A Unique Solar Marking Construct

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Summary: *An assembly of stone slabs on an isolated butte in New Mexico collimates sunlight onto spiral petroglyphs carved on a cliff face. The light illuminates the spirals in a changing pattern throughout the year and marks the solstices and equinoxes with particular images. The assembly can also be used to observe lunar phenomena. It is unique in archeoastronomy in utilizing the changing height of the midday sun throughout the year rather than its rising and setting points. The construct appears to be the result of deliberate work of the Anasazi Indians, the builders of the great pueblos in the area.*

Near the top of an isolated butte in Chaco Canyon, New Mexico, three large stone slabs collimate sunlight in vertical patterns of light on two spiral petroglyphs carved on the cliff behind them. The light illuminates the spirals each day near noon in a changing pattern throughout the year and marks the solstices and equinoxes with particular images. At summer solstice a narrow vertical form of light moves downward near noon through the center of the larger spiral. At equinox and winter solstice corresponding forms of light mark the spirals. We found that the relationship between the shape and orientation of the slabs and the resultant light patterns on the cliff is a complex one and required a sophisticated appreciation of astronomy and geometry for its realization. The site is unique in employing the varying height of the midday sun during the year to provide readings of solar declination. In this respect it is clearly different in concept from the many archeoastronomical sites throughout the ancient New and Old Worlds that tell the passage of the year by marking the rising and setting points of the sun and moon (1).

The Anasazi Indians occupied Chaco Canyon from about A.D. 400 to 1300 (Fig. 1) In this arid and unproductive region, these early inhabitants left evidence of a skilled and highly organized society. They constructed multistory pueblos and large ceremonial centers, and developed extensive systems of roads, irrigation, communication, and trade (2). The Anasazi had established an accurate calendar for agricultural and ceremonial purposes. To do this they determined the recurrence of the solstices and equinoxes (3). This astronomical knowledge was commemorated in the design and alignment of major buildings (4, 5). The precision of the historic Pueblo calendar has been described in a recent study of its synchronization of the monthly lunar cycles with the annual solar cycle (6).

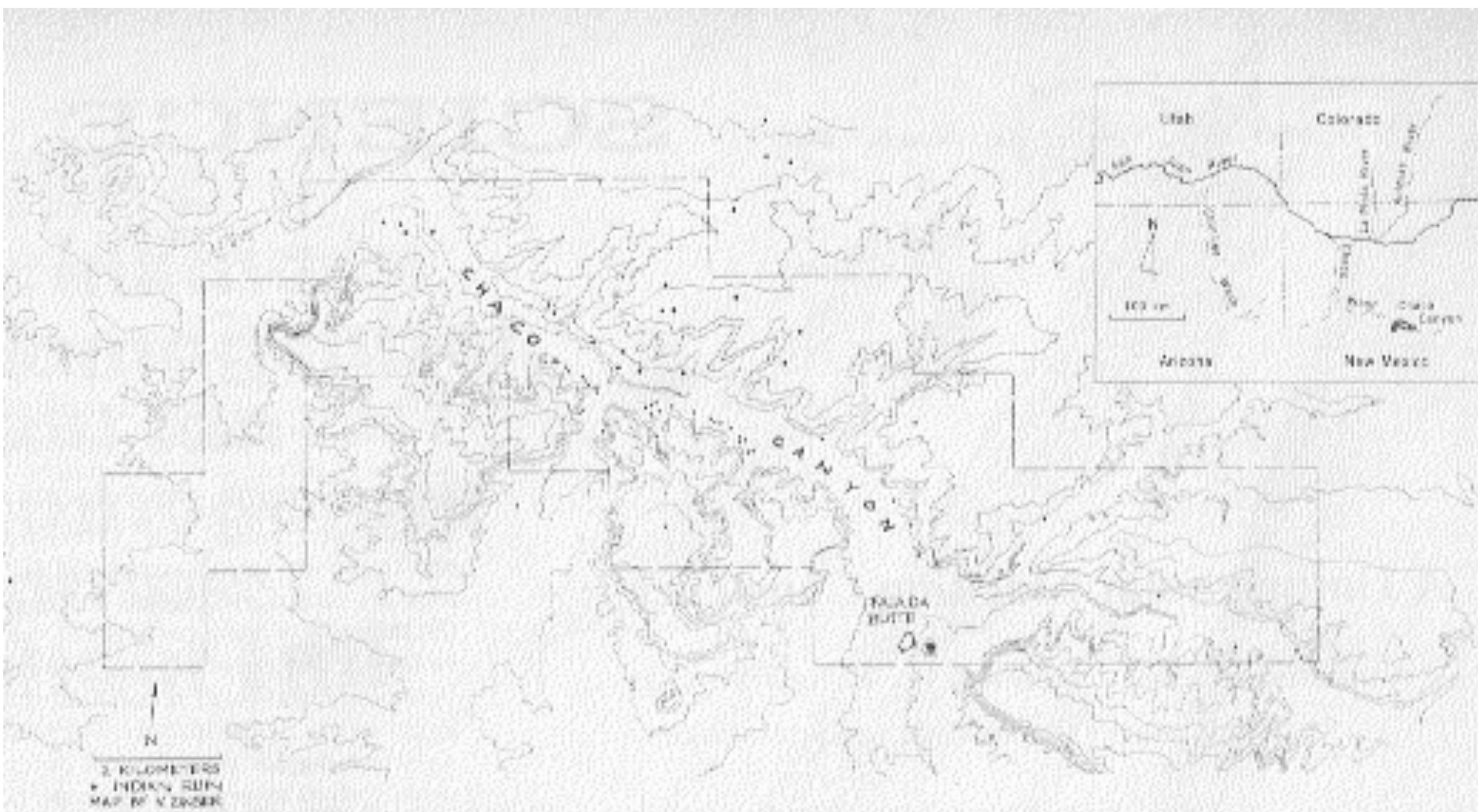


Fig. 1. Map of Chaco Canyon National Monument showing the location of the Indian ruins (circles) and Fajada Butte, and (insert) the Four Corners area of the Southwestern United States.

Fajada Butte stands prominently in the south entrance of Chaco Canyon (Fig. 2), rising 135 meters above the valley floor to an elevation of 2018 meters. The butte is difficult to climb, and there is neither water nor soil on it. Yet from bottom to top are many examples of Indian rock art carved and painted on the cliffs (7), the ruins of a number of small Pueblo buildings, and countless pottery shards. This concentration of remains attests to its active use by the Indians. The butte is a natural site for astronomical observations, with its clear views to distant horizons (4).

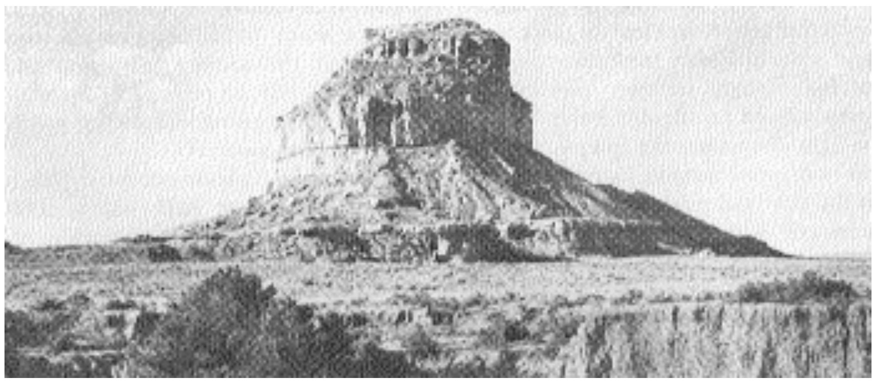


Fig. 2. Fajada Butte from the north.

The site described in this article is just out of sight on the southeast summit.

The last 10 m to the summit of the butte on the southeast face is formed by a vertical cliff with a narrow ledge at its foot. The assembly we will describe consists of an unusual arrangement of three stone slabs 2 to 3 m in height, standing on edge on this ledge and leaning against the cliff. The slabs are slightly off the vertical (Fig. 3) and fan out radially (Fig. 4). They are close together, separated by only 10 centimeters at their inner edges, but do not touch. The slabs keep the cliff face behind them in shadow except near midday, when the sun shines between them to cast patterns of light (8).

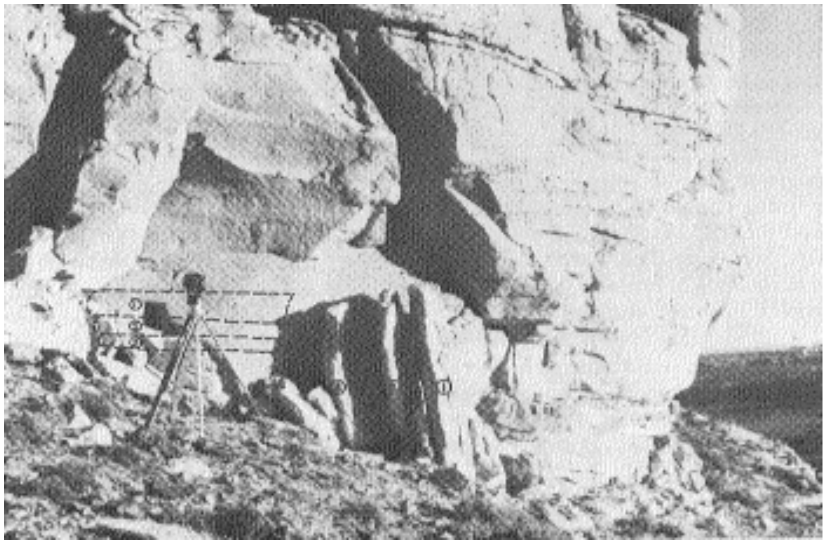


Fig. 3. View of the site from the south.

The slabs are numbered as referred to in the text, and their original placement on the cliff as drawn by Blair (13) is indicated.

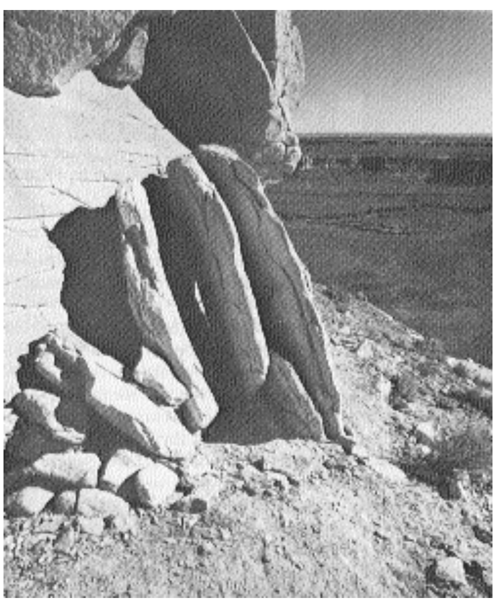


Fig. 4a. Close-up of the slabs from the southwest.

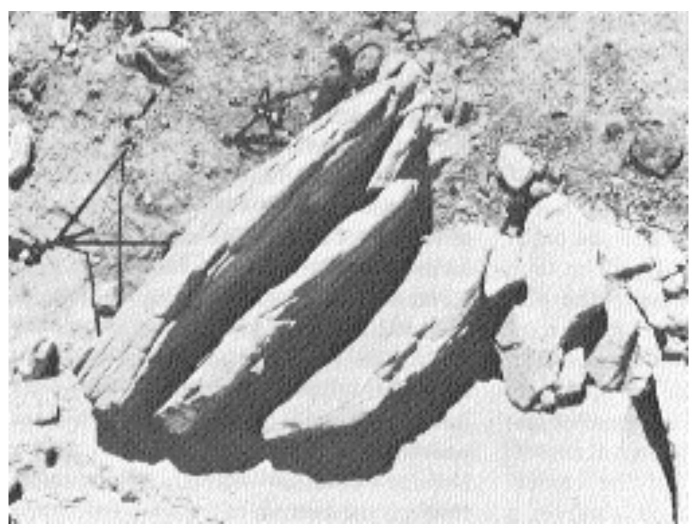


Fig. 4b. Top view of the slabs.

Two spiral petroglyphs are carved ("pecked") on the cliff immediately behind the slabs (Fig. 5). The larger and more prominent spiral is located behind the opening of slabs one and two. It has 9 1/2 turns and is elliptical in shape (34 by 41 cm). The smaller spiral (9 by 13 cm) is above and to the left behind the opening between slabs two and three. It has 2 1/2 turns and a loop extends out of its upper right side. The spirals can be seen in their entirety only from the right of slab one. From this position, the larger spiral appears circular, suggesting that this was the intended viewpoint (Fig. 6). The length of time the sun shines between the slabs onto the spirals varies from 18 minutes near noon at summer solstice (when the sun is highest in the sky) to 3 hours or more at winter solstice (when the sun is lowest).

Fig. 5a. Close-up of spirals (artificially highlighted)

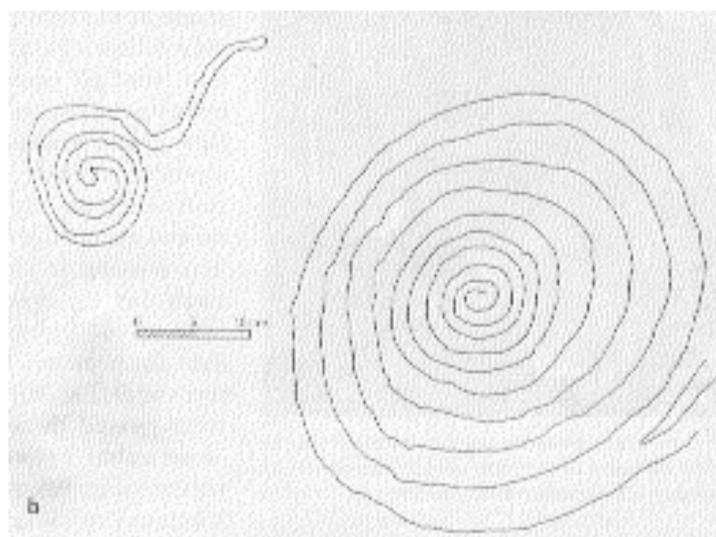


Fig. 5b. Tracing of spirals.

Not surprisingly, moonlight generally creates the same patterns on the spirals as the sun, on nights when the moon is between first and third quarter. The periodic changes in these patterns reflect the complexity of the moon's apparent motion (9), and certain combinations of patterns are associated with specific lunar eclipses.

Fig. 6. Light patterns on the spirals from the viewing point to the right of the slab one on a typical day (28 October 1978, 10:35 a.m.).

The first observations at the site were made on 29 June 1977 by one of us (A.S.), who then initiated the present studies and was soon joined by the other two authors. In what follows, we will describe in detail our record of the patterns of light on the spirals during an annual cycle of the sun. We will show how the combination of the patterns and the spirals can be used to determine accurately the time of recurrence of the solstices and equinoxes. We will describe how geologic, archeologic, and geometric studies of the site have led us to conclude that the assembly was constructed by the ancient Pueblos. Finally, we will speculate on how the assembly could have been used to study some aspects of the complex cycles of the moon's motion. [Preliminary reports on this work have been presented at two recent conferences (10)].

Observations We made records of the patterns of light on the spirals at monthly intervals from 21 June 1978 (summer solstice) to 21 December 1978 (winter solstice) and at some intervening dates. Photographs were taken from several fixed camera locations at 30-second intervals each day as long as light shone between the slabs onto the cliff. Additional photographs were made by moonlight on a few nights. We measured the details of the faces and edges of the rock slabs and determined just what points were casting shadows. From an analysis of this information and theodolite recordings, we made geometric reconstructions of the phenomena.

Solar observations. the solar cycle two consistent characteristics of the movement of the light patterns make possible this solar calendar.

1) Each day the light is a vertical form and moves primarily in a downward vertical motion, while the sun moves essentially horizontally.

2) As the sun's midday passage lowers in altitude from summer solstice to winter solstice, that downward vertical movement gradually takes place farther to the right on the cliff face.

Summer solstice (21 and *22 June).* On this day sunlight first shines through the right opening (between slabs one and two) at 11:05:15 a.m. local apparent time (11). The light first appears as a spot on the top edge of the outside turn of the larger spiral (Fig. 7a). The spot quickly stretches into a thin vertical form, sharply pointed at the tip (Fig. 7b). It lengthens downward and descends through the center of the spiral. At the time halfway between the first and the last appearance of light on the cliff face, the form is centered both horizontally and vertically on the spiral (Fig. 7c). Thereafter, the pattern continues to move downward (Fig. 7d), becomes shorter (Fig. 7e), and finally disappears near the bottom of the spiral 18 minutes after its initial appearance.

Fig. 7. Light pattern moving downward across the larger spiral near summer solstice (23 June 1978):

(a) 11:07:00 a.m.

(b) 11:10:45 a.m.,

(c) 11:13:00 a.m.,

(d) 11:16:45 a.m.,

and (e) 11:20:45 a.m.

On the days after summer solstice the light pattern follows the same sequence but is displaced increasingly to the right of the center of the spiral. Recalling that the phenomenon is symmetrical about summer solstice, the sequence of events from May through July is this: the form of light as it descends vertically each day passes at first to the right of center. On succeeding days, it moves slightly left until at solstice it reaches an extremum, passing through the center of the spiral. Thereafter it moves back to the right each day. On 21 July or 22 May, it passes 3.2 cm to the right of center. A shift of 2 millimeters to the right can be detected by comparing photographs taken on solstice day and 25 June, and thus the time of summer solstice is marked within 4 days, when the sun's declination has shifted only 2 minutes and 3 seconds of arc.

In a related effect at summer solstice, sunlight reaches the cliff face through the left opening (between slabs two and three) for only 2 minutes to cast a small spot of light, which is not noticeable to the casual observer. Only a few days earlier or later, this spot becomes a clearly visible form and its time is longer by I minute or more. The length of time that sunlight reaches the cliff face through the left opening decreases steadily as summer solstice is approached, from more than 2 hours in winter to 2 minutes on 21 June (Fig. 8). If we extrapolate linearly to the maximum declination of the sun in A.D. 1000 [23º34.1' (9)], we find that this length of time would then have been only 1 minute. This minimum is not in itself surprising, since the length of time must vary symmetrically about solstice. But having the minimum time so close to zero is curious and suggests that 1000 years ago it was perhaps even less. We have located those parts of the edges of the slabs that determine how long light shines through the left opening at solstice. A change in the position and height of the top surface of slab two by only I to 2 mm would be enough to reduce the time by I minute. Since this change is a reasonable estimate of the effects of weathering and settling over a millennium *(12),* it is likely that the time during which light entered this opening was close to zero (or reached zero) at summer solstice and thus provided a second precise marking of summer solstice.

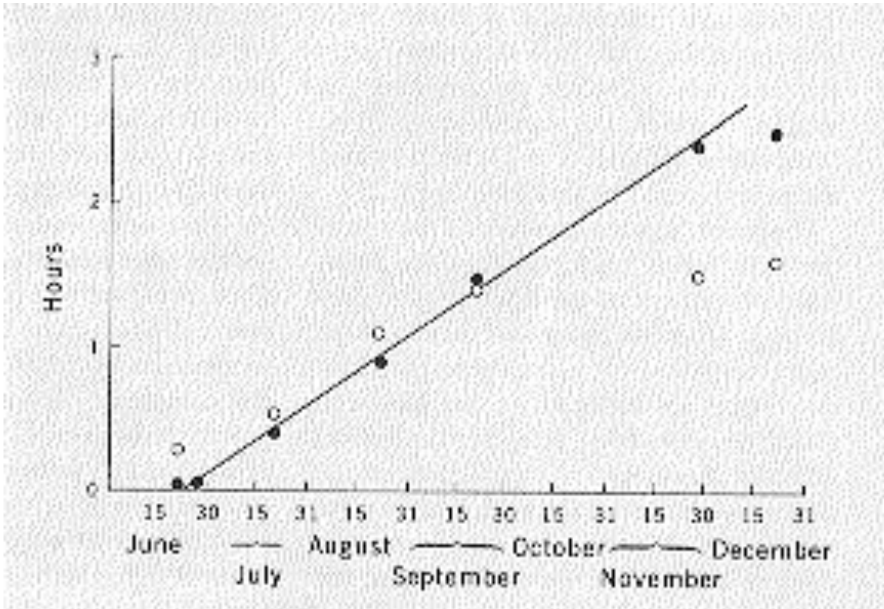


Fig. 8. Variation with date of the length of time that sunlight shines on the cliff face between (O-white) slabs one and two and (O-black) slabs two and three.

Autumn equinox (21 and 22 September). After summer solstice, both the shape of the light patterns and the paths they follow change each day. The time that sunlight shines through the left opening increases, and the pattern of light grows gradually from a spot to a slender inverted triangle. This form starts each day closer to the smaller spiral and eventually moves down across it, first passing to the left of the center. Each day the downward path moves a little to the right, until at equinox the light form passes through the center of this spiral (Fig. 9b), just as the other light form passed through the center of the larger spiral 3 months earlier at summer solstice (Fig. 9a). After equinox, the path continues to move to the right. A week before or after equinox, the form passes clearly to the left or right of the center of the small spiral.

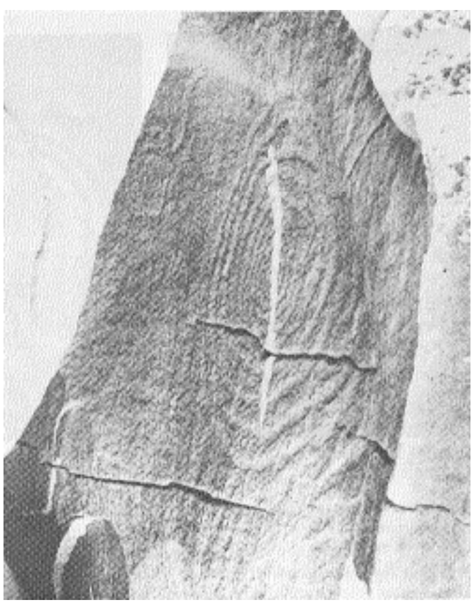
The pattern formed by sunlight shining through the right opening changes gradually from the downward-moving thin vertical form observed at summer solstice (Fig. 7 and Fig. 9a) to a band of light stretching across the larger spiral (Fig. 9b). At equinox this band, as it first spans the spiral, is positioned approximately 7 cm to the right of center, between the fourth and fifth turns -- that is, in the midspace of the nine turns. The daily track of its motion is displaced gradually to the right on successive days.

Winter solstice (21 and 22 December). Between autumn equinox and winter solstice, the pattern produced by sunlight through the left opening still starts each day as a narrow pointed shape and descends downward.

During the next hour or two it becomes a vertical band and moves slowly rightward across a portion of the larger spiral. The track of this light form's motion shifts --like the light formed by the right opening gradually rightward day by day.

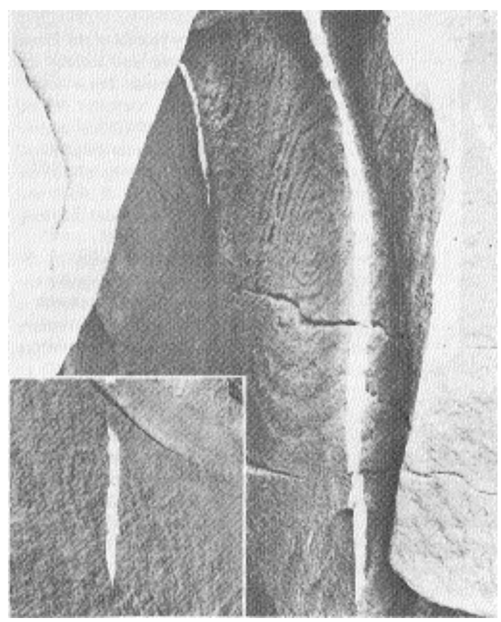
At winter solstice markings occur on both petroglyphs. The first involves the left pattern only. Shortly after its first appearance on 21 December, while still a slender pointed shape, it descends through the bottom of the loop extending to the right from the smaller spiral (in a position 7 cm to the right of the equinox light form) (Fig. 5b). Then later on the same day both bands of light move so as to "frame" the larger spiral (Fig. 9c). This occurs when the left band reaches the left side of the spiral and is in the outer left groove just as the right band crosses the spiral and is in the outer right groove. This framing of the spiral occurs only within 1 week of solstice.

Fig. 9. Light pattern on the spirals at the quarter-year points:

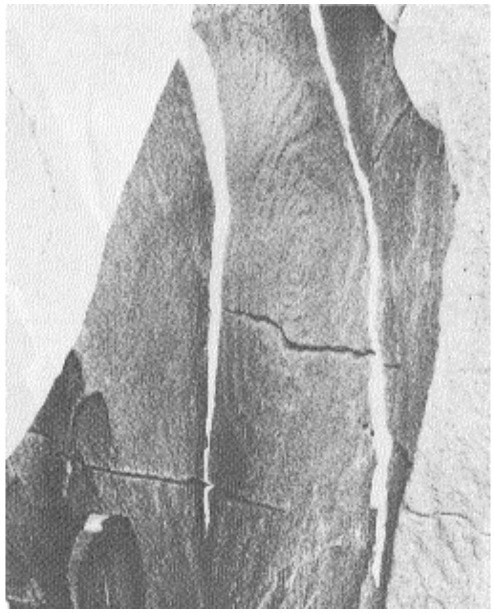


(a) near summer solstice

(26 June 1978, 11:13:15 a.m.),



autumn equinox (21 September 1978, 10:50 a.m.); the inset shows the bisection of the smaller spiral by the left light formation; and



(c) near winter solstice (22 December 1978. 10:19 a.m.).

After winter solstice, the daily change of the patterns of light on the spirals repeats itself in reverse order. By spring equinox (21 March) the patterns and their motion are the same as at autumn equinox, and by summer solstice the solar cycle is completed.

An overview of the light patterns through the solar cycle reveals relationships between the markings of each season (Fig. 9, a, b, and c). The markings of the winter and summer solstices each involve a significant change in the light forms that mark the other quarters. For example, at summer solstice the observer's attention is focused without distraction on the dramatic occurrence of the bisecting light on the larger spiral because no light is formed by the left opening. This phenomenon is especially striking since light shaped by the left opening develops soon after summer solstice into a distinct vertical form, which eventually bisects the smaller spiral at equinox. In another example of the seasonal interrelationships of the light forms, the light shaped by the right opening, which acts significantly at summer solstice, is joined by the light shaped by the left opening, which acts significantly at equinox, to become the bracketing partners that frame the larger spiral, which is "empty" of light at winter solstice.

Lunar observations. The patterns formed at night by moonlight shining between the slabs are just as clear and as noticeable as those formed by the sun, and we easily recorded them on several nights near full moons (Fig. 10). It is not necessary to make a detailed record of these patterns for most positions of the moon, since at a particular point in the sky it will form the same light patterns on the spirals as the sun would at the same point. When the moon's declination is between + 23.5º and - 23. 5º (the solar extremes) we can thus predict the patterns formed by its light by knowing those formed by the sun at the same declination. But the moon's declination can vary outside the solar limits, up to +/- 28.5º over part of an 18.6-year cycle, and whenever it lies beyond the extremes of the sun's declination we have no corresponding solar data. Since this periodic extreme in the moon's declination will not be reached again until 1987, we cannot yet make direct observations of the patterns formed by the moon at such declinations. As discussed later in this article, extrapolations from the solar data suggest that a significant marking of the maximum lunar declination may occur.

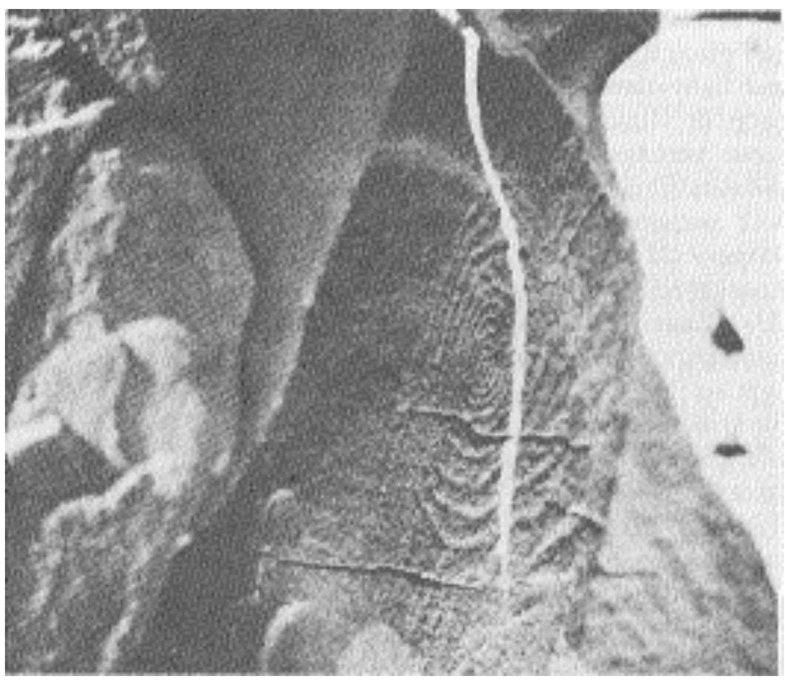
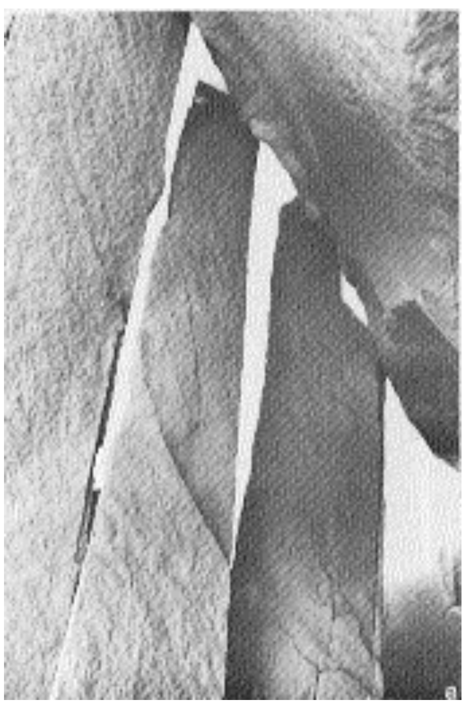


Fig. l0. Patterns cast by moonlight (24 June 1978, 2:45 a.m.).

The Stone Slabs The three slabs stand on the sloping ledge at the foot of the cliff, each contacting the cliff over only a small area (Fig. 1la). On the left of slab three is a supporting buttress of smaller rocks (Fig. 4a) and under the right edge of slab one is a small supporting rock. All the slabs and rocks of the assembly consist of the same soft sandstone as the cliff itself. The slabs are roughly rectangular (2 to 3 m high, 0.7 to 1 m wide, and 20 to 50 cm thick) and weigh about 2000 kilograms each. The outer surfaces and tops are rounded and weathered, the inner surfaces smooth and gently curved with sharp edges (Fig. 11b). By comparing the matching details on the facing surfaces of the slabs, it has been determined (13) that these slabs once fitted together to form one block. The place where this block was joined to the cliff face was found by noting the strata and bedding planes and the curvature of the cliff face *(13).* By such comparison, the original location of each slab was found to within I cm, well to the left of the present locations (Fig. 3). The long dimensions of the slabs were then horizontal, and slab one was on top.



l1. (a) Inside view of slabs g upward to show area of contact with the cliff.

(b) Inside (concave) edges of the slabs.

Several pieces of evidence rule against the slabs' having fallen into their present positions naturally. First, the slabs would have had to move 2 m and more horizontally while the center of gravity of the three together fell only about 80 cm vertically. In particular, the center of slab three by itself is now only 30 cm lower than when it was attached to the cliff. Second, there are no impact marks, either on the cliff face or on the inner edges of the slabs, to suggest a collision. Third, the cliff face above the original location of the slabs shows that another rock mass had broken away from there. This higher rock could not have broken off before the slabs did. Had it broken off with (or after) the slabs, it would have prevented them from falling naturally to their present location. There is no evidence today of this rock mass. Indeed the absence of rubble near the slabs is unusual on the butte, where fallen rock is found below other such cliffs. Fourth, the slabs are set firmly in place on a rocky ledge and are partially supported by buttressing stones. We conclude that moving and setting the slabs in their present position involved deliberate human intervention.

Geometry of the Assembly The daily patterns of light that highlight special features of the spirals at the quarters of the solar year are formed by several components of the assembly acting as a whole. The placement, size, and shape of the slabs, the orientation of the cliff face, and the positions and sizes of the spirals are all critical. Our calculations and drawings have determined the role and importance of these interlocking factors and show that a change in any one would change or eliminate the images marking the quarters. No one component dominates in such a way that the others could be left to chance.

Consider first the downward motion of the light forms each day and the rightward placement of the light as time progresses from summer solstice. These characteristics of the light patterns' movement are essential to the solar calendar because they provide discernibly different markings on a small area of the cliff through the solar cycle. The precise positioning of curved surfaces on the slabs in relation to the cliff face and the sun makes possible the daily vertical movement of light and the seasonal shift in the discretely shaped light forms. The horizontal motion of the sun as it shines against these curved surfaces is transformed into downward vertical movement of the light patterns.

For example, at summer solstice, during the 18 minutes when light shines through the right gap, the sun has moved 4.5º westward almost horizontally across the sky. We would at first glance expect the projected pattern of sunlight to move horizontally across the spiral, shifting to the right on the cliff face. The observed vertical motion is thus in itself surprising. A simple way to picture how this downward motion is effected is as follows: Imagine a long narrow cylinder so oriented that the sun as it moves across the sky can shine through it only briefly onto the cliff to form a spot of light. Immediately below, picture a second cylinder so aligned that sunlight passes through it just as it stops shining through the first one, and now casts a second spot of light immediately below the first. Then continue in a like manner with further cylinders. The result will be that a succession of spots will appear on the cliff, moving downward as the sun moves horizontally. If the cylinders are now joined to form a continuous curved slit, the spot of light on the cliff will move smoothly downward. More generally, a form of light, rather than simply a spot, can be made to move vertically in a similar manner.

Close inspection of the slabs shows that the front left edge of slab one and the right rear edge of slab two form just such a curving slit (Fig. 12). As the sun moves across the sky, different portions of the slabs' curved edges come into play to collimate the sunlight. There is a further requirement that these edges be shaped so as to produce the parallel sides and constant width of the downward-moving light form (Fig. 7). Further, the slabs and their curves must be located so that the pattern bisects the spiral only at solstice. As the sun lowers after 21 June, the curved surfaces cause the entering light to move rightward on the spiral. A simple vertical opening would not provide the visibly rightward displacement of light in the 4 days following summer solstice, when the sun has lowered only 2 minutes and 3 seconds of arc. Similar curved surfaces of the left front edge of slab two and the right rear edge of slab three produce the downward motion of the other light pattern at equinox and the rightward shift of this light pattern as time progresses toward winter solstice. In addition to these requirements on the edges of slab two, this slab must be of such a size and so inclined as to shadow the left opening and form the pronounced minimum at summer solstice.

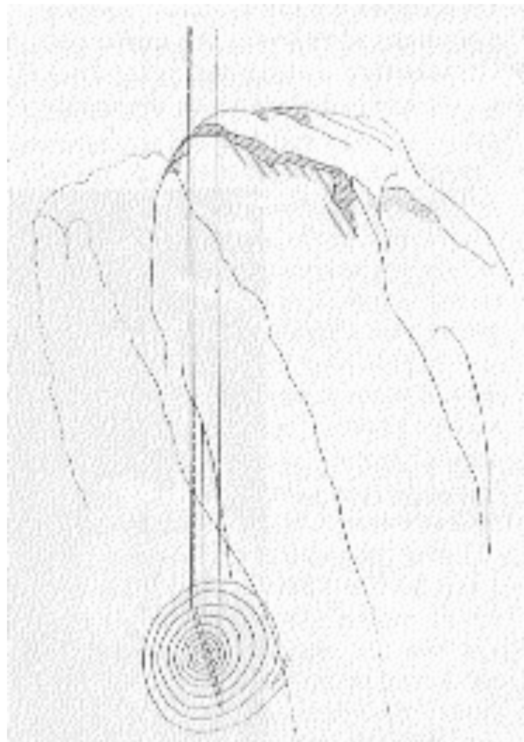


Fig. 12. Formation of the descending light pattern at summer solstice by slabs one and two.

Another feature of the light patterns deserves special notice. The distance from the slabs to the cliff is such that if a pattern of light cast by a small opening between the slabs falls high on the cliff in the winter when the sun is low in the sky, we would expect it to fall on the ground between the slabs and the cliff in the summer. We find, however, that throughout the year, the patterns of sunlight are projected onto only that part of the cliff face around the spirals. This "display area" is just that viewed comfortably from the right of slab one (Fig. 6), which makes it easy to compare patterns at different times of day and of the year. By doing this, the assembly acts like modern instruments that confine the images of interest to a projection screen.

An illustration of how the construct provides information about the solar cycle on a small exhibit space is the contrasting imagery of markings on the larger spiral between the solstices. At winter solstice, when the light forms shaped by both openings bracket the larger spiral, they are equally distant from the center. which was bisected by the light from the right opening 6 months earlier. That this relationship of both light forms to the center of the spiral occurs only at winter solstice is an indication of the intricately controlled relationship of the slabs.

An important question is whether the slabs or the cliff face show evidence of deliberate shaping. Three areas have been noted by specialists as possibly showing signs of modification. Parts of the top edges of slabs one and two have a surface texture different from that of the rest of the slabs and could have been shaped by pecking (14, 15). We find that these surfaces are the portions of the slabs that determine the right sides of the downward-moving light forms between summer solstice and equinox, and one of these surfaces is a critical factor causing the pronounced minimum at summer solstice. Another surface that may have been worked is that on which the spirals are pecked. This portion of the cliff face is different from the adjoining areas in shape and surface texture and may have been dished out and smoothed (16).

Cultural Background Several factors show that the Anasazi inhabitants of Chaco developed the construct between A.D. 900 and 1300 (the approximate date of Pueblo abandonment of the canyon) and indicate that the specific time was between A.D. 950 and 1150, the period of greatest population and development in the canyon (17). The sun- watching practices of the primarily agrarian settlements of Pueblo culture have been extensively documented in ethnographic reports as the means of setting planting and ceremonial calendars. These practices were frequently performed at shrines located on the top or near the top of mountains and buttes within the vicinity of Pueblo settlements (18, 19).

Certain rock art sites of the ancient Pueblos are reported to mark solar positions by the placement of designs to receive shadow and light formation at the rising and setting of the sun at solstice or equinox, and one such site includes a spiral design (20). Two petroglyph sites on Fajada Butte are marked with shadow and light changes at the time of solar noon at summer solstice, and one of these includes a spiral design (21). The spiral is frequently found in association with ancient Pueblo petroglyphs of sun imagery (22, 23). It is identified with the Anasazi rock art style prior to A.D. 1300 (23). Examples of architecture of the same period have openings that channel light so that it shines on key features of the structures such as doorways, niches, and corners at the solstices and equinoxes (4, 24, 25).

Indications that the Fajada Butte solar marking construct was developed within the period A.D. 950 to 1150 are the planning skills and solar interests exhibited by the Chaco occupants at that time.

During this phase of extensive trade and ceremonial activity in the canyon, complex systems of roads, communications. irrigation, and ceremonial architecture were developed. The largest structure of the entire Anasazi culture, Pueblo Bonito ("beautiful village"), a five-story, 800-unit building, was built with its primary elements of design precisely aligned to the rising and setting of the equinox sun and the daily noon position of the sun (7). Pottery shards of the Bonitians are prevalent on and below the Butte -- and several have been found within the immediate vicinity of the slabs. The occupants of Chaco at this time of thriving development clearly had the planning ability and organizational skill to move the assembly of slabs and set them in their present solar marking alignments.

Indications of specific activity of the ancient Pueblos at the site suggest the need for future archeological study. It is possible that there was a single structure located about 50 feet to the west of the slabs and a basal retaining wall built to prevent erosion a few feet down the slope from the slabs (17). Further study might indicate with more certainty the specific group of the Anasazi culture who built the solar marking construct and provide further information about their use of the site.

Possible Significance of the Lunar Markings

The assembly may have been used for lunar observations. Such use would be consistent with the Pueblo culture's emphasis on the moon, which is seen in a dual role with the sun, and association of danger with the occurrence of lunar eclipses (26). The Indians of the Southwest knew of the 18.6-year cyclic extremes in lunar declination and incorporated that knowledge in a major archeological site (27).

We extrapolated some features of the record of solar observations to estimate what lunar light patterns would occur on the large spiral at the extreme maximum declination of the moon. We found that the length of time that light from the sun (and equally well from the moon) shine, through the right opening is a linear function of declination near 23.5 degrees (Fig. 13) and extrapolates to zero close to +28.5 degrees. It is thus likely that as the moon reaches its maximum declination, the length of time that moonlight shines on the cliff would be close to zero or would reach zero. Interestingly, such a marking of the lunar extreme would be similar to the indication of the sun's extreme declination at summer solstice by the pronounced minimum of the light form shaped by the left opening.

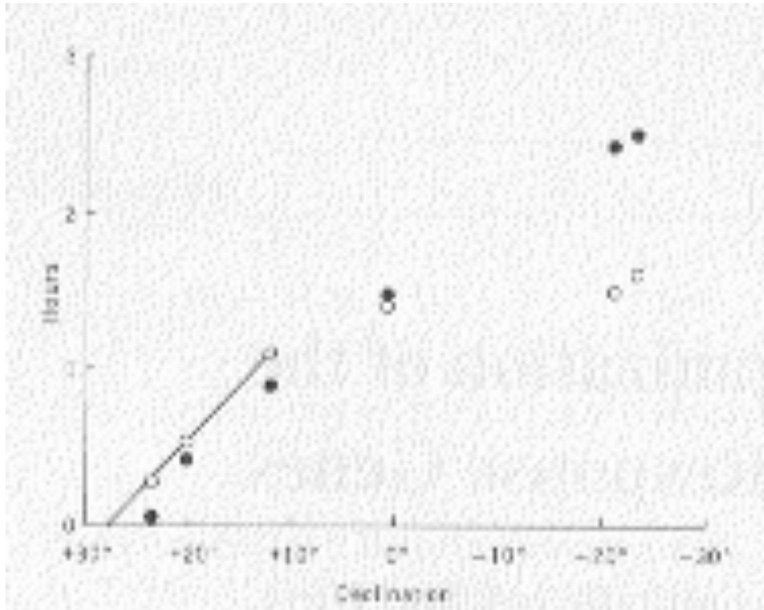


Fig. 13. Variation with declination of the length of time sunlight shines on the cliff face between (O-white) slabs one and two and (O-black) slabs two and three.

In observing the lunar markings on the spirals over the 18.6-year cycle, one would be particularly interested in those times when the declination of the full moon is equal and opposite to that of the sun. This occurs once every 9 to 10 years, within 2 weeks of the solstice. The moon would then cast on the spirals at night the light patterns characteristic of the solstice, opposite the patterns that would be marked within 2 weeks by the sun during the day. Correspondingly, a full moon would cast the equinox pattern within 2 weeks of vernal or autumnal equinox every 9 to 10 years, but out of phase with solstitial eclipses. These striking alternations of patterns would indicate the alignment of sun, earth, and moon that makes possible a midwinter or midsummer solstitial or an equinoctial eclipse. We should, in this connection, mention the interesting parallel between the number of turns in the larger spiral (ten on the left and nine on the right) and the alternation of 10 and 9 years in these eclipse cycles, as well as in the moon's transition from minimum to maximum declination. We speculate that the spiral may record this knowledge. Of addition al interest is the correspondence between the total number of spiral rings and the 19-year cycle of occurrence of the full moon on the same solar date.

Conclusion The Fajada Butte construct is unique in archeoastronomy as the only device known to use the passage of the midday sun to create a solar calendar. Precisely planned relationships of curved rock surfaces make possible the transformation of the horizontal movement of the sun in to vertical movement of light forms that provide accurate measurements of solar positions. Thus, with no reliance on fore sights or horizon markers, the construct is a self-contained instrument that records the sun's changing declination. It shows the times of solstice and equinox in vividly symbolic imagery of light and shadow and provides solar (and lunar) information at other times in the year. While the construct achieves its results with an accuracy comparable to that of the large monuments and structures of other ancient cultures, it does so with a subtle integration with nature that is typical of the North American Indian culture

Finally, we wish to note that the soft sandstone material of the construct is fragile and can easily be damaged. We hope that efforts will be made to preserve this unusual feature of the Native American heritage.

References and Notes

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6. S. C. McCluskey, *J. Hist. Astron.* 8, 174 (1977).

7. A Sofaer and J Crotty, unpublished observations.

8. Light can also shine in from the right of slab one for a short time at sunrise.

9. E. C. Krupp, in (1), pp. 1-37.

10. A. Sofaer, V. Zinser, R. M. Sinclair, papers presented at the symposium of the American Rock Art Research Association, The Dalles, Ore., May 1978, and at the conference on Archeoastronomy in the Americas, Santa Fe, N.M., June 1979. The work was described in K Frazier, *Science News* 114, 145 (1978).

11. Local apparent time is used throughout this article. This is the time that would be told by a sundial at a particular location on a given day, with noon occurring when the sun is on the meridian due south at its maximum altitude for the day. This time differs from local mean ("clock") time by at most a few minutes. The maximum daily altitude of the sun varies sinusoidally during the year from 77.5 degrees to 30.5 degrees at Fajada Butte (latitude, 36 degrees North).

12. B. Wachter, private communication.

13. R. Blair, private communication.

14. R. G. Vivian, in a memorandum dated 11 September 1978, stated: "The top edges of the two argest slabs (the right and center slab when facmg the cliff) *may* show some evidence of shaping through pecking and grinding. These two surfaces are rather flat and are covered with small dimpled marks suggestive of pecking."

15. C. B. Hunt, in a letter dated November 1978, said that the near edge of the middle slab "looks as if it had been pecked and rubbed."

16. R. G. Vivian, in 11 September 1978 memorandum stated: "The surface of the cliff face onto which the spiral had been pecked did appear to have been smoothed-possibly through grinding. This surface was somewhat dished or concave an attribute that may have been achieved through grinding."

17. ____________, private communication.

18. F. H. Ellis, private communication.

19. M. C. Stevenson, *Burl Am. Ethnol. Annul Rep.* 23 (1904).

20. R. A. Williamson, paper presented at the conference on Archeoastronomy in the Americas, Santa Fe, N.M., June 1979. It is interesting to note that parallels in this type of solar marking are found among California Indian cultures (see T. Hudson, G. Lee, K. Hedges, J. *Calif Anthropol.,* in press); one example in the report by Hudson *et al.* includes a spiral petroglyph crossed by shadow at winter solstice.

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