Astronomical Markings at Three Sites on Fajada Butte

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From *Astronomy and Ceremony in the Prehistoric Southwest*, John B. Carlson and W. James Judge, editors, Maxwell Museum of Anthropology, Anthropological Papers, No. 2, 1983.

A seven-year study of prehistoric Pueblo sites of the Chaco culture has revealed that these people possessed a sophisticated astronomy. Evidence of this prehistoric astronomy consists of multiple light markings on petroglyphs and of several alignments of major structures. This paper presents the results of a recent study of 13 markings at three sites on Fajada Butte in Chaco Canyon, New Mexico; these results are presented in the context of earlier research in this area. Each marking is a distinctive pattern of shadow and light that appears on a petroglyph at a key point in the solar or lunar cycle, i.e., at an extreme or midposition of these cycles, including the meridian passage of the sun at solar noon. [Note: times quoted throughout this chapter are in apparent solar time, in which noon occurs each day when the sun is due south on the meridian. The basic astronomical concepts used here are explained in Aveni (1980) and Krupp (1977).] Many of the markings simultaneously record two key points in different cycles, such as noon and solstice or noon and equinox. A minimum of 17 key points are indicated by the markings at these three sites.

The markings define the outer boundaries and midpoints of the recurring cycles of the two most basic celestial bodies: the sun and the moon. The accuracy and redundancy of the markings of these symmetric points, as well as the strong visual effect of the markings themselves, indicate their intentional quality. Several of the markings record meridian passage of the sun within a few minutes, and one marks equinox to within a day. An accuracy equivalent to that of these markings is found in the cardinal alignments of major constructions in the area.

Fajada Butte stands 135 m high at the south entrance of Chaco Canyon. The remains of various structures, including a small kiva, and the presence of potsherds and rock art on and near the butte summit show that it was frequented by prehistoric Pueblo people and by Navajo people. The content and style of the glyphs at the three sites reported here indicate that these markings are of prehistoric Pueblo origin and were probably made between AD 900 and 1300.

From about AD 900 to 1150 Chaco Canyon was the center of a complex prehistoric Pueblo society that thrived in the arid environment of northwestern New Mexico. The Chacoan people planned and constructed large multistory structures, ceremonial centers, and extensive roads throughout the 70,000 sq km San Juan Basin. These achievements indicate sophisticated engineering and surveying skills. Ethnographic reports concerning the historical Pueblos (some of whom are descendents of the Chacoan people) reveal their keen interest and skills in observing the sun and moon for ritual and agrarian purposes (see references cited in Sofaer et al. 1979).

The Fajada markings, although similar to others recently reported in the Southwest, are unique among known archaeoastronomical sites in several respects: (a) they use the changing altitude of late morning and midday sun to indicate the solstices and equinoxes, (b) they record solar noon on rock art, and (c) most especially, they combine recording of both the season and noon in the same markings. The markings at one site are the only known ones in the New World that combine recordings of the extremes and midpositions of the moon and the sun. The use of the features and topography of a prominent land mass to create these complex and varied markings on carved petroglyphs is, also unique in our current knowledge of prehistoric astronomy.

Following a brief summary of earlier findings at one of the three sites near the top of Fajada Butte (see also Sofaer et al. 1979, 1982a), this chapter describes in detail the recently discovered markings that combine noon and seasonal recordings at two additional sites on the east and west sides of the butte (Sofaer et al. 1982b). New observations and analyses regarding the earlier findings are then presented. The sites are referred to in this paper as the three-slab site, the east site, and the west site. The markings of these sites were first observed and studied by Sofaer between 1978 and 1983. The markings are summarized in Table 4.1. Ethnographic and archaeological correspondences with the markings are also discussed.

Table 4.1

Table 4.1. Markings of astronomical cycles on Fajada Butte

	SOLAR					LUNAR	
	Midday				Sunrise	Moonrise	
Petroglyph	Noon	Summer Solstice	Equinox	Winter Solstice	Equinox	Northern Major Standstill	Northern Minor Standstill
Large spiral (three-slab site)	-	X	-	X	X	X	X
Small spiral (three-slab site)	-	*	X	-	-	-	-
East spiral	X	X	X	X	-	-	-
East snake	X	-	X	-	-	-	-
East rectangle	X	X	-	-	-	-	-
West double spiral	X	-	X	-	-	-	-
West rectangle	X	-	-	-	-	-	-

* The absence of light at this location can be taken as a marking (see text)

SUMMARY OF EARLIER FINDINGS At the three-slab site, six markings record solar and lunar positions (Figures 4.1, 4.2, 4- 3). An unusual configuration of three large stone slabs, each about 2 m high, collimates sunlight each day in the late morning and near midday onto two spiral petroglyphs pecked on a cliff face. The streaks of light so formed change noticeably with small changes in the sun's declination. The vertical light/shadow patterns on the petroglyphs thus go through an annual cycle in which the solstices and equinoxes are marked by the intersection of these patterns with the primary features of the spiral forms (Sofaer et al. 1979). This site also marks the northern minor and major extremes of the 18.6- year lunar standstill cycle by a separate pattern of light and shadow at moonrise (Sofaer et al. 1982a). This light and shadow pattern marks events that are unrelated to those of the solar cycle, yet it is also formed on the primary features of the larger spiral by another edge of one of the three slabs that form the midday patterns.

Since the moon can appear throughout the declination range of the sun, all the solar markings listed in Table 4.1 can also be formed at certain times

by the moon. We do not consider most of these to be possible lunar markings owing to a lack of further evidence. The northern minor standstill marking can be formed at certain sunrises away from the solstices and equinoxes; we term it lunar because it occurs as a pair with the northern major standstill marking (which cannot be solar since the moon then exceeds the maximum solar declination). The equinox sunrise marking (Figure 4.1) also indicates the middle of the moon's monthly or 18.6-year declination cycles, in a manner analogous to the markings of the standstill extremes, and is thus possibly also a lunar marking.

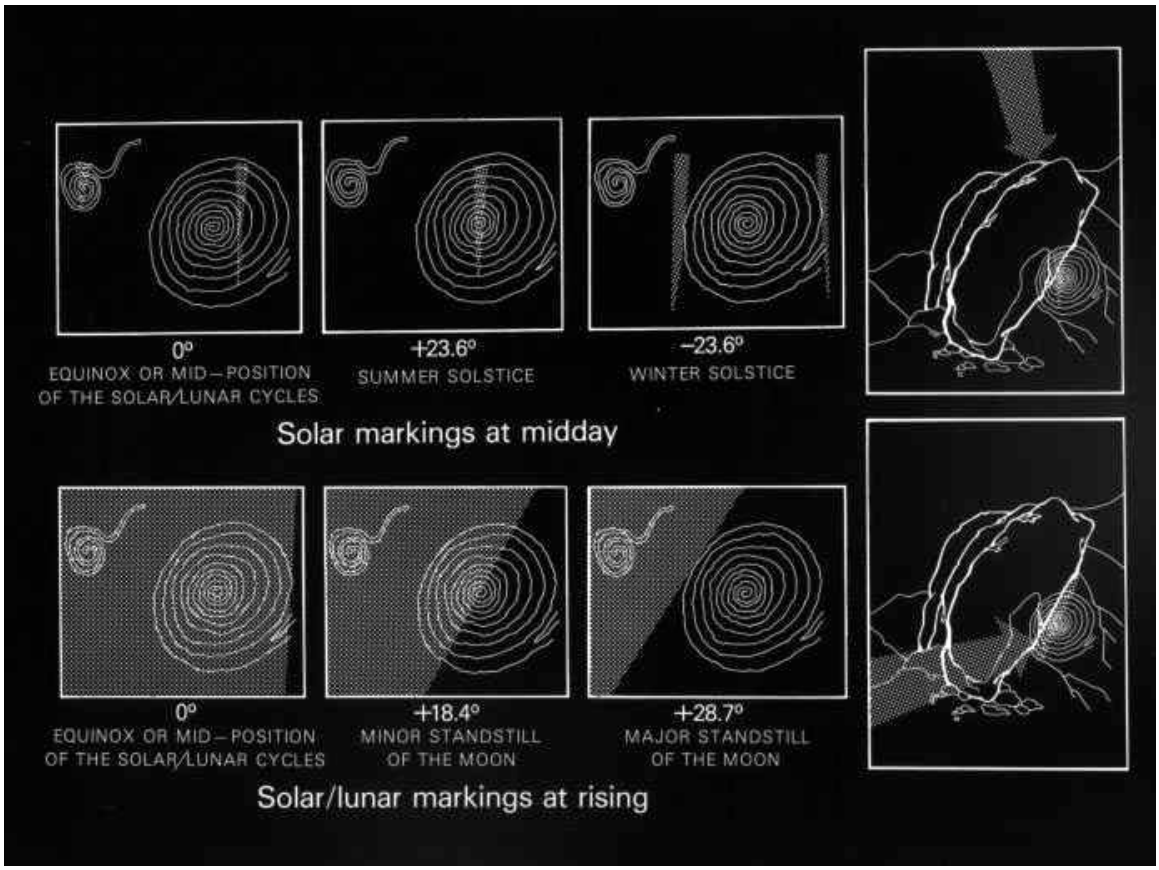

Figure 4.1 The three-slab site. Right: Formation of solar and lunar shadow/light patterns by the three slabs near meridian passage (upper) and at rising (lower). Left: Schematic of the resulting patterns on the spirals at the indicated declinations and seasons (see Sofaer et al. 1979, 1982a for detailed photographs). (Note: an error in an earlier publication [Sofaer et al. 1982a:Fig.4] of rising 0 degrees is corrected here.) Illustration by Pat Kenny, copyright the Solstice Project.

While the solar markings of the three-slab site use the seasonal altitude changes of the late-morning and midday sun to indicate the specific time of the solstices and equinoxes, they do not accurately mark noon. New evidence reveals that two other sites on the butte mark the specific time of noon at the seasonal points. Several features of the three-slab site are shared by the two other sites: spirals, dagger- shaped light patterns, and the repeated use of the same glyph or pair of glyphs at quarter points of the seasons.

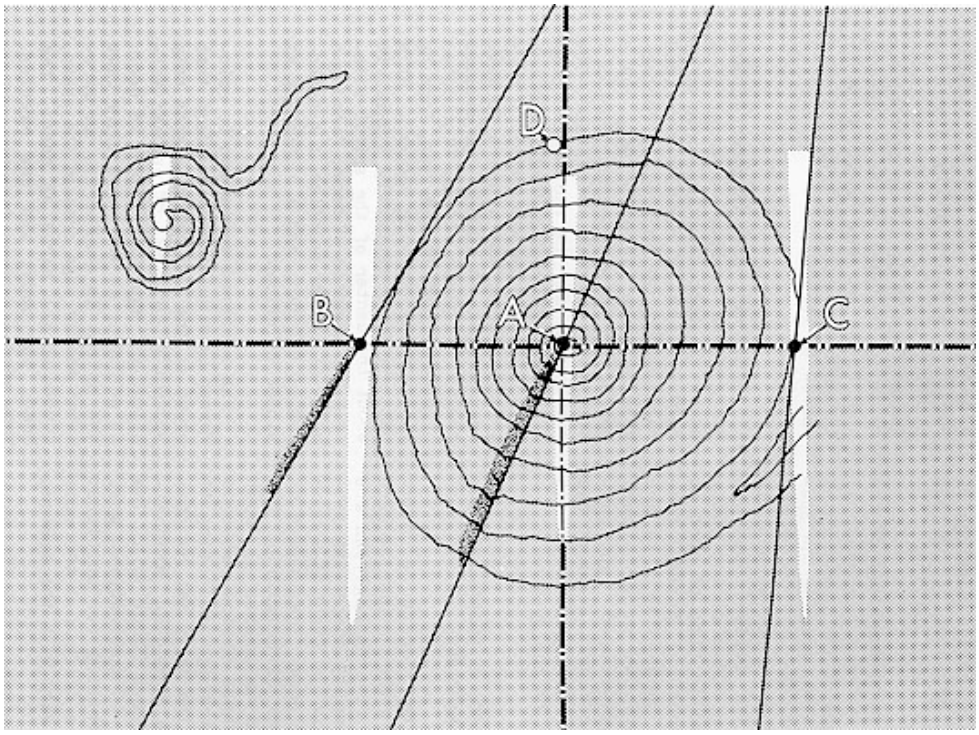

Figure 4.2 The three-slab site. Superposition of the main elements of the six markings (see Figure 4.1) showing the multiple uses of certain key features of the large spiral (A), points of tangency at left and right (B and C), the top (D), and the horizontal and vertical axes. Also shown are the two pecked grooves (see text). Illustration by Pat Kenny, copyright The Solstice Project.

Figure 4.3
Summer solstice light marking on the larger spiral of the three-slab site. The arrows indicate the two pecked grooves with which the lunar shadow patterns are aligned. Photograph by David Brill, copyright 1982, The National Geographic Society

RECENT FINDINGS OF NOON/SEASONAL MARKINGS At two sites located a short distance below the three-slab site (Figure 4.4), five petroglyphs are crossed by visually compelling patterns of shadow and light at a time close to solar noon. The imagery of these patterns distinguishes the solstices and equinoxes in most instances. These shadow patterns form seven markings indicating 11 key points in the daily

and seasonal cycles of the sun- -i.e., midpositions and extremes (Table 4.1). The markings occur in combinations, most of them in striking conjunctions: pairs that are visible at the same site and that vary with the seasons.

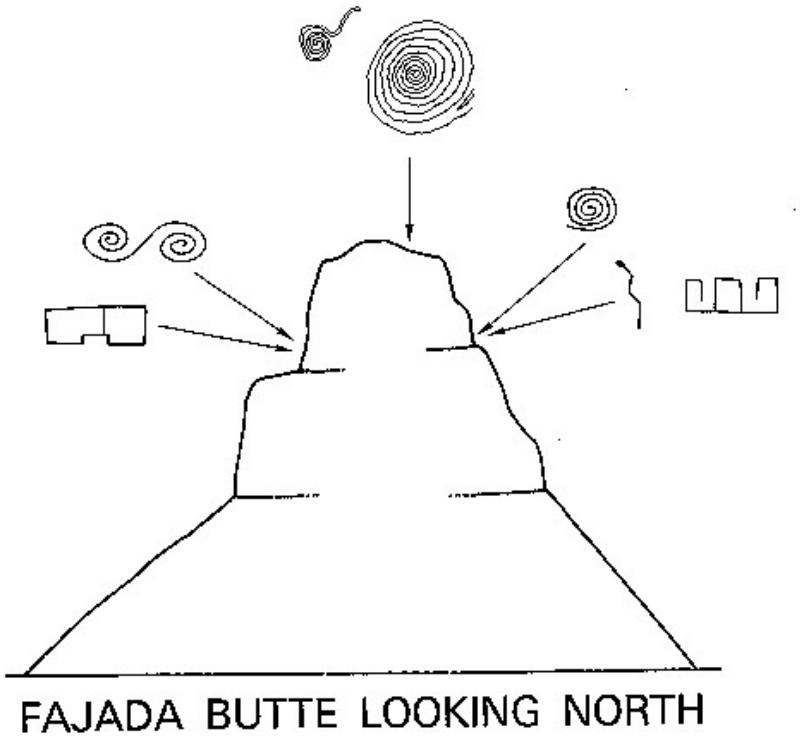

Figure 4.4 Schematic of Fajada Butte (looking north) showing the locations of the petroglyphs at the east, west, and three-slab sites (which are not intervisible). Illustration by Pat Kenny, copyright The Solstice Project.

The shadows that form the noon markings are cast by rock edges of the butte, which is locally very irregular. Since the sun's elevation at meridian passage changes annually from 31 degrees at winter solstice to 78 degrees at summer solstice, the particular edges that cast shadows on the glyphs through the year differ greatly in distance and bearing from them. Some edges are less than a meter away, while others are UP to 30'm distant. During the sun's daily meridian passage, the glyphs at the east site change from fully lit in morning sun to fully shadowed in the afternoon, and those at the west site go through the reverse transition of shadow to light.

At the east site (Figures 4.5 and 4.6), which is located about 25 m below

the butte summit, three adjacent glyphs--a nearly vertical rattlesnake (22 cm long), a rectangular figure (14 cm wide), and a spiral (15 cm wide)--occur 2.0-2.5 m above the current cliff base. The rattlesnake and the rectangular figure are particularly deeply incised. The spiral is pecked within a rectangular area that appears to have been worked. A shadow edge crosses the spiral glyph within 10 minutes of noon throughout the year, forming a seasonally changing pattern. This pattern is momentarily symmetric about the center of the spiral within a few minutes of noon, forming a wedge at summer solstice, a quartering at equinox, and a bisecting at winter solstice.

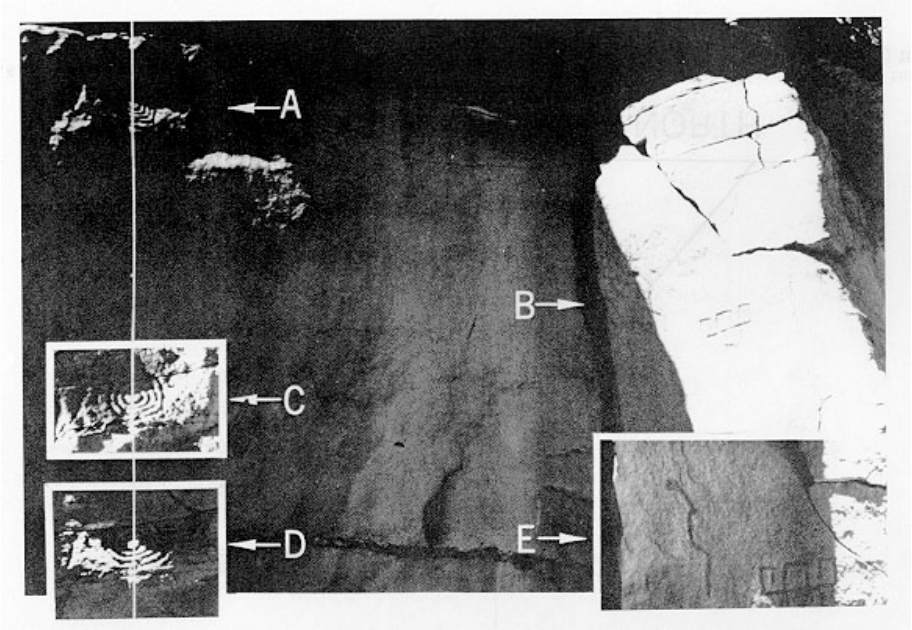

Figure 4.5 East site. Simultaneous markings at equinox on (A) spiral and (B) snake (September 20, 1979, 12:04 pm). Insets: (C) winter solstice marking on spiral (December 20, 1980, 12:00.5 pm), (D and E) summer solstice simultaneous markings on spiral and rectangular figure (June 22, 1978, 12:03 pm). The line through ACD points out the change in the shape of the shadows that centrally mark the spirals at each season around the time of noon. Photograph by A. Sofaer and K. Kernberger, copyright The Solstice Project.

The seasonal variation is reinforced by simultaneous markings that occur on the two nearby glyphs only within a few weeks of summer solstice and equinox, close to noon. At equinox, at the same time that the spiral is quartered, an unrelated shadow edge crosses the snake, touching all parts at once: the head, the body, and the rattles. This shadow pattern deviates noticeably from alignment with the full body of the snake two weeks earlier

or later (Figure 4.6). At summer solstice, at the time that the wedge marks the center of the spiral, the shadow edge is aligned with the centered on astronomically recognizable events. An argument could be made that the petroglyphs were originally placed with no regard for their illumination and that shadows could randomly cross some of them at these times (particularly when the sun and shadows are moving fastest). This argument, however, cannot easily explain the pairings of markings, the multiple use of certain carvings, the repetitions of the alignment of two simple shadow patterns with the basic geometry of the petroglyphs at just the times of astronomical significance, or the consistent use of the spiral motif.

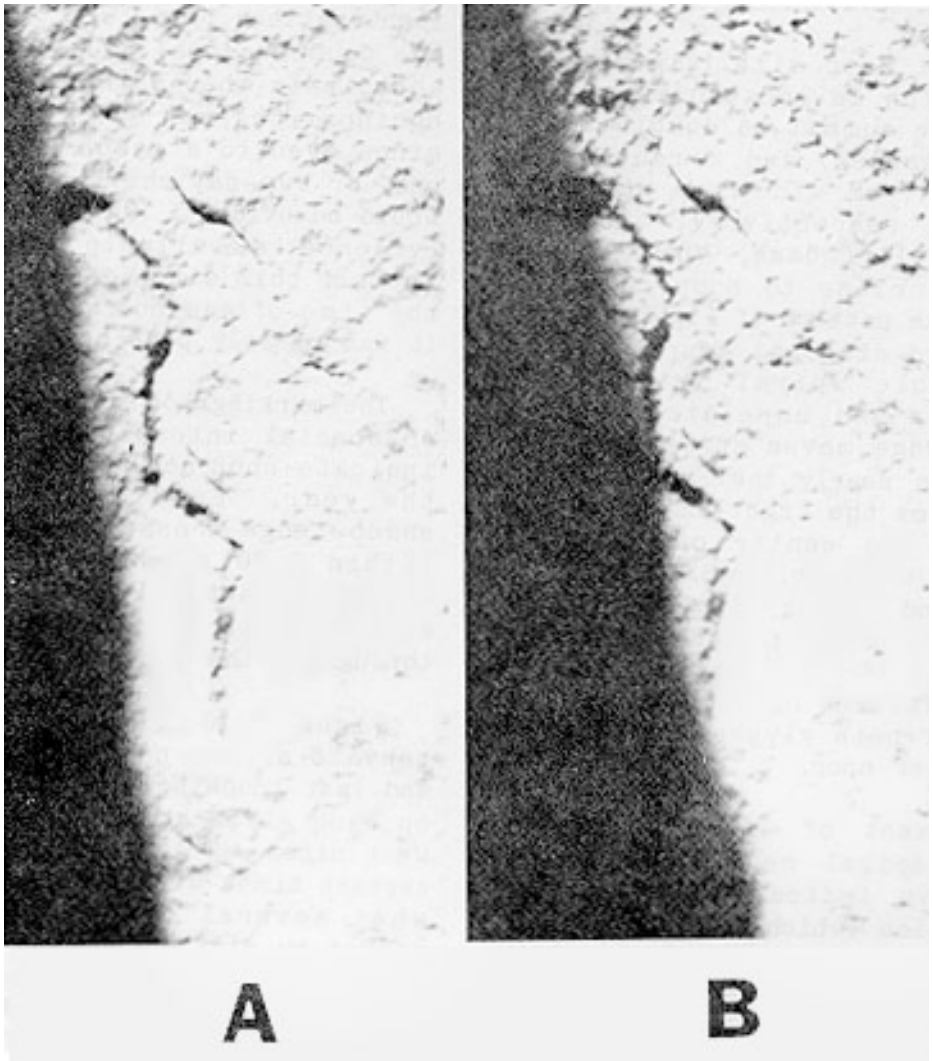

Figure 4.6 East Site. Markings on the snake showing the alignment of the shadow edge with the petroglyph at equinox. (A) 16 days after fall equinox (October 9, 1982, 12:00 m), (B) 3 days before fall equinox (September 20 1979, 2:03.75 pm). [Note: data taken a certain time after (or before) spring equinox are equivalent to data taken the same time before (or after) fall equinox.] Photographs by A. Sofaer, The Solstice Project copyright.

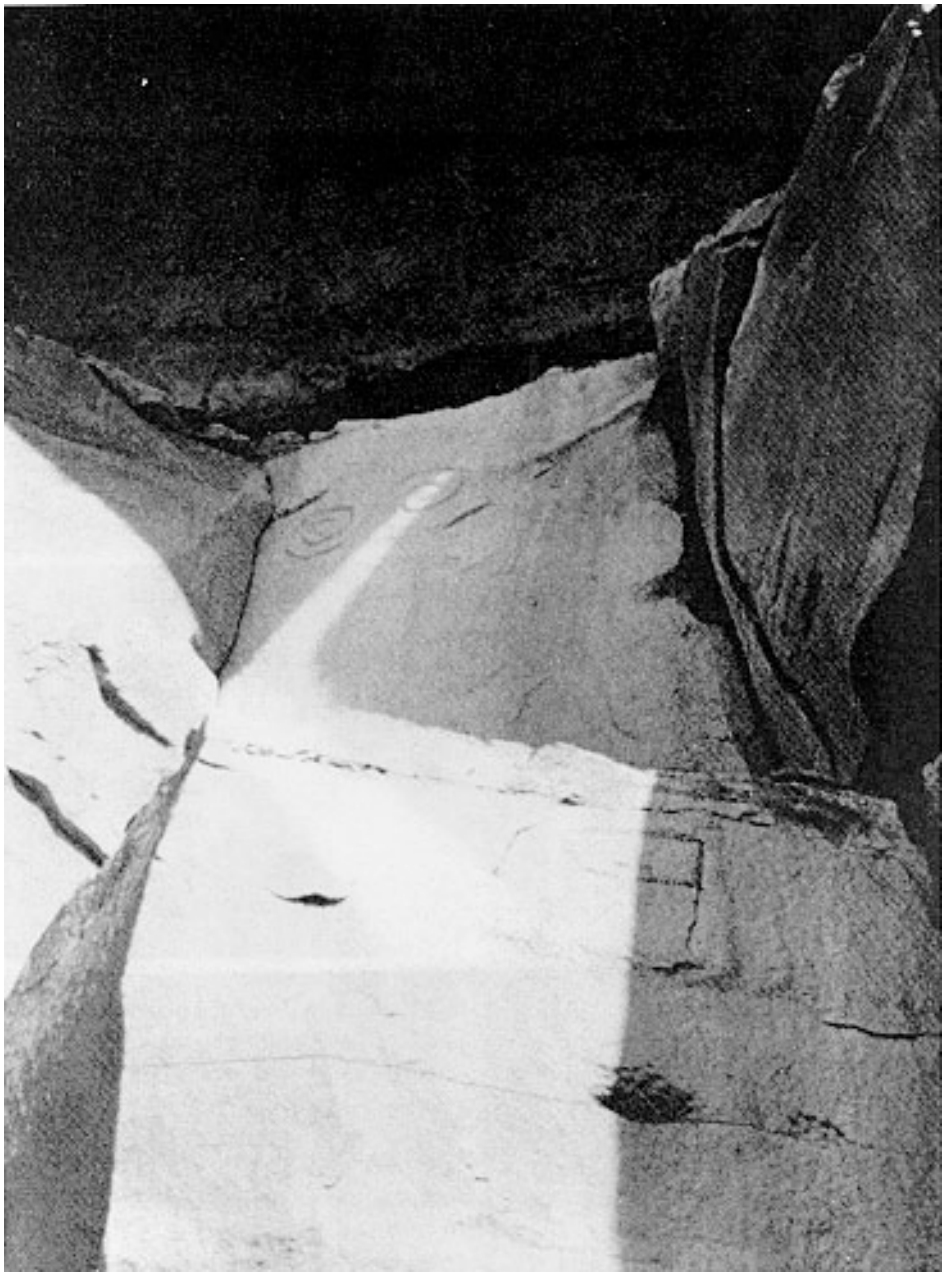

Figure 4.7 West site: 1.5 hours before fall equinox (September 22,1984, 11:50.5 am). The shadow edge moves across the rectangualar glyph (lower right) from left to right, crossing the right edge within three minutes of noon throughout the year. (The outline of this glyph is artificially emphasized in this illustration.) Photograph by Colin Franklin, copyright The Solstice Project.

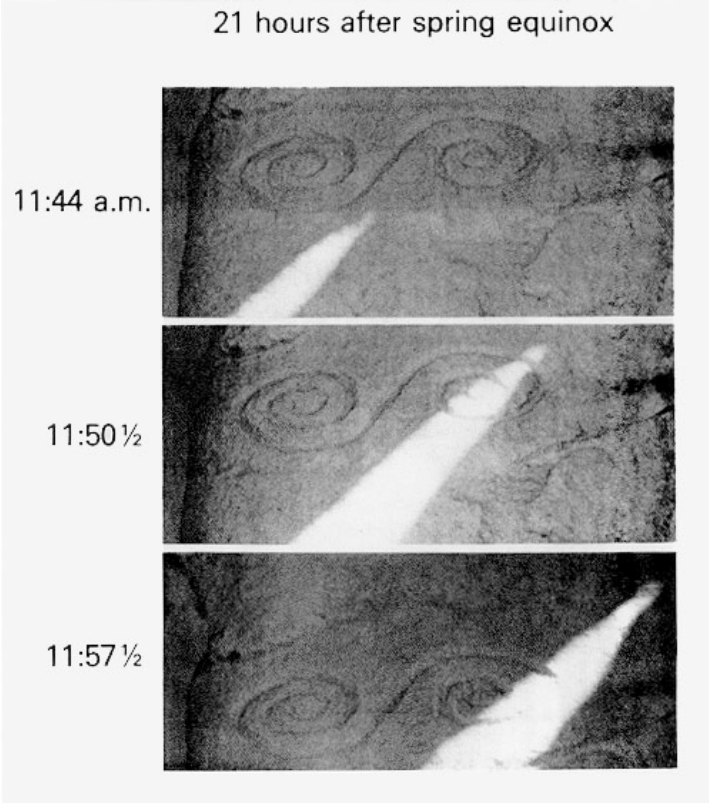

Figure 4.8 West site. Marking on double spiral 21 hours before fall equinox (September 22, 1983, top to bottom:11:44 am, 11:50.5 am, 11:57.5 am). Photographs by Peggy Wier, copyright, The Solstice Project.

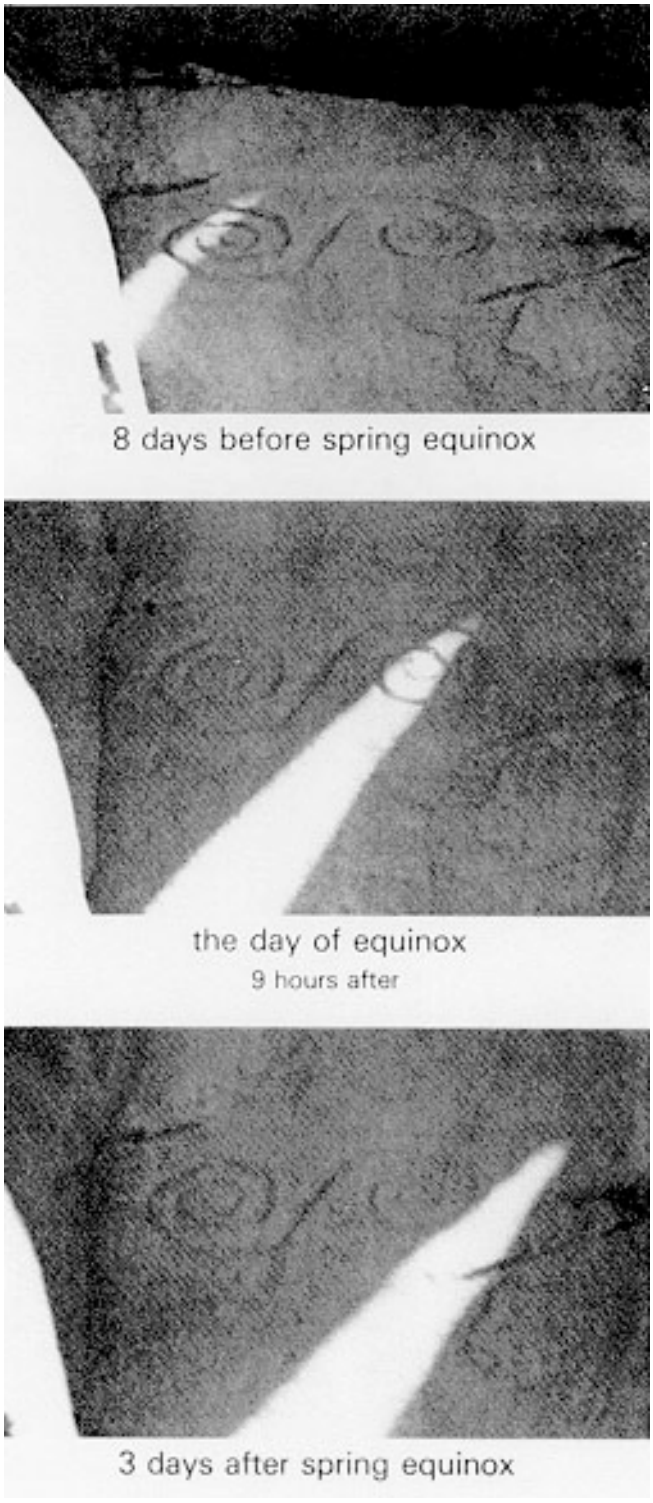

Figure 4.9 West site. Marking on double spiral near equinox. Top: September 30, 1984, 11:42.5 am (8 days after fall equinox). Middle: March 20, 1984, 11:48.5 am (9 hours after spring equinox). Bottom: March 23, 1984, 11:53.5 am (3 days after spring equinox). Photographs by Rolf Sinclair and Michael Marshall, copyright, The Solstice Project.

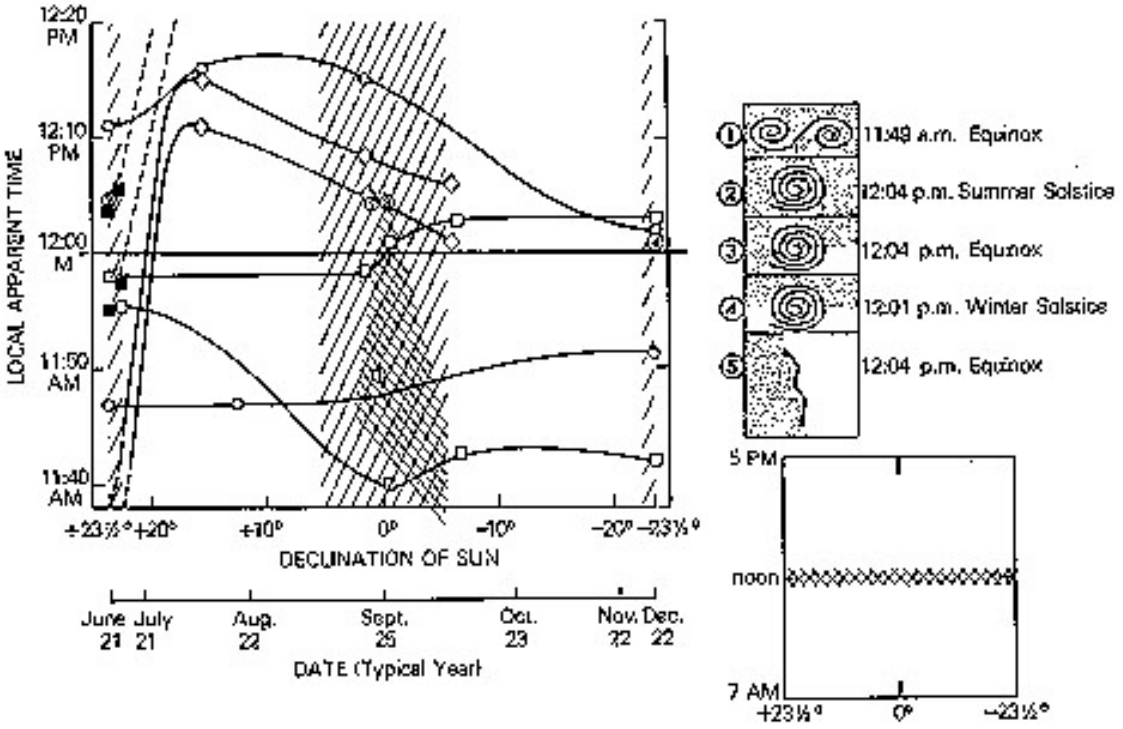

Figure 4.10 Left: Time that shadow first touches a glyph and then just covers it (bottom and top curves of each pair). East site: (black) rectangle, (diamond) snake, (circle) spiral. West site: (white) rectangle, \\\\ range of marking on double spiral. Most points represent multiple observations on adjacent days. //// are the intervals of one month centered on solstices and equinox.

Right: Moments near moon when shadow edges are centrally aligned on certain glyphs. These cases are located by numbers on the graph (left). (1) West site double spiral, March 20, 1984. East site spiral: (2) June 22, 1978; (3) September 20, 1979; (4) December 20, 1978. (5) Snake, September 20, 1979.

Inset: Replotting of graph on left to show the fraction of daylight hours involved in the markings. Illustration by Pat Kenny, copyright The Solstice Project.

FURTHER OBSERVATIONS AND ANALYSIS OF THE THREE-SLAB SITE Lunar Markings New evidence and further analyses of this site support earlier findings that the northern minor and major lunar standstills are marked at moon rising and refute a speculation that the moon's meridian passage is marked.

The large spiral glyph at the three-slab site contains a total of nine and one-half turns, making it unique among the numerous recorded rock art figures in Chaco Canyon. No other spirals recorded in the canyon have so many turns; most have no more than half as many. This fact strengthens the suggestion made earlier (Sofaer et al. 1982a:176) that this number was chosen for the spiral to represent the number of years in the lunar standstill cycle. During the period of 9-10 years between the minor and major standstills, the position of the shadow cast by the most northerly rising moon each year, shifts gradually across the nine and one- half turns of the spiral.

Further examination of the site has disclosed a pecked groove tangential to the large spiral and aligned with the major standstill shadow marking. This groove is similar to the pecked groove aligned with the minor standstill shadow marking (Figure 4.3; Sofaer et al. 1982a:173); these alignments draw attention to the shadow patterns as markings (Figures 4.1, 4.2).

It has been reported (Sofaer et al. 1982a:178) that a standstill could potentially be marked at four moonrises in the years of the extremes. Further analysis shows that the criteria can be met by as many as 13 risings in some of these years (Michael Zeilik, personal communication 1981). This increased frequency would make the marking of the standstills that much easier to conceive of and achieve.

It was speculated earlier that a possible lunar marking could occur at the moon's meridian passage at the declination of the major standstill, when the moon achieves an altitude of about 82 degrees (Sofaer et al. 1979:290). Recent measurements at the site show that an overhanging cliff edge about 10 m above the slabs would block the rays of the moon at this altitude so that no such marking could occur.

It is likely that the ancient Chacoans noticed the 18.6-year lunar cycle in the course of making horizon observations. During the 9-10 years between the standstills there is at Chaco -a 13-degree shift in the extreme northerly and southerly positions of moon risings and settings; this shift is centered around the winter and summer solstice positions. The lunar extreme positions remain close to each standstill limit for a year or more. (The lunar standstill cycle would also be evident as the moon stood higher or lower in the sky in successive years and in the correspondingly changing nocturnal shadow and light patterns in the canyon and around and in the buildings.) In Chaco, the open, flat horizons and the clarity of the desert air of a thousand years ago would have made such observations far from difficult,

especially for a people skilled in surveying. These rhythms of lunar cycles would become quite evident after some years of observation. The creators of the Fajada lunar markings did not necessarily know the standstill cycle to any better accuracy than approximately a year, which is what can be perceived in the movements of the shadows on the large spiral of the three-slab site.

These lunar markings do not necessarily signify that the Chaco culture was predicting lunar eclipses. The 18.6-year cycle is of limited use for this purpose (Chapter 2, this volume). It is worth noting, in this regard, that the modern Pueblo cultures have shown far more interest in cycles than in unusual events (Ellis 1975:60-63). The extremes and midpositions of recurring cycles are themselves significant because they define the limits and order of the cosmos. Recognition of these cycles provides reason enough to commemorate them.

Interrelationships of the Markings and the Assembly of the Three-Slab Site

The three-slab site combines a number of markings in a unique manner. New analyses presented here provide insights into its design and development.

Because of the extensive seasonal altitude changes of the midday and morning sun and the angles of the slabs relative to the cliff face I many different portions of the slabs create different parts of the complex set of markings. Nine separate surfaces are involved in casting the shadows that form six markings of five different declinations. (Note a possible seventh marking: Light is almost entirely blocked by the left and middle slabs at summer solstice [Sofaer et al. 1979:286]; only 10 days later a streak of light is much more evident and then grows through the months to become the bisecting equinox pattern. The effect at summer solstice may have been intended to focus attention solely on the bisecting pattern on the large spiral [Table 4.11]).

Each of the five solar and lunar markings on the large spiral interlocks with the positions of the other markings, in that each of these markings falls on the points and lines of symmetry that define the large spiral (Figure 4.2). There are five points that define the spiral: center, left edge, right edge, top, and bottom. The first four of these points are clearly part of the astronomical patterns. At the extremes and midpositions of the solar and lunar cycles a pattern of shadow and light strikes one and sometimes two of them. Conversely, most of these four points are involved in two markings. To a lesser extent the fifth point, the bottom edge of the spiral,

is also defined by the markings.

At summer solstice the bisecting dagger-shaped pattern is centered simultaneously on both the vertical and horizontal axes of the spiral (Figure 4.1). The minor lunar standstill marking, which is formed by a different rock edge, also crosses the center of the large spiral.

Three shadow markings are tangent to the right and left edges of the large spiral. These are the winter solstice pattern, the lunar major standstill marking, and the lunar/ solar 0-degree declination marking (Figure 4.1). These markings emphasize the right and left edges of the spiral.

The top edge of the large spiral is defined by another aspect of the markings. At summer solstice the dagger-shaped pattern starts as a dot of light on the top turn of the spiral. Only 10 days earlier or later this effect is lost: the first light on the cliff face is 10 cm above the spiral. The bottom edge of the spiral is related to, and hence perhaps defined by, the momentary symmetrical positioning (mentioned above) of the summer solstice light dagger.

It is possible to arrive at some estimates of the degree of sensitivity in the relationships among the rock slabs and the markings. Because of the oblique angle between the slabs and the cliff face, moving the rock edge that casts the moonrise shadows 1 cm to the north or south would create twice this displacement in the positions of the lunar shadows on the spiral and thus discernibly shift the markings. A movement of either the eastern or middle slab by 2-3 cm to the east or west would displace the shadows that form the midday light patterns by that much. The summer solstice pattern is only 2 cm wide, so such a change could block the light entirely. Because each of the slabs forms a part of up to five markings, any such shift would change and probably destroy more than one marking.

A recent report (Newman et al. 1982) presents a scenario in which the rocks could have fallen naturally close to their present positions. The evidence presented in that report does not, however, exclude the possibility of later deliberate movement of the rocks to create the markings. Indications of possible shaping of the slabs and the cliff face where the spirals were pecked are discussed in an earlier publication (Sofaer et al. 1979:289).

Both the interlocking nature of the markings and their sensitivity to the exact positions and shapes of the rock slabs indicate that moving and

shaping of the slabs very likely took place. A few people could have moved and adjusted the slabs in small increments by simple techniques. Such manipulation would have made it easier to attain the interrelated markings. The complexity of the markings suggests that extensive planning, observation, and experimentation were required to achieve them.

The technology for shaping, moving, and using large slabs was well established in Chaco Canyon (Hewett 1936:87-88; Mindeleff 1891:148) and at other places in this cultural area, and many of these slabs are significantly larger than those at the three-slab site (Hayden 1878:429; Mindeleff 1891:58, 147148; Newcomb 1966:137). Some isolated and implanted slabs are also known to have been used in historical times for astronomical purposes (Mindeleff 1891:86, 148).

Caution is appropriate in assessing the degree of artificiality in structures of the Pueblo culture. The natural appearance of many historical and prehistoric sites, especially shrines, conceals elements of construction and may be intended for the purposes of protective secrecy and integration with nature (Alfonso Ortiz, personal communication 1983). Stevenson's description of a shrine at Zia Pueblo illustrates the subtlety of construction at these sites:

"[A] stone slab rested so naturally on the hillside that it had every appearance of having been placed there by other than human agency. The removal of the slab exposed two vases side by side in a shallow cave" (Stevenson 1894:901).

PREHISTORIC PARALLELS TO THE FAJADA MARKINGS Shadow-light formations mark critical times in the solar cycle at many prehistoric sites in the Chaco cultural region and elsewhere in the world. Many share the motifs of the Fajada markings: daggerlike shapes of light, spirals, snakes, and vertical s hafts channeling light patterns at noon.

It is reported that winter solstice is marked when the rising sun's rays are collimated by a window in Pueblo Bonito, a major structure in Chaco Canyon (Reyman 1976). At Hovenweep, in southeastern Utah, an ancient Pueblo community lying just to the northwest of the Chaco region, several light markings are reported (Williamson 1981:68-70). At the solstices and equinoxes light is collimated by portholes to fall in the corners and midpoints of tower structures. At a nearby rock art site two light daggers

bisect two concentric circles and a spiral at summer solstice sunrise. Shadow/ light formations mark these glyphs again at equinox sunrise, at which time they also mark a snakelike form. Recent reports of solstice and equinox markings at an eastern Arizona site near the Chaco region include a great number of bisecting dagger shapes of light on rock art, often on spirals (Chapter 11, this volume). Similar observations are reported in California (Krupp 1983:129-137).

A number of the sites of monumental architecture in Mesoamerica have been noted for their symbolic display of shadow and light (Aveni 1980:284-286). For example, a snake-shaped shadow is formed at equinox along the edge of a Mayan pyramid at Chichen Itza. While this marking is several hundredfold larger than the small snake marked by a shadow on Fajada's east site, the parallel is curious: both sites record equinox with shadow alignments on nearly vertical snakes. At two other sites in Mesoamerica the sun's rays at zenith passage are channeled through vertical shafts to fall as discs of light on the subterranean floors of the structures (Aveni 1980:253-256).

Despite these parallels the Fajada markings remain distinctive in at least three respects: their combining of noon and season, their combining of sun and moon, and their use of rock art and rock slabs in numerous markings clustered on a single, prominent butte. Some of the particular characteristics of the Fajada markings can be understood in the context of historical Pueblo culture.

ETHNOGRAPHIC BACKGROUND Ethnographic accounts of the historical Pueblo cultures describe concepts fundamental to the Pueblo people's world view. These concepts often have significant parallels among findings about prehistoric Pueblo communities.

Some discontinuity between prehistoric and historical Pueblo culture over the intervening 800-1000 years should be expected as a result of environmental and cultural change and migration, including the Spanish entrada in the 1500s (Berry 1982; Cordell 1984; Upham 1984). Certain gaps exist in the ethnographic record of astronomical practices because the Pueblo traditions of secrecy protect all ceremonial activities, including solar and lunar observations.

"Everyone who has worked among Pueblo Indians realizes only too well how averse they are to revealing the details of this manner of life. This attitude on the part of native informants makes it virtually impossible to

secure a complete record of any Pueblo tribe" (Titiev 1944:41).

Fewer than 20 of the 80 or more historical pueblos extant when the Spaniards first came survived to be included in ethnographic studies. Thus, a great deal of information about Pueblo culture is lost or not available. The information that does exist can be used to provide general insights into the significance of prehistoric findings rather than to verify or refute interpretations of specific phenomena.

The historical Pueblos conceived of complementary roles of sun and moon (see references cited in Sofaer et al. 1982a) and used both of them intensively in timing of planting and ceremonial activity. These activities are consistent with the overlapping systems of marking of the solar and lunar cycles at the three-slab site. A recent study (Tedlock 1984:6) describes clearly the complementary roles of sun and moon at Zuni. In timing of the ceremonies for the solstices, the "weak light" of the winter solstice sun is matched with the "bright light" of the full moon, and the "bright light" of the summer solstice sun is matched with the "weak light" of the new moon. The location of the astronomical markings high on the seemingly remote and inaccessible Fajada Butte is in keeping with ethnographic reports of the historical cultures. Buttes, mesas, and mountains are often regarded as sacred places, and shrines are placed on their tops (Boas 1925-1928:39-40; Dumarest 1919:206-207; Ortiz 1969). Some shrines on high sites are used for solstice ceremonies (Kallestewa et al. 1984; Stevenson 1904:109, 149).

Specific features of the complexly organized communities of the prehistoric Pueblos are not found or reported among the historical Pueblos. For example, the elaborately planned multistory architecture and engineered road system of the Chaco culture are not present among the historical Pueblos. Precise equinox markings and cardinal alignments are also not evident. The general period of the equinoxes is of major significance among the Tewa Pueblos, however (Ortiz 1969). Similarly, there are no reports in the ethnographic record of knowledge or markings of the 18.6-year lunar cycle among the historical Pueblo cultures, although there is a possible hint of previous knowledge of this cycle in the cosmogony of one pueblo (Stevenson 1894:71).

There are numerous reports of Pueblo people observing shadow and light patterns cast by upright slabs or by windows and doorways on walls and floors of houses, kivas, and chief's houses to time ceremonial and agrarian activities (Cushing 1979:117; Lange 1959:56, 249; Mindeleff 1891:86, 148).

On ceremonial occasions light might fall on a quartz crystal, a bowl of water, a deer skin, or a kiva bench (Lowie n.d.; Parsons 1929:176; Titiev 1944:105).

Meridian passage is known to be significant in the cosmology of historical Pueblo people and is an integral part of many myths and ceremonies, often involving light markings. One such instance involves the winter solstice noon.

"In the roof of the ceremonial room there is a hole through which at noon the sun shines on a spot on the floor near where the chief stands. . . . All sing the song of "pulling down the sun." . . . This is noon time when for a little while the Sun stands still [Parsons 1932:292-2931].

A similar ritual is practiced at summer solstice (Parsons 1932:297). In keeping with the complementary roles of sun and moon, a report states, "The ritual of bringing down the moon seems to be much the same as that of bringing down the sun," and in this ritual the moon is said to stay "until noon" (Parsons 1932:330). Another study reports that the moon's meridian passage is noted in the timing of Pueblo ceremony (Tedlock 1984:94, 108).

Several other ritual practices and traditions of the Pueblo culture convey the significance of noon as the time when the sun stands still or rests for a short time in the middle of its course through the day (Boas 1925-1928:284; Dumarest 1919:222) and as the time when "he stops for dinner" (Curtis 1926:104; Dumarest 1919:222). The cacique conducts ceremonies in which the sun as a disc is moved across a screen in the arc of its day's course; he orders the sun at the middle of its course to stop for a short while at its noon position (Dumarest 1919:198; Lange 1959:267).

In one pan-Puebloan tradition, the Sun impregnates a virgin and she gives birth to the son(s) of the Sun (Parmentier 1979:609). The impregnation and the birth often occur at noon and sometimes near summer solstice (Benedict 1931:31, 1935:46; Cushing 1931:429, 431, 436; Dumarest 1919:217; Gunn 1917:129; Parsons 1932:393, 1940:55-56; Stephen 1929:11-14). In several versions of this tradition the sun's rays penetrate a window or hatchway of a dwelling and fall on the lap of the maiden. In one version the virgin (yellow woman of the north) stops to rest on her journey to the center of the earth, and the Sun when it is "over the middle of the world" at the "middle of the day" embraces her and she becomes pregnant (Stevenson 1894:44-45). This theme of the impregnating power of the sun's

rays is also evident in the tale of the Sun's son who, as a baby, identifies his father by crawling to the rays of the sun on the kiva floor (Alfonso Ortiz, personal communication 1981; Parsons 1940:56-57).

The use of the rattlesnake as a marked glyph is consistent with the snake's wide ceremonial use and symbolic meaning in historical Pueblo culture, including a close association with the sun. A rattlesnake effigy and a ceremonial staff with the rattles of a rattlesnake indicated on it were found at Pueblo Bonito, which suggest a possible ritual involvement with the rattlesnake as part of the Chaco culture (Pepper 1920:147). Among its many roles, the snake connects the below and above worlds (Tyler 1964:222, 234). At one pueblo it is connected with the zenith and the sun: "Huwaka (Serpent of the Heavens) has a body like a crystal, and it is so brilliant that one's eyes cannot rest upon him; he is very closely allied to the sun" (Stevenson 1894:69). Similarly, at another pueblo a snake with glistening scales is said to fly up to the sun each day and brilliantly reflect the sun's rays (Charles Loloma, a Hopi religious leader, personal communication 1983). Some reports on Pueblo cultures also connect the snake with fertility and equinox (Tyler 1964:228-229, 245-247).

While there is no conclusive information concerning interpretations of the spiral among the historical Pueblos, some Pueblo people have indicated that it conveys the movement of people and clans. In one report, the spiral was described as the movement of people in their search for the center of the earth in the origin story (Roberts 1932:151). The spiral has also been reported to represent the annual movement of the sun (Charles Loloma, personal communication 1983).

ASSOCIATIONS WITH THE PREHISTORIC PUEBLO CULTURE AND CHACO SOCIETY The Fajada markings were probably developed when Pueblo people settled and flourished in the canyon between about AD 900 and 1300. The spiral petroglyph is identified with prehistoric Pueblo people in this region during this period (Schaafsma 1980:135-136; Polly Schaafsma, personal communication 1983).

The achievements of the Chaco culture--elaborate roads, irrigation works, and multistory architecture, all constructed between AD 1000 and 1150--involved highly developed skills of planning, engineering, and surveying (Kincaid 1983; Lekson 1984; Marshall et al. 1979; Powers et al. 1983; Vivian 1974; also see Chapter 1, this volume). During this period the Chaco society used these skills to align accurately several major constructions to the cardinal directions, Primary elements in the symmetric designs of the

isolated great kiva at Casa Rinconada and of one of the central pueblos, Pueblo Bonito, and the initial portion of the North Road are oriented to within 0.25-0.5 degrees of the cardinal points (Sofaer et al. 1986; Stein 1983:8-1; Williamson et al. 1977:208-212; the canyon alignments were confirmed by surveys carried out by the Solstice Project).

The north/south alignments are particularly significant to the phenomenon of noon markings. A likely method of identifying noon is to watch shadows from a vertical object cross the north/south line as the sun crosses the meridian. Knowledge of true north within 0.25 degrees permits knowledge of solar noon at the latitude of Chaco to within less than one minute throughout the year. Similarly, knowledge of east and west to within less than 0.5 degrees allows the determination of the day of equinox. The architectural alignments indicate the Chaco culture's interest in and capability of achieving such accuracy. These alignments may also represent divisions of space that correspond to the markings on Fajada that divide the day and the year.

CONCLUSION Although the astronomical markings and alignments of Chaco incorporate utilitarian calendric information, they do so with a redundancy and accuracy far beyond the practical requirements of time-keeping devices. For example, precise noon markings high on a steep butte serve no apparent useful purpose, nor do the markings of the lunar standstill cycle. The accurate alignments that define the major axes of the central ceremonial structures of the canyon are similarly abstract; for example, the east-west alignments could not have been used to determine (or have been determined by) equinox sunrise/ sunset because of the locally elevated horizons. Similarly, the North Road was built elaborately and accurately in a direction that serves no apparent utilitarian purpose (Sofaer et al. 1986; Stein 1983:8-1). Rather, what may be seen in the alignments and markings is the geometric expression of astronomical concepts and of the culture's cosmology.

Chaco Canyon was the center of an extensive road network and outlier system. Recent analysis indicates that it may have been a center for pilgrimage and ritual (Chapter 1). Fajada Butte may have been a center for the culture's ritual activity related to the sun and the moon.

The clustering of markings found there is so far unique; surveys by the Solstice Project of all the prominent landforms in the Chaco cultural region have disclosed no further astronomical marking sites. When the sun in "the middle of the day" is over "the middle of the earth," the butte's glyphs

commemorate this special moment in time and space. The extremes and midpoints of the solar and lunar cycles are integrated on Fajada. The daily and seasonal passages of the sun are united, as are the sun and moon and the earth and sky in the play of shadow and light on the rock carvings atop Fajada Butte.

ACKNOWLEDGMENTS We are indebted again to Walter Herriman, former superintendent, and the staff of the Chaco Culture National Historic Park for their continued help and cooperation. Peggy Wier, Michael Marshall, Karl Kernberger, James Grant, Colin Franklin, Kenneth Butterfield, and Sheila Rotner helped collect the data, often under adverse conditions. We are grateful to Alfonso Ortiz, Gerald Hawkins, Fred Eggan, Cesare Marino, Rob Blair, Evelyn Newman, Robert Mark, Harold Malde, Fred Nials, and particularly LeRoy Doggett and Stephen McCluskey for a number of helpful conversations. Pat Kenny is to be especially thanked for preparing the illustrations. We again thank our families and friends for their assistance and understanding.

[Note: We understand that an accompanying paper (Chapter 5, this volume) offers other explanations for some of the phenomena discussed here. We have not been given an opportunity to review this alternative analysis or to comment on it.)

REFERENCES CITED

Aveni, Anthony 1980 Skywatchers of Ancient Mexico. University of Texas Press, Austin.

Benedict, Ruth Fulton 1931 Tales of the Cochiti Indians. Bureau of American Ethnology Bulletin 98. Washington, D. C.

1935 Zuni Mythology Columbia University Contributions to Anthropology 21. New York.

Berry, Michael S. 1982 Time, Space and Transition in Anasazi Prehistory University of Utah Press, Salt Lake City.

Boas, Franz 1925- Keresan Texts (2 parts). Publications of the American Ethnological Society 8. New York. 1928

Cordell, Linda S. 1984 Prehistory of the Southwest. Academic Press, New York.

Curtis, Edward S. 1926 The North American Indian 17. The Plimpton Press, Norwood, Massachusetts.

Cushing, Frank M., compiler and translator 1931 Zuni Folk Tales (reprint). Alfred A. Knopf, New York. Originally published in 1901 by G. P. Putnam's Sons, New York. 1979 Zuni (reprint), edited by Jesse Green. University of Nebraska Press, Lincoln. Originally published in 1882 by The Peripatetic Press, Santa Fe.

Dumarest, Noel 1919 Notes on Cochiti, New Mexico. Memoirs of the American Anthropological Association 6(3), edited by Elsie C. Parsons. Lancaster, Pa.

Ellis, Florence H. 1975 A Thousand Years of the Pueblo Sun-Moon-Star Calendar. In Archaeoastronomy in Precolumbian America, edited by A. F. Aveni, pp. 5887. University of Texas Press, Austin.

Gunn, John M. 1917 Schat-chen: History, Traditions and Narratives of the Queres Indians of Laguna and Acoma. Albright and Anderson, Albuquerque.

Hayden, F. V., editor 1878 Tenth Annual Report-Geological and Geographical Survey of the Territories. Washington, D. C.

Hewett, Edgar L. 1936 The Chaco Canyon and Its Monuments. University of New Mexico Press, Albuquerque.

Kallestewa, B., J. Niiha, A. Peywa, A. Pinto, R. Quam, A. Nastacio, and W. Eriacho 1984 Statements by Zuni Religious Leaders on Kolhu wala:wa. Testimony presented to the Select Committee on Indian Affairs, U.S. Senate, April 3, 198-4. Washington, D. C.

Kincaid, Chris, editor 1983 Chaco Roads Project Phase I. Bureau of Land Management, Albuquerque.

Krupp, E. C. 1977 In Search of Ancient Astronomies. Doubleday, Garden City, New York.

1983 Echoes of the Ancient Skies. Harper and Row, New York. Lange, Charles M. 1959 Cochiti: A New Mexico Pueblo, Past and Present. University of Texas Press, Austin.

Lekson, Stephen 1984 Great Pueblo Architecture of Chaco Canyon, New Mexico. National Park Service Publications in Archeology 18B. Albuquerque.

Lowie, R. H. n.d. "Hopi Indian Inside a Kiva." Photo No. 283545. American Museum of Natural History, New York.

Marshall, Michael P., John Stein, Richard Loose, and Judith E. Novotny 1979 Anasazi Communities of the San Juan Basin. Public Service Company of New Mexico, Albuquerque, and New Mexico State Historic Preservation Bureau, Santa Fe.

Mindeleff, Victor 1891 A Study of Pueblo Architecture. In Eighth Annual Report of the Bureau of American Ethnology, 1886-1887 pp. 3-228. Washington, D. C.

Newcomb, F. J. 1966 Navajo Neighbors. University of Oklahoma Press, Norman.

Newman, E. B., R. K. Mark, and R. G. Vivian 1982 Anasazi Solar Marker: The Use of a Natural Rockfall. Science 217: 1036-1038.

Ortiz, Alfonso 1969 The Tewa World: Space, Time, Being, and Becoming in a Pueblo Society. University of Chicago Press, Chicago.

Parmentier, Richard J. 1979 The Pueblo Mythological Triangle: Poseyemu, Montezuma, and Jesus in the Pueblos. In Southwest, edited by Alfonso Ortiz, pp. 609-622. Handbook of North American Indians, Vol. 9. Smithsonian Institution, Washington, D. C.

Parsons, Elsie Clews 1929 The Social Organization of the Tewa of New Mexico. Memoirs of the American Anthropological Association 36. Menasha, Wisconsin. 1932 Isleta, New Mexico. In Forty-Seventh Annual Report of the Bureau of American Ethnology for the Years 1929-1930, pp. 193-446. Washington, D. C. 1940 Taos Tales. Memoirs of the American Folklore Society 34. G. F. Stechert, New York.

Pepper, George M. 1920 Pueblo Bonito. Anthropological Papers of the American Museum of Natural History 27. New York.

Powers, R. P., W. B. Gillespie, and S. H. Lekson 1983 The Outlier Survey. Reports of the Chaco Center 3. National Park Service, Division of

Cultural Research, Albuquerque.

Reyman, Jonathan E. 1976 Astronomy, Architecture, and Adaptation at Pueblo Bonito. Science 193:957-962.

Roberts, F. H. H., Jr. 1932 The Village of the Great Kivas on the Zuni Reservation, New Mexico. Bureau of American Ethnology Bulletin 111. Washington, D.C.

Schaafsma, Polly 1980 Indian Rock Art of the Southwest. University of New Mexico Press, Albuquerque.

Sofaer, A., and J. Crotty 1977 Survey of Rock Art on Fajada Butte. Ms. on file, Chaco Center, University of New Mexico, Albuquerque.

Sofaer, A., M. P. Marshall, and R. M. Sinclair 1986 Cosmographic Expression in the Road System of the Chaco Culture of Northwestern New Mexico. Paper presented at the Second Oxford Conference on Archaeoastronomy, Merida (Yucatan), Mexico.

Sofaer, A., R. M. Sinclair, and L. E. Doggett 1982a Lunar Markings on Fajada Butte. In Archaeoastronomy in the New World, edited by A. Aveni, pp. 169-181. Cambridge University Press, Cambridge and New York.
1982b Noon Markings on Fajada Butte, Chaco Canyon, New Mexico. Bulletin of the American Astronomical Society 14:872.

Sofaer, A. V. Zinser, and R. M. Sinclair 1979 A Unique Solar Marking Construct. Science 206:283-291.

Stein, John R. 1983 Road Corridor Descriptions. In Chaco Roads Project Phase I, edited by C. Kincaid, pp. 8-1 8-15. Bureau of Land Management Albuquerque.

Stephen, A. M. 1929 Hopi Tales. Journal of American Folklore 42:1-72.

Stevenson, Matilda Coxe 1894 The Sia. In Eleventh Annual Report of the Bureau of American Ethnology for the Years 1889-1890, pp. 3-157. Washington, D.C.

1904 The Zuni Indians: Their Mythology, Esoteric Fraternities, and Ceremonies. In Twenty-Third Annual Report of the Bureau of American Ethnology for the Years 1901-1902, pp. 3-634. Washington, D. C.

Tedlock, Barbara 1984 Zuni Sacred Theater. American Indian Quarterly 7(1):93-110.

Titiev, Mischa 1944 Old Oraibi: A Study of the Hopi Indians of Third Mesa. Papers of the Peabody Museum of American Archaeology and Ethnology 22(1). Harvard University, Cambridge, Massachusetts.

Tyler, Hamilton A. 1964 Pueblo Gods and Myths. University of Oklahoma Press, Norman.

Upham, Steadman 1984 Polities and Power--An Economic and Political History of the Western Pueblo. Academic Press, New York.

Vivian, R. Gwinn 1974 Conservation and Diversion: Water-Control Systems in the Anasazi Southwest. In Irrigation's Impact on Society, edited by Theodore Dawning and McGuire Gibson, pp. 95-112. Anthropological Papers of the University of Arizona 25. Tucson.

Williamson, Ray A. 1981 North America: A multiplicity of Astronomies. In Archaeoastronomy in the Americas, edited by R. A. Williamson, pp. 61-80. Ballena Press, Los Altos, California.

Williamson, R. A., H. J. Fisher, and D. O'Flynn 1977 Anasazi Solar Observatories. In Native American Astronomy, edited by A. F. Aveni, pp. 203-217. University of Texas Press, Austin.