we do not have measured values for their elevations, we know from visiting the site that they are situated on hills that are visible form Locality 13. Locality 13 also forms a potentially significant solar angle of -24.73° with Locality 10. This alignment seems plausible because Locality 10 is centrally located, is characterized by a high concentration of ceramic debris and could have been seen from Locality 13. Additionally, Locality 10 bisects Localities 8 and 9 suggesting a possible triple alignment.

Locality 13 also forms a lunar angle of -19.06° with Locality 2. In addition to the aforementioned prominence of Locality 13, this alignment is also considered of interest because Locality 2 contains a central square tomb whose inhabitants may have been connected to *wuism*. Thus, the archaeological discoveries at Locality 2 as well as its position directly south of the Goddess Temple suggest that it may have astronomical significance.

Another set of potentially significant lunar angles are those between the Platform (1b) and Localities 7 (18.92°) and 8 (-5.81°) which are both situated atop a high hill. The Platform also produces a lunar angle of -28.20° with Locality 10 which, as previously stated, is not very prominent but is near the center of the valley and has a large amount of ceramic debris.

Further declination angles of interest include those between Locality 16 and Localities 7 and 9. Locality 7 forms a solar angle of -23.48° with Locality 16, and Locality 9 a possible lunar angle of -20.64°. Locality 16 is considered potentially significant because of the structural remains and jade artifacts excavated there and because it affords a view of the entire site from the westernmost point in the region. Localities 7 and 9 afford similar panoramic views from the northernmost and easternmost parts of the Niuheliang complex, respectively.

Finally, Locality 6 creates a lunar angle of -6.21° with Locality 8. This alignment may be significant because of the two Localities' close proximity to the Goddess Temple (1a) and the Platform area (1b), as well as nearby Localities 7 and 9. The position of Locality 6 atop a hill also points towards possible astronomical significance.

Conclusion

The archaeological evidence at Niuheliang makes a strong argument for *wuism* in Hongshan China. First, many of the jade shapes in burials suggest that thay might have been symbols of the *wu*. Second, the discovery of anthropomorphic statuary and large numbers of bottomless jars imply that ritual activity connected with *wuism* was taking place at Niuheliang, and was particularly connected with the elite. Finally, the existence of a *ya*-shaped temple, hilltop tombs and round and square structures suggest that *wu* were actively involved in connecting heaven and earth at the site. Therefore, the nature of the archaeological evidence argues that the societal leaders were *wu* and used their influence with the Powers to create a celestial-terrestrial connection at Niuheliang.

From the calculations and analysis of the localities at Niuheliang, declination angles corresponding to both significant solar and lunar angles as well as possessing some distinguishing factor about their location or contents were analyzed to highlight promising alignments between the heavens and the terrestrial landscape. Of the 136 possible angles studied among localities at Niuheliang, a striking number of lunar rather than solar alignment angles emerged, and many of them took the artificial hill as their backsight. Assuming the lunar orbit evolution is small since Hongshan times, an integrative interpretation of the Niuheliang site plan relates it to the study of lunar motion - stillstand to stillstand - and the cultural development of ability to predict eclipses based thereupon. This is one implication of this preliminary astronomical alignment survey at Niuheliang.

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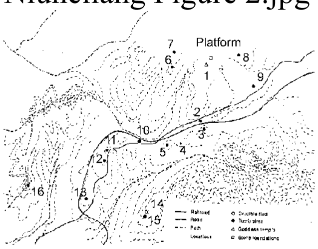
Figure Captions

Niuheliang Figure 1.jpg

Figure 1. Map of Northeast China showing the distribution of Hongshan sites throughout the region. Niuheliang is circled.

Niuheliang Figure 2.jpg

Figure 2. Clay “mask” with inset jade eyes from the Goddess Temple. The rounded facial features suggest it is a representation of a female.



Niuheliang Figure 3.jpg

Figure 3. Map of Niuheliang and its numbered localities.

Niuheliang Figure 4.jpg

Figure 4. Ring, cloud and turtle-shaped jades from the tomb at Locality 5.

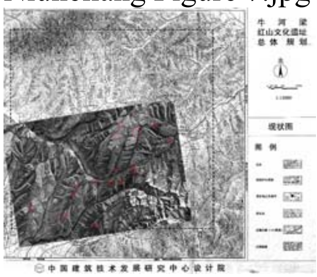
Niuheliang Figure 5.jpg

Figure 5. Jade bird found under the skull of an individual buried at Locality 16

Niuheliang Figure 6.jpg

Figure 6. One of the many black-on-red pottery cylinders excavated at Locality 2 and other tombs throughout Niuheliang.


Niuheliang Figure 7.jpg



Niuheliang Figure 8.jpg

Figure 7. The Goddess Temple (Locality 1) as it appeared after preliminary excavation.

Figure 8. Satellite image of Niuheliang superimposed over a contour map of the site.

Tables

Table 1. Latitude, longitude and elevation values for Niuheliang from the 2000 GPS survey.

Locality	Latitude	Longitude	Elevation	EPE (±)
1a	N 41°19.798	E119°30.834	661	14

1b	N 41°19.857	E119°30.834	676	12
2	N 41°19.310	E119°30.781	644	11
3	N 41°19.215	E119°30.821	648	12
4	N 41°19.039	E119°30.478	628	13
5	N 41°19.005	E119°30.257	639	12
6	N 41°19.940	E119°30.359	687	15
7	N 41°20.088	E119°30.385	698	13
8	N 41°19.747	E119°31.567	660	30
9	N 41°20.197	E119°31.084	647	20
10	N 41°19.038	E119°29.898	610	14
11	N 41°18.939	E119°29.267	604	17
12	N 41°18.762	E119°29.187	615	14
13	N 41°18.384	E119°28.961	579	15
14	N 41°18.97	E119°29.97	616	25
15	N 41°18.87	E119°30.34	619	16
16	N 41°18.541	E119°28.078	569	13

Table 2. Altitude angles [degrees above horizontal] between localities. Entries in the upper half of this and the following tables are blank because they are redundant with the lower set of values.

Locality	1a	1b	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1a	0																
1b	-7.816	0															
2	1.074	1.804	0														
3	0.6897	1.349	-1.242	0													
4	1.2684	1.725	1.398	1.9824	0												
5	0.7531	1.197	0.311	0.5889	-2.008	0											
6	-2.094	-0.929	-1.886	-1.501	-2.015	-1.582	0										
7	-2.572	-1.665	-2.005	-1.659	-2.059	-1.678	-2.28	0									
8	0.056	0.882	-0.674	-0.481	-0.915	-0.527	0.901	1.236	0								
9	0.9821	2.309	-0.101	0.0309	-0.472	-0.184	2.055	2.941	0.696	0							
10	1.5237	1.891	1.467	1.6428	1.2782	3.299	2.464	2.447	1.074	0.783	0						
11	1.2101	1.492	1.035	1.1349	0.8114	1.45	1.983	2.043	0.908	0.717	0.3834	0					
12	0.8819	1.142	0.681	0.7804	0.3988	0.884	1.514	1.602	0.682	0.49	-0.257	-1.79	0				
13	1.2716	1.473	1.218	1.313	1.1533	1.607	1.779	1.829	1.05	0.871	0.9981	1.257	2.6142	0			
14	1.3231	1.688	1.242	1.446	0.9574	3.255	2.167	2.185	0.952	0.646	-2.136	-0.609	-0.044	-1.09	0		
15	1.2998	1.672	1.404	1.7954	1.4041	4.154	1.965	2.005	0.997	0.602	-0.748	-0.498	-0.123	-0.96	-0.28	0	
16	1.1751	1.349	1.069	1.1274	0.9759	1.273	1.65	1.718	0.976	0.862	0.872	0.98	1.4428	0.396	0.858	0.778	0

Table 3. Computed terrestrial azimuths [in degrees] observable along sight lines between localities.

Locality	**1a**	**1b**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1a	0																
1b	40.87	0															
2	-3.94	-2.959	0														
3	-0.504	0.019	16.09	0													
4	-17.71	-16.24	-32.93	-40.17	0												
5	-25.67	-24.03	-40.21	-44.19	-49.91	0											
6	-48.01	-48.63	-26.07	-24.88	-6.979	3.623	0										
7	-41.29	-43.38	-21.32	-20.77	-5.164	3.944	5.947	0									
8	48.585	48.84	40.44	37.299	38.25	40.35	48.76	47.37	0								
9	24.208	28.11	13.98	11.225	20.048	25.22	46.98	50.81	-32.8	0							
10	-34.43	-32.9	-44.48	-45.93	-47.41	-45.13	-18.2	-16.7	-42.8	-31.88	0						
11	-40.13	-39.1	-45.85	-46.58	-47.66	-47.1	-32	-30	-44.3	-37.53	-47.53	0					
12	-38.72	-37.75	-44.62	-45.62	-46.87	-46.23	-30.8	-29	-43.3	-36.4	-44.68	-19.26	0				
13	-35.78	-34.98	-40.94	-42.1	-42.54	-41.19	-28.8	-27.4	-40.8	-34.13	-37.18	-20.37	-20.79	0			
14	-31.8	-30.29	-42.71	-44.82	-47.15	-44.98	-14.7	-13.7	-41.6	-29.83	31.405	48.01	46.504	39.56	0		
15	-19.75	-18.47	-31.02	-36.11	-27.31	26.11	0.533	-0.26	-36.8	-21.12	43.901	48.06	48.28	44.21	46.21	0	
16	-42.04	-41.46	-45.23	-45.75	-46.39	-46.04	-38.4	-37.1	-44.3	-40.38	-45.6	-44.5	-46.03	-47.3	-46.3	-47.2	0

Table 4. Computed celestial declinations [in degrees] observable along sight lines between localities. Potentially significant lunar and solar sight lines have been indicated in boldface and italics, respectively, at declinations of 0, ±5, ±18.5, ±23.5 and ±28.5, within ±1.5 degrees.

Locality	**1a**	**1b**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1a	0																
1b	40.87	0															
2	-47.24	-46.59	0														
3	-47.98	-47.32	-44.94	0													
4	-41.70	-41.95	**-28.98**	**-18.65**	0												
5	-36.77	-37.44	-21.98	-14.79	-7.89	0											
6	11.00	6.81	37.01	38.02	46.13	46.73	0										
7	**22.18**	**18.92**	40.23	40.74	46.38	46.57	45.48	0									
8	-2.95	**-5.81**	20.93	25.50	**23.50**	21.35	**-6.21**	-11.18	0								
9	40.37	39.14	45.20	46.54	41.30	37.95	15.93	8.59	31.33	0							
10	-27.11	**-28.20**	-11.78	-7.04	**0.77**	**6.12**	-39.78	-40.74	-16.34	-31.06	0						
11	-20.31	-21.24	-9.60	-6.79	-3.01	-1.91	**-28.97**	-30.96	-13.80	**-24.79**	**-6.43**	0					
12	**-22.94**	**-23.74**	-13.67	-11.05	-8.80	-8.98	-30.99	-32.59	-16.22	-26.58	-15.95	-44.81	0				
13	-25.96	-26.56	**-19.06**	-16.93	-16.52	**-17.81**	-32.54	-33.71	**-19.63**	**-28.53**	**-24.73**	-40.02	-37.87	0			
14	-30.29	-31.22	-16.02	-11.02	**-5.17**	-3.06	-42.20	-42.73	**-18.52**	-33.27	-32.68	*1.49*	11.09	21.38	0		
15	-40.38	-40.70	-30.94	*-24.64*	-34.43	-36.18	-46.71	-46.64	-25.16	-40.41	-15.99	-3.09	3.94	13.80	-11.49	0	
16	-17.34	**-17.94**	-11.14	-9.57	-8.13	-8.15	-21.93	**-23.48**	-13.54	-20.64	-10.82	-13.13	-7.48	7.82	-8.99	**-5.69**	0