Journal of Astronomical History and Heritage, 19(1), 3–17 (2015).

PICTOGRAPHS AT PAINT ROCK, TEXAS: EXPLORING THE HORIZON ASTRONOMY AND CULTURAL INTENT

Gordon L. Houston
Ilia State University, P. O. Box 841352, Houston, Texas 77284, USA.
Email: gordon.houston.1@iliauni.edu.ge

and

Irakli Simonia
Ilia State University, Cholokashvili Str; 3/5, Tbilisi 0162, Georgia.
Email: irakli.simonia@iliauni.edu.ge

Abstract: The Paint Rock pictograph site on the Campbell Ranch near Paint Rock, Texas, contains over 1500 pictographs. A monument erected on the bluff by the State of Texas indicates it is the largest pictograph site in Texas. Twelve active solar markers have been identified at the site, and with additional observations, possibly more will be discovered. These solar interactions at the Paint Rock site make it one of the most interesting archaeoastronomical sites in Texas. An initial study of Paint Rock suggested that the native cultures did not use the horizon for calendrical purposes, as both the eastern and western horizon are flat and almost featureless. As a result, these characteristics led to our primary research question: How did the cultures so accurately place these rock art glyphs so that they could interact with light and shadow on important solar points of the year? We will detail our search for the place of observation, and the discovery of a significant horizon notch. Our observations support the discovery of the potential horizon calendar and show how it was tied to the material culture. These data answer the primary research question. Interpretation of rock art is one of the great challenges of cognitive archaeology. The existence of solar markers in rock art can provide the most rigorous interpretation and evidence of intentionality in rock art. We detail the accuracy and precision of two of the most significant solar markers. Finally, we propose a tool to evaluate rock art solar markers called the 'Solar Marker Matrix of Intentionality'. This Matrix can be used to help identify potential solar markers and evaluate the strength of identified solar markers. Use of this tool will lead to a database for future statistical analysis.

Keywords: Archaeoastronomy; solar markers; rock art; landscape archaeology; cognitive archaeology

1 PAINT ROCK PICTOGRAPHS AND TEXAS ROCK ART

Paint Rock on the Campbell Ranch is the most archaeoastronomical-impressive rock art site in Texas. Other pictograph sites reported to have solar interactions with rock art only involve one glyph, but at Paint Rock there are no less than twelve pictographs with potential solar interactions that would qualify as 'solar markers' (a proposed definition will be provided later in the narrative). The largest pictograph site in Texas, Paint Rock, is reported to have 1,500 pictographs. A monument erected by the State of Texas provides these facts. The site is a cliff running NNW-ESE for more than a kilometer, consisting of broken layers of limestone (Figure 1). The site is approximately 175 meters north of the Concho River, and lies at the southern end of the Great Plains, surrounded by elements of the Texas ecoregion called the Edwards Plateau. The pictographs run for 300 meters on the cliff's largest outcrop section, which has the most exposed layers for the rock art (see Figure 2, which shows a site map of the locality). There are several locations along this section of the cliff that provide protection from the weather, room for habitation, and a potential place from which to observe the Sun along the horizon. Based on these characteristics and the number of solar markers, it is plausible that Paint Rock was a major Sun-watching station.

The site has a primary archaeological trinomial site number of 41CC1.[1] The only formal archaeological survey of the site was published by Turpin et al. (2002), which states that there is evidence of cultural use extending to the Middle Archaic Period. The Middle Archaic is an archaeological period that runs from approximately

Figure 1: A panoramic view of the cliff at Paint Rock, Texas on the Campbell Ranch. This view was taken from the center of the 300-meter span of the cliff that contains the pictographs. The cliff extends for approximately 1,200 meters with an orientation of northwest to southeast. This panorama extends approximately from 260° west to 130° southeast (photograph: Gordon L. Houston).

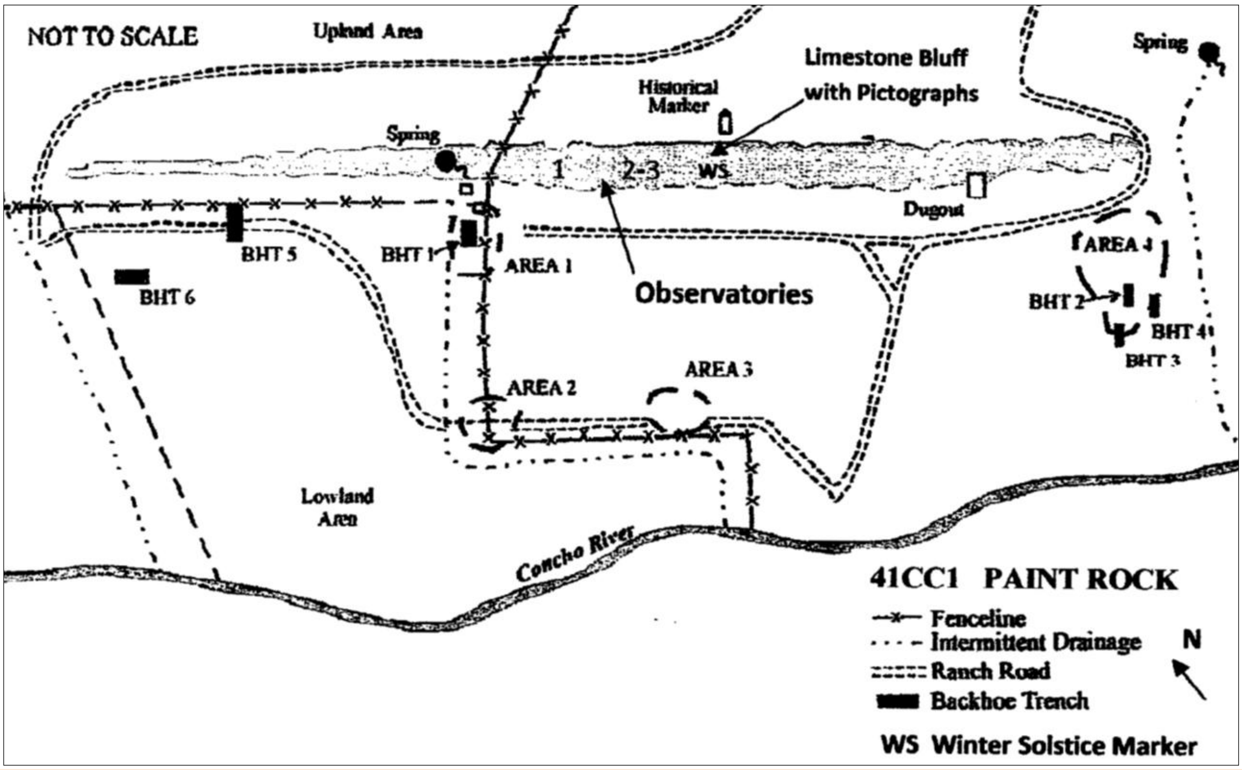


Figure 2: Site map of the Paint Rock Pictographs 41CC1. Numbers 1, 2, 3 in the shaded area of the bluff, indicate the approximate location of the three potential observation sites discussed in the narrative. WS is the location of the winter solstice solar marker (adapted from Turpin et al. (2002), map: Gordon L. Houston).

4000 to 2000 BCE (Pertulla, 2004). Turpin et. al. (2002) state that the pictographs have been known for 125 years, and to archeologists for at least 70 years. Texas artist, Forrest Kirkland, and his wife visited Paint Rock in 1934, which ignited his passion for rock art, and he spent the rest of his life painting rock art sites in Texas. These paintings became the basis of the book written by Kirkland and Newcomb (1967), with pages 146–158 dedicated to the Paint Rock site. This site also is mentioned prominently in the book by A.T. Jackson (1938).

The topography of Paint Rock lends itself to many advantages for cultural adaptation. The cliff runs NNW to ESE, and there are several areas that provide protection from the weather, especially the harsh winter winds and cold fronts. In the summer, the breeze is predominately from the SE, and the terrace provides protection from the heat. The site has multiple sources of natural water, one being the Concho River, and the other being springs that are located at each end of the most prominent portion of the cliff. The archaeological survey by Turpin et al. (2002) indicated that the largest habitation sites were near these springs. The bend in the river and the topography of this location have allowed a deep alluvial plain to develop along the cliff and across the river, making it a fertile agricultural location. At this location there is exposed bedrock that provides a natural ford across the Concho River. As a result, many paths, trails, and roadways in the landscape have converged on this location since Middle Archaic times. Hence, the site has been considered mainly as a nomadic site, and these characteristics made it a cultural cross-roads, enabling cultural diffusion.

General Robert E. Lee, the commander of the Confederate Army in the American Civil War, camped near the western spring on 16–17 July 1856 (Ashmore, 2010). The historical military road between US Army western forts, Ft. Mason and Ft. Chadbourne crosses the river at this site, as illustrated in a map by Rister (1946). The pictographs have been partially destroyed by what is now considered historic graffiti. The oldest graffiti relates to Lee's encampment, but much of it dates to the second half of the nineteenth century.

The Paint Rock pictographs were most likely produced during the Toyah Phase, a Texas archaeological period dating from CE 1300 to 1750 (Black, 1986). Evidence of this is Toyah Phase pottery found in association with hematite (iron oxide), the primary pigment of the monochrome pictographs (Turpin et al., 2002). There are many methods of painting pictographs, and these contrast with rock art known as petroglyphs, which are pecked or incised into the rock surface (Grant, 1967). The pictographs at Paint Rock have no analogues in Texas (Kirkland and Newcomb, 1967). Paint Rock's limestone exposures limit the size of the rock art, with the thickest strata being approximately 1 meter high. Many of the rock art sites recorded by Kirkland and Newcomb (ibid.) and by Jackson (1938) are small rock shelter sites. These sites are limited in size and scope, with the rock shelter being the delimiting factor. An exception to the size analogy is the area known as the Pecos River, an extremely rich rock art region, with more than 200 documented rock art sites.

The Lower Pecos River rock art region lies 300 km southwest of Paint Rock. It is an area bordered on the south by the Rio Grande River, and intersected by two tributary rivers from the north. The western river is the Pecos River, and the eastern river is the Devils River (Boyd, 1996; 2004; Shafer, 1977). The rock art in the Lower Pecos River dates to as early as 4500 BCE and as recent as CE 1280 (ibid.). The latest date is approximately equal to that of the earliest reported Paint Rock pictographs. Existing in large rock shelters, the Pecos River rock art motifs were painted on large parietal walls, allowing anthropomorphic figures to be as much as 8 feet in height (Boyd, 2004). Kirkland and Newcomb (1967) describe the Pecos River rock art as having no other comparison. On the basis of the descriptions published in books and research papers there are no confirmed rock art solar markers in the Pecos River area.

Our primary research question deals with discovering how the prehistoric occupants of Paint Rock were able to identify specific solar points and scribe the various rock art panels with such accuracy. Hence our interest in the use of the horizon for calendrical purposes. A secondary consideration is to verify the interactions that are reported to have occurred at major solar points. In this paper, we will discuss our method that was used in searching for the horizon astronomy, and we will highlight the precise positioning of the two main pictographs. But first, we will start by discussing solar markers in rock art, and finally, we will provide a preliminary 'intentionality matrix' to help identify solar markers in rock art.

2 SOLAR MARKERS IN ROCK ART

Rock art solar markers are one of the more objective of all material remains of Sun-watching, since they are open to rigorous interpretation. A review of the literature does not provide a concise definition of a 'solar marker', so on the basis of our study of the Paint Rock pictographs and archival records of other sites we propose the following definition:

> A 'solar marker' is an intentional rock art glyph or panel which records a significant component of the astronomical knowledge of a culture, preserving the interactions of light and shadows on the rock art at specific solar points.

The term 'solar point' defines the point on the ecliptic and the celestial sphere of the Sun on significant calendrical days and is referenced by the coordinate systems of right acension and declination, or altitude and azimuth. The visible signs of the solar points are reflected in the travel of the Sun along the horizon. The solar marker acts as a mnemonic device, and this knowledge is passed from one generation to the next. According to McCluskey (1993), in the absence of writing, this transfer of knowledge is encoded in various mechanisms to preserve the knowledge. The use of solar markers in rock art is one such mechanism.

The number of interactive rock art sites that have been identified over the years builds a *prima facie* case for the recording of astronomical knowledge. Johnson (1992) states he has documented more than 300 panels in northeast Utah. Preston and Preston (2005) claim to have identified 109 examples at 46 sites in the 'four corners region', excluding Colorado, while Fountain (2005) reports 219 observations at 45 sites. These and many other examples led Schaefer (2006: 52) to state:

> With other identical examples, the probability of the null hypothesis ("random" coincidences of shadow and [light on] petroglyphs) become very small, and we are forced into the realization that the only way to make all those spirals work on the solstice is if the designers did this intentionally.

The recording of astronomical knowledge represents a widespread pattern of behavior by prehistoric cultures. The operations of the solar markers are so precise in many cases that this would rule out a coincidental or accidental interaction hypothesis. In virtually all cases, the shift of a glyph or panel by as little as a centimeter would negate the claimed astronomical inference by eliminating the interaction with the focal point of the glyph.

Rock art solar markers are a unique form of the archaeological record in that they represent an intentional act by tying the landscape to the celestial sphere. Rock art is considered to be a form of writing (Jackson, 1938; Kirkland and Newcomb,1967; Robinson, 2001), while rock art tally marks are thought to be a rudimentary form of arithmetic (Closs, 1986b; Jackson, 1938; Murray, 1986). Research on astronomical ties to rock art has two significant advantages over other archaeological investigations. Firstly, rock art remains *in situ*, and is essentially unchanged by site formation processes (Murray, 1998). Personal conversations with the Campbells about the geological conditions of the site confirm this statement. Geologists have stated the site is stable and has been so for longer than the oldest pictographs, and as the top layer

Figure 3: The equinox panel at Paint Rock. This photo was taken on the day of the autumnal equinox, 22 September 2012 at 15:39:04 pm CST/ 20:39:04 UTC. The sun line advances across the pictograph on the equinoxes, aligning with the feet of the funeral figure on the upper right, making it appear to be walking up the line. On the day before and after, the sun line does not touch both feet at the same time: see Figures 4 and 5 (photograph: Gordon L. Houston).

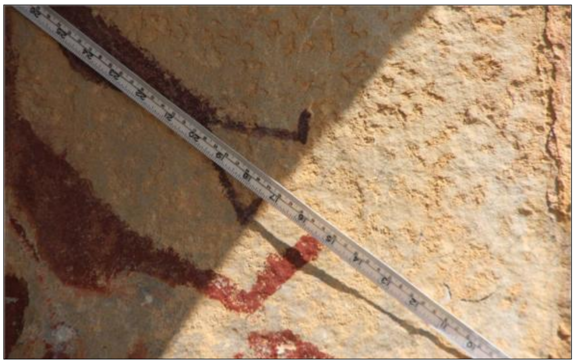


Figure 4: This equinox panel photo was taken 21 September 2012 at 15:38:16 CST, 20:38:16 UTC, the day before the equinox. The sun line has reached the rear foot but is clearly away from the upper heal of the figure; see Figure 5, taken the day after the equinox for comparison (photograph: Gordon L. Houston).

Figure 5: The equinox panel solar interaction taken the day after the equinox on 23 September 2013, at 15:34:33 CST, 20:34:33 UTC. Although taken about 2 minutes prior to the time of the photograph taken on the day of the equinox, the sun line is already up on the ankle of the lower foot (photograph: Gordon L. Houston).

Figure 6: The winter solstice marker at Paint Rock, Texas. This sequence is just over 20 minutes of the interaction. Solar noon is at 12:38 CDT obtained by U.S Naval Observatory Almanac program MICA (2005). The time sequence from left to right in Central Standard Time is 12:27:40; 12:38:04; 12:48:00 (photograph: Gordon L. Houston).

monochrome pictographs are only 400–600 years old, weathering along the shadow-casting edges in that time frame would not significantly alter the interaction, if any. Secondly, we can observe the celestial sphere and the rising and setting of the Sun almost exactly as prehistoric cultures observed it. The rock art glyph and the solar interactions displayed are the whole archaeological record for a particular glyph or panel. It is a record of part of the astronomical knowledge of a culture. Hence, the recording of astronomical knowledge in rock art by prehistoric cultures provides the most rigorous interpretation and evidence of the artisan’s intentions. The study of solar markers has evolved from the necessity of an *a posteriori* requirement to *a priori* in status. In the next section, two of the most significant solar markers at Paint Rock, the Winter Solstice Marker and the Equinox marker, will be examined.

3 EQUINOX AND WINTER SOLSTICE SOLAR MARKERS AT PAINT ROCK

The first solar marker was noticed by Kay Campbell in 1996 while giving a tour of the pictographs during the spring. She noticed that a Sun line happened to line up with the feet of a funeral figure interpreted to be walking up the Sun line to heaven. This interaction is shown in Figure 3 and has become known as the ‘Equinox panel’. Later that same year, she noticed a dagger of sunlight interacting with a shield-shaped glyph on the winter solstice. This interaction is shown in Figure 6, and has come to be known as the ‘Winter Solstice marker’ (see Yeates and Campbell, 2002).

These were the first two solar markers discovered at Paint Rock. The Winter Solstice Marker was observed by Dr R. Robert Robbins, and he found the interaction to culminate within minutes of solar noon, adjusting for the equation of time. He gave an oral report of his observations of the site at the 1999 American Astronomical Society Meeting (Robbins 1998). This report also was the basis for the first two research questions.

The photograph of the Equinox panel shown in Figure 3 was taken on the day of the autumnal equinox, 22 September 2012, at 15:39:04 pm CST or 20:39:04 UTC, and shows the precise alignment of the Sun line relative to the bottom of the feet of the funeral figure. At first glance, one could say that this is purely coincidental and that the alignment occurs at a random time in the afternoon. However, close empirical observation of the interaction on the day before and the day after, at the same time of day, provides the evidence that this was an intentional act. Photographs taken the day before and the day after the equinox (Figures 4 and 5) show the Sun line interaction.

These photographs show how the rapid movement of the Sun along the horizon changes the angle of the Sun line, so there is no precise alignment on these days. On the day before the equinox, the Sun line reaches the lower rear foot before touching the upper leading foot shown in Figure 4. On the day after the equinox, Figure 5, the Sun line is across the ankle of the lower foot and just touching the heel of the upper foot. Hence, the exact alignment of the Sun line touching the bottom of both feet simultaneously only occurs on the day of the equinox. The precision of this alignment marks the day of the equinox and is a result of the geometric alignment of the shadow casting gnomon and the panel. The precision strongly argues the intentionality of the recording of astronomical knowledge.

Next, the winter solstice marker sequence is shown in Figure 6. The photographs of the 'Sun dagger' sweeping across the face of the glyph on the winter solstice shown in the three photographs is an approximate 20-minute sequence. The winter solstice marker is unique in that it operates at solar noon, meaning the 'Sun dagger' points directly at the focal point of the glyph at that time. The focal point is the center or primary feature of a glyph or panel, which will be discussed in the following sections (see Section 5.2, below). Long-term observation of this panel would indicate that it has calendrical characteristics as well. Once the Sun proceeds through the vernal equinox, most of the pictographs remain in shadowed areas until the autumnal equinox.

The operation of a solar marker at solar noon is more common than one might expect. Solar noon is when the Sun crosses the local meridian. Determination of solar noon adds an additional step of intentionality on the part of the culture that scribed this glyph and a strong indicator of their astronomical knowledge. The following are but three examples of solar markers whose main interaction occurs at solar noon. Preston and Preston (1983) detail a number of solar markers that operate at solar noon and glyphs that exhibit calendrical interactions. The primary interaction of the Three Slab site on Fajada Butte occurs at solar noon, and it has been shown that there are additional calendrical interactions (Sofaer and Sinclair, 1983). Bostwick (2005) details a star-shaped light pattern that occurs at solar noon in the Shaw Butte Rockshelter.

4 EXPLORING HORIZON ASTRONOMY

Sun-watching gave cultures the ability to define temporal cycles within their spatial environment. Watching and measuring the travel of the Sun along the horizon was the primary method of most Sun-watching cultures. Zeilik (1989: 149) indicates that horizon calendars "… have the most and best ethnographic information about them." Identifying the Sun-watcher's observing location is the first step in discovering a culture's horizon astronomy. Young (2005) states that some Sun-watching stations were marked by iconographic elements of an astronomical nature. In discussing the Pueblos of the American Southwest, Zeilik (1989: 146) indicates that the observing sites were rarely marked, and he asks: "What would be the material evidence for a sun watching station?" The challenge is to connect the place of observation to the material record. The evidence worldwide is manifested in architecture, megalithic structures, megaliths, early wood construction, and rock art (Aveni, 1978; 1997; 2001; Burl, 1995; Ruggles, 1999; Simonia et al., 2009; Krupp, 1978a; Zeilik, 1984; 1985; 1989; Zoll, 2010).

The first paradigm of archaeoastronomy is to measure the horizon in order to establish solar declinations for interesting points on the horizon The potential horizon astronomy for any site purported to have archaeoastronomical implications must be established. The place of observation becomes critical and inversely proportional to the distance of the horizon. Horizons that are ≥10 km away allow a wider variance of a specific location to observe the same phenomena (Ruggles, 1999; Zeilik, 1989).

On the initial site inspection of Paint Rock to examine its astronomical potential, the first azimuth taken was a magnetic compass reading of the orientation of the cliff. The reading was 112°/114°–292/294°, without compensation for magnetic declination, which is 5.38° east. Hence, the cliff ran approximately from WNW to ESE. The first reaction was that the ESE direction was of interest for potential winter solstice interaction. However, at that time, a horizon 'notch' was not noticeable, yet it was right there, even when viewed from ground level. Once the observing position was determined and the notch of the horizon became apparent (to be discussed in later sections), the exact azimuth of the eastern notch was determined to be 110.04°. The calibration of the horizon notch will be discussed later and is shown in Figure 17. That first trip was spent observing the pictographs, including the equinox markers and, more importantly, observing the horizons, both to the east and the west.

When one stands on top of the bluff, the horizon is devoid of any significant topographical features. It is virtually a straight line, with only a few dips or rises within the 'solar arc', which is the path of the Sun along the horizon for a given location. The solar arc at Paint Rock, defined by the sunrises at the Summer and Winter solstices, is 62° to 117° as determined by MICA software program for the US Naval Observatory (2005). This is confirmed in Figure 7 (the east-

Figure 7: From the upper bluff area, the east horizon is virtually featureless (photograph: Gordon L. Houston).

Figure 8: The west horizon from the upper bluff area. The horizon is virtually featureless (photograph: Gordon L. Houston).

ern horizon) and Figure 8 (the western horizon), where both horizons are straight and almost featureless. A field survey of these two horizons from the upper bluff area confirmed that it was impossible to measure the movement of the Sun along the horizon, using horizon features, due to the lack of any topographical relief.

Figure 9: A photograph taken from the western end of the upper bluff area, looking east. Where the cliff meets the far eastern horizon, a 'horizon notch' occurs (photograph: Gordon L. Houston).

Figure 10: The 'horizon notch'. It was not until the photographs were reviewed following the first survey trip that this photograph produced one of those 'ah ha' moments with the realization that the cliff intersected the far horizon, created a significant horizon feature or 'notch' that could be used to measure the travel of the Sun along the horizon (photograph: Gordon L. Houston).

Figure 9 shows the first indication of a horizon feature that could be used to measure the Sun's travel. This dip is created by the bluff visually meeting the distant horizon. Figure 9 was taken from the western end of the main cliff area above the portion containing the pictographs. The entire length of the bluff was surveyed for possible observing positions and/or material evidence of observations. No evidence was found of an observing position along the top of the bluff, which provides no protection from the weather or the Sun. One of us (G.H.) experienced the winter weather during several survey trips, and the Arctic north winds were so cold that even with modern thermal clothing it was difficult to withstand the conditions without taking advantage of the shelter provided by the cliff. Hence, this lack of weather protection was one reason that we eliminated any position on top of the bluff as a place of observation. Ultimately, there were no signs along the bluff above the cliff face to suggest a position where solar observations were carried out. The few horizon features noted were not in positions that provided any type of anticipation or confirmation of a calendrical solar point.

Figure 11: Observation Site 1 has a limited viewshield, with the horizon notch blocked from view. Other negative features include a limited living area, a low ceiling, and the roof and weather protection was poor (photograph: Gordon L. Houston).

The next area to be surveyed was the terrace at the base of the pictographs. The terrace is at the top of the debris fall, along the broken slabs of limestone containing the pictographs. This terrace was not continuous, and there were only three potential areas that could have provided space for human activity. For the purposes of this discussion, these are referred to as Observation Sites 1, 2 and 3. The survey along the base of the cliff continued for two more fieldtrips. A photograph was taken from Observation Site 3, east of the other two sites, on the first survey trip, but it was only after reviewing the photographs taken on this fieldtrip that a 'horizon notch' became apparent (see Figure 10). Indeed, 'horizon notches' were noted to the east *and* the west where the cliff intersected the horizon. The initial compass bearing of the orientation of the cliff suggested that these notches may have been significant for horizon astronomy.

When Observation Site 1 (Figure 11) was examined it was found to possess one major flaw: the horizon and the notch were not visible. An obstructed view also was true for Observation Site 2 (Figure 12). Both of these locations had additional negative qualities. Observation Site 1 had limited living space, a low ceiling, and the roof slabs did not provide protection in wet weather. Observation Site 2 had a larger potential living area, but the overhead rock layers were broken and would not provide good weather protection. Observation Site 3 (Figure 13) had all the right qualities: a good view of the horizon and the 'horizon notch', a large living area, and a large rock for seating purposes. It also had a solid roof, which provided excellent protection from Sun, wind and rain (see Figure 14).

Figure 12: Observation Site 2. This was the first area selected. It has an extended living area, but the viewshield did not include the 'horizon notch' or that portion of the horizon traversed by the Sun (photograph: Gordon L. Houston).

The other distinctive feature of Observation Site 3 was the presence of 47 tally marks (Figure 15) on a layer of rock just above the large rock that would have been used to sit on. In fact, there are a number of other sets of tally marks only in this area of the cliff, with some being in black and underneath portions of other tally marks. No one has suggested why these are here, as they are limited to this area and do not have any design similarities to the pictographs. This material evidence is surely the key to the horizon astronomy. Marshack (1985) discusses record keeping, and Murray (1986) describes tally marks at Northern Mexico rock art sites. If you count 47 days from 6 November (the midway point between the autumnal equinox and the winter solstice), the date when the Sun is at the 'horizon notch', you arrive at the day of the winter solstice. If you counted backwards from this date, identification of the equinox would also be possible. This indicates that Observation Site 3 was a primary Sun-watching location.

Figure 13: Observation Site 3. This was the final site considered as a Sun-watching location. It had all the qualities that neither of the other potential sites possessed, including a clear view of the horizon and the 'horizon notch' (photograph: Gordon L. Houston).

Figure 14: Observation Site 3 has a continuous, unbroken rock slab layer, providing excellent weather and rain protection (photograph: Gordon L. Houston).

A horizon survey of Observation Site 3 was then carried out. Figure 16 is a sketch of the horizon, with significant points of interest marked, and calibrated with calculated declination points. The 'notch' created by the intersection of the cliff and the horizon has a calculated declination of –16° 03′ 47.9″, which closely matches the Sun's declination on 6 November. The calculated declination tallies with that provided by the MICA program (see U.S. Naval …, 2005) of –16° 16′ 12.0″, Aveni's (2001) Solar Declination

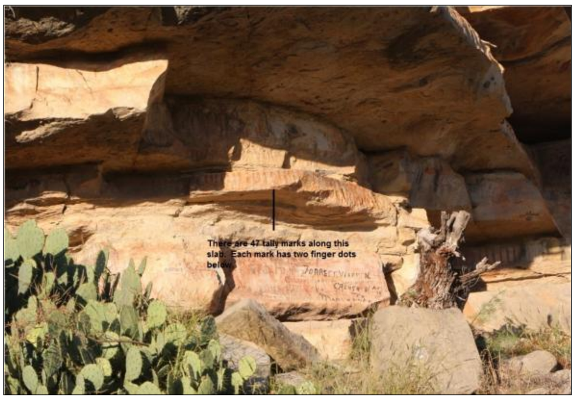
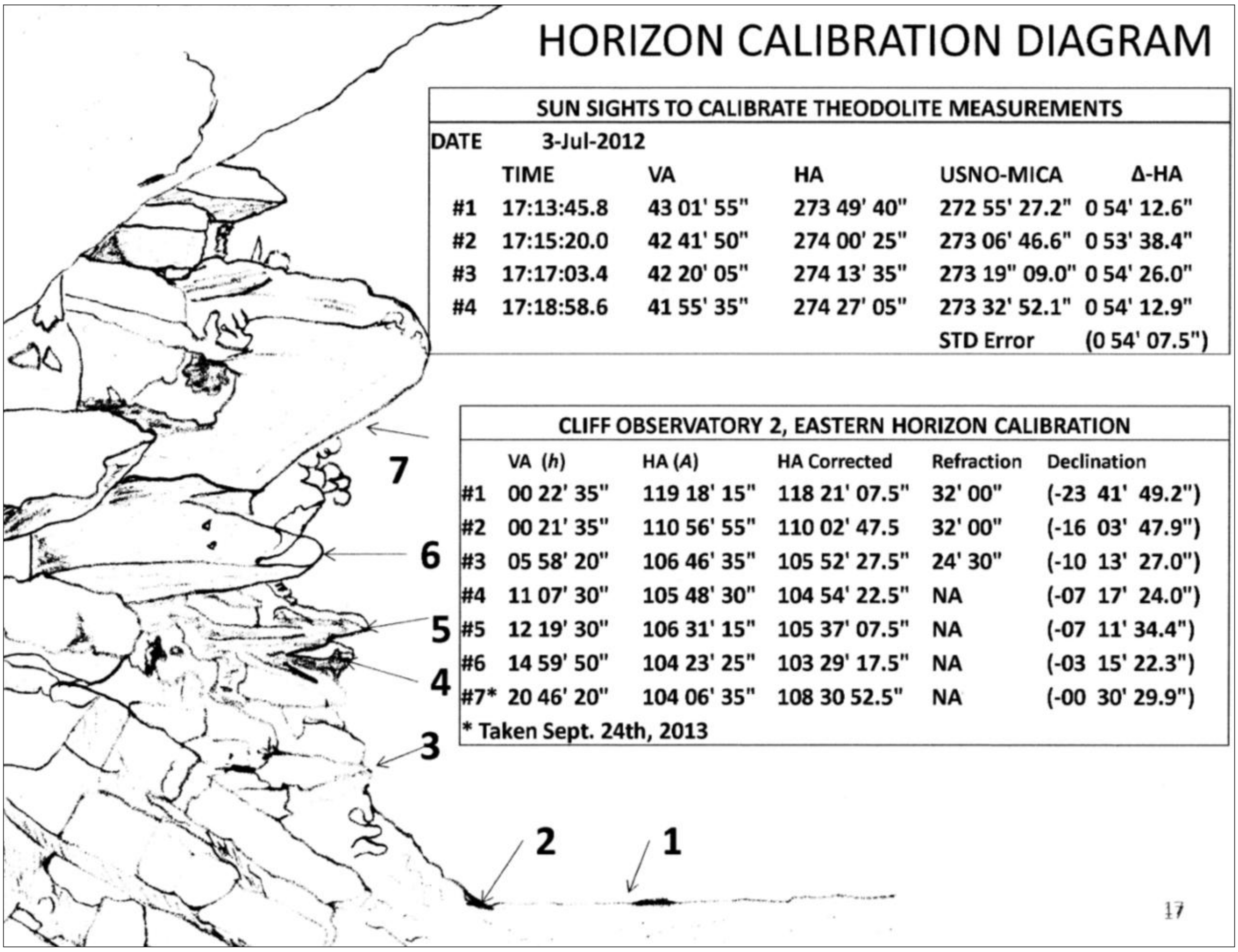


Figure 15: Observation Site 3 has a slab with 47 tally marks. Each tally mark has two small marks below, suggesting their use in multiple counting sequences. No marks of this nature exist at the other two sites (photograph: Gordon L. Houston).



SUN SIGHTS TO CALIBRATE THEODOLITE MEASUREMENTS

DATE 3-Jul-2012

	TIME	VA	HA	USNO-MICA	Δ-HA
#1	17:13:45.8	43 01' 55"	273 49' 40"	272 55' 27.2"	0 54' 12.6"
#2	17:15:20.0	42 41' 50"	274 00' 25"	273 06' 46.6"	0 53' 38.4"
#3	17:17:03.4	42 20' 05"	274 13' 35"	273 19" 09.0"	0 54' 26.0"
#4	17:18:58.6	41 55' 35"	274 27' 05"	273 32' 52.1"	0 54' 12.9"
				STD Error	(0 54' 07.5")

CLIFF OBSERVATORY 2, EASTERN HORIZON CALIBRATION

	VA (*h*)	HA (*A*)	HA Corrected	Refraction	Declination
#1	00 22' 35"	119 18' 15"	118 21' 07.5"	32' 00"	(-23 41' 49.2")
#2	00 21' 35"	110 56' 55"	110 02' 47.5	32' 00"	(-16 03' 47.9")
#3	05 58' 20"	106 46' 35"	105 52' 27.5"	24' 30"	(-10 13' 27.0")
#4	11 07' 30"	105 48' 30"	104 54' 22.5"	NA	(-07 17' 24.0")
#5	12 19' 30"	106 31' 15"	105 37' 07.5"	NA	(-07 11' 34.4")
#6	14 59' 50"	104 23' 25"	103 29' 17.5"	NA	(-03 15' 22.3")
#7*	20 46' 20"	104 06' 35"	108 30 52.5"	NA	(-00 30' 29.9")

* Taken Sept. 24th, 2013

Figure 16: Horizon calibration. This sketch shows the cliff intersecting the horizon at notch number 2. Solar sights were taken to calibrate the theodolite to true north. Points along the cliff profile were recorded and, using spherical trigonometry and adjusting for atmospheric refraction, the declinations of each point were determined (diagram: Gordon L. Houston).

Table 11, of –15° 48′, and Starry Night Pro (2009) of –16° 11′ 31.9″. Figure 16 details the Sun sights taken to calibrate the theodolite, and the determination of solar declinations using spherical trigonometry of significant horizon points. A review of the survey shows that the Sun-watcher could have used the whole outline of the cliff for calendrical purposes.

5 THE MATRIX OF INTENTIONALITY

The best interpretation of rock art involves a holistic approach. As a result of observations made during the 20 planned field surveys and a review of the literature, it became evident that there needed to be a way to quantify rock art solar markers in a uniform manner. The Matrix will allow individual observers to evaluate a potential solar marker objectively by using standardized parameters. Fountain (2005) attempted to create a database using a pool of observers, and he concluded that the available data con-firmed the intentional placement of glyphs for calendrical solar interactions. However, the data were insufficient to evaluate the interactions statistically. We believe that some of the variables chosen could not be used for statistical analysis, and that not a broad enough range of variables was provided. We therefore propose the Solar Marker Matrix of Intentionality, shown in Table 1, which expands the number of variables to be measured and resolves the issues encountered by Fountain.

The idea of the matrix was conceptualized from two other matrices used in archaeology: Harris' (1997) matrix for stratigraphy and Parker's Borderland Matrix, which deals with intercultural exchanges along boundaries. Initially, the introduction of these matrices was met with skepticism (Harris, 1997: xi–xii), but now they are accepted as part of every-day archaeological practice. As Parker (2006: 77) states in his abstract, his matrix is applicable to "… proposed terminology, models or conceptual frameworks …" for borderland processes. We propose our Solar Marker Matrix of Intentionality with these same intentions. Following is a brief overview of the Matrix and its functions, while the following sections provide further details. The Matrix is preliminary and will be revised as new observations and information come to hand.

In the Matrix (Table 1) the astronomical analysis is in four categories, namely

Table 1: The Solar Marker Matrix of Intentionality (credit: Gordon L. Houston).

Points	1. Solar Points	A	Points	3. Interactive Characteristics	B
5	1.1 Winter/Summer Solstice (WS, SS)		5	3.1 Focal Point(s)—Geometric Alignments	
4	1.2 Cross-quarter Days (V, S, A, W)*		4	3.2 Register Mark Alignment	
3	1.3 Confirmed Anticipatory Points		3	3.3 Rapid Interactions	
2	1.4 Equinox (VE, AE)		2	3.4 Tangent Alignment	
1	1.5 Random Days		1	3.5 Random	
Points	2. Time of Day		Points	4. Supporting Evidence	
5	2.1 Solar Noon		5	4.1 Horizon Astronomy**	
4	2.2 Sunrise		4	4.2 Geometric Conditions	
3	2.3 Sunset		3	4.3 Informed Sources	
2	2.4 Random Morning		2	4.4 Formal Examination	
1	2.5 Random Afternoon		1	4.5 Analogy/Symbolism	
	Total Point: Column A			Total Point: Column B	
	Intentionality Factor			Column A & B Totals	
	Very High 19–≥20				
	High 14–18				
	Medium 8–13				
	Low 4–7				

* Key: V = vernal; S = summer; A = autumnal; W = winter.
** The Horizon Astronomy category may include confirmation of any form of astronomical knowledge.

1. Solar Points
2. Time of Day
3. Interactive Characteristics
4. Supporting Evidence

There are five entries below each of these categories, listed in descending order of importance, and each entry attracts points, which range from 5 to 1. Thus, the highest characteristics in each of the four categories are interactions that occur during the winter solstice (1.1), at solar noon (2.1), where the interactions intersect the focal point of the glyph (3.1) and where horizon astronomy has been established for that location (4.1). A 'solar marker' with all four of these characteristics would have an 'Intentionality Factor' of 20 points. However, it is possible to have a score >20, as more than one category can be scored in Category 4 (Supporting Evidence). Sections 4.2 (Geometric Conditions) and 4.3 (Informed Sources) may also be scored, in addition to 4.1 (Horizon Astronomy), making the highest possible score 27 points.

The scores for each of the four categories are totalled, and the final score gives the 'Intentionality Factor'. An interactive panel with a score of >20 would have the highest intentionality. The Matrix can be used as a guide to evaluate encountered light and shadow interactions or as a tool to search for solar markers. Scores using the matrix will help rule out coincidental or accidental light and shadow interactions, which are the most common arguments against these interactions.

As an example, the winter solstice marker at Paint Rock would be scored as follows:

Category 1, Solar Points
  1.1 Winter Solstice (WS) = 5
Category 2, Time of Day
  2.1 Solar Noon = 5
Category 3, Interactive Characteristics
  3.1 Focal Point—Geometric Alignments = 5
Category 4, Supporting Evidence
  4.1 Horizon Astronomy = 5
Total: 20

Hence, the objective interpretation based on the Matrix is that the 'sun dagger' and winter solstice marker was an intentional act of the culture and the artisan who scribed the pictograph.

In the following Sections, we will discuss each of the four Categories.

5.1 Astronomical Analysis: Categories 1 and 2

The first category of astronomical analysis, Solar Points, relates to the apparent travel of the Sun along the ecliptic. There are four major solar points along the ecliptic: the Vernal Equinox (1.4), Summer Solstice (1.1), Autumnal Equinox (1.4) and the Winter Solstice (1.1). There are also four minor solar points: the mid-points between sets of the four major points, referred to as 'cross-quarter days' (1.2) and designated by the time of the year. Each of the solar points may have significant meaning to various cultures. The winter solstice is one of the most significant points, as rituals are performed to entice the Sun to return. Light and shadow operations that occur on specific solar points have the highest significance or level of intentionality.

Use of the term 'cross-quarter days' has been met with some resistance, and seen as 'Eurocentric', mainly due to lack of ethnographic evidence of their importance. We offer the following evidence in support of this term. Preston and Preston (1983) report that 11% of their recorded interactions were "… about 45 days before and after winter solstice.” and Fountain (2005) reports fully 20% of the interactions to occur on cross-quarter days. McCluskey (1977) indicates the Hopi’s most important celebrations were known as Wuwuchim, and the dates were fixed by horizon observation “… some 45 days before the winter solstice …”, which corresponded to the autumn cross-quarter day. As we have shown above, the horizon astronomy at the Paint Rock pictograph site marks a notch on the horizon where the Sun rises 47 days before the winter solstice. In fact, this is the approximate period from any solstice or equinox to a cross-quarter day. Thus, with further study, evidence may point to cross-quarter day significance. It is important to note that the Solar Marker Matrix of Intentionality is proposed for all rock art worldwide and is not limited to solar markers in the USA.

The second category of astronomical analysis is the time of day. Light and shadow operations occur throughout the day at many rock art sites. The categories used in our analysis, in order of relevance of intentionality by the artisan, are ‘solar noon’ (2.1), ‘sunrise’ (2.2), ‘sunset’ (2.3), ‘random morning’ (2.4) and ‘random afternoon’ (2.5). The interaction of light and shadow that has the highest intentional rating occurs at or within ten minutes of solar noon. Young (2005) discussed solar noon as one of the three daily stations of the Isleta Puebloans, and their ceremonies occurred around noon. Sofaer and Sinclair (1983) detail the primary interactions of the three slab site on Fajada Butte occur at solar noon. A glyph or panel that operates at solar noon requires an additional step of intentionality. Solar noon has to be determined and is site specific, i.e. the transit of the Sun across the local meridian. Determination of solar noon is the reason that solar noon has the highest point value of all time of day categories.

Malville (2008) indicates that many Sunwatchers observed both at sunrise and sunset, and he also states that sunrise was a ‘crucial’ time for horizon astronomy. Young (1986) also details the importance of sunrise, sunset and solar noon. Some American Southwest tribes divided the year by which horizon they watched, east or sunrise from Winter Solstice to Summer Solstice, and then the western horizon. He indicates that eastern Puebloans watched the sunrise and the Zuni both sunrise and sunset. Rock art that interacts with light and shadow within a one-hour window of sunrise or sunset is governed by the geometrical alignment of the geologic structure and the Sun. Hence, interactions occurring within one hour of sunrise and sunset have the next level of significance, with sunrise being more important than sunset operations.

The term ‘random’ in 1.5, 2.4, 2.5 and 3.5 refers to random days in the Solar Points, Time of Day and Interactive Characteristics categories. In most cases, these are coincidental interactions with glyphs and panels of rock art that have no astronomically-significant meaning. These have the lowest level of intentionality. However, it should be noted that a solar marker for anticipatory observations in preparation for rituals on major solar points may occur on a random day and at a random time. The only way to verify an anticipatory marker is through sources of informed or formal analysis; since these may never be known, the interactions should simply be classified as coincidental.

5.2 Interactions With Rock Art: Category 3

The appearance of the ‘sun dagger’ at Fajada Butte is the most recognizable example of a solar interaction with rock art. Preston and Preston 1983) state that the interactions they observed occurred with the leading or trailing tip. A literature review of other sites indicates a point (i.e. like the tip of a capital ‘A’) or corner shape (i.e. an ‘L’ shape) or Sun lines (i.e. straight lines) are the predominant operations (Hudson et al. 1979; Lehrburger, 2005; Preston and Preston, 1983). The Sun or shadow lines have no points but still interact with significant design elements of rock art. These Sun and shadow lines are not always straight and can have crooked shapes. The crooked shapes can then line up with or match the designs of a rock art glyph, an example being the equinox marker at the Pathfinder petroglyphs site in south-eastern Colorado (Lehrburger, 2005). This is illustrated in Figure 17. Observations of the pictographs at Paint Rock reveal that the solstice markers are involved with the ‘point’ of the sunlight shaft, pointer, or dagger, and a moving Sun line (e.g. see Figure 6). Whatever the shape, these types of interactions align with shapes on the rock art or can create a framing of the pictograph. Space limits a full discussion here on the shapes of light and shadow forms. The position of the light and shadow on the rock art is more important than the shape.

Interaction of light and shadow with rock art is dependent upon the solar altitude, which changes with solar declination. There is an inverse relationship between the solar altitude and the position on the panel or glyph of the solar interaction: the lower the Sun's altitude, the higher the interaction is on the panel. For example, at the winter solstice, the Sun is at its lowest altitude, so the solar interaction is at the highest point on a glyph, and *vice versa* for the summer solstice interaction. The solar declination also has a seasonal impact, as it changes; some panels are in the shadow for a significant portion of the year.

The concept of a ‘Focal Point’ (3.1) was introduced by Preston and Preston (1983) in desribing the position on the rock art intersected by the light and shadow mechanics. The Focal Point is the central feature, especially when dealing with spirals or concentric circles. There may also be multiple Focal Points that are a function of both the glyph or panel design and features. Interactions with the Focal Point are the primary recording of the astronomical intentions of the artist. Any additional calendrical activity may be purely coincidental.

A 'Register Mark' (3.2), introduced by Zoll (2010), is an intentionally-placed mark on a glyph that acts as a specific day identifier other than on one of the primary solar points. Zoll describes the importance of the agave harvest in the Sinagua Culture, which occurs in late April. The register mark on the equinox marker aligns with the Sun line 30 days after the vernal equinox, and therefore occurs at the end of April. As Zeilik (1989: 144) states, it is a burden of proof for archaeoastronomy that "… the site must 'work' culturally …", and this is an excellent example. The placement of a Register Marker is intentional and may also be found to be an anticipatory maker. For these reasons, a Register Mark is assigned the second highest score in this category.

Reports of 'Tangent Alignment' interactions (3.4) have been associated with the markings at Fajada Butte. The tangentially-aligned Sun daggers occur at the winter solstice, and the rock formation creates two daggers, one on either side of the spiral. The question is: did the hand that created the spiral know how big to make the spiral so that these winter solstice daggers would strike on either side, just barely touching the spiral? There are no reports of the spiral being created in stages, say a smaller one for the original summer solstice interaction and then expanded to be framed by the dual winter Sun daggers. These interactions are a form of Tangent Alignment interactions as many times they align with the outer edges of the design.

As the Sun moves along the ecliptic, its altitude changes throughout the year. Thus, the Sun's rays hit the Earth's surface at different angles virtually every day of the year. These geometric configurations, the angle of the Sun's rays and the angular position of rock surfaces and gnomons, are unique to each rock art site. Thus, these geometric conditions create unique 'Geometric Alignments' (3.1) with the rock art. There are two types of Geometric Alignments. One is formed by a Sun or shadow line, usually straight in nature, which moves across a panel

Figure 17: The sketch and picture shows a geometric alignment (3.1) on the equinox morning sunrise. The right edge of the shadow mimics the outline of the glyphs. The alignment is precise, except at the upper and lower portions, which is possibly explained by changes in the edge of the shadow casting rock (adapted from Lehrburger, 2005: 13–14. Photograph and sketch by Carl Lehrburger).

or glyph. The other is a Sun or shadow line that mimics the design in the rock art, so the usually-irregular Sun or shadow line matches the design (see Figure 17). At Paint Rock, this geometry is responsible for the equinox panel interaction (see Figure 3).

The overall length of time that the interactions operate on a solar marker is another important aspect to consider. The observed solar markers at Paint Rock have two basic properties, 'Rapid' (3.3) and 'protracted'. The winter solstice primary solar marker, shown in Figure 6, has a rapid interaction, with a timeframe of twenty minutes. Another winter solstice solar marker, described by Yeates and Campbell (2002), is a large circular shield, whose mid-morning random interaction starts with a light point. This point of light then stretches across the shield and expands to frame the shield tangentially before moving off to the right. From the time the first point of light appears to the time of the tangent alignment is more than an hour, so this would be defined as a 'protracted interaction'. Rapid Interactions (3.3) required the hand that inscribed the rock art to be more aware of the location of the interaction in order to align the rock art, and thus a greater degree of intentionality can be considered than for protracted interactions. Thus, Rapid Interactions are another defining characteristic of solar markers and intentionality.

5.3 Supporting Evidence: Category 4

Supporting evidence is the last section of the Matrix, which includes both astronomical and archaeological considerations.

5.3.1 Horizon Astronomy: Sub-Category 4.1

The top entry in this category, with 5 points, is documentation of the horizon astronomy for a site. Discovering and documenting the horizon astronomy, a key component of any sun-watching culture's astronomical knowledge, is a big step towards confirming a culture's ability to accurately place glyphs and panels in order to record specific solar points. Hence, the highest point given in category 4. Discussion of an example of this was the primary focus of this paper.

5.3.2 Geometric Conditions: Sub-Category 4.2

The geometric conditions of a glyph or a panel involve an examination of the operation of a solar marker. This examination details the accuracy and precision of the interactions. As illustrated in the discussion of the operation of the equinox marker, the precision shown on the day of the equinox, compared to the day before and the day after, reflects the astronomical knowledge. Two facets define the precision of the interactions. Firstly, the precise knowledge of the day of the equinox had to be known to the culture scribing the pictograph. Secondly, the geometric conditions casting the Sun line need to be examined. In some instances, there is evidence of manipulation of the shadow-casting gnomon (e.g. see Fountain, 2005; Zoll, 2008) or even a suggestion that artificial gnomons were used (Hudson et al., 1979).

5.3.3 Informed Sources, Formal Examination and Analogy Symbolism: Sub-Categories 4.3, 4.4 and 4.5

In their paper, "An archaeology of rock-art through informed methods and formal methods", Chippendale and Tacon (2004b) provide a methodological framework for the study and interpretation of rock art. The three primary focal points are: 1. Informed methods, 2. Formal methods and 3. Analogy. These three methods set the standards followed by the rock art community. Examples include Tacon and Chippindale (2004) and Whitley (2011), who discuss the informed and formal methods, and Boyd (2004), who discusses the interpretation of rock art using several examples of analogy.

'Informed Sources' is a method based upon knowledge provided by people and cultures connected with the rock art, through ethnography or ethno-historical documentation. In an archaeological context, this is also known as the 'Direct Historical Approach'. 'Formal Methods' are the opposite of Informed Sources, as there is no access to ethnographic data for the rock art being studied. 'Analogy Symbolism' is indirectly related to the Formal Method in that it, too, has no access to ethnographic data and is further isolated from the original rock art site by inferring interpretation from other sites in the primary study area. This final method becomes very subjective.

These methods hope to ensure that rock art studies are made within a scientific framework and methodology. They come under the cognitive-processual approach in archaeology, which is the interpretation of a culture's ideology, including their ritual practices connected with astronomical observations, and their worldview (Fagan and DeCorse, 2005). A holistic approach incorporates all facets of evidence to draw the best conclusions, which applies to rock art as it relates to the recording of astronomical knowledge. The rock art itself is a significant part of the archaeological record, and a cultural process (Judge, 2008), or technology, that has many archaeological implications about a culture's world view.

6 CONCLUSIONS

We have introduced the largest pictograph site in the state of Texas, Paint Rock. It is the most important archaeoastronomical site known in

Texas. Over the course of 20 survey trips, we have observed the interactions of twelve solar markers and believe that there are more to be discovered. We have shown their accuracy and precision by detailing the first two solar markers discovered at Paint Rock. The challenge was to determine how the cultures responsible for them were able to place the glyphs so accurately in order to accommodate the solar interactions. The search for the place of observation, which involved four field trips, was detailed. We have shown how the place of observation is tied to the material record and the horizon astronomy. Confirmation of the place of observation came through linking the material record—in this case the pictograph tally marks—to the location. Identifying the place of observation then led to the discovery of the horizon astronomy. This allowed us to answer our primary research question, which was: "How did the cultures so accurately place these rock art glyphs to interact with light and shadow on important solar points of the year?"

The enigma that is rock art has led to a sequence of hypotheses that have attempted to interpret their meaning, and these have evolved over time. This changing of hypotheses supports the positivistic ideology that any attempt to interpret rock art is purely speculative. Many would postulate that the solar interactions are nothing more than fortuitous events, but we have argued to the contrary. Murray (1998: S4) states that the intentionality of rock art "… solves the *a posteriori* test of replication required of other archaeoastronomical evidence." In the American Southwest and Great Basin alone, the number of analogous sites with interactive rock art solar markers is extensive, with Paint Rock being within the broad region defined by these areas. Schaefer (2006) concludes that the large number of operating solar markers defines the intent. Hence, the astronomical knowledge recorded by rock art solar markers is one of the more rigorous interpretations of rock art.

We have provided a working definition of a 'solar marker'. Our preliminary Solar Marker Matrix of Intentionality has been explained in detail. The hope is that it will assist those whose knowledge of solar interactions is limited. The Matrix will be a guide for observed solar interactions, and a tool that can be used to search for unknown solar markers. The numbers of solar markers reported in Section 1 by various researchers will populate the data sample rapidly. The hope is that through time, with enough observations and scoring of solar markers, a database of solar markers may lead to better statistical analysis and support of our hypothesis.

7 NOTES

1. The Smithsonian Trinomial Site Designation system was designed for archaeological sites in the United States. The first number is the assigned State number, the second set of letters the county or parish, and the third number is the site number for that county.

8 ACKNOWLEDGEMENTS

We want to thank Kay and Fred Campbell, whose generosity and stewardship of the pictographs made this research possible; the whole Campbell family, Bill and Scott, for their valuable input; and Bill Yeates and Bill Anderson, who have studied the pictographs for many years and provided valuable input; and Professor Wayne Orchiston and Dr Duane Hamacher for helping with the revision of this paper. Finally, we want to dedicate this research to Scott Campbell, who lost his battle with cancer in March 2013.

9 REFERENCES

Ashmore, T., 2010. Archeological Investigations Paint Rock 1800s Historic Camp Sites (41cc290) Concho County, Texas. Concho Valley Archaeological website http://cvassanangelo.org/news-letters.html, accessed March 14, 2012,

Aveni, A.F., 1978. Astronomy in ancient Mesoamerica. In Krupp, 1978b, 165–202.

Aveni, A.F., 1997. *Stairway to the Stars. Skywatching in Three Great Ancient Cultures.* New York, John Wiley.

Aveni, A.F., 2001. *Skywatchers. A Revised and Updated Version of Skywatchers of Ancient Mexico.* Austin, University of Texas Press.

Black, S.L., 1986. *The Clemente and Herminia Hinojosa Site, 41 JW 8: A Toyah Horizon Campsite in Southern Texas.* The University of Texas at San Antonio, Center for Archaeological Research (Special Report 18).

Bostwick, T.W., 2005. Rock art research in the American Southwest. In Loendorf, L.L., Chippindale, C., and Whitley, D.S. (eds.). *Discovering North American Rock Art*. Tucson, University of Arizona Press. Pp. 51–92.

Boyd, C.E., 1996. Shamanic journeys into the Other-World of the Archaic Chichimec. *Latin American Antiquity*, 7, 152–164.

Boyd, C.E., 2004. Pictographic evidence of peyotism in the Lower Pecos, Texas Archaic. In Chippindale and Tacon, 2004a, 229–246.

Burl, A., 1995. *A Guide to the Stone Circles of Britain, Ireland and Brittany.* New Haven, Yale University Press.

Carlson, J.B., and Judge, W.J., (eds.), 1983. *Astronomy and Ceremony in the Prehistoric South-west*. Albuquerque, University of New Mexico (Papers of the Maxwell Museum of Anthropology, Number 2).

Chippindale, C., and Tacon, P.S.C. (eds.), 2004a. *The Archaeology of Rock-Art.* Cambridge, Cambridge University Press.

Chippendale, C., and Tacon, P.S.C., 2004b. An archaeology of rock-art through informed methods and formal methods. In Chippindale and Tacon, 2004a, 1–10.

Closs, M.P. (ed.), 1986a. *Native American Mathematics.* Austin, University of Texas Press.

Closs, M.P., 1986b. Tallies and the ritual use of number in Ojibway pictography. In Closs, 1986a, 181–212.

Fagan, B.M., and DeCorse, C.R., 2005. *In The Beginning.* Upper Saddle River, Pearson Prentice Hall.

Fountain, J., 2005. A database of rock art solar markers. In Fountain, and Sinclair, 2005, 101–108.

Fountain, J.W., and Sinclair, R.M. (eds.), 2005. *Current Studies in Archaeoastronomy. Conversations Across Time and Space*. Durham, Carolina Academic Press.

Grant, C., 1967. *Rock Art of the American Indian.* New York, Promitory Press.

Harris, E., 1997. *Principals of Archaeological Stratigraphy*. *Second Edition*. London, Academic Press.

Hudson, T., Lee, G., and Hedges, K., 1979. Solstice observers and observatories in native California. *Journal of California and Great Basin Anthropology*, 1, 38–63.

Jackson, A.T., 1938. Picture-writing of Texas Indians. In Pearce, J.E. (ed.). *Anthropological Papers. Volume II.* Austin, University of Texas (Publication No. 3809). Pp. 267–286.

Johnson, C., 1992. Coincidence and alignment: examining an alternative hypotheses to explain interactive panels. *Utah Rock Art*, 12, 13–26.

Judge, W.J., 2008: Archaeology and astronomy, a view from the Southwest. In Aveni, A. (ed.). *Foundations of New World Cultural Astronomy*. Boulder, University Press of Colorado. Pp. 794–797.

Kirkland, F., and Newcomb, W.W. Jr., 1967. *The Rock Art of Texas Indians.* Austin, University of Texas Press.

Krupp, E.C., 1978a. Astronomies, pyramids, and priests. In Krupp, 1978b, 203–240.

Krupp, E.C. (ed.), 1978b. *In Search of Ancient Astronomies.* New York, McGraw-Hill.

Lehrburger, C., 2005. Ancient Colorado rock art site employs light animation to mark equinoxes: astronomical alignments predate Anasazi civilization. *Ancient American*, 65, 12–17.

Malville, J. McK., 2008. *Guide to Prehistoric Astronomy in the Southwest*. Boulder, Johnson Books.

Marshack, A., 1985. A lunar-solar year calendar stick from North America. *American Antiquity*, 50, 27–51.

McCluskey, S.C., 1977. The astronomy of the Hopi Indians. *Journal for the History of Astronomy,* 8, 174–195.

McCluskey, S.C., 1993. Space, time and the calendar in the traditional cultures of America. In Ruggles, C. (ed.). *Archaeoastronomy in the 1990's.* Loughborough, Group D Publications. Pp. 33–44.

Murray, W.B., 1986. Numerical representations in North American rock art. In Closs, 1986a, 45–70.

Murray, W.B., 1998. Models of temporality in archaeoastronomy and rock art studies. *Journal for the History of Astronomy, Archaeoastronomy Supplement, No 23,* 29(1M), S1–S6.

Parker, B.J., 2006. Toward an understanding of borderland processes. *American Antiquity*, 71, 77–100.

Pertulla, T.K., 2004. An introduction to Texas prehistoric archaeology. In Pertulla, T.K. (ed.). *The Prehistory of Texas.* College Station, Texas A&M University (Anthropology Series, No. 9). Pp. 5–14.

Preston, R.A., and Preston, A.L., 1983. Evidence for calendric function at 19 prehistoric petroglyph sites in Arizona. In Carlson and Judge, 191–204.

Preston, R.A., and Preston, A.L., 2005. Consistent forms of solstice sunlight interaction with petroglyphs throughout the prehistoric American Southwest. In Fountain and Sinclair, 2005, 109–119.

Rister, C., 1946. *Robert E. Lee in Texas.* Norman, University of Oklahoma Press.

Robbins, R. R., 1998. A Central Texas sun dagger [abstract]. *Bulletin of the American Astronomical Society*, 30: 1264.

Robinson, A., 2001. *The Story of Writing: Alphabets, Hieroglyphs & Pictograms.* London, Thames & Hudson.

Ruggles, C., 1999. *Astronomy in Prehistoric Britain and Ireland.* New Haven, Yale University Press.

Schaefer, B.E., 2006. Case studies of three of the most famous claimed archaeoastronomical alignments in North America. In Bostwick. T.W., and Bates, B. (eds.). *Viewing the Sky Through Past and Present Cultures: Selected Papers from the Oxford VII International Conference on Archaeoastronomy*. Phoenix, City of Phoenix Parks and Recreation Department (Pueblo Grande Museum Anthropological Papers No. 15). Pp. 27–56.

Shafer, H.J., 1977. Art and territoriality in the Lower Pecos Archaic. *Plains Anthropologist*, 22, 13–21.

Simonia, I., Ruggles, R., and Bakhtadze, N., 2009. An astronomical investigation of the seventeen hundred year old Nekresi Fire Temple in the eastern part of Georgia. *Journal of Astronomical History and Heritage*, 12, 235–239.

Sofaer, A.P., and Sinclair, R.M., 1983. Astronomical markings at three sites on Fajada Butte. In Carlson, and Judge, 43–70.

Starry Night Pro, 2009. Simulation Curriculum Corporation.

Tacon, P.S.C., and Chippindale, C., 2004. An archaeology of rock-art through informed methods and formal methods. In Chippindale and Tacon, 2004a, 1–10.

Turpin, S., Riemenschneider, L., and Robinson, D.G., 2002. Archaeological investigations at Campbell Ranch, Paint Rock, Texas. In *Current Archaeology in Texas*, Volume 4, Number 2. Austin, Texas Historical Commission. Pp. 8–19.

U.S. Naval Observatory Multiyear Interactive Computer Almanac 1800–2050. Richmond, Willmann-Bell (2005).

Whitley, D.S., 2011. *Introduction to Rock Art Research.* Walnut Creek, Left Coast Press.

Yeates, W.P., and Campbell, F., 2002. Archeoastronomical Features at the Paint Rock, Texas Pictograph Site. On Concho Valley Archaeological Website. http://cvassanangelo.org/newsletters.html, accessed March 14, 2012,

Young, M.J, 1986. The interrelationship of rock art and astronomical practice in the American Southwest. *Journal for the History of Astronomy, Archaeoastronomy Supplement*, 17(43Y), S44–S58.

Young, M.J., 2005. Astronomy in Pueblo and Navajo world views. In Chamberlain, V.D., Carlson, J.B., and Young, M.J. (eds.). *Songs from the Sky.* Leicester, Ocarina Books. Pp. 49–64.

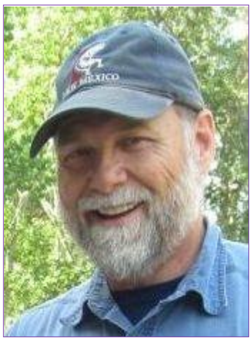
Zeilik, M., 1984. Summer solstice at Casa Rinconada: calendar, hierophany, or nothing? *Archaeoastronomy,* 7, 76–81.

Zeilik, M., 1985. Ethnoastronomy of the historic Pueblos. I: Calendrical Sun watching. *Archaeoastronomy,* *The Journal of Astronomy in Culture*, 8, 1–24.

Zeilik, M., 1989. Keeping the sacred and planting calendar: archaeoastronomy in the Pueblo Southwest. In Aveni, A.F. (ed.). *World Archaeoastronomy*. *Selected Papers from the 2nd Oxford International Conference on Archaeoastronomy*. Cambridge, Cambridge University Press. Pp. 143–166.

Zoll, K.J., 2008. *Sinagua Sunwatchers, An Archaeoastronomy Survey of the Sacred Mountain Basin.* Sedona, Sunwatcher Publishing.

Zoll, K.J., 2010. Prehistoric astronomy of central Arizona. *Archaeoastronomy,* 23 154–164.



Gordon L. Houston has a Master of Science in Astronomy from Swinburne University of Technology, Melbourne, Australia, where he researched the scientific history of the Lick Observatory to 1900 for his final year project. He is on the faculty of Blinn College, where his primary responsibilities are public outreach through star parties and operating the telescope at the Schaefer Observatory. Currently he is a 5th year Ph.D. student, studying archaeoastronomy, through Ilia State University. He resides in Houston, Texas.

Dr Irakli Simonia is a Professor of Astronomy in the School of Natural Sciences and Engineering at Ilia State University in the Republic of Georgia. His primary research interests are in the physics and chemistry of the small bodies of the Solar System; the physics and chemistry of interstellar and circumstellar matter; archaeoastronomy and the history of astronomy. Irakli has published widely in these fields. Currently, he is Director of the University's part-time off-campus Ph.D. program in archaeoastronomy and cultural astronomy. Gordon Houston is one of his students.