# Inter-Site Alignments of Prehistoric Shrines in Chaco Canyon to the Major Lunar

#### Standstill

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## Abstract

In and near Chaco Canyon, New Mexico - the center of monumental ceremonial architecture of the Ancestral Puebloan culture – ancient peoples appear to have intentionally interrelated numerous small masonry structures on alignments to the major standstill moon. The structures include low-walled C-shaped, circular, and cairn configurations located on prominent positions near the tops of three mesas that form the south side of Chaco Canyon and mesas located beyond the canyon, with inter-site alignments spanning 5 to 15 km. Deposits of turquoise and other offerings at these small sites, and their similarity with later Puebloan features, suggest their use as shrines. Geographic Information System analysis of the spatial distribution of these sites – with precise geodetic coordinates determined by the National Oceanic and Atmospheric Administration's National Geodetic Survey – shows clustering of their interrelationships along azimuths to the rising and setting moon at its major standstill. Previous extensive investigation by the Solstice Project, with geodetic support by the National Geodetic Survey, documented the Chacoans' commemoration of the lunar standstill cycle at the Sun Dagger petroglyph site on Fajada Butte and in the wall alignments and inter-building relationships of numerous Chaco Great Houses. Other research documented the relationship of the Chacoan Great House of Chimney Rock, Colorado, to the major lunar standstill. Our findings of the inter-shrine-site

alignments to the major standstill moon provide significant evidence for a hitherto undocumented small scale of lunar astronomical expression of the Chaco culture. The placement of these shrines also appears to possibly have marked a correspondence between the topographic trajectory of Chaco Canyon and the alignment to the moon at its major standstill, suggesting a specific effort to integrate Chaco's land formations with celestial patterns. These preliminary findings are part of a study in progress of cosmographic expressions throughout the Chacoan cultural region.

## **I. Introduction**

In this paper, we present evidence that numerous masonry structures located on elevated topographic positions in and near Chaco Canyon – the monumental center of the Ancestral Puebloan world from 850-1150 AD – were intentionally interrelated on alignments to the major lunar standstill. Previous work by the Solstice Project and others has documented expression of knowledge of the lunar standstill cycle by the ancient Chaco culture at the Sun Dagger petroglyph site (Sofaer et al. 1982; Sofaer and Sinclair 1983) and in the alignments of Chacoan Great Houses (Sofaer 2007; Malville 2004). The twelve sites involved in this study include low-walled, C-shaped, circular, and cairn configurations located on prominent positions near the tops of three mesas that form the south side of Chaco Canyon and mesas located up to 15 km beyond the canyon. The presence of ritual deposits such as turquoise at these sites and formal analogy with features of the descendant Puebloan cultures suggest a primary purpose as shrines. Here, we report on the results of a collaborative effort by the Solstice Project and the National Oceanic and Atmospheric Administration's National Geodetic Survey (NOAA/NGS) to 1) determine the precise geodetic coordinates of these shrine-sites and 2) use Geographic Information System

(GIS) technology to plot this data in real-world space, and, in accompaniment with cluster analysis, to investigate possible astronomical inter-site relationships. Our findings suggest that the ancient Chacoans intentionally positioned twelve shrine-sites considered in this study on five inter-site alignments to the rising and setting positions of the moon at its major standstills. In addition, the placement of these shrine-sites may have also marked a correspondence between the topographical alignment of Chaco Canyon itself and the bearing between the rising of the southern major standstill moon and the setting of the northern major standstill moon.

The Chacoans appear to have placed value on the commemoration of the repeating cycles of the sun and moon – encoding their rise and set azimuths of mid-positions and extremes in architectural features, light markings, and inter-shrine alignments. The resulting spatial order and heirophany of light and shadow events are expressions of the "Science of Time" which – while complexly interrelated – are in marked contrast to ancient astronomical recordings in codices, tablets, or other written documentation.

# II. The Lunar Standstill Cycle

The moon's standstill cycle is longer (18.6 years) and more complex than the sun's annual cycle, but its rhythms and patterns also can be observed in its shifting positions on the horizon, as well as in its relationship to the sun. In its excursions each month, the moon shifts from rising roughly in the northeast to rising roughly in the southeast and from setting roughly in the northwest to setting roughly in the southwest, but a closer look reveals that the envelope of these excursions expands and contracts through the 18.6-year standstill cycle. In the year of the major standstill, this envelope is at its maximum width, and at the latitude of Chaco, the moon rises and sets approximately 7° north and south of the positions of the rising and setting solstice suns. These positions are the farthest to the north and south that the moon ever reaches. In the

year of the minor standstill, nine to ten years later, the envelope is at its minimum width, and the moon rises and sets approximately the same angular distance within the envelope of the rising and setting solstice suns. The progression of the sun and the moon in their cycles can also be quite accurately observed in their changing heights at meridian passage and in the accompanying shifts in shadow patterns. A number of factors, such as parallax and atmospheric refraction, can shift and broaden the range of azimuth where the risings and settings of the solstice suns and the standstill moons appear on the horizon. In addition, judgments in determining a solar or lunar event introduce uncertainties. These judgments involve determining which portion of the object to sight on (e.g., lower-limb, center of body, upper-limb) and what time to sight it in its rising or setting, as well as identifying the exact time of a solstice or a standstill. In this study, we evaluate inter-site shrine alignments for their possible relationships to the moon's major standstill at both the southern major standstill, when it rises in the southeast at  $-53.5^{\circ}$  and sets in the southwest at 53.5°, and the northern major standstill, when it rises in the northeast at 53.5  $^{\circ}$ and sets in the northwest at  $-53.5^{\circ}$ . These standstill rise/set azimuths of  $\pm 53.5^{\circ}$  were computed by standard formulation described in Wood (1978); they were checked against tables computed by Anthony Aveni and provided by one of the anonymous reviewers of this paper.

In this paper, we follow the convention established in Sofaer (2007) in which we use astronomical azimuth values that show the reflective (i.e., close to, but not exactly, symmetrical) relationships of opposing rising and setting azimuths of the solar and lunar events. We use  $53.5^{\circ}$  (east of 0°) for the moon rising at northern major standstill and for the moon setting at southern major standstill, and  $-53.5^{\circ}$  (west of 0°) for the moon rising at southern major standstill and setting at northern major standstill. It should be noted that these calculated azimuth values, which take into account standard adjustments for parallax (+0.95°) and atmospheric refraction at the

horizon (-0.55°), have been averaged between the computed azimuths of the moon's rising and setting at its northern and southern extremes, because the relationships of the rising and setting azimuths of the solstice suns and the minor and major standstill moons are slightly asymmetric in their relationships to 0° and 180° (note: this averaging has the effect of removing the impact on azimuth of the choice of moon's tangency [upper-limb, lower-limb, center of moon] for rise/set events, thereby eliminating the uncertainty accompanying this subjective choice). We do not attempt to specify the direction from which the inter-shrine alignments were conceived (i.e., viewed from the rising or setting direction), and we do not know which directional orientation of alignments would have been more or less significant for the Chacoans. Therefore, it seems especially appropriate to maintain the averaged value, as established in Sofaer (2007).

It is of further note that we do not claim visibility between the shrine-sites as a necessary condition to establish the astronomical significance of their inter-site relationships. Most of the shrines reported here to be interrelated on lunar alignments are not intervisible on these alignments, and in many instances they do not have visibility to the standstill moon at its rise or set major standstill azimuths on the true/sensible horizon. This does not discount the significance or intentionality of their lunar inter-site alignments. Certain inter-building relationships extend the lunar bearings of central buildings on alignments to outlying buildings across topography that blocks visibility (Sofaer 2007). The ability to maintaining an astronomical orientation between non-intervisible points is especially evident in the Chacoan Great North Road, which was aligned on a northern bearing over a distance of 50 km and terminates at a badlands canyon not visible from the roads' origin in Chaco Canyon nor from most positions along its length (Sofaer et al.1989). Preliminary proto-surveying studies and field experiments by the Solstice Project and others demonstrate various methods (e.g., "wiggling in") by which inter-site astronomical

alignments between non-intervisible sites could be established without modern technology within the accuracies of the inter-shrine alignments reported here (Williams et al. unpublished; Lekson 2015:153 fn6 – 154 fn 6,7).

# III. Background Research on the Archaeology and Archaeoastronomy of the Chaco

# Culture

Chaco Canyon, the center of the Ancestral Puebloan world from 850-1150 AD, has received considerable attention for its unprecedented size and complexity in the ancient American Southwest (**Figure 1**). In an attempt to understand Chaco's socio-political



**Figure 1.** Southeast aerial view of Chaco Canyon and shrine-site mesa-tops at right, Great House Pueblo Alto in foreground, and Fajada Butte (location of Sun Dagger site on its summit) in far background. © Adriel Heisey

organization and emergent social hierarchy, scholars have intensively studied the canyon's Great Houses and other monumental architecture which demonstrate massive labor investments despite housing very few inhabitants (Lekson 2006). Currently, Chaco Canyon is widely understood to have been a center of ceremonial and ritual practice for the Ancestral Puebloan people (Kantner 2004; Van Dyke 2007a) rather than playing a redistributive, economic role as posited by previous scholarship (Judge 1989, but see Lekson 2015). Chaco Canyon held influence over a 200,000 sq. km region throughout which 150 to 200 Great Houses emulated the architectural principles of the central canyon (Marshall et al. 1979; Powers et al. 1983). Vast amounts of pottery – as well as more than 200,000 timbers from 70-90 km distance (Toll 2006) – were imported into this inhospitable canyon in an apparently one-way trade relationship in which Chaco seems not to have exported economic goods, but rather religious experience (Renfrew 2001). Various attempts have been made to understand the ideology and practices through which Chaco derived its power and influence, including the positioning of architecture to facilitate visibility towards striking landscape features such as mountain peaks and buttes in a commemoration of "sacred geography" (Van Dyke 2007a); sensory ritual practices that utilized Mesoamerican exotic imports such as cylinder vessels containing cacao, scarlet macaws, copper bells, and elaborate shell jewelry<sup>1</sup> (Weiner 2015); and complex astronomical knowledge communicated through light and shadow hierophanies on petroglyphs (Sofaer and Sinclair 1983) and the alignment of buildings (Sofaer 2007).

Previous extensive investigations by the Solstice Project meticulously documented the Chacoans' considerable knowledge of solar and lunar astronomy. Sofaer and colleagues have demonstrated that at the Sun Dagger petroglyph site on Fajada Butte in Chaco Canyon, three

<sup>&</sup>lt;sup>1</sup> We note that the astronomical knowledge demonstrated by the Chaco culture may have been another form of "exotica" the Chacoans acquired in their dynamic trade/ideological relationship with Mesoamerican cultures (Sofaer 2008:xviii; Tuwaletstiwa 2015:xv; Weiner 2016).

upright slabs of sandstone channel sunlight to produce a series of iconic light markings on a spiral petroglyph on the days of summer solstice, winter solstice, and the equinoxes (**Figure 2**; Sofaer et al. 1979). This same petroglyph also records the lunar standstill cycle with a shadow cast on the spiral by the rising moon at its northern major and minor standstills (**Figure 3**; Sofaer et al. 1982). Subsequent work by the Solstice Project, with survey support of NOAA/NGS, revealed that the major walls of numerous Great Houses in Chaco Canyon and the wider region are aligned to cardinal, solstitial, and lunar standstill azimuths (Sofaer 2007).



Figure 2. Diagram of shadow and light markings on the Sun Dagger petroglyph at key points in the solar and lunar cycles; sun and moon declinations in degrees . © Solstice Project



**Figure 3.** Simulated shadow of moonrise at northern minor lunar standstill at the Sun Dagger site. © Solstice Project

Other evidence for commemoration of lunar astronomy among the Chacoans is documented at the outlying Great House of Chimney Rock in the foothills of the Rocky Mountains near Pagosa Springs, Colorado –135 km from Chaco Canyon. Malville (2004:138-139) demonstrated that the Chimney Rock Great House is positioned to have visibility to two large rock-pillars that perfectly frame the rising moon at its northern major standstill, and tree-ring cut dates confirm construction of the Great House in years of major standstills (AD 1018, AD 1076, and AD 1093)<sup>2</sup> (see also Lekson 2015:195-196). These previous documentations of the Chaco culture's numerous commemorations of the lunar standstill cycle initiated our interest in the inter-site alignments of twelve shrine-sites on elevated positions of the mesas of and near Chaco Canyon (see Sofaer 2007:250n24).

<sup>&</sup>lt;sup>2</sup> It is of interest to note that an additional cut date from Chimney Rock dates to 1011, the year of the minor lunar standstill (Lekson 2015:196).

# IV. Crescents, Cairns, and Circles in Chaco Canyon

While the majority of research has attempted to understand the Chaco culture and their expressions of astronomical knowledge through monumental architecture, small archaeological features such as mesa-top masonry crescents, circles and cairns have been less studied (but see Hayes and Windes 1975; Van Dyke 2007a; Van Dyke et al. 2016). Building on several earlier surveys, the Solstice Project comprehensively documented masonry crescentic, circular, and cairn sites throughout Chaco Canyon and the surrounding landscape in the 1980s with archaeologist Michael Marshall.

#### Site Forms

The stone crescents, circles, and cairns of our study are located on elevated landforms such as mesa cliff edges, butte tops, and mesa summits in and near Chaco Canyon. We wish to emphasize that the sites included in this study are solely those found on prominent elevated positions, and it is their placement at high elevations that unites these various forms of crescents, circles, and cairns. We follow Van Dyke et al. (2016) in categorizing the various Chacoan feature types of crescent, circle, and cairn features as shrines. Crescentic site sizes range from 3.5 m to 18.0 m across the long axis (**Figures 4 & 5**; Marshall and Sofaer 1988:254). The majority of the crescentic structures open towards the east and southeast. Their walls are normally low (50 cm to 1 m tall), and it is apparent these partial enclosures were open and unroofed. While ceramics are sparse at crescentic sites, the wares that are found at them suggest temporal

affiliation with the late Pueblo I through early Pueblo III periods<sup>3</sup> – contemporary with the pinnacle of Chaco Canyon's regional influence (Marshall and Sofaer 1988:264). Marshall and Sofaer (1988:256) note: "the celestial exposure and cycloramic perspective from these elevated locations is clearly a principal factor to be considered in any attempt to decipher the function and significance of crescentic structures." C-shaped and circular low walled masonry features have served as shrines in later Puebloan contexts (Fowles 2009; Harrington 1916; Ortiz 1969; Snead 2004:81-112), suggesting a possible ceremonial association with these Chacoan features.

Also included in this study are a site of interlinked, small walled circular structures (the Poco Site) and three sets of cairns<sup>4</sup> – cylindrical stacks of rocks – also located on elevated locations. The cairns at LA 41088 have been noted for their impressive size (up to 1.5 m in diameter and 1.5 m in height) and Bonito-style masonry known in Chaco buildings (**Figure 6**; Marshall and Sofaer 1988:238-244). Since the mesa tops of Chaco Canyon have been comprehensively surveyed over five decades of archaeological study, it is probable that the sites included in our study are the full set of such elevated sites in and near Chaco Canyon.

#### Site Functions

The presence of ritual deposits such as turquoise and projectile points at these sites (Marshall and Sofaer 1988), their careful masonry construction, and analogy with later Puebloan features suggest their having a primary purpose as shrines. For example, investigations at the crescent located at 29SJ423 [LA 40423] revealed a buried "stone bowl…covered by a large stone slab" that held 146 turquoise beads, found frequently as ritual deposits in burials and sealed in kiva

<sup>&</sup>lt;sup>3</sup> The most common types include Red Mesa Black-on-white, Escavada Black-on-white, Gallup Black-on-white, Chaco-McElmo Black-on-White, and Cibola plain, banded, and corrugated-indented (Marshall and Sofaer 1988:264).

<sup>&</sup>lt;sup>4</sup> Two other small cairn sites on Chacra Mesa (29SJ184 & 29MC463), located approximately 3 km southeast of our study area, have also been brought to our attention (Ruth Van Dyke, personal communication Jan 7, 2016). It is of interest that preliminary examination, using locational information provided by Van Dyke, shows that both appear to be on the inter-site same alignments to the lunar standstill presented in this paper.

niches at other sites throughout Chaco Canyon<sup>5</sup> (Figure 7; Hayes and Windes 1975:149). However, two other hypotheses have been offered to explain the primary function and location of these shrine-like sites: that they served to establish visibility both between themselves and with Chacoan buildings (Hayes and Windes 1975), and that they served as signaling stations for outlying Great Houses in the Chaco region (Van Dyke et al. 2016). It is certainly possible that some of the features of our study – especially those located in the greater landscape beyond Chaco Canyon – may have been involved in intervisibility networks. Most provide dramatic views of the larger landscape of the San Juan Basin and, in some cases, Great Houses or other shrines (Marshall and Sofaer 1988; Van Dyke 2007a). However, several points suggest that most of the features of our study likely did not have signaling as their primary purpose. No evidence for fires or ash pits (i.e., to produce smoke signals or night time light) has been found at these sites (Marshall and Sofaer 1988:255). While it is proposed that the Chacoans may have used selenite – a reflective mineral that is found frequently in the San Juan Basin – to signal from shrines, the potential times for signaling would be curtailed to only the specific times of day when the sun was properly positioned. We note also that the study area of 15 km is of such a limited distance, and the crescentic structures so closely spaced, that messages within the canyon and nearby landscape could be more easily carried by a runner than through smoke signals or signaling with selenite. Despite these observations, the shrine features in and near Chaco Canyon certainly could have played more than one role in Chacoan society. The primary purpose of our analysis is not so much to consider the various proposed uses of these features, however, as to test whether there is a significant underlying pattern to their spatial distribution.

<sup>&</sup>lt;sup>5</sup> LA 40423 also is located next to a Basketmaker III site that predates the Bonito-era occupation of Chaco Canyon, and might be understood as attempting to express a link with real or imagined ancestors (Van Dyke 2007a:142).



Figure 4. Maps of the seven crescentic sites discussed in this paper (Marshall and Sofaer 1988)



Figure 5. Crescentic shrine-site LA 40710 and view to the west. Photo by William Stone, NOAA's National Geodetic Survey



**Figure 6.** One of 12 cairns at shrine-site LA 41088 on cliff edge of West Mesa with view to the west. © Anna Sofaer



Figure 7. Turquoise filled repository at LA 40423 (Mathien 2005: Figure 5.24)

As noted earlier, this analysis includes all the masonry crescents, circles, and cairns known at the time of this study that are positioned on elevated locations within and near Chaco Canyon – i.e. within the 15 km of our study area. Only two of the sites of our study are located on the north mesa of Chaco Canyon: most are located on the mesas forming the south side of Chaco Canyon. There are other known circular stone features, but these are located on significantly lower elevations and exclusively on the mesas forming the north side of Chaco Canyon. Furthermore, the northern mesa stone circles constitute a different class of architectural features, consisting of circles of single stones rather than constructed low walls in distinct contrast to the sites of this study (Windes 1978). Additionally, herraduras – U-shaped/crescent masonry features frequently found in association with Chaco roads and especially in the wider Chaco region (Nials et al. 1987) – are considered a separate feature class and not included in this study, as the features considered here are not associated with roads, include more and different types of votive offerings, and are located in dramatically high topographic positions on the mesas of the central canyon. Again, we wish to emphasize that our study is concerned with shrine-sites located on high elevations in contrast to the other circle and crescent features of the Chaco culture described above.

The features included in this study consist of: seven low-walled, crescentic masonry structures on elevated mesa tops/edges (Peñasco Crescent [LA 40423], South Crest Structure [LA 40706], Werito Crescent [LA 40710], Rinconada Crescent [LA 41207], South Mesa Crescent [LA 42113], Chacra Mesa Crescent [LA 42386], and LA 42859); a set of two stone cairns (Gateway Cairns [LA 51167]) and a series of thirteen cairns (Poco Cairns, [LA 51489]); one circular rock alignment located on top of an isolated mesa approximately 15 km from Chaco Canyon (Pretty Rock [LA 37676]), one circular rock alignment with twelve nearby stone cairns located on the edge of a steep mesa (LA 41088), and a site consisting of three inter-locking circular rock alignments (the Poco Site [LA 41010]).

Site Number	Name	Туре
LA 40423	Peñasco Crescent	Crescent
LA 40706	South Crest Structure	Crescent
LA 40710	Werito Crescent	Crescent
LA 41207	Rinconada Crescent	Crescent
LA 42113	South Mesa Crescent	Crescent
LA 42386	Chacra Mesa Crescent	Crescent
LA 42859	n/a	Crescent

LA 51167	Gateway Cairns	Two Cairns
LA 51489	Poco Cairns/ Chaco North Cairn	Thirteen cairns
	Complex	
LA 37676	Pretty Rock	Circle
	5	
LA 41088	Chaco West Cairn Complex	Circle and twelve cairns
LA 41010	Poco Site	Inter-locking circles

Table 1. Shrine-sites in and near Chaco Canyon of this study.

## V. Methods

The shrine-sites considered in this study were documented by the Solstice Project during archaeological fieldwork in 1984 and 1985 (Marshall and Sofaer 1988). All sites were drawn to scale, their probable cultural-temporal affiliation determined, and their topographic positions and visibility to other landscape features and archaeological sites were described, along with any artifacts present. In subsequent years, precise geodetic coordinates were obtained for eleven of the twelve sites studied here during three fieldwork sessions in 2007, 2009, and 2014. Site coordinates were determined by GPS observations collected with survey-grade equipment and processed through the NOAA/NGS Online Positioning User Service

(http://geodesy.noaa.gov/OPUS/). Three other shrines (Pretty Rock, LA 41088, and the Gateway Cairns) could not be GPS occupied at the time of this study, so their latitude and longitude were obtained using Google Earth. A digital elevation model (DEM) was constructed for the study area by combining enhanced 10 meter grid LiDAR rasters freely available from the New Mexico Resource Geographic Information System website (http://rgis.unm.edu). The DEM and sites locations were then imported into Esri's ArcMap 10.2 for analysis.

Next, a Python script, based on the formulation of the NOAA/NGS geodetic inverse tool (http://geodesy.noaa.gov/TOOLS/Inv\_Fwd/Inv\_Fwd.html), was written to calculate the azimuths between every possible combination of shrine-site pairs and to help determine if a predominant cluster of inter-site azimuths appeared and whether such a cluster might correspond with any significant solar or lunar alignment. The data derived from these calculations were plotted into a histogram using Microsoft Excel for visual analysis.

Line features were then drawn in ArcMap to connect those series of shrines which, based on the inter-site azimuth calculations and histogram analysis, appeared to be positioned on intersite relationships to the major lunar standstill. After first using the NOAA/NGS geodetic inverse tool to compute inter-site azimuths, it was determined that Google Earth's measure tool provided equally accurate calculations of inter-site azimuths; thus, Google Earth was used to determine the azimuths presented in this paper.

### VI. Results

The table of all possible azimuths of alignments between shrine-site pairs, when plotted in a histogram, presents a clear clustering of azimuths near  $-53.5^{\circ}$ , corresponding with the alignment between the rising of the southern major standstill moon and the setting of the northern major standstill moon (**Appendix; Figure 8**). In other words, the most common intersite azimuth is clustered at  $-53.5^{\circ}$ , with fourteen pairs (see pairs bolded in **Appendix**). Five azimuths of inter-site alignments close to  $+/-53.5^{\circ}$  are presented in **Table 2** and are shown plotted onto a GIS map in **Figure 9**. Four of these five azimuths fall within  $1.1^{\circ}$  of the major standstill SE-NW moonrise/set (i.e.,  $-53.5^{\circ}$ ), with the other falling within  $1.6^{\circ}$  of the major with a modern compass, although consistent with certain of the alignments found in Chacoan building orientations (Sofaer 2007:Figure 9.6).



**Figure 8**. Histogram of inter-site alignments of all possible pairings of shrine-sites/cairns and clustering at the major lunar standstill -53.5° azimuth. Plot by Demetrios Matsakis (US Naval Observatory).

Sites Involved in Inter-site Alignment	Calculated Ideal Lunar Azimuth	Measured Geodetic Azimuth of Inter-Site Alignments	Difference between Calculated Ideal Lunar Azimuth and Measured Inter-Site Bearings
<b>A.</b> Pretty Rock (LA 37676) to LA 40423 to LA 42859	-53.5°	-53.6°	0.1°
<b>B.</b> Gateway Cairns (LA 51167) to LA 41088 to LA 42113 to LA 40710	-53.5°	-54.6°	1.1°
<b>C.</b> LA 40423 to LA 40706	-53.5°	-52.6°	0.9°
<b>D.</b> LA 42386 to Isolated Great Kiva 1253 (LA 41253) to LA 41207	-53.5°	-53.5°	0°
<b>E.</b> Isolated Great Kiva Casa Rinconada (LA 814) to the Poco Site (LA 41010), passing through the center of the thirteen Poco Cairns (LA 51489)	53.5°	55.1°	1.6°

**Table 2.** Measured geodetic azimuths of inter-site alignments of crescentic, circle, and cairn sites in Chaco Canyon as compared with calculated ideal lunar azimuths. Sites are listed in order from northwest to

southeast (except alignment E, the NE-SW major standstill alignment, lists sites from southwest to northeast). Alignments A-E are also labeled on map (Figure 9).



**Figure 9.** LiDAR terrain map of Chaco Canyon, with survey-grade GPS positions of crescentic, circle, and cairn sites and proposed inter-site alignments to the major lunar standstill. The letters labeling alignment lines correspond with those provided in Table 2. Popular names are given for sites that are referred to by their popular name throughout the text.

The inter-shrine alignments to the major standstill as proposed here also appear to be associated with another architectural feature type – isolated Great Kivas. Great Kivas are monumental, semi-subterranean circular chambers widely thought to have served a ceremonial and integrative function in ancient Chacoan society, measuring, in the case of Casa Rinconada (LA 814), 19.5m in diameter (**Figure 11**; Van Dyke 2007b). While many Great Kivas occur in the courtyards of Great Houses, four are located in isolated positions unassociated with Great Houses. There are only two isolated Great Kivas in or close to the central Chaco Canyon complex (Van Dyke 2007b:112-116) and both are located on the lunar inter-shrine alignments found in this study. Isolated Great Kiva 1253 (LA 41253) falls on the lunar standstill alignment from the Chacra Mesa Crescents to the Rinconada Crescent at a bearing of -53.5°, and the isolated Great Kiva Casa Rinconada is positioned on the lunar standstill alignment between the Poco Cairns and Poco Site at a bearing of 55.1° (Alignment E, **Figure 9).** It is also of interest that the Peñasco Blanco Great House, which itself is aligned to the rising of the southern major standstill moon, is located on an inter-site alignment with Casa Rinconada – an alignment which parallels most of the inter-shrine alignments discussed in this paper <sup>6</sup> (Sofaer 2007:250n25).

In summary, our preliminary findings using cluster analysis support that crescentic, circular, and cairn sites in and near Chaco Canyon were intentionally positioned on inter-site alignments to the major lunar standstills.

<sup>&</sup>lt;sup>6</sup> In addition, the Great House Una Vida, which itself is aligned to the setting of the southern major standstill moon, is also positioned on an alignment with isolated Great Kiva 1253 at a bearing of 55.3°, paralleling the inter-site alignment of the Poco Site to Casa Rinconada.



**Figure 10**. Shrine-site 1088 and northwest view of setting northern major standstill full moon over Chaco River, January 4, 2007. © William Stone



**Figure 11.** Casa Rinconada, an isolated Great Kiva, located in central Chaco Canyon. Note its position on two major lunar standstill inter-site alignments. It is of interest that its niches of ritual offerings number 28. © Anna Sofaer

### **Discussion and Conclusion**

Cultures across ancient America incorporated cosmological principles in their architecture and settlement patterns (e.g., Ashmore and Sabloff 2002; Aveni 1980; Broda 2015; Pauketat 2013; Snead and Preucel 1991). Recent studies suggest that the ancient inhabitants of Cahokia (Pauketat 2013; Pauketat et al. 2016), the Hopewell culture (Hively and Horn 2013), and the ancient Maya people at Palenque (Mendez et al. 2005) and numerous sites in the Maya Lowlands (Šprajc 2016) oriented their monumental works to the lunar as well as the solar cycles. Relating physical structures to these celestial cycles appears to have been especially important to the Chaco culture, who built multi-storied Great Houses in a pattern of alignments to the cardinal directions and lunar standstill azimuths (Sofaer 2007). A particular interest in lunar astronomy and the standstills is also evidenced among the ancient Chacoans in light and shadow markings at the Sun Dagger petroglyph site (Sofaer et al. 1982; Sofaer and Sinclair 1983), wall and interbuilding alignments of Great Houses (Sofaer 2007), and the positioning of the Chimney Rock Great House in view of two rock spires that frame the major standstill moonrise (Malville 2004). It has been proposed that these astronomical alignments and commemorations were also essential to the timing of ceremonial events and pilgrimage into Chaco Canyon, and that control over this regionally shared calendar was one source of Chaco's power (Judge and Malville 2004; Sofaer 2007). The multiplicity and diversity of these commemorations of lunar astronomy by the Chaco culture offer further support for the intentionality of the lunar inter-shrine-site alignments proposed here.

Certain key numbers associated with the archaeological features involved in the inter-site alignments also appear to underscore their lunar significance. LA 41088 consists of twelve cairns in association with its stone circle, and the Poco Cairns site consists of thirteen cairns – numbers

which correspond closely with the lunar months (12.3) in the solar year. The proposed alignment to the setting of the southern major standstill moon between the Poco Site and Casa Rinconada may also be supported by evidence from the internal features of Casa Rinconada. It has 28 niches – the number of days in the lunar month – evenly positioned around its circular walls<sup>7</sup> (**Figure 11**). Great Kiva niches often held votive deposits of turquoise, shell, or other ideologically charged materials, suggesting their ritual importance in ancient Chacoan society (Van Dyke 2007a:125). We further note that the crescent-shaped back wall of Peñasco Blanco – a great house that is both aligned to the rising of the southern major standstill moon and positioned on that bearing to Casa Rinconada – contains twenty-nine rooms, offering a possible correspondence with the number of days in the lunar cycle.

The symbolic significance of the Chacoans' expressions of solar and lunar astronomy is suggested by parallels in descendant Puebloan cultures.<sup>8</sup> Puebloan people have for centuries commemorated and observed the sun and moon for ritual and calendric purposes (Ellis 1975; McClusky 1977), often at small stone sites similar to those found in the Chaco region (Stevenson 1904:355). Such sites are typically located on elevated positions and at significant distances from the pueblos, and sometimes in the form of small crescentic and circular stone structures.

Phillip Tuwaletstiwa, geodetic scientist and member of the Hopi tribe, offers insight into the significance of the Chacoans' astronomical alignments of its central complex from the perspective of Puebloan traditions. He sees the alignments as "a way to transfer the orderly

<sup>&</sup>lt;sup>7</sup> Astronomer Carl Sagan drew a correspondence between Casa Rinconada's twenty-eight niches and the number of days in the lunar cycle (Sagan 2013:43).

<sup>&</sup>lt;sup>8</sup> While there are many parallels of the Chacoan culture with the traditions of historic and contemporary Puebloan cultures, there are also distinct differences. For instance, the Chacoans' multi-storied Great Houses with up to 400-800 rooms and engineered roads of 9 m width are not present in the historic Pueblos. Similarly, there are no known historic Puebloan alignments to the 18.6 year standstill cycle of the moon. It has been frequently stated that Pueblo people deliberately left Chaco and the knowledge and hierarchy manifested there for a choice to live in a more "reciprocal relationship with Mother Earth" (Ortiz 1992:72 ; interviews in Sofaer 1999). For these reasons, we do not find it necessary or appropriate to refer to ethnographically documented Puebloan practices for validation of the findings of astronomical expression by the Chaco culture.

nature of the cosmos down onto what seems to be chaos that exists here....to then integrate both heaven and earth – and this would be.... viewed typically in Pueblo culture as a center place" (Sofaer 1999). The late anthropologist Alfonso Ortiz of Ohkay Owingeh noted the importance of the moon in Puebloan cosmology (predicting the presence of lunar markings at the Sun Dagger site) because of its complementary relationship with the sun (Alfonso Ortiz, personal communication 1978). He also guided us to the significance of land formation and elevated sites in Puebloan cosmology as essential insight into the cosmographic implications of the findings of this study (Ortiz 1969; Alfonso Ortiz, personal communication 1986).

It is of special interest that the lunar inter-shrine alignments reported here parallel the land formation of Chaco Canyon itself, revealing the canyon's approximate topographic alignment to the major standstill moon. This distinctive correspondence of its land formation with the moon's cycle may have been an important factor in the Chacoans' decision to commemorate the lunar standstill cycle on the tops of the mesas forming the south side of the canyon. Such deliberate acts to integrate land formation with the moon's cycle would have been a profound unification of land and sky.

Numerous instances have been documented of the Chaco people's labor-intensive investments to incorporate land formations in their astronomical alignments as well as in their road alignments. The 50 km Great North Road of the Chaco culture appears to have been built with the purpose of both commemorating the direction north and articulating with special topographic features by terminating at the steepest descent into the badlands of Kutz Canyon (Sofaer et al. 1989). The 57 km South Road ends at towering Hosta Butte, a singularly prominent feature on Chaco Canyon's southern horizon (Sofaer et al. 1989; Marshall 1997). Chimney Rock Great House is set on a narrow, sharp precipice to incorporate the view of the major standstill moon rising between two massive rock pillars (Malville 2004). The Sun Dagger site and other petroglyph light markings are positioned remotely near the top of the 135 m high Fajada Butte (Sofaer et al. 1979; Sofaer and Sinclair 1983). In this context, it would not be surprising that in addition the Chacoans noted and marked the canyon's topographic alignment to the moon's cycle with the placement and inter-relationships of shrines on high sites. We suggest that the Chacoans' inspiration to so extensively commemorate the lunar standstill at Chaco Canyon may have been in part inspired by the canyon's apparently close alignment to the moon's major standstill azimuths. This paper is part of a larger Solstice Project study currently in progress to explore these concepts of Chacoan cosmography.

The Chaco culture's expression of the "Science of Time" appears to commemorate astronomical cycles in ways distinctive from written documentations by other ancient societies. First, the Chacoans marked repeating cycles in azimuth positions rather than in tabulated periodicities or the documentation of historic astronomic events (e.g., the appearance of comets, meteors). Second, they translated temporal celestial cycles into a spatial order on the landscape. Third, they did so through the establishment of a geometric plan in the layout of Chaco Canyon's central complex to the rising and setting of the key positions in the solar and lunar cycles.

In this paper, we have presented evidence that crescentic, circular, and cairn sites in and near Chaco Canyon were intentionally interrelated on alignments to the major lunar standstill. A cluster analysis of all possible inter-site alignments suggests that the spatial distribution of these sites appears to be organized in relation to the setting and rising positions of the moon at major standstill. Our findings of the inter-shrine alignments to the major standstill moon provide significant evidence for a hitherto undocumented small scale of lunar astronomical expression of the Chaco culture, in parallel with its large-scale architectural alignments. Further support is provided by the lunar numbers built into some of the shrine-sites. In future work, we propose to evaluate the significance of the inter-site alignments of crescentic, circular, and cairn shrines in the larger context of the Chacoans' cosmography and ritual landscapes (e.g. Marshall 1997; Sofaer 2007; Sofaer et al. 1989; Stein and Lekson 1992; Van Dyke 2007a). Such research has the potential to further illuminate the many ways this ancient culture integrated astronomy, the natural landscape, and architecture in cosmographic expressions across a vast region of the American Southwest.

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# Appendix

A list of all inter-site azimuths (reckoned from north at  $0^{\circ}$  and expressed as  $\pm$  degree bearings east/west of  $0^{\circ}$  that acknowledge the reflective [i.e., close to, but not exactly, symmetrical] relationships of the rising and setting azimuths of northern and southern major lunar standstill positions) between the twelve sites included in this study, with the cluster within  $\pm 1.5^{\circ}$  of the major standstill azimuth (-53.5°) bolded.

6.94	-18.47	-54.61
8.85	-19.03	-54.75
13.83	-19.13	-55.37
17.22	-21.11	-56.73
18.68	-23.51	-58.06
21.37	-24.06	-58.84
34.76	-31.78	-58.86
36.45	-36.87	-59.96
37.48	-41.29	-60.20
47.01	-46.00	-60.98
48.98	-46.70	-61.18
49.40	-46.98	-61.68
89.72	-47.93	-61.71
22.67	-48.39	-64.01
38.66	-48.51	-64.89
46.42	-51.16	-65.06
60.53	-51.20	-66.55
61.23	-51.68	-66.89
61.84	-52.13	-67.38
62.77	-52.15	-70.41
79.33	-52.54	-70.45
82.78	-52.89	-70.94
84.53	-53.19	-73.70
85.37	-53.35	-73.95
87.62	-53.42	-74.57
-8.77	-53.43	-75.53
-13.60	-53.54	-77.74
-13.70	-53.77	-77.77
-18.37	-53.87	-82.66
-18.46	-54.04	-86.26
		-87.23