Lunar Markings on Fajada Butte, Chaco Canyon, New Mexico

By A. Sofaer, Washington, D.C. R. M. Sinclair, National Science Foundation, Washington, D.C. L. E. Doggett, U. S. Naval Observatory, Washington, D.C.

Appeared in *Archaeoastronomy in the New World*, ed. A.F. Aveni, pp. 169-86. Cambridge University Press.

Fajada Butte is known to contain a solar marking site, probably constructed by ancient Pueblo Indians, that records the equinoxes and solstices (Sofaer et al. 1979 a). Evidence is now presented that the site was also used to record the 18.6-year cycle of the lunar standstills. Fajada Butte (Figure 1) rises to a height of 135 m in Chaco Canyon, an arid valley of 13 km in northwest New Mexico, that was the center of a complex society of precolumbian culture. Near the top of the southern exposure of the butte, three stone slabs, each 2-3 m in height and about 1,000 kg in weight, lean against a cliff (Figures 2, 3). Behind the slabs two spiral petroglyphs are carved on the vertical cliff face. One spiral of 9 1/2 turns is elliptical in shape, measuring 34 by 41 cm (Figure 4). To the upper left of that spiral is a smaller spiral of 2 1/2 turns, measuring 9 by 13 cm (Figure 4).

Fig. 1 Fajada Butte from the north. The solar/lunar marking site is on the southeast summit.

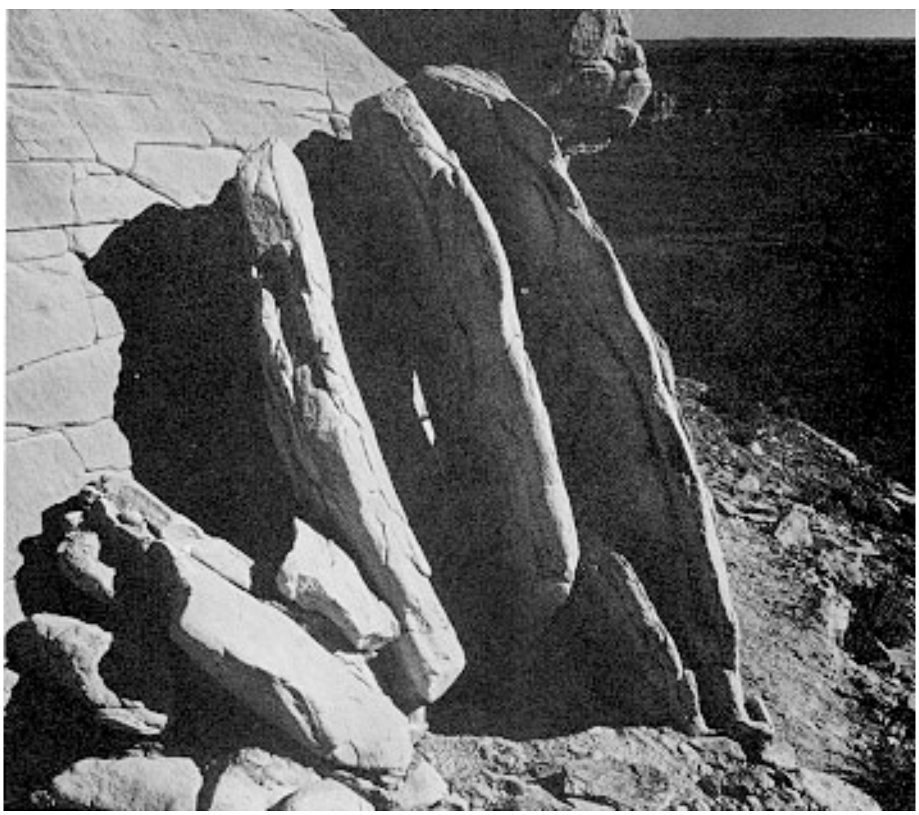

Fig. 2 The slabs from the south

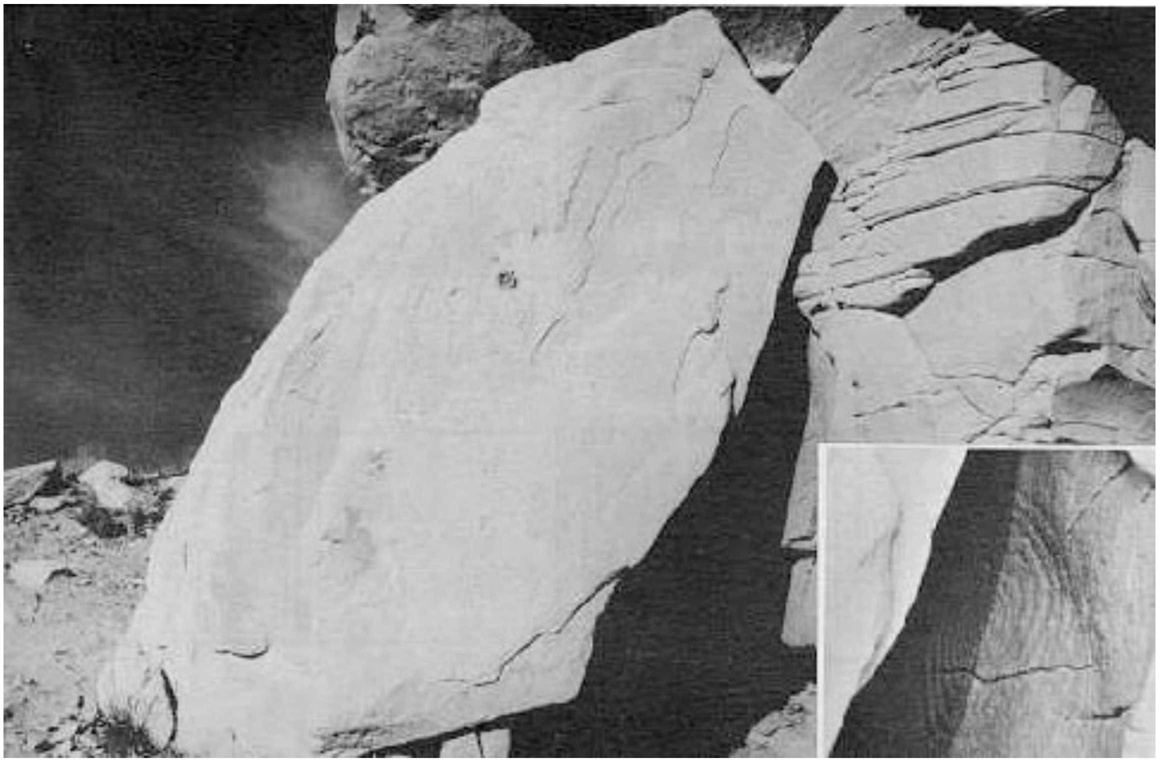

Fig. 3 Eastern slab casting a sunrise shadow on the spiral. The inset shows the shadow of sunrise at declination plus 18.4 degrees (i.e., northern minor standstill).

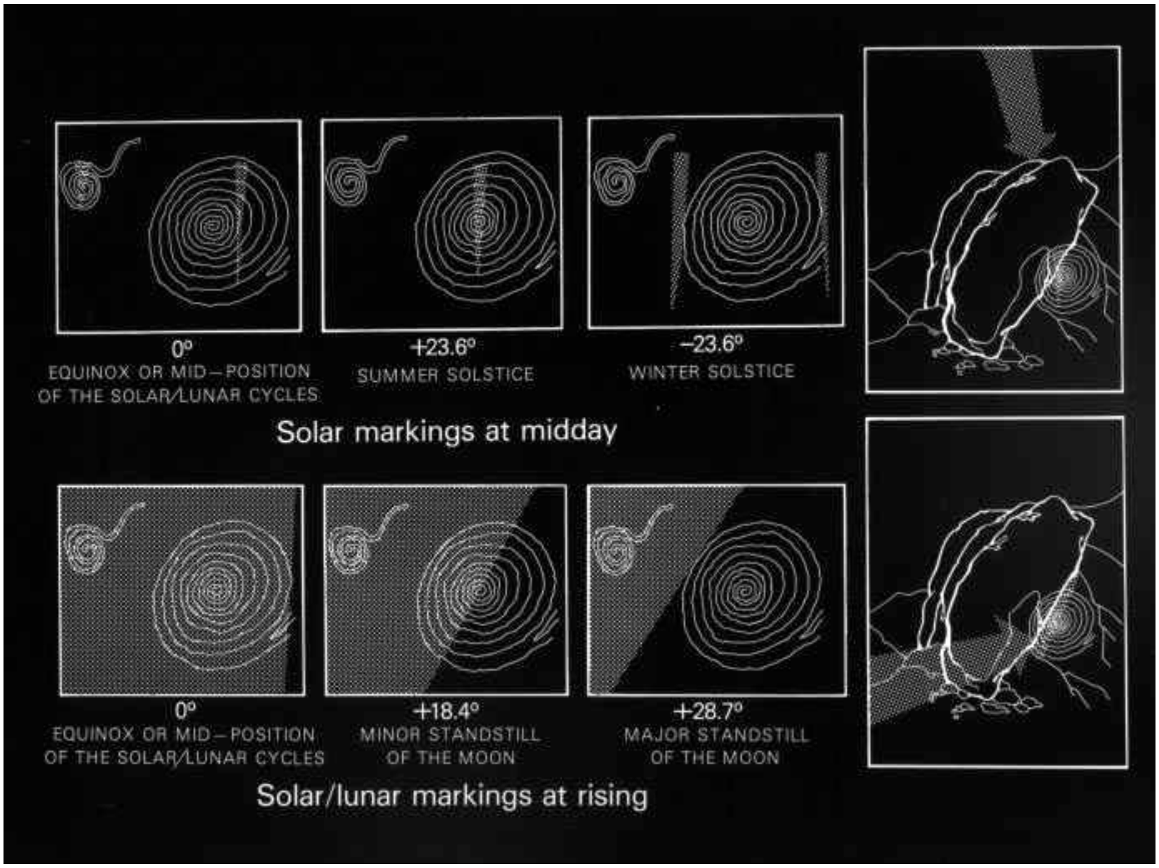

Fig. 4 Solar markings at midday and solar/lunar markings at rising.

SOLAR MARKINGS Throughout the year midday the two openings between the slabs form vertical shafts of sunlight on the cliff face. The daily paths of these dagger-shaped patterns on the cliff change with the sun's declination. As the patterns intersect the spirals, the equinoxes and solstices are uniquely marked.

At summer solstice one dagger of light descends through the center of the large spiral (Figure 4). On succeeding days the dagger descends discernibly to the right of center. As summer progresses and the sun's declination decreases, the position of the dagger shifts progressively rightward across the large spiral and a second dagger of light appears to the left.

At the autumnal equinox this second dagger bisects the smaller spiral (Figure 4). From fall towards winter the daggers continue their rightward movement, until at winter solstice the two daggers bracket the large spiral, holding it empty of light (Figure 4). Following the winter solstice the cycle reverses itself until the next summer solstice.

In addition to the midday solar markings, we previously noted (Sofaer et al. 1979 b) that at sunrise the inner edge of the eastern slab casts a shadow on the larger spiral (Figure 3). The edge of this shadow crosses the spiral when the sun's declination is positive, and its position shifts leftward an average of 2.5 cm per week between the equinox and solstice (Figure 5). At the equinoxes the shadow edge falls in the far right groove of the spiral. Noting this second possible marking of equinox, we assumed that the sunrise shadows might form a second set of intentional solar markings. However, the locations of the shadows of the summer and winter solstices arc of no particular note: at summer solstice the shadow edge falls between the center and the left edge of the spiral (Figure 5); at winter solstice the edge is not on the spiral at all. We noted the location of the shadow edge on the spiral as a sensitive indicator of changing solar declination for half the year, but with no certainty of its use or purpose.

Further observations through the year showed that when the sun is at declination +18.4º (mid-May and late July), the shadow at sunrise bisects the large spiral, putting the left half in shadow and the right half in light (Figures 4-6). At these times the sun is approximately at the declination of the moon at northern minor standstill. The edge of this shadow is aligned with a pecked groove (Sofaer et al. 1979 a, Figure 7) that runs from the spiral's center to the lower left edge, emphasizing this particular occurrence. A further stimulus to search for lunar significance within this assembly was provided by Alfonzo Ortiz (1979), who suggested that because of the dual roles of sun and moon in Pueblo culture, a site in which the sun was so clearly marked would also include the moon.

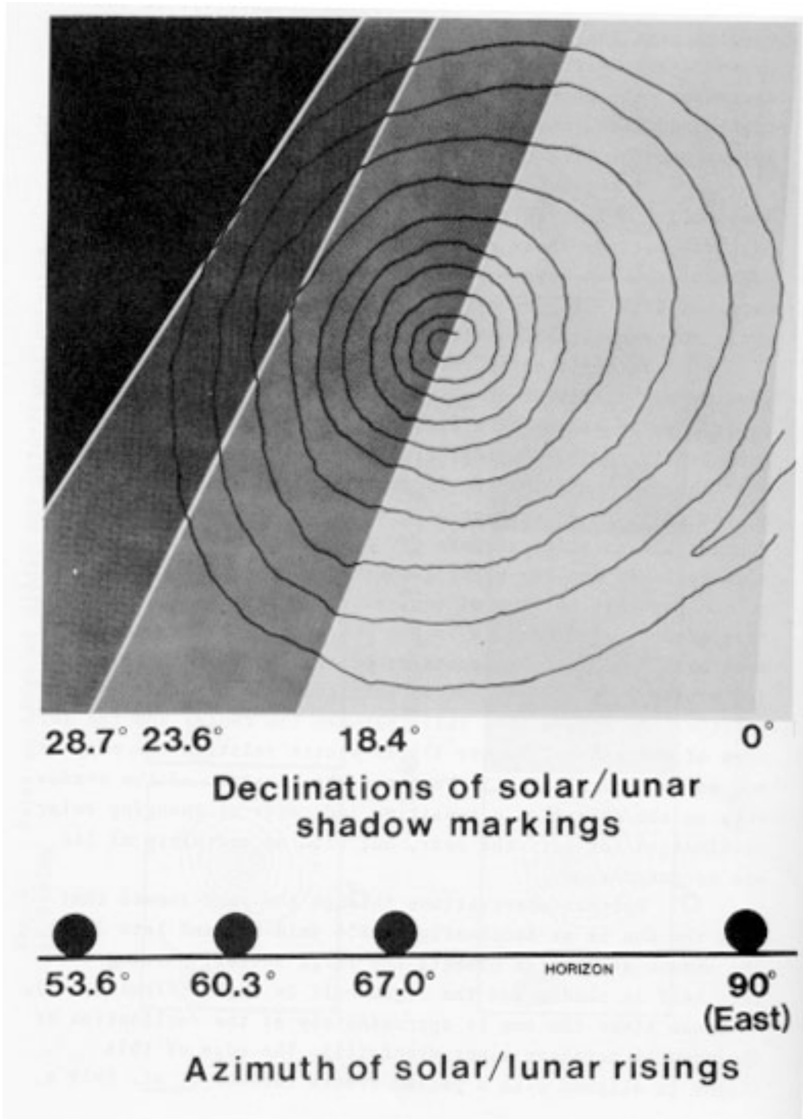

Fig. 5 Solar/lunar markings and solar/lunar risings on the northeast and eastern horizon.

LUNAR MARKINGS Just as the rising sun casts a shadow, so too does the rising moon, provided the moon is in the proper portion of its monthly cycle of phases. Thus under the correct conditions (see Construction of the Site) the rising moon at minorstandstill casts a shadow bisecting the large spiral.

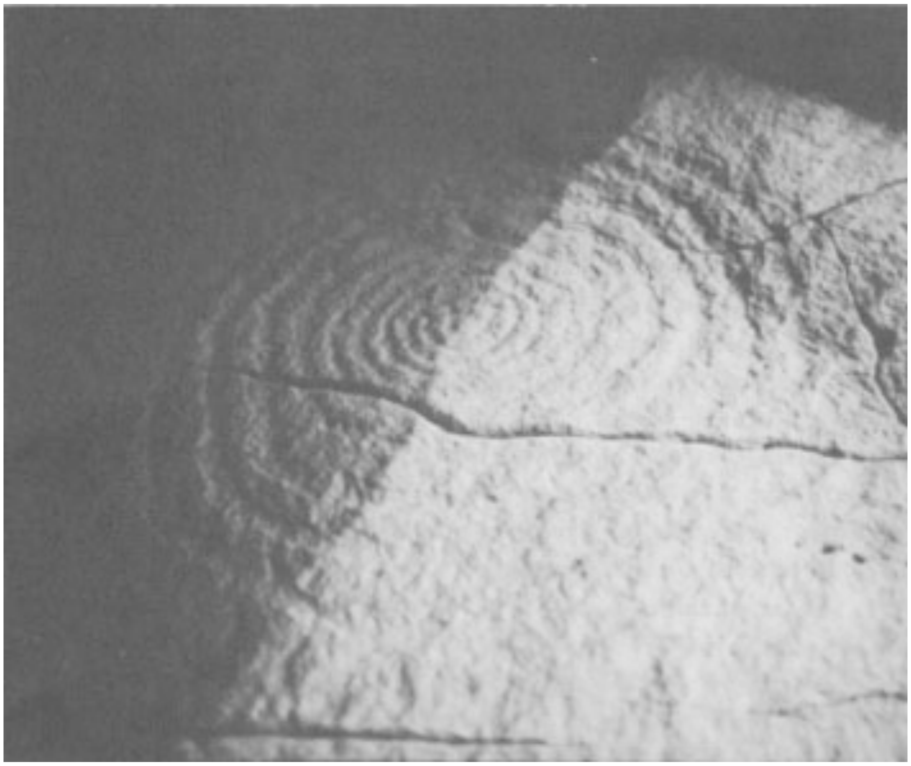

Fig.6 Simulated shadow of moonrise at northern minor lunar standstill

While the sun provided a convenient simulation of moonrises up to declination +23.4º, we had to use artificial light sources to simulate the moon at higher declinations. (The next major standstill will not occur until 1987.) We used a laser for accurate alignment and near-parallel light from a floodlight to form the shadows. A series of simulations was calibrated against observations of various sunrises, with corrections made for the obliquity of the ecliptic of AD 1000, the estimated era of construction of the site. Also taken into account were the effects of lunar parallax and atmospheric refraction (Thom 1971) and the height of the eastern and northeastern horizon.

The simulation of the northern major standstill at declination +28.7º (epoch AD 1000) showed a shadow falling tangential to the far left edge of the spiral (Figures 4, 5).

We conclude that the Pueblo Indians recorded the extreme northern rising positions of the moon at major and minor standstills. In addition, as we speculated earlier (Sofaer et al. 1979 a), the number of grooves in the spiral (counting horizontally from the left edge to the right edge) may record the length of the cycle. This appears in two possible ways: (1) as the cycle moves from minor to major standstill over 9 to 10 years, the extreme position of the lunar shadow shifts over the 10 grooves on the left side of the spiral; (2) the length of the full cycle (18.6 years) may be recorded by the count of 19 grooves across the full spiral. The number of grooves may also record a knowledge of the 19-year Metonic cycle. In addition the passage of the shadow edge through the far right groove of the spiral may record the midpoint of the declination cycles of the sun and moon.

The following factors can affect the position of the edge of the shadow for a given sunrise or moonrise (Thom 1971): variations in atmospheric refraction (+/- 0.4 cm), the lunar wobble of 9' amplitude and 173-day period (+/- 0.3 cm), and variations in lunar parallax (+/- 0.1 cm). None of these introduces an appreciable uncertainty in the display.

In addition it is not clear what position of the rising moon would have been used by the ancient Pueblos to observe shadows. The difference in the shadow position on the spiral of two reasonable possibilities - the lower limb just tangent to the horizon and the lower limb positioned one lunar diameter above the horizon - is only 0.6 cm. The phase of the moon does not affect this, as long as a consistent definition of moonrise is used.

CONSTRUCTION OF THE SITE We previously presented evidence (Sofaer et al. 1979 a) that the slabs were deliberately placed and were possibly shaped on critical edges to form the midday patterns on the spiral. In doing so the builders had control over the placement of the edge that casts shadows at sunrise and moonrise. Calibration of this edge could have required shaping of the inner surface of the eastern slab (Figure 3). Further examination of this edge is required to determine whether its shape is natural or artificial.

Prior knowledge of the standstill cycle would most likely be necessary to relate the shadow casting edge in proper orientation to the spiral. This knowledge could most easily have been gained by accurate horizon watching, a practice reported by McCluskey elsewhere in these Proceedings to have been extensive among an historic Pueblo group, the Hopi.

Under clear weather conditions a majority of moonrises and moonsets are visible each month, with the shifting azimuthal position revealing first the moon's monthly cycle in declination and then, over the years, the standstill cycle. At Chaco Canyon the monthly declination cycle causes the azimuth of moonrise to vary from 67º to 113º near a time of minor standstill. These limits gradually increase over 9.3 years until at major standstill the azimuth varies from 54º to 126º. On the western horizon the setting cycles mirror the rising cycles on the eastern horizon.

Near a standstill the azimuthal limits change very slowly, making it difficult to pinpoint the exact year in which a standstill occurs. However, this makes possible a reasonably accurate determination of the amplitude of the standstill cycle, even if some potential observations are lost because of bad weather or the moon being at the wrong phase. With a desert environment of clear skies and an unpolluted atmosphere, the Pueblos had the advantage of optimal observing conditions.

Once the standstill cycle was known and the device constructed, the northern limits would be indicated on the spiral by appropriate moonrises that are bright enough to cast shadows. In New Mexico we have observed lunar shadows at moon rise, within a few minutes after the lower limb is tangent to the horizon, from the night after full moon to a few nights after third quarter. Since the moon's phase cycle (29.5 days) is longer than its monthly cycle in declination (27.3 days), the phase at successive declination maxima slowly changes. Thus in any given year there are approximately four shadow casting moonrises occurring near the northern limit for that year (Figure 7).

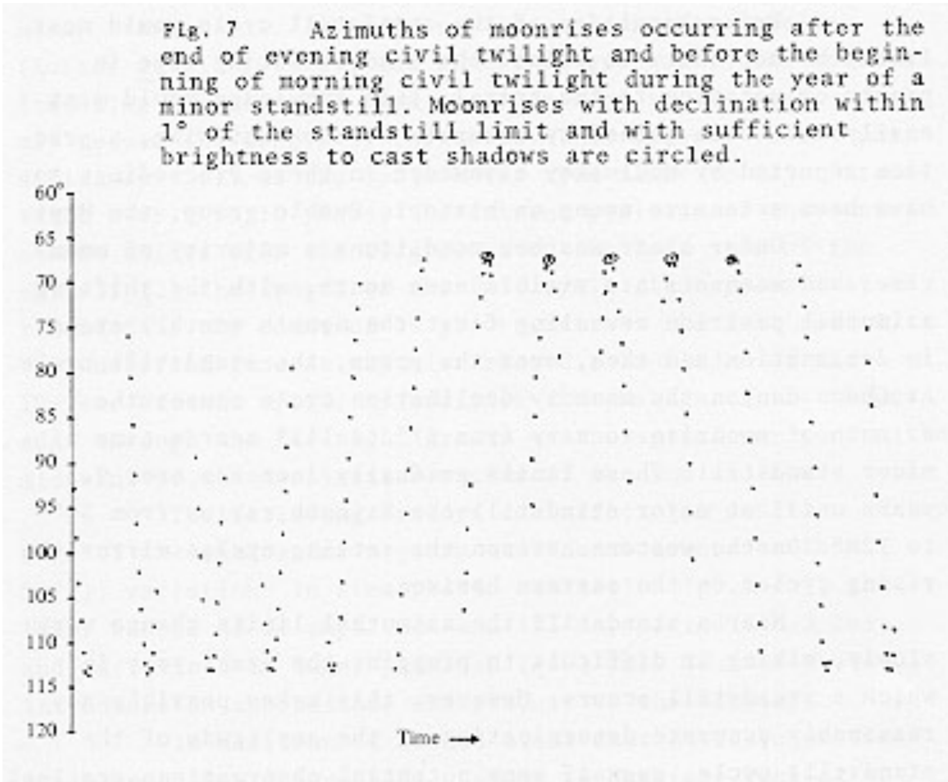

Fig. 7 Azimuths of moonrises occurring after the end of evening civil twilight and before the beginning of morning civil twilight during the year of a minor standstill. Moonrises with declination within 1° of the standstill limit and with sufficient brightness to cast shadows are circled.

CULTURAL BACKGROUND The cultural and technological sophistication of the ancient Pueblo Indians of Chaco is evident in their development of an extensive trade and road network and in their planning and building of elaborate multi-story pueblos (Hayes et al. 1981). Interest in astronomical orientation is found in the reported (Williamson et al. 1975) solar and cardinal alignment of several pueblos and kivas (the Pueblo ceremonial structures in Chaco Canyon). It is also interesting to note the possibility of cultural contact with the Mesoamerican societies that had studied eclipse cycles (Lounsbury 1978) and developed complex calendric systems. In the absence of direct knowledge of the customs of the prehistoric Pueblos, we turn to the historic Pueblos for insights into the ceremonial importance given to bringing together the cycles of the sun and moon. Many ethnographic reports of the scheduling of the winter solstice ceremony indicate strong desire to have the date coincide with the full moon (Stevenson 1904; Bunzel 1932; Ellis 1975). McCluskey (1977) reported that the Hopi synchronized the lunar and solar cycles over 2 to 3 years in setting their ceremonial calendar. More recently McCluskey (1981) has suggested that the Hopis' attention to the moon must have brought them close to observing the standstill cycle: "It would have been a short step for them to look for the moon's house, the theoretical lunistice which the moon reaches every 18.6 years.

Spier (1955) reports that common to most of the historic Pueblos is the starting of the new year with the new lunation closest to winter solstice. Frequent planting of prayer flags at full moon, especially at winter solstice, also indicates the moon's significance in the Pueblos' ritual life (Bunzl 1932). The duality theme in Pueblo cosmology links sun and moon as male/female: sun-father and moon-consort or sister (Stevenson 1904). Ortiz (1981) reports the Tewa Pueblo group as seeing the moon as the mask of the sun.

There was thus a consistent effort to seek the synchronization of lunar and solar cycles. We speculate that there was success in this quest on Fajada Butte in bringing together at the spiral's center and outer boundary the highest and lowest positions of sun and moon (Figure 4).

With the possible exception of Casa Grande (Evans & Hillman 1981), we know of no other evidence of markings of the lunar standstill cycle in the Americas. We have searched for other possible explanations for the timing of the shadow phenomena in the culture and weather patterns in Chaco. A scholar of Chaco's agrarian prehistory (Truell 1981) found nothing significant in the dates when the sun reaches declination +18.4º, and weather patterns of Chaco do not indicate these dates as consistent times of rain or other climatic events. And of course the marking of declination +28.7º is not relevant to the annual solar calendar. The evidence does point to this site as a place where ancient Pueblos integrated on one set of spirals with one set of slabs the cycles of the sun and moon.

ACKNOWLEDGEMENTS We are indebted to A. Schawlow and T. Hansch for supplying the laser used in the simulations; to A. Aveni, J. Carlson, M. Cohalan, J. Eddy, F. Eggan, G. Hawkins and J. Young for many fruitful discussions; to K. Kernberger for photography; to J. McGrath and P. Wier for field work; to B. Jones, R. Nugent, T. Plimpton and R. White for moonrise shadow observations. Finally we wish to express our appreciation to W. Herriman, Superintendent, Chaco Canyon, for his essential help to this research.

REFERENCES

Bunzel, R. L. (1932). Introduction to Zuni ceremonialism. In 47th Annual Report. Bureau of American Ethnology, pp. 467-1086. Washington: Smithsonian Institution.

Ellis, F. H. (1975). A Thousand Years of the Pueblo Sun-Moon-Star Calendar. In Archaeoastronomy in Pre-Columbian America, ed. A.F. Aveni, pp. 59-88. Austin: University of Texas Press.

Evans, J. H. & Hillman, H. (1981). Documentation of Some Lunar and Solar Events at Casa Grande. In Archaeoastronomy in the Americas, ed. R. A. Williamson. Los Altos, California: Ballena Press.

Hayes, A. C., Brugge, D. M. & Judge, W. J. (1981). Archaeological Surveys of Chaco Canyon. Washington: National Park Service.

Lounsbury, F. G. (1978). Maya Numeration, Computation, and Calendric Astronomy. In Dictionary of Scientific Biography. ed. C. C. Gillispie, Vol. XV, pp. 759-818. New York: C. Scribner's Sons.

McCluskey, S. C. (1977). The Astronomy of the Hopi Indians. J. for the History of Astronomy, 8, 174-195.

McCluskey, S. C. (1981). Comment on the paper Stone Age Science in Britain? by A. Ellegard. Current Anthropology, 22, no. 2, 119.

Ortiz, A. (1979). Private communication.

Ortiz:, A. (1981). Private communication.

Sofaer, A., Zinser, V. & Sinclair, R. M. (1979 a). A Unique Solar Marking Construct. Science, 206, 283-291.

Sofaer, A., Zinser, V. & Sinclair, R. M. (1979-b). A Unique Solar Marking Construct of the Ancient Pueblo Indians. American Indian Rock Art, 5, 115-125.

Spier, L. (19SS). Mohave Culture Items, pp. 16-33. Flagstaff: Northern Arizona Society of Science and Art.

Stevenson, M. C. (1904). The Zuni Indians. 23rd Annual Report. Bureau of

American Ethnology, pp. 9-I57. Washington: Smithsonian Institution.

Thom, A. (1971). Megalithic Lunar Observatories. Oxford: Clarendon Press.

Truell, M. (1981). Private communication.

Williamson, R. A., Fisher, H. J. & O'Flynn, D. (1975). The Astronomical Record in Chaco Canyon, New Mexico. In Archaeoastronomy in Pre-Columbian America, ed. A.F. Aveni, pp. 33-43. Austin: University of Texas Press.