Paint Rock Archaeoastronomy:
The Science and Technology of a Nomadic Campsite

by

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Dissertation Submitted to Ilia State University, Faculty of Arts and Sciences, in accordance with the requirements for the awarding of the Degree of Doctor of Philosophy in Archaeology

Interdisciplinary Doctoral Programme in Social Sciences and Humanities
(Archaeology)

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Ilia State University

Tbilisi, 2019

Statement of Originality

I, Gordon L. Houston, do hereby certify that the submitted dissertation is a result of my own independent research and does not contain any plagiarisms to the best of my knowledge.

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ACKNOWLEDGEMENTS

I would be remiss if I did not first acknowledge my wife Sharon, who has had to deal with the trial and tribulations that the educational process requires. She supported all my efforts, even when field trips occurred on her birthday. She has been the sounding board for all the challenges that are encountered in the process.

I extend special gratitude and acknowledgment to Kay and Fred Campbell for allowing me to pursue my research at their ranch. They always welcomed me with open arms and treated me as part of the family. Their continued personal stewardship of the pictographs is to be commended. For the whole Campbell family, thank you for your impute and assistance, Bill, Scott, and grandson Auggie Campbell. I have truly enjoyed each visit with them out on the ranch. I thank you for all the hospitality and the great fun and meals at Lowake.

I want to thank Bill Yeates and Bill Anderson for their contributions and conversations about the pictographs. They each have spent many days at the pictographs and provided a different perspective.

I want to thank the folks at Caddo Mounds, Anthony Souther and Rachael Galan, for their assistance and input. Tony went above and beyond, photographing a Winter Solstice Sunrise, and on two different occasions the Summer Solstice Sunrise.

I want to acknowledge the time spent with the folks at Surveying Equipment Specialists, Inc. They kept my equipment calibrated and answered a multitude of questions about surveying and operations. This includes Terry Swann, President/General Manager, Rudy Meneses, VP of Sales & Marketing, and Truoc Nguyen, Master Technician.

I want to acknowledge my supervisors. First, to Dr. Irakli Simonia who developed the Archaeoastronomy and Cultural Astronomy program at Ilia State University. Together we have stuck through this nine-year process, with all the ups and downs. Thanks for all you have done. Dr. Nikoloz Tushabramishvili who has stepped in as my supervisor upon transferring my dissertation defense to the School of Arts and Sciences. I thank you for taking on the task.

DEDICATION

To my family, parents, grandparents and in-laws.

Finally, I want to dedicate this research to Julia Lee Houston, my sister, Scott Campbell, and his father, Fred Campbell. It is with a heavy heart that during my research, Scott Campbell passed away March 2013 prematurely. Mr. Fred Campbell passed away in September 2017. My sister Julia passed away prematurely January 25th, 2020. They will be missed and always remembered.

ABSTRACT

The Paint Rock Pictograph site is the largest pictograph site in the State of Texas, USA. The ranch owner discovered active solar markers in 1994 by accident. Astronomer R. Robert Robbins of the McDonald Observatory studied the site for two years and discovered a Summer Solstice solar marker. He suggested more solar markers might be identified. Subsequently, five more solar markers were identified, making a total of eight. The horizon appears so flat in a 360° circle that he concluded there did not seem to be any interest watching the sun's movement along the horizon by the Native Americans. His conclusion and the number of active solar markers set the challenge to study the sites potential horizon astronomy. The horizon has to have some topographical relief to measure the sun's movement through the tropical year. A significant "notch" was discovered in the horizon. Accurate horizon watching of the sun's movement requires a fixed place of observation. The search for the place of observation led to the connection of the material culture to the horizon astronomy. The solar markers, which were previously identified prior to the research, were examined. Hours of observation and photography during all hours of the day led to the discovery of six additional solar markers. Two panels were examined with calendrical interactions. Complete interactions were identified on a winter solar marker, and an interaction at a different solar point of a winter solstice marker was identified, which may be the primary solar interaction. Hence, there may be as many as 14 active solar markers at Paint Rock, making it the most active solar marker site in Texas. Considering the close proximity of the solar markers, it may be the single most active solar marker site reported to date worldwide. The iconographies of some glyphs were examined for possible representations of supernova. The original claim was falsified. A second glyph was examined that meets the criteria establishing it as a probable representation of Tycho's supernova SN1572. As a cultural crossroads, the site is surrounded by completely different cultures, all of whom demonstrate various degrees of astronomical knowledge. An unexpected outcome of the research was the development of the Matrix of Intentionality. The Matrix can be used as a guide to confirm existing reported solar markers, or help researchers identify new solar markers. The hope is that it will encourage identification of solar markers worldwide. Rock art is ubiquitous around the world, yet, there is a paucity of reported solar markers outside of the American Southwest. As new reports of solar markers are made, the hope is that enough data will enable statistical analysis of solar interactions. A positive outcome for each of the seven research questions can be reported.

LIST OF FIGURES

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[1] Adapted from Yeates & Campbell (2002)

LIST OF TABLES

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Introduction to Paint Rock

Paint Rock is the largest pictograph site in Texas, and is located on the Campbell Ranch, near San Angelo, Texas. The site contains over 1500 pictographs. The State of Texas erected a large granite monument on the top of the cliff, Figure 1. More than eight pictographs exhibit some form of solar interactions.

FIGURE 1. Monument erected by the State of Texas.

These solar interactions make the Paint Rock pictographs the most active archaeoastronomical site in Texas. In contrast, there are only four other reported rock art sites with solar interaction in Texas, and they each are very small sites with interaction on one glyph. The cliff containing the Paint Rock pictographs runs northwest to southeast for over a kilometer. The pictographs are located on the most exposed 300-meter section of the cliff. Figure 2 is a panoramic photograph of the cliff. Most of the pictographs are on panels that are protected from the elements.

Figure 2. A panoramic picture of the cliff taken from the center of the 300-meter section containing the pictographs.

Paint Rock lies at the southern end of the Great Plains of central North America (Johnson 2010), and is surrounded on three sides by the Edwards Plateau. The Concho River runs approximately east/west about 150 meters south of this cliff. The cliff was created by a geologic uplift exposing broken layers of limestone; the uplift formed a multitude of panels for painting rock art. Figure 3 shows the location of Paint Rock within the rolling plains ecoregion of Texas.

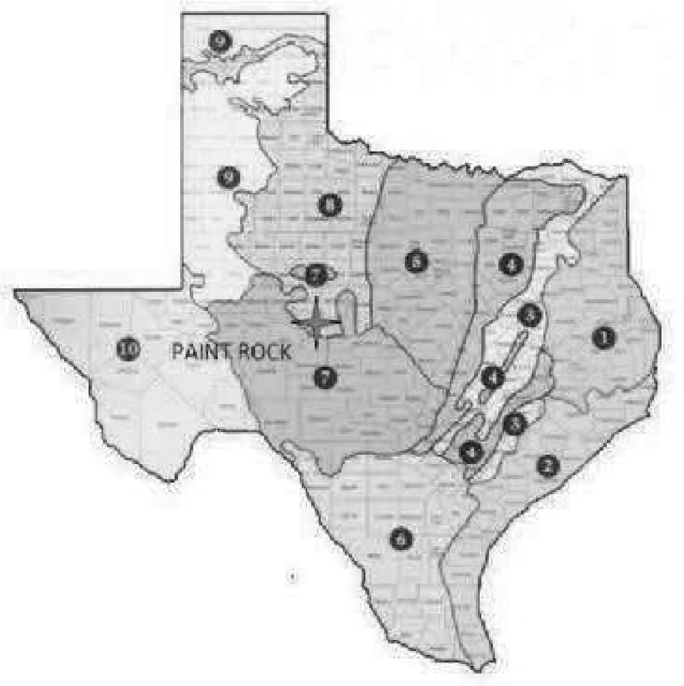

Figure 3. Location of Paint rock within the ecoregion of Texas. Adapted from the Texas Parks and Wildlife website.
https://www.tpwd.state.tx.us/huntwild/wild/wildlife_diversity/wildscapes/ecoregions/

Texas is one of the most diverse areas in North America. The numbered regions shown in Figure 3 are as follows:

1. East Texas Pineywoods, 2. Gulf Coast Prairies and Marshes, 3. Post Oak Savanna, 4. Blackland Prairies, 5. Cross Timbers and Prairies, 6. South Texas Plains, 7. Edwards Plateau, 8.Rolling Plains, 9. High Plains, 10. Trans-Pecos.

The Texas ecoregions has led to a diversity of native cultures, each with their own characteristics, subsistence activities, and life ways.

The geographic location of Paint Rock places it in a position to act as a cultural crossroads, connecting many different cultures. Foster (2008) describes the various lifeways of the Native groups of Texas to range from nomadic to sedentary, and having networks of interaction and trade. To the east lie the Mississippian Mound Cultures, to the west, the Pueblo cultures of the American Southwest, to the north the Plains cultures, and to the south, the native cultures of central and South America, including the Aztec, Maya, and Incas. There is evidence of contact and trade with many of these regions. This evidence of cultural contact is evident at Paint Rock habitation sites, as well as material evidence at middens in the adjoining cultures.

Kay Sims Campbell, the current owner of the ranch, stated that it has been in her family since her grandfather purchased it in 1877 (Personal Communication). Paint Rock's archeological site number is 41CC1, based on the Smithsonian Trinomial Site Designation system for archaeological sites in the United States. The first number refers to the state, the letters are the county or parish, and the numbers after the letters are the archaeological site number in that county or parish. There has been a variety of site-specific archaeological investigations at Paint Rock.

The only broad archaeological survey of the whole site was done by Turpin et al. (2002), and a study of historical sites by Ashmore (2010). They identify many habitation sites, each with its respective trinomial site number. Turpin et al. (2002) found 14 associated sites in the immediate area, and evidence of cultural use extending back to the Middle Archaic period, an archeological period that dates from 4000 B.C. to 2000 B.C. (Pertulla 2004). Figure 4 is a sitemap of the location.

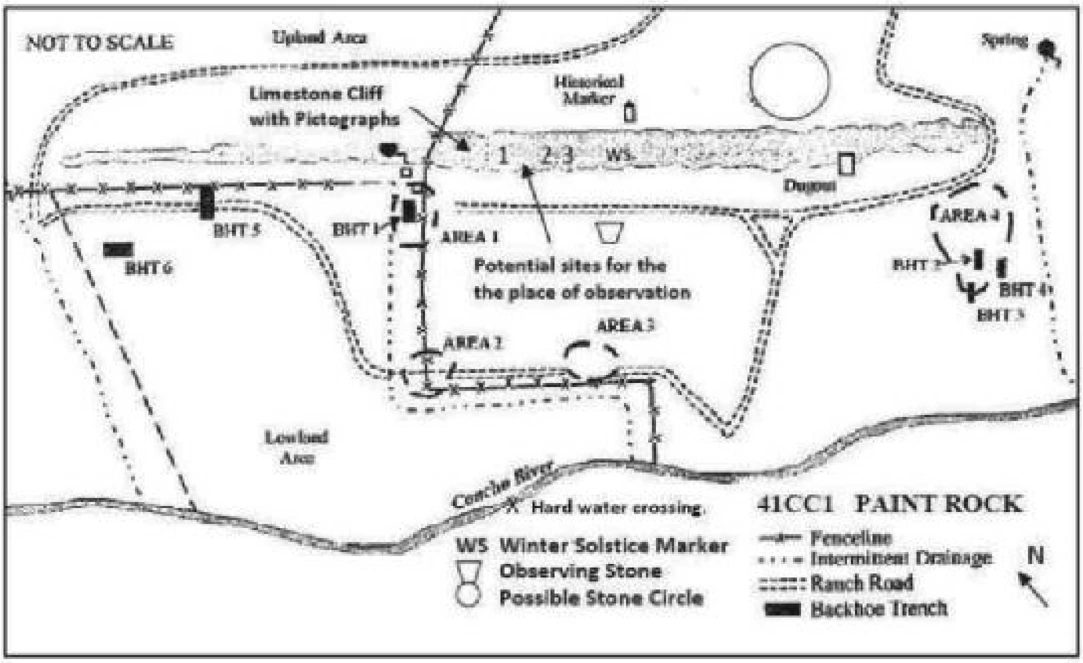

Figure 4. The sitemap of Paint Rock identifies the research areas. Adapted from Turpin et al. (2002).

The site has been considered a nomadic site, a habitation site, and a ritual site. The site offers many advantages over the surrounding topography, which is arid and dry. As a nomadic site, the location is adjacent to a hard rock crossing of the Concho River consisting of exposed bedrock, Figure 5. This crossing was used by wild game, native cultures, and the US military, as military roads connecting forts in the American frontier crossed at this point. There is evidence of temporary military encampments.

The cliff has several habitation areas at the top of the debris or talus slope at the base of the limestone layers. The cliff provides weather protection from rainstorms and harsh winter winds. During the hot, dry summer months, the area is cooled by breezes from the southeast, which make the cliff habitations sites very comfortable.

Figure 5. The hard rock crossing across the Concho River adjacent to the site.

There are multiple sources of water, which include springs at each end of the main cliff area and the Concho River. The habitation areas along the cliff can also act as a defensive position in times of conflict. There are areas below the cliff indicative of larger, long-term habitation.

As a ritual site, the cliff of broken limestone layers provided a canvas for rock art and celestial observations. Both Grant (1967) and Edberg (1985) suggest that small sites may be associated with a family group, whereas large sites are used by villages or groups of villages. The size of Paint Rock argues strongly for use by large groups and the fact that the solar markers are on public display, suggests a ceremonial or ritual nature of the site. One habitation site along the cliff will be shown to be the primary place of observation of the sun-watcher.

Regardless of what type of occupancy, the Concho River provides the opportunity for freshwater fish and game. There is a mussel only found in the Concho River. The alluvial plain, built up in front of the cliff due to a slight bend in the river that begins at the western end of the cliff and across the river, provides suitable grounds for agricultural pursuits. There are fresh water springs at each end of the main cliff, which provides another source of fresh water, not only for human habitation (Turpin et al. 2002) but also for wild game inhabiting an otherwise semi-arid region.

1.2 The Pictographs at Paint Rock

The broken limestone cliff delimits the size of the pictographs, with all the glyphs being on single layers. Multiple glyphs that appear to be related on the same layer constitute a panel. There are several instances where adjacent panels appear to be related to a panel above or below the layer. The 300-meter section of the cliff containing the pictographs is the most exposed portion of the cliff, which also is the only part of the cliff with protected layers of limestone. Kirkland and Newcomb (1967) state that the Paint Rock pictographs have their own distinct style and have no analogs in Texas. Both Kirkland and Newcomb (1967) and Jackson (1938) recorded many Texas rock art sites, but most were in small rock shelters. There is no comparison to the pictographs to the Pecos River area, some 250 km to the southwest, which has over 200 documented rock art sites. The Pecos River area has no reports of interactive solar markers.

Forrest Kirkland was the first to record the Paint Rock Pictographs in a visit with his wife in 1934. This visit to Paint Rock began a passion for Kirkland who went on to paint and record many rock art sites in Texas. The book, *The Rock Art of Texas Indians*, (Kirkland & Newcomb 1967), was published years after his premature death. It details his painting of the rock art and pages 146-158 are his record of the Paint Rock pictographs. A second book, *Picture-Writing of Texas Indians*, by A.T. Jackson, also examines the Paint Rock pictographs, along with many other sites in Texas (Jackson 1938). The Texas Archaeological Society's Rock Art Task Force has recorded the pictographs of Paint Rock.

Turpin et al. (2002) give a broad date for the creation of the pictographs. They found material culture in the form of Toyah Phase[1] pottery in archaeological context with hematite. Hematite is a rust-colored iron oxide found naturally in the region that provides the pigment or color of the monochrome pictographs. Monochrome defines pictographs of one color; polychrome pictographs have multiple colors. There are two primary styles of rock art, which is based on the methods to create the rock art. Pictographs are painted onto the rock, and there is a variety of ways to apply the "paint" of a pictograph. The other style is petroglyphs, created by pecking or incising into the rock (Grant 1967). No petroglyphs are found at Paint Rock.

Who painted the pictographs at Paint Rock is a question that will remain unanswered. During the two years of field surveys, there have been several Native American tribes visiting, all of which referred to Paint Rock as an ancestral site. Through all the literature and search for answers, there is not a statement providing a definitive answer to the question. Paint Rock is a large public display of pictographs, and a nomadic site, which was used by small groups, tribes, and or multiple tribes or villages, which makes the search for the answer extremely challenging. Ultimately, how the pictographs ended up here is probably due to the cultural diffusion. These issues will be expanded in the results section concerning research question 7.

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[1] Different resources give approximate dates of the Toyah Phase archaeological period in Texas. Most agree on the beginning date of 1300 CE, but the ending dates are as early as 1600 CE to 1750 CE, with the most common being 1700 CE.

1.3 Paint Rock in Historical Times

Contact with Europeans changed the native cultures of the Americas. The Spanish and French explorers first entered the Texas territory in 1528 beginning with Cabeza de Vaca (Foster 2008). The transition into historical times was not on an even timeline. Foster (2008) has a detailed map of eleven of the major expeditions in the Texas territory. These range in dates from 1528 to 1721. A review of the map, Figure 6, shows the only expedition that appeared to travel to or near Paint Rock was the expedition of Mendoza in 1684.

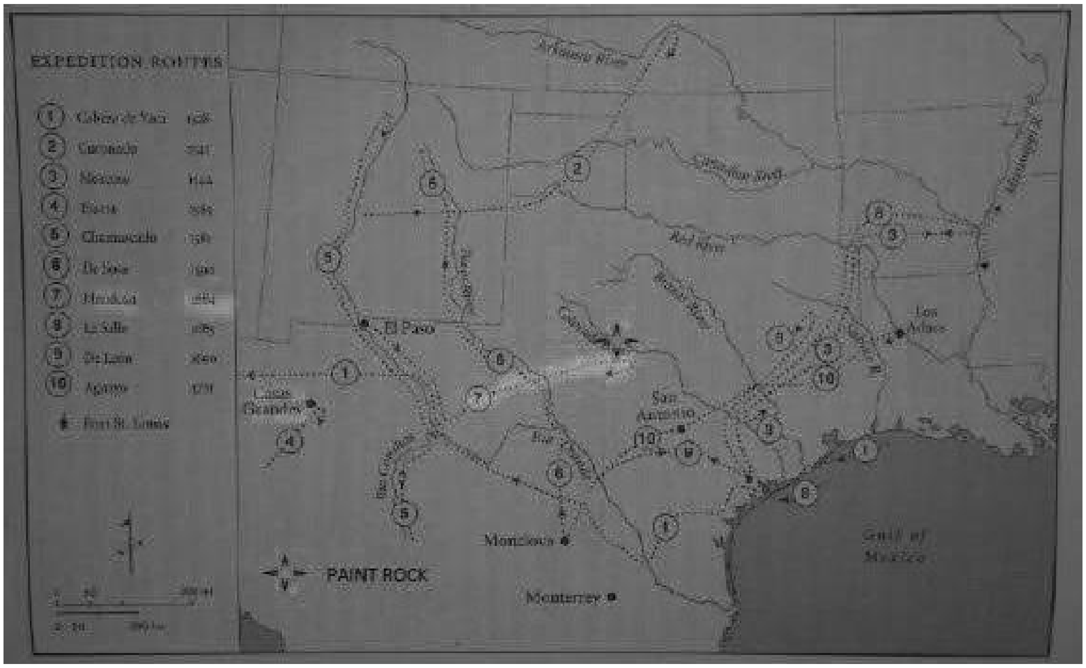


Figure 6. Map showing the expedition routes of the Spanish explorers. Only one, Mendoza in 1684 appears to have been at Paint Rock. Adapted from Foster (2008).

In the 19th century, there was a military road between Ft. Mason and Ft. Chadbourne, which crossed at the hard rock crossing. These roads are illustrated on a map in Rister (1946). The cliff with the pictographs is also covered in many areas with historical graffiti. The earliest graffiti dates to 1856. This date coincides with the encampment of General Robert E. Lee while stationed in Texas (Ashmore 2010). Lee, who later became the commander of the Confederate Army in the American Civil War 1861-1865, camped near the spring at the west end of the pictographs July 16-17, 1856. The site is still an active site for graffiti, as new ones seem to appear on a semi-regular basis.

1.4 Solar Markers at Paint Rock

The jagged nature of the cliff creates a unique play of sunlight and shadow on the layers of the cliff. Native cultures have painted pictographs on many of these layers, with some interactions occurring on significant calendar dates, known in western culture as equinoxes, solstices, and cross-quarter days. There are other pictographs that have star shapes. There are claims that several panels represent the sighting of historical super novae, a significant celestial event, and other panels appear to be seasonal calendars.

Kay Campbell noticed the first sunlight interaction approximately in 1994, where she observed a sun-line lined up with a walking figure (Yeates & Campbell 2002). She took note and began to watch this interaction for several years. She discovered that this interaction occurred on the equinoxes in March and September. Giving a tour in the fall of 1996, she mentioned the interaction to the group, and one of the participants contacted the McDonald Observatory, a major research facility run by The University of Texas.

Dr. R. Robert Robbins contacted Mrs. Campbell and advised that other interactions would possibly found on the summer and winter solstice. As a result, Mrs. Campbell observed the 'sun dagger' interaction on the winter solstice.

Dr. Robbins, the only professional astronomer to study the site, spent almost two years observing the interactions. He confirmed the operation of the Winter Solstice Solar Marker and reported it occurs within minutes of the suns culmination on the meridian (Robbins 1998). He reported his findings in an oral paper given at the 1999 Annual Meeting of the American Astronomical Society. He stated that there were solar interactions at Paint Rock that had to be intentional based on information about the activities of the Native Americans who used the site. He states that Kay Campbell relayed information from her grandfather about five bands of Native Americans who used the Winter Solstice Marker to divide hunting lands. According to Dr. Robbins, this ruled out the interaction as coincidental.

A summary of Dr. Robbins verbal report (UTexweb 1999) indicated that the potential horizon astronomy needed further study. He stated there did not seem to be any interest in the sun's travel along the horizon. This lack of interest is due to the lack of any topical relief along the horizon, in other words, the horizon is virtually flat around the mathematical horizon. Figure 7 is an example of the flat horizon without relief at Paint Rock. The accuracy observed in the operation of the solar markers as stated by Dr. Robbins provided the primary need for the research to discover the method of sun watching and study the site in detail. The discovery of the horizon astronomy at Paint Rock is a primary research goal.

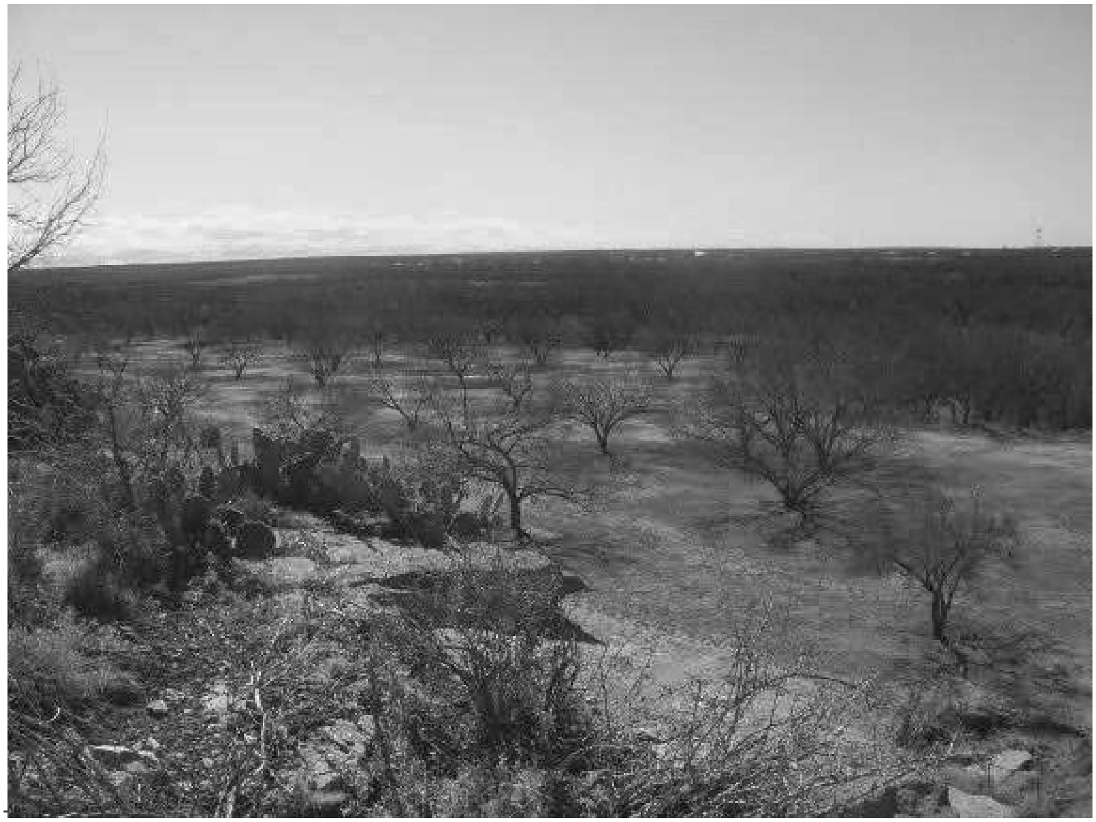


Figure 7. Taken from on top of the cliff looking southeast, the horizon is virtually flat and offers no relief to track the travel of the sun.

There is no precise definition of a solar marker found in the literature on rock art or solar markers. A direct outcome of observing the interactions of sunlight and shadow on the pictographs, and finding no definition in the literature, a definition was proposed in Houston & Simonia (2016) as follows:

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

As a point of reference, I defined a “solar point” as a point on the ecliptic and the celestial sphere, of the Sun on significant calendrical days. In addition to this definition, a guide to confirming solar markers or identifying new ones was proposed in the same article, called the Solar Marker Matrix of Intentionality. Here in after referred to as the Matrix, will be discussed in detail in the first results section.

1.5 Rock Art Sites in Texas

Forrest Kirkland stopped at Paint Rock on the way home from a family reunion in 1933, which began his ten-year study of Texas Rock art by himself and his wife, Lula. They had copied all the known major rock art sites in Texas, and Forrest had hoped to publish a book of their efforts but died prematurely in 1942. Ultimately, their efforts were published in *The Rock Art of Texas Indian,* 1967, with W. W. Newcomb as co-author.

Kirkland & Newcomb (1967) state that there are no other sites in Texas that exhibit the same design characteristics as the pictographs of Paint Rock. Comparing other sites recorded by Kirkland (Kirkland & Newcomb 1967), almost all of which are located in rock shelters with large walls as a canvas, the broken limestone layers at Paint Rock limit the size of the glyphs. Many of these rock shelters are small rock art sites, with only one panel or wall displaying the rock art.

One of the richest rock art areas in the world is only approximately 250 km to the southwest of Paint Rock, known as the Lower Pecos River region. Three converging rivers define the region; the main river is the Rio Grande, and two smaller rivers are the Pecos and Devils Rivers (Boyd 1996, Boyd 2004, Shafer 1977). The Rio Grande River is running approximately east and west at this point, with the Pecos and Devils rivers intersecting from the north and northwest.

Each of these rivers has cut canyon-type structures through the topography, with many rock shelters in the canyon walls. These rock shelters have large walls, and there are over 200 documented rock art sites, consisting mainly of large parietal rock art, with anthropomorphic figures up to eight feet tall. The relative timeline dates this rock art to as old as 4500B.C. up to 1280 A.D. (Boyd 1996, Boyd 2004, Shafer 1977). Kirkland and Newcomb (1967) make the same statement about the Lower Pecos rock art, indicating that they have no analogous sites with the Paint Rock pictographs. No Lower Pecos sites have been identified in the literature as having solar interactions. That is not to say that solar interactions do not exist, but only future surveys with archaeoastronomy as a prime research question may provide an answer.

1.6 Archaeoastronomy

The science of archaeoastronomy encompasses all past human activity related to observations of the celestial sphere and is primarily rooted in the study of monumental constructions and use of the landscape as observing tools. The time span of study is from the earliest times of man, up to the beginning of the historical period of a culture.

Once a culture had contact with more advance civilizations, the original astronomical knowledge and practices changed. This is especially true in the Americas after contact with European explorers.

Michell (1989) gives a brief history of 'astro-archaeology,' indicating that the first person to suggest an astronomical alignment of an ancient monument, Stonehenge, was the Rev. William Stukeley in 1740. Contemporaries of Stukeley, John Wood, and the Rev. E. Duke made various celestial claims of the countryside around Bath and Stonehenge. It was not until Sir Norman Lockyer's book *The Dawn of Astronomy (1894)*, reporting on his research of the temples in Egypt and their alignments to the rising and setting of celestial bodies, did astro-archaeology take on a scientific approach.

Archaeoastronomy has only become a formal area of study in the last 60 years. Interest in the subject expanded significantly with the publication of *Stonehenge Decoded* Hawkins (1965). Hawkins suggested Stonehenge was a form of a celestial computer. His follow up book *Beyond Stonehenge* (1973) detailed astronomies of cultures around the world. Hawkins applied scientific methodology in his investigations. He followed the example set by Alexander Thom who measured hundreds of standing stones and stone circles with survey equipment in Britain (Thom 1955). They used methods from archaeology, astronomy, and surveying.

Archaeoastronomy is the newest interdisciplinary science. It has not been fully integrated into the anthropology and archaeology disciplines. It is an anthropological science that asks social questions: how did cultures utilize and incorporate astronomy into their daily lives? Sinclair (2005) defines archaeoastronomy as the search in the archaeological record for astronomical alignments. As archaeoastronomy has developed, other areas of study related to astronomy have come into play. They are the history of astronomy, historical astronomy, and ethnoastronomy. Combining these three areas with archaeoastronomy, collectively they are now referred to as cultural astronomy.

A formal definition of archaeoastronomy does not have universal agreement among researchers. Archaeoastronomy is part of the history of astronomy, which differs from historical astronomy, the study of recorded astronomical observations. Ethnoastronomy is the study of current astronomical practices by cultures today. Ethnohistorical-astronomy is the use of records of early chroniclers who recorded practices of other cultures, including their astronomy. Recently new variations have been introduced, such as the new journal "Skyscape Archaeology."

Just by the very word archaeoastronomy, the science combines the two disciplines of archaeology and astronomy. Scientific methods from many disciplines are also utilized, but archaeology and astronomy are the main platforms used for analysis and interpretation. They are employed to study the cultural context of astronomy and the celestial sphere, and how this knowledge is manifested into both the material remains and the landscape. Other scientific areas involved include the sub-disciplines of anthropology and archaeology, geology, dendrochronology, climatology, art history, and many others.

Archaeoastronomy is rooted in naked eye observations of the celestial sphere, and the study of the movement of the sun along the horizon. The earliest calendars were developed observing the rise and set points of the sun along the horizon. The evidence of archaeoastronomy is manifested in monumental architecture, rock art, stone circles, and rows, as well as many other techniques employed to watch the sun. Many monumental constructions around the world are aligned with the cardinal points of the compass or rise points of the sun on significant calendrical days. The study of these alignments was the first area of study of archaeoastronomy. For example, the group E Maya structures were built in a north-south line with an observing platform to the West. A large pyramid occupied the center of the north-south platform, with two smaller ones on opposite sides to the north and south. The observing platform was positioned such that the North pyramid or structure aligns with the summer solstice sunrise, the central pyramid or structure aligns with the equinox sunrises, and the southern structure aligns with the winter solstice sunrise.

The rise and set of the sun observed against a horizon with dramatic relief connects the landscape to the celestial sphere. The study of horizon astronomy is combined with the monumental construction alignments. This connection requires archaeoastronomy to study the complete environment. The celestial sphere represents a significant portion of any cultures environment. During the day, the constant movement of the sun dominates the sky. Modern cultures today rarely are aware of the sun's changing location of the rise and set points or the altitude in the sky during the different seasons. These movements were observed by many ancient cultures and found these cycles to be consistent with many aspects of their environment.

The rise and set locations changed with the seasons, as did the altitude in the sky. These regular cycles matched migratory habits of wildlife, growing seasons of plant life, and changing weather patterns, all which were important to survival. The directions of these rise and set points became important, providing a spatial context to their environment. There are many examples worldwide of monumental architecture aligned to the cardinal directions. The regularity of the movements led to a rudimentary form of daily timekeeping and with extended Sun-watching, a concept of annual time. Hence, this led many cultures to adopt some form of formal Sun-watching. These temporal-spatial observations oriented cultures to their environment.

At night, the celestial sphere is dominated by another bright luminary, the Moon. The moon crosses the sky, but the appearance and cycles are much different from that of the Sun. The moon exhibited changing shapes we know as phases. The cycle of the moon occurs in a much shorter period than that of the sun. The moon travels the complete ecliptic in one month. Ultimately, many of the earliest cultures used a lunar cycle for a primary timekeeping device. The complete synodic lunar cycle is 29.53 days, which is the approximate length of a month and formed the basis for lunar calendars. The study of the moon cycles and how cultures utilized them, became the second major area of archaeoastronomical study.

The moon cycles through the ecliptic in one sidereal month, whereas the sun takes a full year. The rise and set of the moon are very irregular from day to day and month to month. Half the rises and sets are during daylight hours. There are claims of lunar standstill alignments, but most are in a stone circle or ring configurations that make these purely coincidental. Schaefer (2007) indicates that there are no valid lunar alignments. Lunar alignments involved with monumental construction are still under debate.

Sharing the celestial sphere at night with the moon were many other bright luminaries. The stars moved across the night sky with the same regularity as the Sun and Moon, changing ever so slightly each day. Other bright luminaries were more mystifying to the ancient cultures. These we now know as planets had movements independent of the fixed bright luminaries and the moon. They were sometimes visible in the morning before sunrise, sometimes at night after sunset, sometimes all night, other times not at all.

The third area of archaeoastronomical study and the newest is the interaction of sunlight and shadow on rock art (Sinclair 2005). Rock art is ubiquitous around the world in locations where there are abundant outcrops of rocky terrain, rock shelters, and caves. The first reported solar interaction was by Ken Hedges during the winter solstice of 1976 in Baja California. Hedges report has led to a multitude of discoveries in the American Southwest, California, and Baja California. These interactions recording some of the astronomical knowledge of a culture are known as "solar markers." Interestingly, there is a paucity of reports worldwide, yet rock art is ubiquitous around the world.

1.7 Objectives and Research Questions

The hypothesis is that Paint Rock is a major sun watching station, as there are significant clues to suggest advanced astronomical knowledge is encoded in the material culture and landscape. The observed accuracy and function of the first solar markers discovered at Paint Rock, strongly suggested that the Native American cultures could define the travel of the sun along the horizon. The horizon having no topographical relief led to the first two research questions. Establishing the horizon astronomy and the place of observation are paramount in archaeoastronomy investigations. There are a multiple images that depict stars and solar images on the cliff. This material culture would indicate those that spent time at Paint Rock possessed astronomical knowledge. Hence, the study of the astronomy at the site is broken down into seven research questions. The complete lists of seven research questions developed to begin the research are:

1. Determine the horizon astronomy or other method of fixing the major solar positions and calendar operations.
2. Determine the observing position(s) used to watch the sun, moon, and stars.
3. Observe the calendrical light and shadow mechanics on the pictographs already identified, for verification of their operation at the stated times and major solar positions.
4. Identify any new solar markers and determine if there are pictographs that exhibit calendrical operations throughout the year.
5. Determine any other bright celestial objects, including bright stars, planets, the moon, and constellations that may have potential calendrical significance.
6. Can any of the iconography of the pictographs match any significant astronomical phenomenon, i.e., comets, supernovas, eclipses?
7. What evidence is there for the cultural transmission of astronomical knowledge either from or to cultures in adjacent areas?

The organization of the dissertation is set around each of these seven questions.

An unexpected outcome of the research, and tied directly to research questions three and four, is the Matrix of Intentionality, referred to as the 'Matrix' throughout the dissertation. It was realized through hours of field observations and review of the literature attempting to create a statistical database that a guide was needed to help identify new solar markers or confirm reported solar markers. The examination of the Matrix is in a dedicated section prior to the sections related to the seven research questions.

Throughout the dissertation there are numerous figures, which are photographs of pictograph interactions taken during hours of observation. Three thousand seven hundred and sixty seven photographs were taken during 20 trips over two solar years. Appendix 1 details the research activity. Finally, before proceeding with the dissertation, it can be stated that positive outcomes for each of the seven questions resulted from the field research, which confirms the hypothesis that Paint Rock was a major sun-watching station.

2.0 LITERATURE REVIEW

Archaeoastronomy has only been a formal area of study by scholars since the 1960s. The modern literature on archaeoastronomy has evolved over this 52-year time span. The multi-disciplinary nature of archaeoastronomy requires knowledge in a broad range of topics, and as a result, a wide variety of literature. The literature review will be organized by topics encompassing archaeoastronomy. Rock art literature is a primary area to be covered. Astronomy will be the first area covered, followed by archaeoastronomy, archaeology, rock art, methodology, and other related topics. However, before any of this, the literature directly related to Paint Rock will be examined.

2.1 Paint Rock Literature

The two publications directly related to the pictographs at Paint Rock are an abstract by Dr. R. Robert Robbins (1998), a summary article of Robbins verbal report on the McDonald Observatory website (UTexasweb), and the article by Yeates and Campbell (2002). There are two additional articles, one by Ashmore (2010) dealing with historical encampments in the 1800's, and Turpin et al. (2002) a broad archaeological investigation of the site. These articles sum up the state of the study and research of the Paint Rock site. The only peer-reviewed article is Turpin et al. (2002), with no publications of any of the articles in scholastic journals. Hurt (1980) wrote a master thesis on archaeological investigations in the middle Concho Valley, which was not published.

The abstract by Dr. R. Robert Robbins as published in the program of the 1999 American Astronomical Society Annual Meeting program. A press release (UTexasweb) of the report is located on the McDonald Observatory website. He reported on the solar markers discovered by Mrs. Kay Campbell and had indicated where one exists there may be others. He found a summer solstice marker involving a shield with a turtle. He indicated that there appeared to be no interest in the rise/set points of the sun along the horizon, but recommended further study. It was this press release report that provided the necessary challenge to study the astronomy of Paint Rock. Finally, Dr. Robbins provides some interpretation of the Winter Solstice marker, suggesting it had multiple meanings. Starting with the turtle symbol in the middle, he draws some potential Mesoamerican connection. He also states that the design is a marker used for dividing lands for hunting among five tribes in the area.

The next paper is an article co-authored by the ranch owner, Mr. Fred Campbell, and Bill Yeates, which was posted to the Concho Valley Archaeological Society website, Yeates & Campbell (2002). This article discussed archaeoastronomy and the Winter, Summer, and Equinox markers. As found in other literature, some of the pictographs are reported to be possible astronomical representations of eclipses and supernovae. This paper was used to identify those solar markers already identified, whose operations are to be studied as outlined in research question 3.

The paper by Turpin et al. (2002) is the most comprehensive archaeological survey of the Paint Rock site. The paper gives the most definitive dates for the scribing of the monochrome pictographs. They base this on cultural remains found in context as previously stated above. The paper supports the extended use of the site back to the Archaic period and lends support to the site as a nomadic site, and a cultural crossroads. The paper by Ashmore (2010) of encampments in the 19th century helps give a complete picture of the sites use into the late historical period.

2.2 Astronomy Literature

In archaeoastronomy, it is important to know basic naked eye astronomical concepts, including, movements of the sun, moon, and planets, the celestial sphere and the constellations, and the cause of the changing of the seasons. Every textbook on astronomy starts with historical background and basic astronomical concepts (Fix 2004, Chaisson & McMillan 2005, and Freedman & Kaufmann 2008). Although not an astronomy textbook, the book by Hockey (2011) is completely dedicated to how we view the sky and naked eye astronomy.

The requirement to have knowledge of naked eye astronomical concepts is also borne out in the literature on archaeoastronomy, mainly books, which generally start out with discussions of these basic astronomical concepts. Aveni (2001) devotes Chapter 3 to these concepts, Aveni (1997) devotes Chapter 2 to naked eye astronomy, and Malville (2008) introduces astronomical concepts throughout the book, which relates to the astronomy of the particular site under discussion. Ruggles (1999) introduces astronomical concepts in special boxes throughout the book, and the topics are in line with the particular site being investigated. Williamson (1987) devotes Chapter 3 to "Celestial Motions" of the sun, moon, planets, and stars. Krupp (1978A) devotes Chapter 1 discussing basic astronomical concepts and their relations to specific sites as examples of the concepts. Holbrook & Baleisis (2008) paper is devoted to understanding naked eye astronomy for cultural astronomers. In this paper they use screenshots from Stellarium astronomical software. One must have a clear understanding of these basic naked eye concepts of astronomy, as without such knowledge, the ability to understand the literature relating to archaeoastronomy becomes a moot point.

2.3 Archaeoastronomy

There is a growing amount of literature since the 1960's. The literature that deals with archaeoastronomy methodology are the first to be considered. References which deal with methodology include: Williamson (1984), Ruggles (1999), Aveni (1975, 1982, 1993, 2001, 2008), Schaefer (2000, 2006, 2007), Polcaro & Polcaro (2009), Iwaniszewski (2011), Simonia (2011), Simonia, et al. (2009, 2015), Simonia & Simonia (2005, 2011), Zeilik (1984, 1985A, 1985B, 1989). This list is not exhaustive, but within these publications, a comprehensive methodology can be extracted. Each paper provides insight into concepts to be considered in the study of any archaeoastronomy site. The references with the best details of methodology for archaeoastronomers from the above list are Ruggles (1999), Aveni (2001), and Polcaro & Polcaro (2009). The methodology used in this study is primarily a combination of these three sources and several on archaeology.

There is a wealth of archaeoastronomy literature contained within the conference proceedings of conferences held dealing directly with archaeoastronomy. These conferences include the "Oxford" conferences, SEAC conferences, INSAP, and conferences held by the Society for Cultural Astronomy of the American Southwest. Publications referenced from these conferences include: Aveni (1982), Bostwick & Plum (2005), Carlson (2000), Chamberlain (2006), Chippindale & Tacon (2004), Fisher (2010), Fountai (2005), Heggie (1982), Hoskinson (2005), McCluskey (2010), Munro & Malville (2010), Ninnemann & Malville (2010), Rodriquez, P. (2010), Ruggles (2011), Ruggles and Saunders (1993), Schaefer (2006), Simonia and Simonia (2005), Sinclair, & Chase (2005), Sinclair & Chase (2006), Vogt (1993), Whitley (2006), Zeilik (1989), and Zoll (2010).

Each of the above references is important to this thesis. Singling out those that have the most direct impact are Aveni (1982), Fountain (2005), Heggie (1982), Ruggles (2011), Schaefer (2006), Zeilik (1989), and Zoll (2010). Aveni (1982) and Heggie (1982) are the Oxford I proceedings known as "green" and "brown" archaeoastronomy. Ruggles (2011) discusses the state of the science of archaeoastronomy. Schaefer (2006) makes a case for the operation of rock art solar markers. This paper is part of the first main section of the Oxford VII proceedings titles "Methodological and Theoretical

Issues," which is a set of seven papers that are unique in that they have a strong scholastic banter on the methodology used at various sites with opposing views. Zeilik (1989) in one of the several similar papers has set some methodology requirements. Zoll (2010) discusses concepts that have been adopted in dealing with solar markers, which have been incorporated into the Matrix.

The above conferences are held on a regular schedule. There are some significant conference publications, in which the conference was a one-time occurrence. Four of the most significant are Native American Astronomy symposium in 1975 at Colgate Univerity, proceedings edited by Aveni (1977), the Maxwell Museum symposium in 1983, and a symposium held at California State University, Northridge held in 1983, the "First International Conference on Ethnoastronomy: Indigenous Astronomical and Cosmological Traditions of the World" also held in 1983. These proceedings not only deal with archaeoastronomy, but many of the papers deal with rock art and solar markers. The Maxwell Museum symposium deals with the American Southwest. The Northridge symposium with rock art solar markers in California, and the third conference deals with issues of ethnoastronomy worldwide, but over half the papers deal with Native astronomical traditions in the Americas. It is important to point out that the first two conferences were held only six years after the first reported solar marker by Ken Hedges in Baja California. The specific articles of importance will be discussed in the section on rock art literature.

Books and journals are the last two remaining sources of literature for archaeoastronomy. Starting with books, two books are guides to archaeoastronomy methodology and deserve separate discussion. The updated book by Aveni (2001) has significant discussions on horizon observations of the sun and stellar objects. The book has the best set of formulas for precise determination of horizon declination points. Conversion of a geographic azimuth to a celestial declination point on the horizon is the primary goal of field surveys. Ruggles (1999) is very deep on methodology and has a description of the process and nature of archaeoastronomy fieldwork. There are many books that have archaeoastronomy as their main topic. Each these books add a similar but different view on individual sites and how they are investigated. These include Aveni (1975, 1977, 1978, 1982, 1993, 1997, 2001, 2008a, 2008b), Burl (1995), Chapman (2001), Hadingham (1983),

The number of journals dedicated to archaeoastronomy is few, in fact, since starting this program, one of the premier journals, Archaeoastronomy, The Journal of Astronomy in Culture has recently shut down. That journal was the primary journal for ISAAC. For over twenty years, the Journal for the History of Astronomy used to publish a supplement called Archaeoastronomy from 1979 to 2002. The supplement has been incorporated into the main journal after 2002. Both of these journals contain papers of significance to the subject of archaeoastronomy. The following papers are from the above referenced journals: Aylesworth (2004), Brandt & Williamson (1979), Broda, J., 2000, Fisher (2010), Koenig (1979), McCluskey (2010), Munro & Malville (2010), Murray (1998), Ninnemann & Malville (2010), Rodriquez (2010), Ruggles (2000), Schaefer (2000), Young (1986), Zeilik (1984), Zeilik (1985a), and Zeilik (1985b).

2.4 Archaeoastronomy Iconography

A subset of archaeoastronomy and challenge to rock art research is the interpretation of motifs in rock art panels. The literature directly related to rock art will be addressed under separate categories in the following sections. This section deals with the literature related to rock art interpreted as an astronomical or celestial, and the backup scientific literature. There are many rock art interpretations of motifs as stars, comets, supernovae, eclipses, and constellations. At Paint Rock, there are motifs that have been interpreted as all of these, except for comets. The interpretation of motifs as supernovae has the largest body of literature.

After the first report of a motif as a possible representation of the 1054 supernova (SN1054) by Miller in 1955, there have been an ongoing number of claims across the American Southwest. The background scientific literature includes: Baade & Zwicky (1938), Brecher et al. (1983), Clark & Stephenson (1977), Eldridge (2008), Fix (2004), Green (2002), IAUweb-Con (2016), IAUweb-SN (2016), SEDSweb (2016), Simbadweb (2016), and van den Bergh (1973). The literature discussing SN1054 iconography include: Brandt & Williamson (1979), Collins et al. (1999), Ellis (1975), Fisher (2010), Hamacher (2014), Kidwell (1985), Koenig (1979), Krupp et al. (2010), Malville (2008), Marshack (1985), Mayer (1975), Mayer (1979), Olowin (2005), and Young (1986).

2.5 Archeology

The other primary discipline of archaeoastronomy is archaeology. As archaeoastronomers, one is not practicing general archaeology, often an investigation will include interfacing with archaeologists, so it is essential to be aware of the methods employed in archaeology. In addition, all archaeoastronomy sites are archaeological sites, so a broad understanding of archaeology is necessary. Like with the literature on astronomy, the basic textbooks on archaeology are great starting points. One of the more widely used textbooks is *In the Beginning, An Introduction to Archaeology,* by Fagan & DeCorse (2005). Used by many colleges and universities, the book provides a comprehensive overview of archaeology. Although somewhat mislabeled, there is a chapter on intangible archaeology called Astroarchaeology and Stonehenge. There is discussion in this chapter dealing with sacred landscapes. A second textbook, *Field Methods in Archaeology* (Hester et al. 1997) provides a detailed methodology for archaeologists. Several advanced books on archaeological theory include Renfrew & Bahn (2007), and Johnson (1999).

Beyond the basic archaeology textbook, the literature on individual topics related to archaeoastronomy includes those on Texas, landscape archaeology, cultural diffusion, and related anthropology topics. The edited book *The Prehistory of Texas* (Pertulla 2004) is a comprehensive edited book on the archaeology of Texas. The *Handbook of Landscape Archaeology* (David & Thomas, Editors 2008) is a primary book used on the topic of landscape archaeology. The paper by Tilley (2008) deals with an approach to landscape that discusses a holistic approach to a site, which is very appropriate for archaeoastronomy investigations. Devereux (2010) and Wilson & David (2002) are two books about landscape that also deals with sites containing rock art.

2.6 Rock Art

The literature of rock art can be broken down into two areas. They are general rock art studies, and the literature dealing directly with solar markers and astronomical motifs. There is a multitude of books dealing with rock art. These include Grant (1967), Schaafsma (1980), Chippendale & Tacon (2004), Loendorf et al. (2005), and Whitley (2011), besides the two already mentioned on Texas rock art. These books describe various methods of producing rock art, recording rock art, interpreting rock art, and who scribed most of the rock art within tribes, villages, or groups of villages. It is essential to understand how archeologists deal with rock art and how they deal with interpretation. Most concur that rock art is not simply doodling on rock by these cultures, in other words, it is not simply graffiti.

The investigation by archaeoastronomers is focused on the astronomy of a site or location. The search for embedded astronomical knowledge in the cultural remains is the primary research goal. Rock art solar markers are a prime example. Ken Hedges first reported solar interactions with rock art in 1977, which was the start of investigations into solar markers. His observations were at a cave in La Amuroase, Baja California, during the 1976 winter solstice. Hedges reported a sunlight triangular dagger interacting with a rock art motif, which is mentioned in other articles (Fountain 2005, Sinclair 2006), as the first identification of a solar marker involving rock art. Not too long after this, Anna Sofaer discovered the "three-slab" site on Fajada Butte in Chaco Canyon (Sofaer & Sinclair 1983).

The paper by Murray (1998) discusses the *in situ* nature of rock art and may be the first to defend the operations of solar markers as intentional. Young (1986) is skeptical of solar markers, indicating that they are simply coincidental interactions. In the conference and symposium proceedings mentioned above, there is a wealth of papers directly related to rock art solar markers, which include: Hudson et al. (1979), Preston & Preston (1983, 2005), Sofaer & Sinclair (1983), Williamson (1983), Hedges (1985), Hudson (1985), Buckskin (1985), Edberg (1985), Spanne (1985), Armbruster & Hull (2005), Bates (2005), Bostwick & Plum (2005), Chamberlain et. al. (2005), Chamberlain & Rogers (2005), Fountain (2005), Hoskinson (1985, 2005), Olowin (2005), Whitley (McCluskey (2010), Krupp et al. (2010), and Zoll (2010).

There is an entirely different assertion of astronomical association with rock art not involving solar interactions. These claims assert that the design motif of the rock art represents significant astronomical events including supernovae, comets, and eclipses. References of these events include Brandt & Williamson (1979), Brecher et al. (1983), Ellis (1975), Fisher (2010), Hamacher (2014), Hedges (1985), Kidwell (1985), Koenig (1979), Krupp et al. (2010), Malville (2008), Mayer (1975, 1979), Olowin (2005), Rodriquez (2010), Schaafsma (1985), and Yeates & Campbell (2002).

There are claims of representations of stars, star maps, constellations, and star clusters. References include, but not limited to, O'Brien (1986), Patterson (1992), Chamberlan & Rogers (2005), Olowin (2005) and Schaafsma (2005).

2.7 Anthropology

The unique aspect of archaeoastronomy in the American Southwest is the access to ethnographic records of the Native Americans in the region. Early chroniclers spent time with villages, recording all activity, including some astronomical practices. Cushing (1970) spent time in the Zuni Pueblo of what is now western New Mexico. He records the sun watching of the Sun Priest. Fewkes (1898) studied the Hopi mesas in 1895, recording their activity. The early Spanish explorers starting in the 16th century had expeditions that crisscrossed the southern half of Texas and into the upper Rio Grande pueblo areas of New Mexico. These chroniclers recorded all they saw and Foster (2008) explains their records in detail. Two problems exist with these records, first, the lack of astronomical knowledge of the chronicler, and secondly, in most instances, astronomical knowledge was closely guarded within a village or tribe, and many times unknown even to the members within the group. Hence, the records are sketchy and incomplete but offer more than many other cultural groups worldwide.

The challenges at Paint Rock are compounded by the fact that it is a nomadic site. The site contains habitation, ritual, and ceremonial inferences, but no record that establishes which group inscribed the pictographs. A discussion of cultural diffusion is required to help fill the full understanding of Paint Rock. A book of edited papers by O'Brien (2008) discusses various transmission processes, and the paper by Parker (2006) discusses the interaction between cultures or villages/tribes within cultures along the adjoining boundaries of their respective territories.

The literature on Native Americans is almost too numerous to do it justice here. Dividing it into two categories, one being descriptive anthropology and literature devoted to spiritual ideas and mythology will be consulted for a better understanding of the mind and practices of the Native American. Foster (2008) is dedicated to the record of early European expeditions of the Texas region. Beginning in 1528, he used the primary source material of the chroniclers of those expeditions. He gives a detailed description of the pre-Columbian Native Americans. Individual articles and books on Native Americans include: Baugh (1986), Bolton (1910), Collins, (1971), Driver, William &

Massey (1957), Ewers (1973), Hämäläinen (2003), Hickerson (1994), Kidwell (1985), Newcomb (1986), Newcomb & Kirkland (1967), Parks & DeMallie (1992), Wallace & Hoebel (1986), and Wilcox et. al. (2008). Articles in the second category that deal with mythological and spiritual issue of the Native Americans include: Benedict (1922), Jones & Molyneaux (2004), McGaa (1990), Miller (1997), Miller (1996), Monroe & Williamson (1987), O'Brien (1986), Spence (2004).

The reference section contains many additional entries not directly included in the literature review categories, but are important as a overall reference list of arcaheoastronomy. This completes the literature review, which as will be seen in the next section, Methodology, is the first step in any archaeoastronomy investigation.

3.0 METHODOLOGY

A rigorous methodology in research will enable the researcher to secure accurate empirical data, which in turn, will help avoid errors and observer bias. Accurate data provide a sound basis for evaluating the general hypothesis and the underlying research questions. Methodology in archaeoastronomy has three phases, which are: 1) research the background literature, 2) employ standard field research methodology, and 3) data analysis. Each phase will be discussed in depth.

3.1 Research Background Literature

Many tasks can be done before proceeding to a site for an initial field survey. The first step is to review all background literature available on the site. The literature review gives one a sense of the site, with archaeological evidence of use and habitation extending back "thousands of years" (Turpin et al. 1999). The literature review may lead to additional research questions and or used to modify the research plan. The literature of the Paint Rock archaeological site was outlined in the literature review section. Reviewing and employing internet resources is a new addition to the background research on a site.

The 2-page press release of Dr. R. Robert Robbins (UTweb 1999) provided the primary astronomical analysis that led to this research. This preliminary step may involve many months before the first field visit, depending on the depth of the literature surrounding a site. In the case of Paint Rock, there were just three primary articles to review before the first field visit. The literature review step is an ongoing process and only concludes when the results are summarized and or published.

3.2 Internet Resources

Establishing the horizon arc in advance of the trip is useful in using online resources, as well as horizon observations in the field. The horizon or solar arc is the angular distance and maximum travel of the sun's rise/set points north and south along the horizon. Knowing the extent of the sun's travel before the field survey stage allows one to take note of topographical relief within the arc of these rise set points. The horizon arc is very site specific based on latitude, and is only a rough approximation, except for sites whose east and west horizons have 0° elevations. The ends of the arc may change based on the altitude of the horizon at that point. The horizon solar arc can be calculated using Formula 1.1 (Menon 2012).

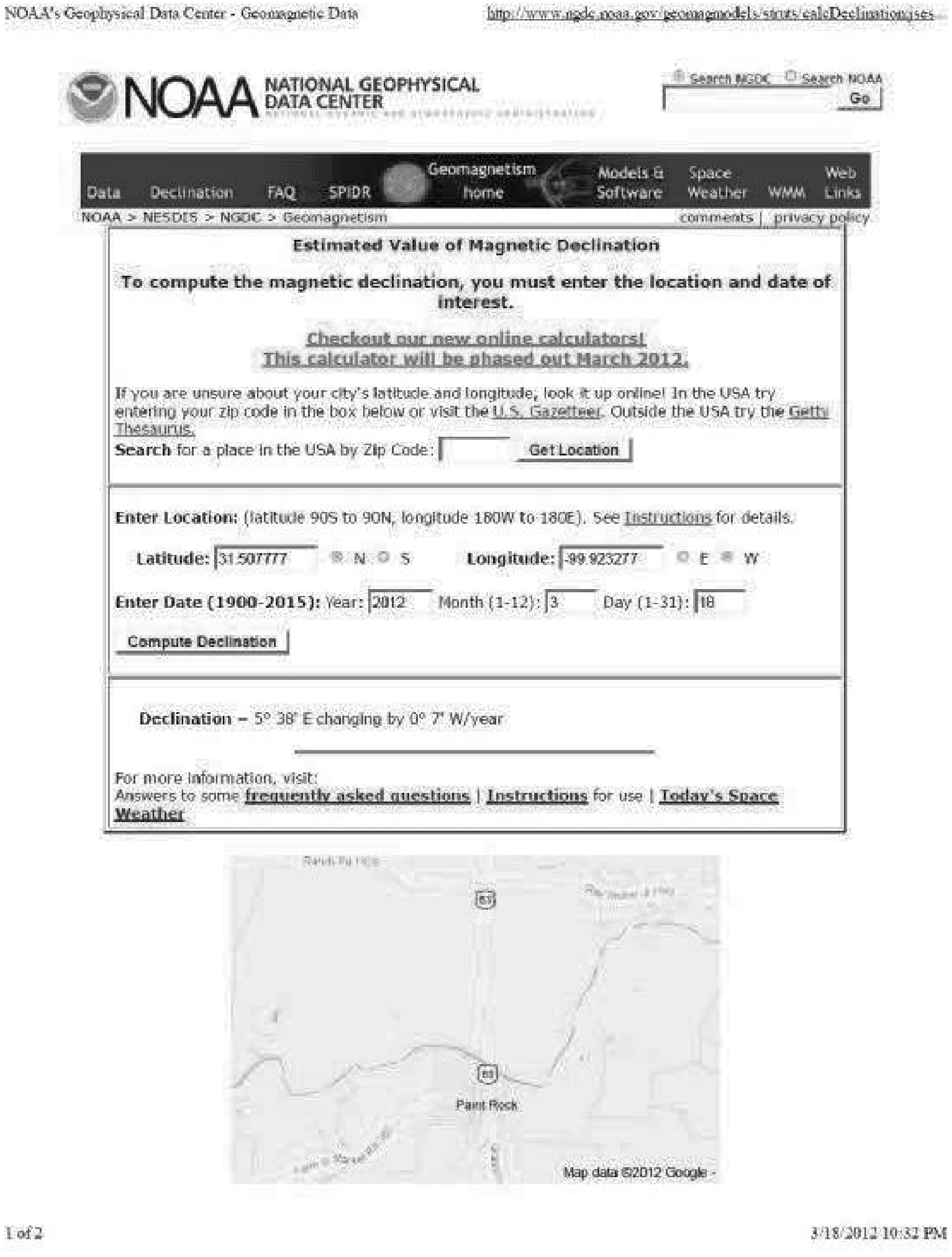
$$1.1 \ \alpha = 2 \times 23° \, 26' \, 29'' / \cos \varphi$$

The terms of the formula are: α is the angle of arc delimited by the solstices, and φ is the observer's latitude. The calculated solar arc for Paint Rock is a combined angle of arc of 55.15°. Dividing this angular range in half, then adding and subtracting this amount from the east and west points of 90° and 270° respectively, will define the local horizon arc for the east and west horizons. At Paint Rock, the east horizon arc is 62.4° to 117.6°, and the west horizon arc is 242.4° to 297.6°. The main topographical feature of Paint Rock is the flat and featureless horizon, especially within the solar horizon arc. This feature was addressed by Robbins (1999) was the major underlying cause of this research The horizon's at Paint Rock has a 0° elevation using a clinometer. Therefore, no adjustment was required.

Consulting on-line resources available today provides a wealth of information. Today, topographic maps are available, which can be studied and provide a glimpse into the possible horizon astronomy, using the calculated solar arc from the section above.

Satellite views of the location are available from many platforms. Google Earth is the most well known of these applications. ACME Mapper 2.1 and Bing are two more applications that offer excellent flexibility to examine a site at the desk before the actual field survey. These resources were utilized in the research of the site.

Figure 8 is a readout from NOAA (NOAAdec) using their magnetic declination calculator which was accessed on March 18, 2012. The magnetic declination calculated for Paint Rock is 5° 38' east. The declination figure was used to adjust the Brunton Transit to compensate for the local magnetic declination. Figure 9 is a downloaded and labeled topographic map of the Paint Rock area, with the visual horizon marked by a dashed line. Figure 10 is an aerial view of the east horizon. Figure 11 is from Google Earth, which was used to assist the field survey. From this view, a potential horizon rock cairn was discovered, which will be discussed in the results section. The next step is the preparation of the equipment.



NOAA's Geophysical Data Center - Geomagnetic Data http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination;jses...

NOAA NATIONAL GEOPHYSICAL DATA CENTER

● Search NGDC ○ Search NOAA

Go

Estimated Value of Magnetic Declination

To compute the magnetic declination, you must enter the location and date of interest.

Checkout our new online calculators!
This calculator will be phased out March 2012.

If you are unsure about your city's latitude and longitude, look it up online! In the USA try entering your zip code in the box below or visit the U.S. Gazetteer. Outside the USA try the Getty Thesaurus.

Search for a place in the USA by Zip Code: Get Location

Enter Location: (latitude 90S to 90N, longitude 180W to 180E). See Instructions for details.

Latitude: 31.507777 ● N ○ S **Longitude:** -99.923277 ○ E ● W

Enter Date (1900-2015): Year: 2012 Month (1-12): 3 Day (1-31): 18

Compute Declination

Declination = 5° 38' E changing by 0° 7' W/year

For more information, visit:
Answers to some **frequently asked questions** | **Instructions** for use | **Today's Space Weather**

1 of 2 3/18/2012 10:32 PM

FIGURE 8. NOAA declination calculator showing magnetic declination for Paint Rock.

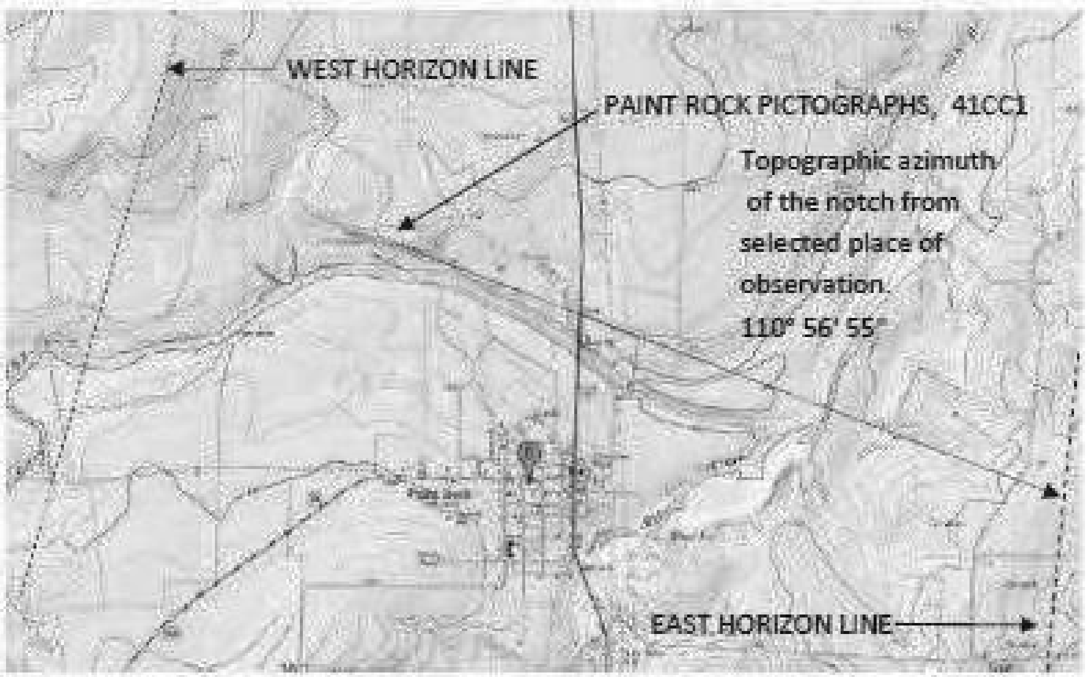


FIGURE 9. TOPO map from the web labeled with features, adapted from ACMEweb.

FIGURE 10. Aerial view from Google Earth with a potential rock cairn on the east horizon.

3.3 Equipment Preparation

The following list contains the equipment used during the field research, with some items being acquired during the course of the field research, and thus, they only became available later in the process. A description of the use and purpose of each of the items will be given to give context to the preparation and overall methodology.

1. Brunton Transit magnetic compass with a non-metallic tripod.
2. Suunto sighting magnetic compass.
3. Suunto clinometer
4. Canon 40D camera, with tripod and solar filter
5. Olympus FE5010 camera, with solar filter
6. Garmin Oregon 450 GPS
7. Nikon NE-103 electronic theodolite, with a tripod and solar filter.
8. Casio Atomic watch
9. 100-meter tape measure
10. Grundig shortwave receiver
11. Hewlett Packard laptop computer

The Brunton transit is a magnetic compass and a clinometer. It can be used handheld for quick measurements, and a non-metallic tripod is available for making more precise survey measurements. The transit was adjusted for magnetic declination as outlined above using the NOAA web magnetic declination calculator. The Suunto sighting magnetic compass and clinometer comes as individual instruments or they can be obtained as one combined unit. These are duplicate functions similar to the Brunton Transit, but offer quicker results during a walking survey of a site, and can act as a redundant check against measurements from the Brunton transit. These were acquired after the beginning of the field research.

The two cameras serve similar functions, and a solar filter was constructed for each camera. The Olympus FE 5010 camera is a 12 mp camera, that is travel size, which I recommend should be carried at all times. The Canon 40D camera is a large format SLR and has the capabilities of changing lenses. The Canon 40D initially came with a short-range zoom lens. This lens was replaced with a Tamaron 18-270mm zoom lens. This zoom lens acted as a monocular, magnifying the field of view for inspection purposes, like a spotting scope or pair of binoculars.

The cameras are a vital recording device in rock art solar marker research. Each camera is calibrated to the correct time before each trip. Throughout the observation phase of sunlight and shadow on the rock panels, a picture would record the local time of the occurrence. Time becomes important when determining a sequential interaction.

The Garmin Oregon 450 GPS provides a location record for points of interest and provides an elevation figure. The accuracy is <33 ft. (10m), which can be improved performing waypoint averaging, which gets the accuracy down to 10 to 16 ft (3 to 5 m). Garmin GPS products use the WAAS or Wide Area Augmentation System. The primary function is to obtain an accurate location figure for the use and calibration of the theodolite. Since 1" arc second on the earth equals ~30 meters or over 100 feet, readings without waypoint averaging is accurate enough for archaeoastronomy surveys.

The Nikon NE-103 is a dual display electronic theodolite, with 5" second accuracy. The theodolite is used to survey the horizon. The atomic watch is critical to maintaining correct time. It is used for sun sights and to calibrate the cameras, which offer a time stamp. The surveyor's 100-meter measuring tape is used for a variety of site measurements and mapping. The Grundig shortwave receiver is used to calibrate and act as a double check for the time. The Hewlett Packard laptop can be used as a time check, as time on the computer is maintained through an NTP synchronization, but is used only as a last resort. The computer is used in the field to calibrate the theodolite with the sun sights taken and the USNO MICA program. Initial measurements of the horizon were taken without resetting the theodolite. In this instance, the horizon figures must be corrected in the data reduction step.

The equipment needs to be checked and made ready before any field research. First, much of the equipment, cameras, theodolite, shortwave receiver, GPS, and the computer all run on batteries. Before each trip, all batteries were checked and charged, since most are rechargeable. Backup batteries were charged, and backup standard batteries were checked. The charging unit for each piece was located and packed, as well as back up batteries. The second main step was to calibrate and set all the time functions on the equipment. The atomic watch is placed on a windowsill overnight, per the instructions, to receive a radio time signal calibration. The watch receives up to six calibrations a day from NIST, National Institute of Standards and Time from Ft. Collins, Colorado, USA. The cameras were calibrated to the correct time using the atomic watch.

The Grundig shortwave receiver receives a time signal on several frequencies, which can be used to calibrate time in the field if there is a concern that time on a device is off. It can also be used as a recheck of time.

3.4 Field Survey

The next step was to perform fieldwalking surveys. The study of rock art sites with solar markers requires a field survey every month for a year. Doing surveys every month means surveys are held in months that do not include a significant solar point, which are the solstices, equinoxes, or cross-quarter days. The primary reason for this twelve-month effort is to rule out possbile coincidence of solar interaction with the rock art. Therefore, the first year there were 12 visits, and the second year the visits were only on solar points. Twenty visits to the site were conducted (Appendix 1). The field surveys are used for preliminary inspection of any archaeological site. One sub-discipline of archaeoastronomy is landscape archaeology. Field surveys in landscape archaeology are similar to the surveys in archaeoastronomy, only cultural remains on the surface or constructed monuments are observed. Hence, no test pits are dug looking for material culture, as the rock art is the material culture.

A major portion of the first four trips to Paint Rock was to identify the place of observation and study the site for the potential sun watching along the horizon. A secondary goal was to inspect the horizons and any related features that may be used as a foresight in the horizon astronomy. Hence, the field survey of the area included extensive walks to each of the far horizons. Finally, a portion of each of the 20 trips taken over the two-year study period was devoted to observing the interaction of sunlight and shadow on the pictographs. The cameras were a major portion of recording what was seen. The set of photographs can be studied after each trip. The photographic study led to the discovery of the horizon "notch," which will be discussed in the results section.

3.5 Horizon Survey

The primary tool for archaeoastronomy investigations of the horizon and monumental architecture alignments is a transit or theodolite. The instrument used in this study is a Nikon NE-103 electronic theodolite. It has and accuracy of 5" arc seconds. A sun filter is a minimum accessory to perform sun sights to calibrate the data or the theodolite. The Nikon NE-103 has many advantages for archaeoastronomy. First, it has a dual display, which saves time and helps eliminate errors, which can be set to read in hours, minutes, and seconds. Secondly, it has an illuminated reticle allowing for taking measurements in low light situations, or celestial objects at night. Finally, the reticle has four linear lines in a box, which provides a 40' arc minute box for centering the sun, Figure 13. This feature also makes taking sun sights much faster and does not require mathematical reductions that may induce additional error.

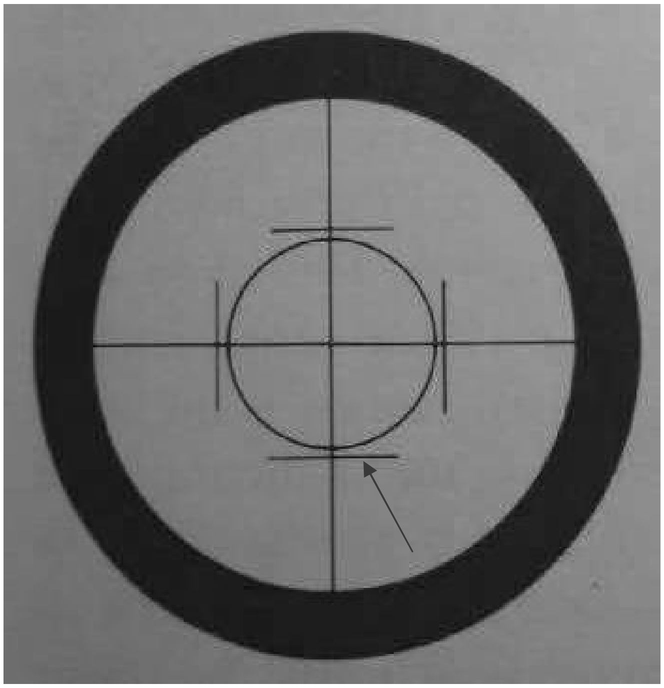


Figure 11. The reticle from the Nikon NE-103 theodolite. The arrow points to one of four lines that create a 40' arc minute box. Figure from the web, creative commons.

After setting up the theodolite over a survey peg, and leveling the instrument, an initial reference point (RP) should be established. The RP acts as a check to ensure that the theodolite has not been compromised during the measurement phase. An occasional check of the RP should be performed throughout the measurement period. The next step is to calibrate the theodolite taking a series of sun sights. In archaeoastronomy, the sun sight is the most critical operation for calibrating the theodolite for accurate azimuth readings. Today's measuring devices are far more accurate and easier to read than the older model units. The 40' minute reticle in the Nikon NE-103 that allows for centering the sun, which subtends an angle of 32' arc minute. When the sun is centered there are 4' minutes on each side, top, and bottom, as potential sighting errors. Visually, it is straightforward to center the sun with very little error.

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The second aspect of sun sight-readings is time. Timing devices that are appropriately adjusted to a standard time signal as discussed above make readings of sun sights well within an accuracy required for archaeoastronomy. This accuracy as stated in the literature is 1/2°, which is 30' arc minutes (Aveni 2001). Recording the time and the horizontal and vertical angles give all the information necessary to calibrate the theodolite. Using the US Naval Observatory program MICA, the information calculates the position of the sun at the recorded time. A standard deviation from sun sights is determined and used to bring the theodolite to read true readings before the horizon survey. Table 1 details the sun sights that were taken to calibrate the theodolite.

TABLE 1, 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")

Table 1. Sun sights taken with the Nikon NE-103 theodolite. The USNO-MICA readings used to calculate the standard error used to adjust the theodolite setting.

The next step, using standard survey methodology, was to perform the horizon surveys. A rough sketch of the horizon and interesting features were drawn for each horizon. Not all horizons are simple line drawings in the field and must be determined by the study of topographic maps and magnified spotting scopes. Figure 14 is a sketch of the east horizon from the place of observation. This drawing was in the field notebook. Due to space considerations, each point was numbered and the horizontal and vertical angles recorded. The completed diagram will be discussed in the results section.

The above steps are the suggested steps for detailing the horizon features. There is an open discussion on calibrating the theodolite in the field. Some say it may cause observer bias, finding significant horizon points to fit the research. On the other hand, without the calibration, a horizon that is partially obstructed may cause one to miss significant points completely. This was the case in taking the horizon surveys at Paint Rock. The horizon measurements had to be corrected and several significant features had to be measured months later that were not recorded during the first survey. The multiple steps of data reduction may cause a significant error without field calibration, and field calibration reduces the data reduction time.

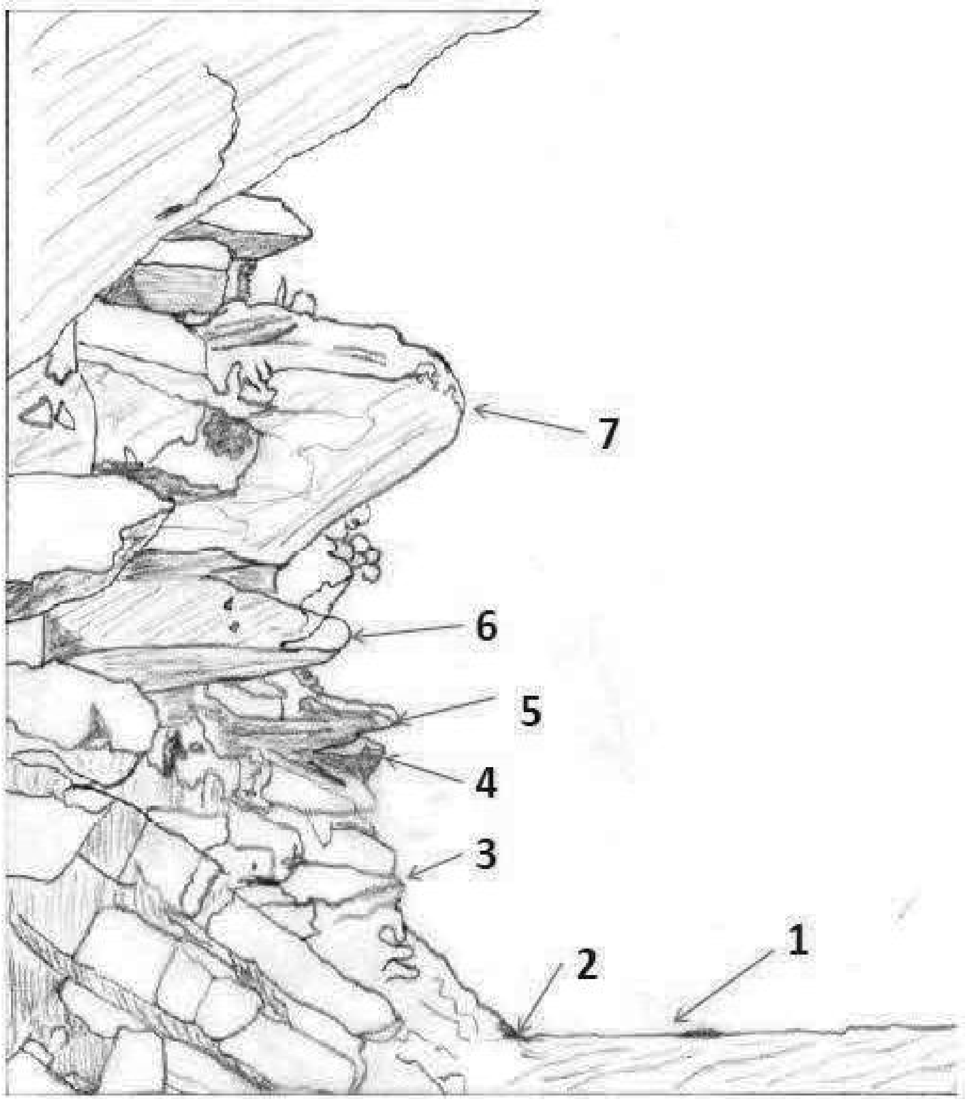


Figure 12. East horizon sketch with interesting points numbered.

3.6 Observing Variables

The apparent travel of celestial objects and their interaction with the horizon are affected by three variables. These variables and the topographical relief affect the appearance and disappearance of celestial objects as seen by ancient cultures. Hence, knowing these variables is important in the visualization of the horizon. The three variables are:

1. The latitude of the site.
2. The altitude of the horizon.
3. Atmospheric refraction.

Beginning with the latitude of the site, it affects celestial objects in two ways. In the northern hemisphere, all celestial objects that are not exactly on the equator rise with a deviation from the perpendicular. This angle is equal to the latitude of the site. This angle increases as you move further north until you reach the true North Pole. At the North Pole, the angle is 90°, so all celestial objects move in a circle around the observer. The opposite is true in the southern hemisphere. For example, the latitude of the Paint Rock site is 31° 31', which means the North Celestial Pole (NCP) has a zenith distance of 58° 29', a complimentary angle to the latitude of the site. Therefore, celestial objects rise with a 31° 31` angle toward the south of perpendicular.

The second effect caused by the latitude of the site is that it expands the solar arc beyond the Earth's obliquity. Only at the equator do the topographic azimuth of the sun's rise and set points equal the obliquity. As one travel's north or south, these points expand wider north or south of the solstice solar declinations. For example, at Paint Rock if you add the Earth's obliquity of 23° 26' to due east 90°, then the Winter Solstice rise azimuth of the sun would be simply 113° 26'. The actual topographic azimuth of the Winter Solstice sunrise is 117° 45', which is over four degrees wider than that just calculated.

This expansion continues as you continue to travel north or south of the equator, but the situation changes dramatically when one approaches the Arctic or Antarctic Circles. In archaeoastronomy, most sites and cultures are in temperate latitudes, so the special situation is not necessary to define in the context here. Just suffice it to say if one is investigating a site close to the Arctic Circle, the rise set points operate by a different set of circumstances dependent on the time of year.

The second variable is the altitude of the horizon. Not all horizons are flat with a 0° reading. Depending on the location of the site, the rise and set points of the Sun and all celestial objects will change based on a horizon altitude in relation to that site. The horizon could have a positive or negative altitude in relation to the observer. If the altitude of the horizon is a positive height above a 0° level horizon, objects will rise later, and if it is a negative horizon, objects will rise sooner. The final variable is atmospheric refraction.

Atmospheric refraction causes an object to appear higher than its actual position. At the horizon, it is the greatest, with a refraction effect of 35' arc minutes, which is .58 of a degree. What this means is that when the full sun is sitting on top of the horizon, in reality, it is still below the horizon. As the altitude of the horizon increases, the refraction is reduced. Atmospheric refraction increases all the way to the zenith. The effect above a 10° horizon is negligible, and does not have to be adjusted for in data reduction. Table 2, Atmospheric Refraction, was devised by interpolation from multiple refraction tables.

TABLE 2-ASTRONOMICAL REFRACTION			
Correction in are minutes and seconds			
h altitude		h altitude	
0° 00'	35' 00"	2° 45'	15' 12"
0° 15'	32' 00"	3° 00'	14' 24"
0° 30'	29' 00"	4°00'	12' 00"
0° 45'	27' 42"	4°30'	11' 00"
1° 00'	24' 30"	5°00'	10' 06"
1° 15'	22' 48"	6°00'	8' 48"
1° 30'	21' 12"	7°00'	7' 36"
1° 45'	19' 42"	8°00'	6' 36"
2° 00'	18' 12"	9°00'	6' 00"
2° 15'	17' 00"	10°00'	5' 24"
2° 30'	16’ 00”		

Table No. 2, Astronomical Refraction. The amount of astronomical refraction corresponding to the height of the horizon point to be subtracted from the azimuth reading before calculation of the declination using formula 1.2.of The chart was adapted from Aveni (2001) and Thomas et al. (1999). Credit Gordon L. Houston.

Atmospheric refraction affects the topographic azimuth and the actual time of the rise or set of an object. Therefore, it too has a compound effect on observations. Being aware of these variables when observing celestial bodies at a site make it easier to understand, and as will be shown in the next section all of these variables will be involved in the data reduction of the horizon survey.

3.7 Data Analysis

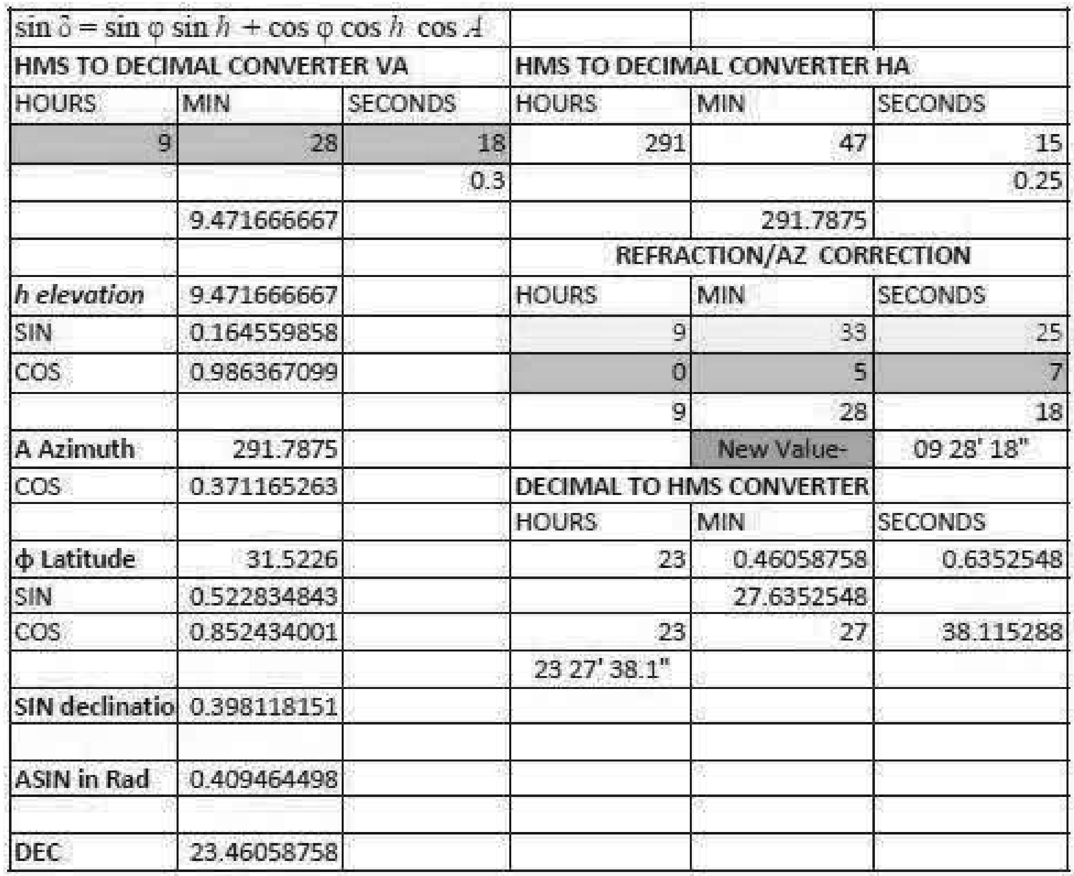
After the literature and field surveys, a variety of data has been acquired. Photographs are the bulk of the data. The other data is from the field surveys of the horizons using the theodolite. Analyzing the data was an ongoing part of this research. After each trip, photographs had to be reviewed to discover mechanics of potential solar markers, to help verify the interactions of reported solar markers, and the study of the horizon for interaction with the celestial sphere. The photographs required a constant review process, as sometimes there were clues or interactions that were not noticed the first time, or later pictures suggested potential interactions. Before any further analysis can be completed, the horizon data needs to be reduced from simple topographic azimuths to celestial declinations. Once the declination of a specific point on the horizon has been determined, using astronomical software, the interaction of celestial objects can be modeled.

3.7.1 Data Reduction

The data from the horizon survey needs to be reduced to a usable form. Having used the Nikon NE-103 digital theodolite to obtain topographic readings, the azimuths must be converted to astronomical declinations. Using the following spherical trigonometry formula 1.2 declinations of each recorded position on the horizon can be calculated.

$$1.2 \qquad \sin\delta = \sin\varphi \sin h + \cos\varphi \cos h \cos A \text{ (Aveni 2001)}$$

Where δ is the declination, φ is the latitude of the site, h is the elevation of the horizon point, and A is the azimuth. It should be noted that this formula is very specific to the observer's position. Once the azimuths are converted to astronomical declinations, the use of astronomical software programs can be used to model the potential 'interaction' of celestial objects with the horizon.



$\sin \delta = \sin \varphi \sin h + \cos \varphi \cos h \cos A$					
HMS TO DECIMAL CONVERTER VA			**HMS TO DECIMAL CONVERTER HA**		
HOURS	MIN	SECONDS	HOURS	MIN	SECONDS
9	28	18	291	47	15
		0.3			0.25
	9.471666667			291.7875	
			REFRACTION/AZ CORRECTION		
h elevation	9.471666667		HOURS	MIN	SECONDS
SIN	0.164559858		9	33	25
COS	0.986367099		0	5	7
			9	28	18
A Azimuth	291.7875			New Value-	09 28' 18"
COS	0.371165263		**DECIMAL TO HMS CONVERTER**		
			HOURS	MIN	SECONDS
ϕ Latitude	31.5226		23	0.46058758	0.6352548
SIN	0.522834843			27.6352548	
COS	0.852434001		23	27	38.115288
			23 27' 38.1"		
SIN declinatio	0.398118151				
ASIN in Rad	0.409464498				
DEC	23.46058758				

Figure 13. Declination calculator converts topographic points along the horizon to celestial declination.

An Excel worksheet was created to reduce error and increase the speed of the calculations Figure 13. Formulas were inserted into the worksheet to convert from degrees, minutes, seconds (HMS), to decimal degrees, and from decimal degrees back to HMS. Then, the horizontal and vertical theodolite readings for various points of interest in the horizon survey to calculate that points celestial declination.

3.8 Astronomical Modeling

There are a multitude of astronomy software programs that can be used to model the celestial sphere. The can help recreate the interactions of celestial objects with the horizon for any site or location in the world. In each instance, by inserting the locations coordinates, latitude and longitude, as well as, the general altitude above sea level, these programs will give a reasonable approximation of the celestial sphere at that site for any given date. The following celestial interactions were modeled using astronomical software: 1) Sunrises and sunsets, solar noon. (Solar noon is defined at any location on earth as the moment the sun is on the observer's meridian.), 2) Heliacal rise and set of stars and planets, 3) Acronychal rise and set of stars and planets, 4) Heliacal rise of constellations, 5) Constellations and star clusters used as astronomical clocks, 6) Rise and sets of planets, 7) Modeling transient phenomena and the configuration of the celestial sphere, and 8) Lunar rise and sets and major and minor lunar standstills.

A variety of programs were used to determine the suitability and ease of use for archaeoastronomy. There are reviews of many of these programs on the web, including. Luxorionweb, SourceForgeweb, The astronomical software programs used at various times included SkyWatch (TheSky), Stellarium, SkyMap Pro 11, and Starry Night Pro 6. The SkyWatch (1998-2000) program is produced by Software Bisque, the same company that produces the program SkyX and the Paramount series of astronomical equatorial mounts. The Skywatch program used is an early version of the SkyX astronomical software that is extremely advanced for its time and is comparable to their less advance program TheSky. It is the most user-friendly of the programs listed. For modeling of the celestial sphere, it is the quickest and easiest to manipulate.

The next program is the worldwide freeware Stellarium (Chereaux 2017). This program may be the most used program in archaeoastronomy. It uses the Simbad database as its basis for astronomical ephemeris and list of celestial objects. This program is discussed as a tool for archaeoastronomy by Ruggles (2015) who authored a paper in the book he was the primary editor of same, *Handbook of Archaeoastronomy and Ethnoastronomy.* One of the best features, which was used in answering research question 6, a plugin that can show the historical supernovae in the celestial sphere. The program gives a realistic view of the celestial sphere. The paper on 'Naked Eye Astronomy for Cultural Astronomers' by Holbrook & Baleisis (2008) used Stellarium for celestial sphere graphics. Zotti (2016) presented a paper at the SEAC Conference 2015 on the use of Stellarium and it benefits. The Stellarium program has been used in section 9.3 Cliff Celestial Clock and section 10 on the five historical supernovae. Modeling the position of the historical supernovae in relation to the moon, other celestial objects, and position on the date of maximum brightness provided a basis for evaluating various claims of supernovae representations.

SkyMap Pro 11 is built on a similar platform as the SkyWatch program. There are many similarities between the two, such as information boxes, display of the celestial sphere and control icons. A check of object data was done between the two programs and readings of declination were within one arc second. Its unique feature for archaeoastronomy is the ability to draw in a rough horizon line of your study site. The last program, Starry Night Pro 6 has the most realistic celestial sphere, yet is the most difficult to use. It is hard to insert specific times and dates, and the object information readout is on the screen, which requires a right click and a search of a menu to find the object information. Then, a second step requires various boxes to be expanded looking for the information. It is not user friendly for archaeoastronomy purposes.

The accuracy of all of these programs is based on the motions of the Earth in relation to the celestial sphere that are known today. The biggest motion is known as precession, a 26,000-year cycle of the Earth's rotational axis. It wobbles like a top so that it significantly changes the position of the celestial poles over the cycle. Precession changes the position of the stars on the celestial sphere, although very slowly. Additional motions of nutation (an oscillating motion of the precessional movement) and polar motion (a change with the earth's rotational axis) are small variations or wobbles that occur mainly because of the Earth, Moon, and Sun system. Aveni (2001) states that for research of sites involving horizon astronomy of the sun that is fewer than 2000 years in age, that precession can be disregarded. Stars also have proper motions of their own.

There may be other motions we are unaware of or singular events that occurred in the past that are not accounted for in these programs. These may affect the motion or position of the Earth in relation to the celestial sphere, so that data from these programs are reasonably accurate, but never exact.

3.9 Ground Truthing

The final methodology is called ground truthing. A "ground truth" is a photograph or series of photographs of the actual interactions measured in the horizon survey. They support the hypothesis and research questions. Ground truth photos are part of the results section, confirming the field research.

4.0 RESULTS-THE SOLAR MARKER MATRIX OF INTENTIONALITY

The following sections will be set up to provide the results of each of the seven research questions. However, before proceeding, the next section presents a guide to help confirm existing solar markers or identify new ones. This guide has been called the "Solar Marker Matrix of Intentionality," which will simply be referred to as the "Matrix" from now on. The Matrix was a result of the multitude of hours spent observing the sun and shadow interactions on the pictographs during the 20 field survey trips.

4.1 Solar Marker Matrix of Intentionality

The Matrix came about as I realized there needed to be a uniform way for researchers to evaluate reported solar markers or identifing new solar markers. Fountain (2005) attempted to quantify solar markers setting up a database, but he only used a limited set of qualities. Although, he reported he was unable to quantify the results statistically, thus reporting a negative result, it was concluded that the solar interactions on rock art were an intentional act. It appeared that he used qualities that were not appropriate for statistical methods, and he had a limited quantity. The matrix as presented is always open for revision or change as new data becomes available. I got the idea from two other matrixes used in archaeology, the Harris Matrix on stratigraphy (Harris 1997), and the Parker Matrix of Borderland Processes (Parker 2006).

Both of the mentioned matrixes were met with skepticism when first presented. The Harris Matrix on stratigraphy is now universally used in archaeology. The Parker Borderland matrix first purpose was to "propose terminology, models or conceptual frameworks" for borderland processes. These matrixes created a uniform set of ideas, allowing researchers to be on the same page. It was with this in mind that I developed the Matrix. Table 3 is the "Solar Marker Matrix of Intentionality." The Matrix applies to all rock art worldwide.

TABLE 3. SOLAR MARKER MATRIX OF INTENTIONALITY

PTS.	**1. Solar Points**	**A**	**PTS.**	**3. Interactive Characteristics**	**B**
5	1.1Winter/Summer Solstice (WS, SS)		5	3.1 Focal Point(s)-Geometric Alignments	
4	1.2 Equinox (VE, AE)		4	3.2 Register Mark alignment	
3	1.3 Cross-quarter (XQ) days (V, S, A, W)		3	3.3 Rapid Interactions	
2	1.4 Confirmed anticipatory points		2	3.4 Tangent alignments	
1	1.5 Random days		1	3.5 Random	
PTS.	**2. Time of Day**		**PTS.**	**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	
	Point Values Total Column A			**Point Values Total Column B**	
	INTENTIONALITY FACTOR			**COLUMN A & B TOTALS**	
	HIGH PROBABILITY 18-20+			V-Vernal	
	PROBABLE 14-18			S- Summer	
	LOW PROBABILITY 8-13			A-Autumnal	
	NO PROBABILITY 4-8			W-Winter	

Table 3. Solar Marker Matrix of Intentionality. Analyses in four categories are scored. The final score determines the strength of a solar marker. * More than one category may be scored in section 4. Supporting Evidence. + The scores may exceed 20 if additional points are scored in section 4. Supporting Evidence. # The Horizon Astronomy category may include confirmation of any form of astronomical knowledge. Matrix Credit: Gordon L. Houston.

Points are scored in each of the four sections from five to one, from the point's column adjacent to individually listed characteristics. The guide at the lower left of the Matrix creates an "intentionality" factor after a solar marker is scored. The four sections to be scored are 1. Solar Points; 2. Time of Day; 3. Interactive Characteristics; and 4. Supporting Evidence. Each characteristic has the section number listed, for example, section 1. Solar points, the first characteristic is Winter/Summer Solstice (WS, SS) is section (1.1). These section numbers will be in parenthesis throughout the rest of the dissertation, so references back to the Matrix can be made. The use of capital abbreviations will be used throughout as well for solar points, so the Winter Solstice is WS (1.1), Summer Solstice is SS (1.1), the Autumnal Equinox is AE (1.2), and the Vernal Equinox is VE (1.2). The cross-quarter days will also use the W for Winter, S for Summer, A for the Autumnal, and V for the Vernal cross-quarter days (WXQ (1.3), SXQ (1.3), AXQ (1.3), and VXQ (1.3)). Confirmed anticipatory days (1.4) and random days (1.5) are the last two categories. These abbreviations will be used throughout the thesis.

The top score in each section is 5 points, making the best score 20. However, as the Matrix footnotes describe, Category 4, Supporting Evidence may be scored in multiple sections, which would give rise to a score greater than 20. The "Intentionality Factor" guide establishes levels of intentionality. As a rule, a score below 14 is probably not a solar marker. However, all points must be considered carefully before making a final decision. The hope is that the Matrix will help rule out coincidental interactions or help identify new solar markers based on the strength of the score. Examples of scoring will be used in the sections on verifying reported solar markers at Paint Rock and the section on newly discovered interactions. The following sections will provide in-depth discussions of each of the four sections and the individual characteristics.

4.2 Astronomical Analysis-Categories 1 and 2

Solar Points is the first category of astronomical analysis. As defined above, a solar point relates to the apparent position of the sun on the celestial sphere and the sun's position on the ecliptic. The four major solar points are the WS (1.1), SS (1.1), AE (1.2), and the VE (1.2), and the minor solar points are the cross-quarter days VXQ (1.3), SXQ (1.3), AXQ (1.3), and the WXQ (1.3). The minor solar points are the point on the ecliptic between the four major solar points. Solar markers that operate on these solar points have calendrical interpretations and can have ritual meaning to various cultures. Preston & Preston (1983) reported the solar interactions with the WS and SS, both AE and VE, and report interactions 45-48 days before and after the WS. They report the following percentages, 1) 39% for SS, 2) 35% for WS, 3) 15% for both AE and VE, and 4) 11% 45 days before and after WS. The last percentage is showing a statistically significant number for the AXQ and WXQ days. The first two show strong support for the solstices having the highest points in the Matrix.

The statistical reports above for the "cross-quarter days" verify that days within the 45-48 day range of a solstice were marked. Although the native cultures did not use the western terms for any of these calendrical days, there has been some resistance to the use of the term. The "cross-quarter day" has been labeled "Eurocentric," yet as further statistical evidence from Fountain (2005) shows that 20% of the interactions occur on those days. The most important Hopi festival of Wuwuchim was fixed by watching the sun along the horizon "some 45 days before winter solstice" (McCluskey 1977), which is the approximate period counting from any solstice forward or backward to any XQ day. It is interesting to note that equinox and cross-quarter days were very close statistically as reported above. In the next section on the horizon astronomy at Paint Rock, the discovered horizon feature marks the AXQ and WXQ days, consistent with the above reports

The next characteristics to be considered is Section 2, Time of Day, as solar interactions with rock art have been observed to occur throughout the day at many sites. The scoring starts with *solar noon* (2.1), the highest scoring characteristic. Solar noon is the culmination of the sun across the local meridian, which requires an additional intentional step by the sun-watcher. Hence, the highest score for interactions that occur within 5-10 minutes of solar noon. The Isleta Puebloans ceremonies occurred at noon and solar noon was one of their three daily stations (Young 2005). The three primary interactions at the three-slab site at Fajada Butte in Chaco Canyon operated at solar noon (Sofaer & Sinclair 1983). *Solar noon* (2.1) is followed by *sunrise* (2.2), *sunset* (2.3), *random morning* (2.4) and *random afternoon* (2.5). Sun-watchers observed both the east and west horizon, but the sunrise was the 'crucial' time for horizon astronomy (Malville 2008). Young (1986) stated that there are three times of day with the greatest significance, sunrise, sunset, and solar noon.

Young (1986) goes on to describe sun-watching practices of different cultures. Some divide the year as to sunrise for half year and then sunsets. The eastern Puebloans just watch the sunrises and it is stated that the Zuni watched both sunrise and sunsets. Based on the variations, the scoring for sunrise (2.1) and sunset (2.2) are for interactions that occur within one hour of the event, and sunrise scores higher than sunset.

There are four places that the term *random* scores in the Matrix. *Random* is in three different sections, *Solar Points*, *Time of Day*, and *Interactive Characteristics*, sections 1.5, 2.4, 2.5, and 3.5. They are at the bottom of the scoring, as this reflects the fact that these are coincidental interactions, and they have no significant calendrical importance. The observer must be aware that these times may be the time that a sun line or unique design appeared that drew their interest, so other aspects of the glyph still need to be studied. The researcher must also consider that some interactions may occur at times other than the eight solar points. These interactions may be anticipatory to prepare for rituals, signify wildlife movement or even time to plant, or harvest the fields. These would be revealed through informed sources or formal analysis, but without this information, the interactions can only be concluded to be coincidental.

4.3 Interactions With Rock Art-Category 3

The three-slab site on Fajada Butte in Chaco Canyon has one of the most famous solar interactions with rock art. There is a light patch, the shape of a dagger, referred to as the 'sun dagger,' which intersects the main spiral glyph at solar noon. The interactions are with the leading tip of the dagger. Interactions have various forms and shapes, with Preston & Preston (1983) stating that the interaction occur with the leading tip or trailing tip. Other shapes that have been reported are varied, and most have some corner or point shape, but others are sun or shadow lines. The sun or shadow lines are usually straight moving lines, which is true of the Equinox Marker at Paint Rock. Some interactions are alignments in the design of the glyph with the shape or outline of a moving line having the same shape. These lines momentarily line up with the design elements in the glyph. These interactions are very rapid and typically last for a very short time as the sun is constantly moving, so the light or shadow is constantly moving. The position and alignment of the interactions are the most important aspect, regardless of the shape of the interaction.

It is important to nderstand how the interactions of light and shadow with rock art change through the seasons. As discussed in methodology, the sun's daily path is deflected from the vertical by an angle equal to the latitude of the site, and also by the time of year or the seasons. In the northern hemisphere, the sun is lowest at Winter Solstice (WS) and highest at Summer Solstice (SS). Thus, the season changes the solar altitude during the day. The position of the interaction on a glyph has an inverse relationship to the altitude of the sun. The higher the sun, the lower on the glyph is the interaction. The altitude changes by the seasons, but also by the time of day. As the sun's declination changes with the seasons, this inverse relationship constantly changes. At Paint Rock, the sun's altitude and declination place most of the pictographs in permanent shadow for several months, roughly from mid May to mid July.

The sun's altitude and declination affect the interaction, but ultimately it is the cultures' scribing of the glyph to interact with sun or shadow designs that are the most meaningful to consider. Reading the literature on solar markers has led to the adoption of some terminology. The terminology has been incorporated into the Matrix. It is hoped that the terminology will become standard usage amongst researchers. Preston & Preston (1983) used the term *focal point* (3.1), which is the central feature of a glyph. Spirals and concentric circles, and other designs have a center point of the design, which is the *focal point* for those glyphs. This interaction is the primary recording of some of the astronomical knowledge.

The second form of interaction, which has the same point value as *focal point* (3.1), is *geometric alignments* (3.1). The intentionality of these alignments, especially when a crooked line matches with design elements in a glyph, provides a strong indication of a deliberate act. As has been discussed, the sun's altitude creates different angles, and this angle changes during the day and throughout the year. When these unique *geometric alignments* (3.1) occur, they happen momentarily and will change from one day to the next. There are two types of interactions, one caused by a straight line, and the other by a crooked shaped line. The straight line, which can be a moving sun or shadow line, aligns with a design element or intersects the focal point, whereas the second type, a crooked line, aligns with the design in the rock art.

Another design element in a rock art glyph is a *register mark* (3.2). These register marks align with solar interactions on the glyph, which act as a confirmation or mark important calendrical days. The concept of a *register mark* (3.2) was introduced in Zoll (2010). Investigation of the Sinagua culture in Arizona determined that the harvest of agave occur in late April or about 30 days after the Vernal Equinox (VE). It was noticed that a mark added to a glyph aligned with a solar interactions 30 days after the VE. Hence, these are included in the matrix as intentional additions to the glyph, and they represents some of the cultures sky knowledge. Zeilik (1989) states, "the site must 'work' culturally," which support the burden of proof required of archaeoastronomy investigations. The ***register marks*** (3.2) may act as a time marker, an anticipatory marker, or as a confirmation marker, which justifies the second highest scoring position in this category.

The next characteristic is the length of time of the interaction. The scoring is awarded for interactions that are considered ***rapid interactions*** (3.3). Interactions can be either ***rapid*** or protracted, which is based on the length of time from the first point of contact to the primary design element, to the culmination with the focal point, geometric alignment, or tangential framing of the glyph. As will be seen in the section on confirming existing solar marker operations 5.0, or identifying new solar markers 6.0, the length of time of the interactions vary and the scoring changes accordingly. A rapid interaction suggests that a culture must have been acutely aware of the interaction to place the glyph properly for the interaction, hence a higher degree of intentionality. A protracted length of time may put the interaction open to coincidental interpretations.

The next to last interaction is referred to as ***tangent interactions*** (3.4). These are created when the sun or shadow shapes align to opposite sides of the glyph. These type interactions occur with circular or spiral glyphs. For example, at Fajada Butte, one of the alignments is created by two daggers that align tangentially to the spiral on the Winter Solstice (WS). The primary alignment at Fajada Butte is the single dagger intersecting the center of the spiral at solar noon on the Summer Solstice (SS). The tangent alignment that occurs may not have been known to the sun-watcher who scribed the spiral. If the original focal point alignment had a smaller spiral that was then expanded to touch the Winter Solstice (WS) daggers, then the deliberate act would solidify the intentionality. However, there are no reports of different ages of the spiral, which is a clear example of why each interaction has to be scrutinized.

The last category is for *random interactions* (3.5) that occur, which typically are lines that sweep across multiple glyphs at the same time and depending on the time of day, may last for hours without any focal point or geometric alignments.

4.4 Supporting Evidence-Category 4

The last section of the Matrix is Supporting evidence. Interpretation of rock art is a holistic process, and on that basis, astronomical considerations and archaeological considerations must be included in the evaluation of a solar marker. For this reason, scoring in more than one category is acceptable in this section. For example, the discovery of the horizon astronomy, or other sun-watching methods documented at a site scores the highest in this section, but a second category or more may be scored, such as ethnographic data confirming the sun-watching method or confirming the use of rock art as a calendrical device or solar marker.

The documentation of the *horizon astronomy* (4.1), or another method of fixing the significant calendrical days, establishes a key component of the cultures astronomical knowledge. The method could be a window and wall recording the sun's annual movement. Determining the "how" is a crucial step in establishing a cultures ability to place a glyph accurately to record a calendrical day. The *horizon astronomy* combined with the solar marker is a deliberate recording of some of their astronomical knowledge. This is significant in prehistoric and preliterate cultures.

The section *geometric condition* (4.2) is the study of the mechanics of the solar marker. Zeilik (1985) discusses the resolving power of a site and states that observations can be observed within a centimeter or two. This accuracy is related to a wall calendar using a window or portal. He states in another section that the day of the solstice needs to be determined within a day or two, which somewhat contradicts the accuracy of centimeters. Obtaining this in a rock art site dealing with large panels is not near as precise, yet depending on the rock surface casting the sun or shadow, and its distance from the glyph plays an inverse role on how fuzzy or sharp the interaction is. The culture had to know the calendrical day precisely, and the geometric conditions would allow for the accuracy. There are reported cases of rock faces being chipped or manipulated that cast the solar interaction (Fountain 2005, Zoll 2008), and cases of gnomons used to cast the interaction (Hudson et al. 1979).

4.5 Informed, Formal, Analogy and Symbolism-Categories 4.3, 4.4, 4.5

The three methods titled above, *informed, formal, and analogy/symbolism* are methods in archaeology for the study and interpretation of rock art (Chippendale and Tacon 2004). These methods offer a formal process to use with the interpretation of rock art. These methods are consistently used in rock art studies. The informed and formal methods can be seen in use in Tacon & Chippindale (2004), and by Whitley (2011). Whitley's book *Introduction to Rock Art Research* goes in-depth on all three methods and suggests that they provide a scientific framework for the study of rock art. Boyd (2004) has several examples of analogy in the interpretation of rock art.

Ethnographic, ethnohistorical records, and historical records are the basis for the *Informed* method, which is knowledge provided by the people and cultures connected to the rock art. It can also include interpretation through an understanding that has been verified to pass on ancient knowledge Tacon & Chippendale (2004). When there are no records available, then the *Formal* method is utilized. This method deals with the iconography of the glyphs in relation to the landscape or archaeological context. The final method, *Analogy/Symbolism*, is utilized in many facets of archaeology and archaeoastronomy. There is no direct access to any informed sources and only attempts to interpret rock art from similar sites nearby, which is very subjective.

The underlying purpose of these methods is to provide a scientific methodology for interpreting rock art. Cognitive-processual archaeology deals with a culture's ideology. The ritual practices of many cultures are rooted in their astronomical knowledge, and worldview (Fagan & DeCourse 2005). Rock art is a large part of material remains of some cultures (Judge 2008). Solar markers are another cultural technology that embeds part of a cultures astronomical knowledge and worldview.

5.0 RESULTS AND DISCUSSION-RESEARCH QUESTION NUMBER 1.

'**Determine the horizon astronomy or another method of fixing the major solar positions and calendar operations**.'

This research question was the first and obvious choice based on the site report by Robbins (1999). He had indicated that due to the horizon being so flat there did not appear to be any interest in watching the sun along the horizon. The challenge to discover the horizon astronomy was intriguing. On the first field survey trip, using the Brunton transit, a bearing was taken of the direction of the cliff at 112-114° to 292-294°. The southeast direction suggested possible sunrise significance in the autumn or winter. Even before the notch was discovered, this southeast direction gave a visual indication of a notch more so than the northwest. This is because from the ground the cliff looking northwest has higher terrain behind it. The cliff as it travels west also tends to curve towards a westerly direction and flattens out.

The discovery of the "notch" in the horizon line and its unique intersection with the celestial sphere provided the basis to pursue the investigation. In this situation, identifying a horizon feature that could be used to measure the travel of the sun had to be first. A horizon needs some dramatic topographical relief in which to measure the sun's travel along the horizon. Once the "notch" was discovered, a search for the place of observation would be next. Research question 2 addresses the identification of the place of observation. The results provided in answering the second research question present a strong argument for its location. This fact should be kept in mind as the results for question 1 are presented.

5.1 Discovering the "Notch"

As reported by Robbins (1999) the horizon was very featureless and suggested that the site needed further study. After the first field survey trip, my initial reaction was in agreement with Robbins report. The horizon as shown in Figure 7 is very flat, and it seemed challenging to determine how the solar markers were placed so accurately. It was not until returning from the trip and reviewing the photographs that a significant horizon feature was identified. Figure 14 is the photograph that was reviewed that led to the realization that the cliff meets the far horizon creating a notch. This photograph was taken the second day in the field. A review of all the photographs led to a full notch photograph and the magical realization that this was the horizon feature that could be used for calendrical purposes, Figure 15.

These two photographs led to discovering a fixed place of observation. As can be first seen in Figure 14, the notch is very subtle but very obvious in Figure 15. These

Figure 14, This picture was the one that was reviewed that helped discover the "notch" in the horizon.

two photographs demonstrate the importance of the field walking survey and photographic recording of a site. Why this notch was never apparent or discovered before, and the place of observation identified will be discussed in the results section. Confirming a place of observation and constricting its area reduces the chance for observer bias in the horizon survey. The next three trips included extensive field surveys, searching for the place of observation, and inspecting the far horizons. Once the place of observation was determined, east and west horizon surveys were performed using the Nikon NE-103 theodolite.

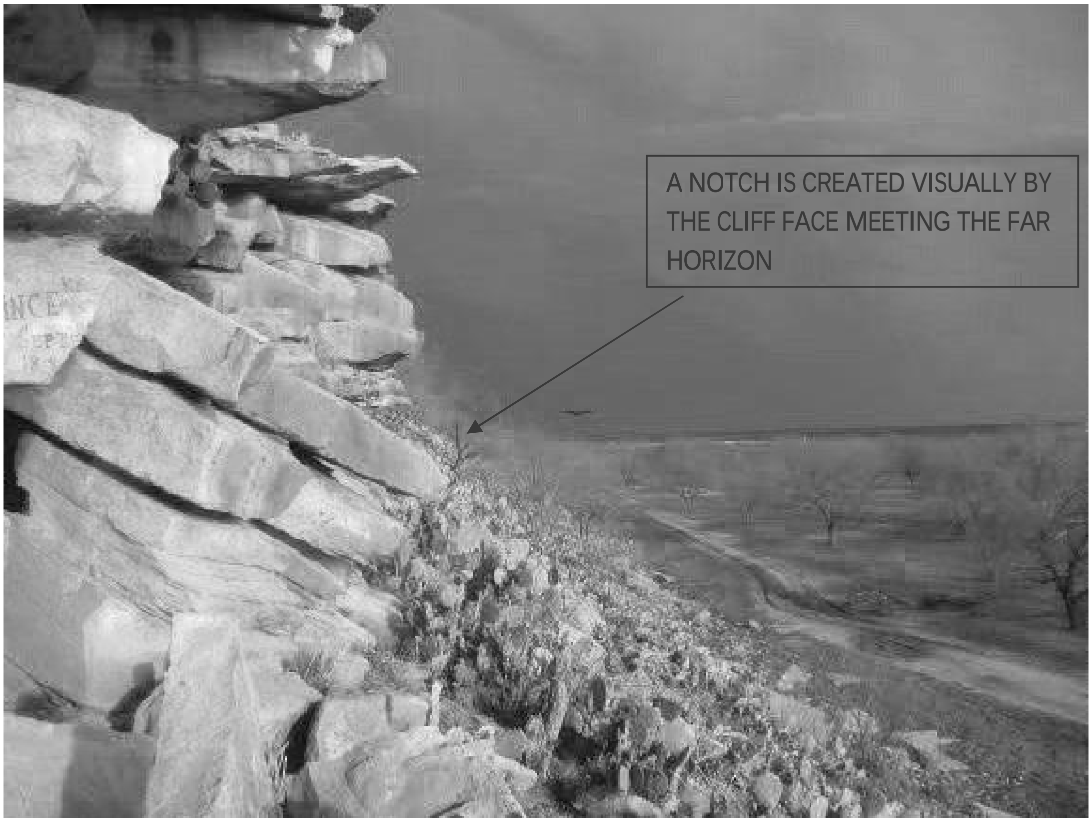
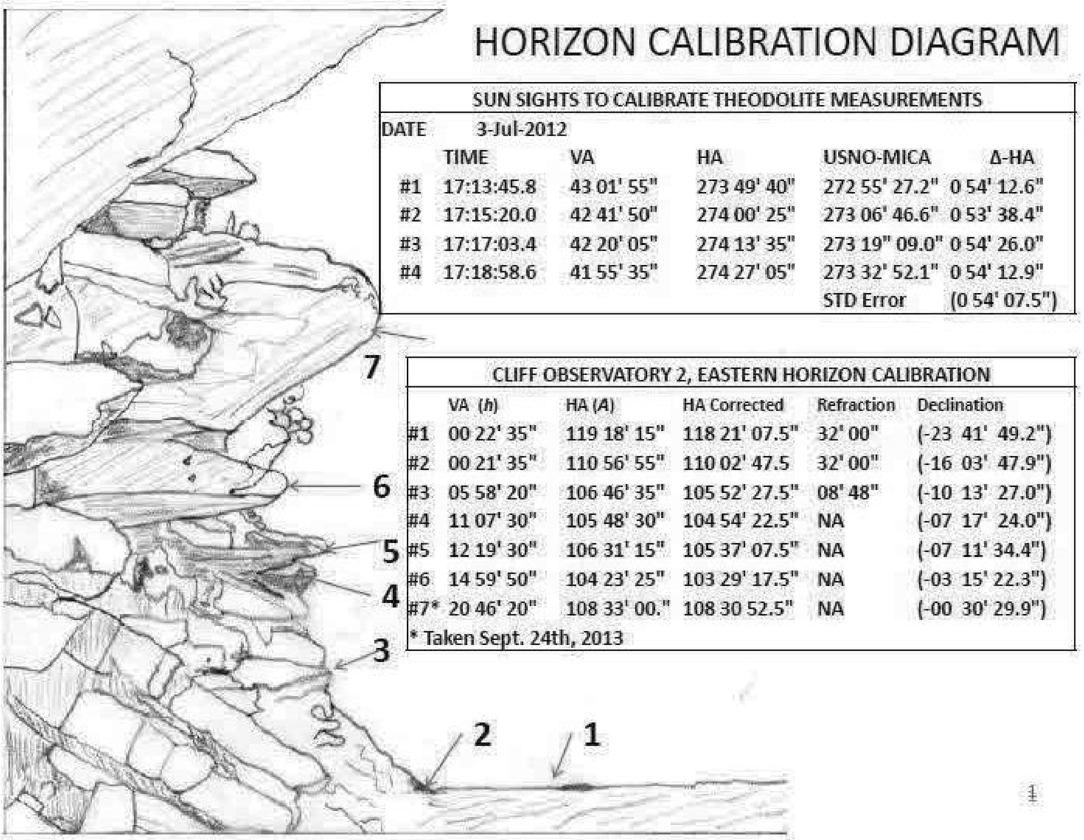


Figure 15, The face of the cliff in the foreground creates a notch where it meets the horizon.

5.2 Eastern Horizon Survey

It took four months to identify the place of observation with strong evidential support, which will be discussed in the next section. The Nikon NE-103 was set up over a survey peg. Sketches of the east and west horizons were drawn. Sun sights were taken to calibrate the horizon data. The horizon survey records the vertical and horizontal angles of interesting points along the horizon. The discovery of the "notch" in the horizon was critical to establishing the horizon astronomy. As previously noted, the horizon has almost no dramatic topographic relief. Figure 16 is the results of the east horizon survey.



HORIZON CALIBRATION DIAGRAM

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"	08' 48"	(-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"	108 33' 00."	108 30 52.5"	NA	(-00 30' 29.9")

* Taken Sept. 24th, 2013

Figure 16. East horizon survey, with sun sights, and calculated declinations.

The intersection of the vertical outline of the cliff from the place of observation intersecting the flat horizon creates the "notch." Point 2 is that intersection, and the calculated celestial declination is -16° 03' 47.9". This declination closely matches the sun's declination on the autumnal (AXQ) and winter cross-quarter days (WXQ), November 6th and February 3rd respectively. These days are at the midpoints between the equinoxes (Autumnal AE, Vernal VE) and the winter solstice (WS). As a cross-check of this declination, multiple sources and programs used in this research had the following declinations: 1) MICA (2005) program of -16° 16' 12.0", 2) Solar Declination

Table, Aveni (2001) -15° 48', 3) SkyWatch Program -16° 11' 43", 4) Stellarium -16° 11' 36.8", and 5) Sky Maps Pro -16° 11' 44.0". The three astronomical software programs figures are within a few arc seconds of each other, and all are within about eight arc minutes of the calculated declination. Besides the "notch" the vertical portion of the cliff could have been used by an observer to mark the equinoxes. Point 7 on Figure 16 is within a half a degree of the equinox declination. However, as will be seen, a count from any cross-quarter day would give the culture the equinox.

As a form of astronomical modeling, a composite picture was created using the Skywatch program, Figure 17. The celestial sky was shown on the AXQ day, with the sun rising in the notch.

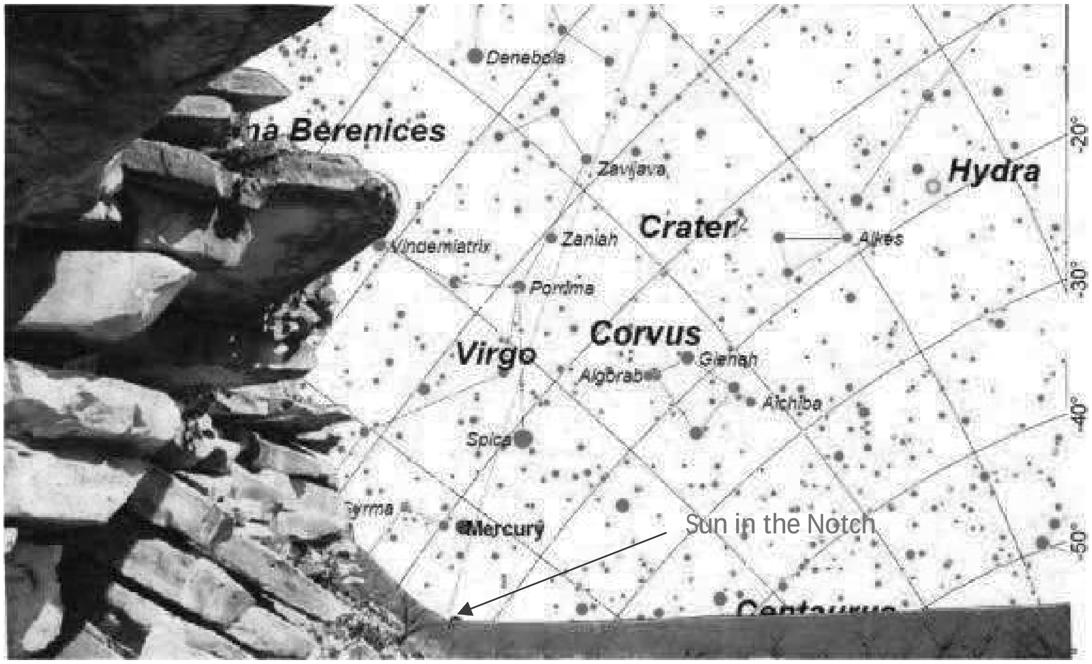


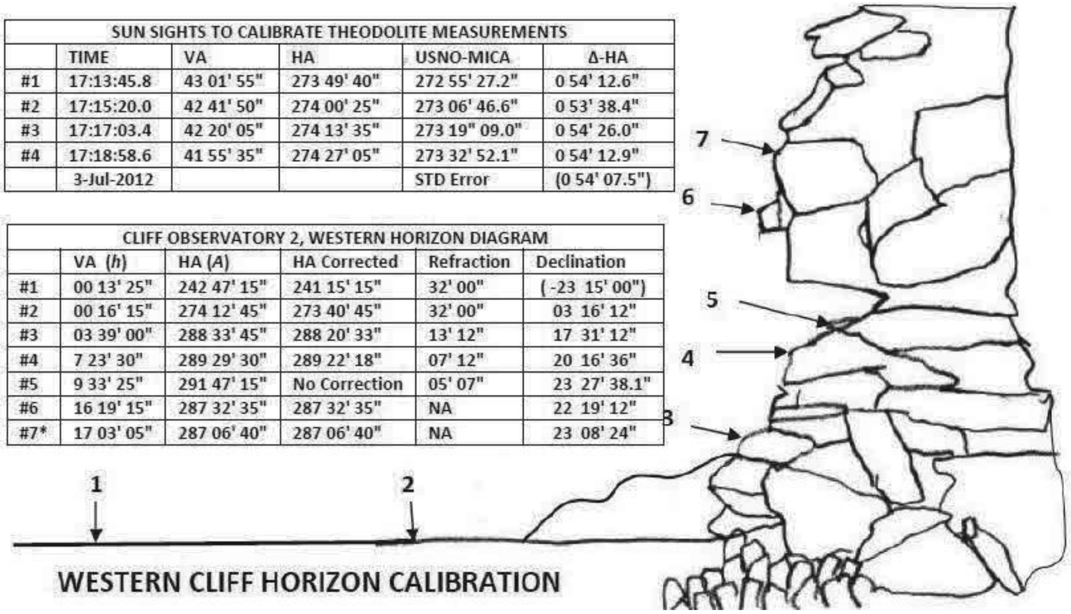
Figure 17. Eastern horizon composite picture, the sun rising in the notch. Celestial sphere taken from Skywatch, Software Bisque (2000).

This picture is showing what should be happening. The final methodology in any archaeoastronomy research is a ground truth photo. Figure 18 is the actual sun rising in the "notch." This created topographical relief is the key to the horizon astronomy at the Paint Rock pictographs.

Figure 18. The sun is rising in the eastern horizon "notch" on the WXQ day.

5.3 Western Horizon Survey

The same day after doing the eastern horizon survey, the theodolite was turned to the western horizon. A sketch was drawn and points numbered of various notches and rock outcrops. Figure 19 is the western horizon survey with the respective data. Because the topographical configuration of the western end of the cliff, and the overgrowth of trees blocking sight lines, the notch is not well defined. However, reviewing Figure 19, point 3 is a rock just above the notch that has a declination close to the sun's declination measured for that spot. The Skywatch show a declination of + 16° 20' 56" or about 1° 10' difference. The configuration at a site, when sight lines are obscured makes accuracy challenging.



SUN SIGHTS TO CALIBRATE THEODOLITE MEASUREMENTS

	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"
	3-Jul-2012			STD Error	(0 54' 07.5")

CLIFF OBSERVATORY 2, WESTERN HORIZON DIAGRAM

	VA (*h*)	HA (*A*)	HA Corrected	Refraction	Declination
#1	00 13' 25"	242 47' 15"	241 15' 15"	32' 00"	(-23 15' 00")
#2	00 16' 15"	274 12' 45"	273 40' 45"	32' 00"	03 16' 12"
#3	03 39' 00"	288 33' 45"	288 20' 33"	13' 12"	17 31' 12"
#4	7 23' 30"	289 29' 30"	289 22' 18"	07' 12"	20 16' 36"
#5	9 33' 25"	291 47' 15"	No Correction	05' 07"	23 27' 38.1"
#6	16 19' 15"	287 32' 35"	287 32' 35"	NA	22 19' 12"
#7*	17 03' 05"	287 06' 40"	287 06' 40"	NA	23 08' 24"

Figure 19. Western horizon cliff calibration.

NOTCH CREATED WHERE THE CLIFF MEETS THE WESTERN HORIZON. SUN SETTING IN NOTCH AUGUST 6, 2012.

FIGURE 20. Sun in the western horizon "notch" summer cross-quarter day.

As is shown in Figure 20, the sun shows through the foliage as it sets on the summer cross-quarter day (SXQ). However, this setting is difficult to pinpoint as being exact to which notch. The landscape has changed in the last 50-60 years, with the proliferation of mesquite trees. The ranch owner has continued to chop back much of the mesquite that would have otherwise hidden the pictographs. I was shown an aerial photograph of the ranch from the 1960's, and it was open grassland. In the printed booklet by Mrs. Campbell's father, Judge Orland Sims, her father bought the ranchland with the pictographs. He grew up a mile from them and relayed that the Native Americans regularly set the prairie grasses on fire in the spring. He recalls the prairie grass belly high to a horse. The grass fires kept the mesquite at bay.

The declination calculated for point 5 in the horizon survey, which is a "notch" in the cliff matches the Summer Solstice (SS) declination very closely. The calculated declination for that point is 23° 27' 38.1". This reading had minimal astronomical refraction due to the vertical angular height of the notch. This matches closely to the Skywatch figure of 23° 26' 03" for the sun at the altitude of the notch on the Summer Solstice. Figure 21 is a ground truth picture of the sun in the notch on the Summer Solstice (SS).

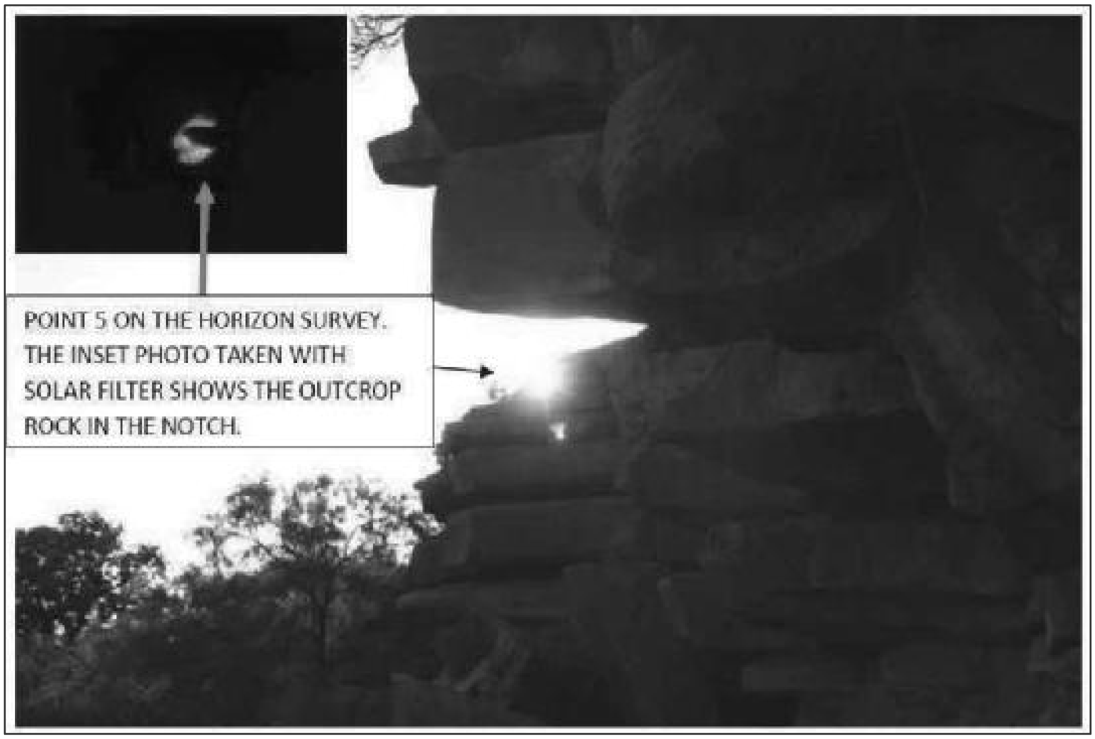


Figure 21. Summer Solstice sun setting into the western cliff "notch."

5.4 Horizon surveys to locate possible markers to mark an anticipatory sunrise.

As part of the horizon astronomy survey, walking surveys were carried out to the edge of the visible horizon as seen from the place of observation. Figure 22 shows the extent of the landscape visible from the pictograph site. The viewshield from the place of observation is delimited by the cliff outline cutting off much of the northern half of both horizons. As a result of these surveys, a potential rock cairn was located on the eastern horizon. It was made of very large boulders. In fact, the one thing that was noticed in all of the walking surveys, the rocks in the field were no more than a foot in diameter. The rocks at this potential cairn were much larger. Observing the landscape, this rock pile had to be made by humans, as they do not appear to be a result of any geologic processes. The possible rock cairn is also located at a strategic point, as from the rock pile, the viewshield is wide open to the west back towards the pictographs, but it is also placed so that you can see the next far eastern horizon. It is interesting as you approach the rocks from the west, you do not see over the rise until you get into the rocks and realize you can see another horizon 6-10 kilometers or more distant horizon.

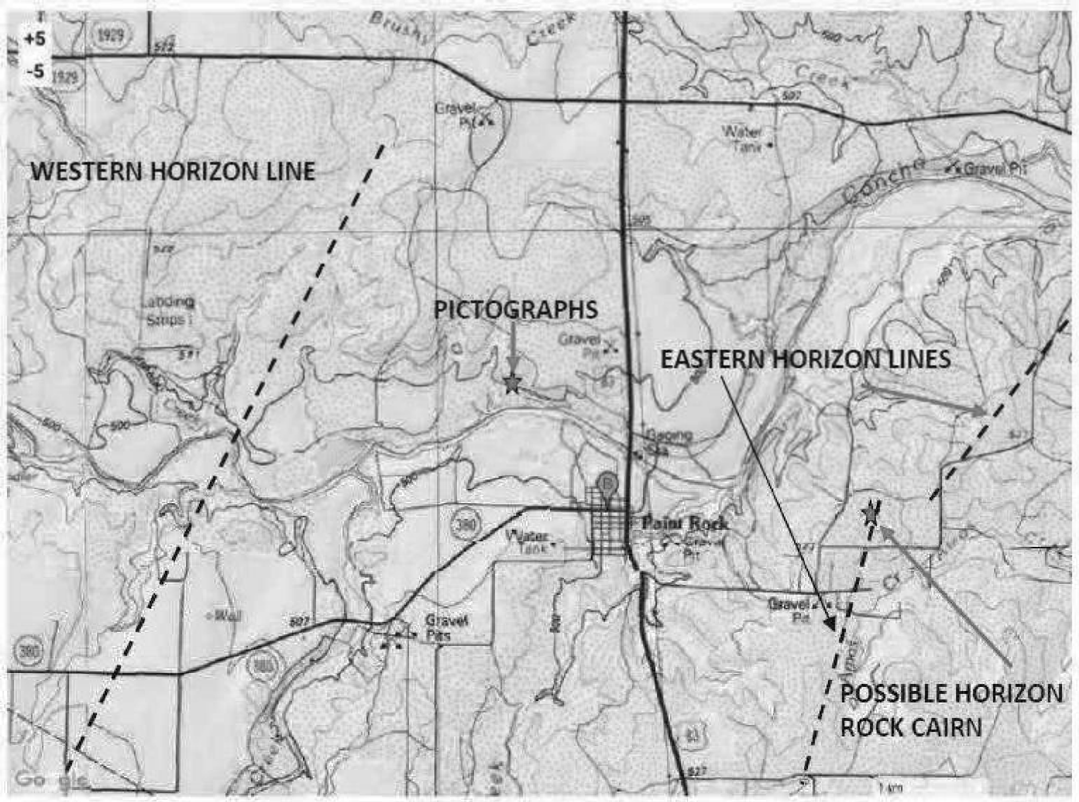


Figure 22. Location of the possible horizon rock cairn on the eastern horizon line.

on the field survey. The Google Earth Pro freeware was used to confirm the location of the photographs, Figure 23. After these initial steps, the landowner was contacted and access granted to take a closer look. Figure 24 is a photograph of the potential rock cairn.

Possible rock cairn is located on the crest of the horizon. From the rock cairn, you can see the next horizon to the east and see the pictograph cliff face to the west.

Figure 23. Google Earth with the rock cairn location identified.

Figure 24 is looking to the east, and the next horizon can be seen in the background of the photograph. Bright orange surveyors tape was placed in line with the pictographs, which were visible in the telescope of the Nikon NE-103 theodolite. Topographic readings of HA 115° 40' 35" and VA 0° 1' 5.7" were recorded from the place of observation. The declination for this point using Formula 1.2 and the excel declination worksheet is -21 20' 38.9". The significance of this location is that on the date the sunrise is at this declination, the rock cairn would be illuminated from behind and easily visible by the native cultures. Using the SkyWatch program, the Sun's topographic azimuth and corresponding declination occur on November 21st, which is 15 days later than the cross-quarter day and about 32 days before the winter solstice.

Figure 24, The potential rock cairn on the far eastern horizon from the pictographs.

5.5 Tying the Material Culture to the Horizon Astronomy

In the search for the place of observation, the final selection had many qualities that solidified the selection. These qualities will be discussed in the next section. One aspect of the place of observation is a multitude of tally marks. There are two sets of tally marks, which are closest to the probable position of the sun-watcher, Figure 25. These sets have significant astronomical implications. The number of days from the AXQ day in November to the WS is approximately 47 days, as the actual date of these calendrical days can vary by one day or more. If you were to use these to work backward, the autumnal (AEQ) would be identified. There are double hash marks below the 47 tally marks suggesting multiple counts. The second set of 28 tally marks are located on the rock layer just above the 47 tally marks.

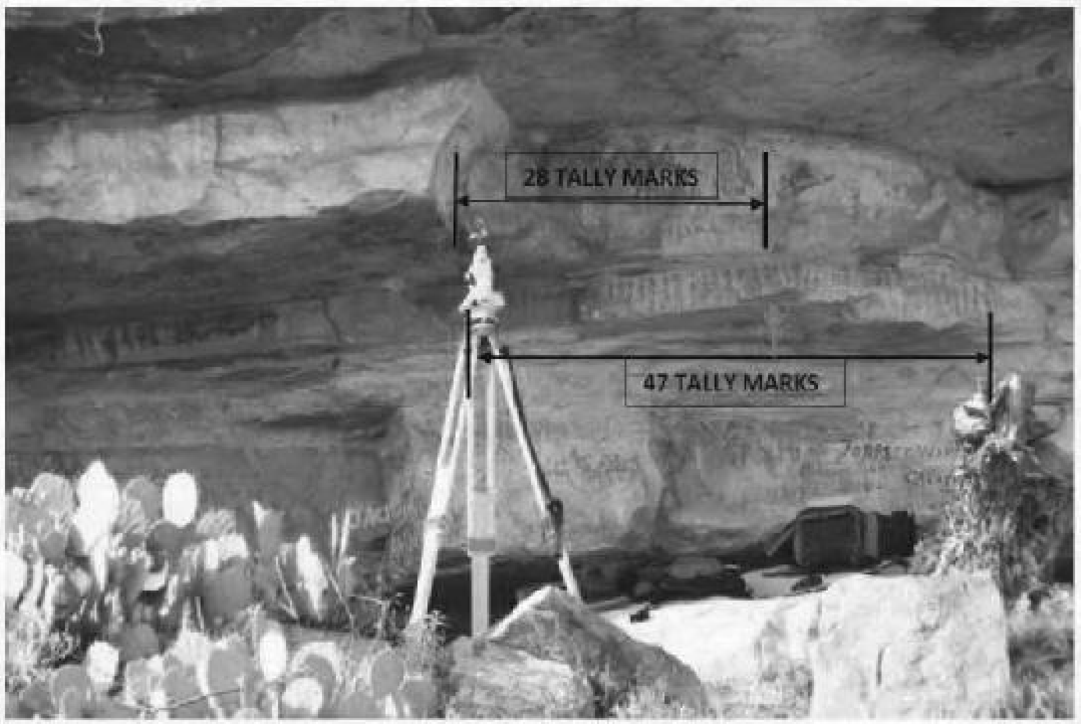


Figure 25. Two different sets of tally marks in the place of observation.

These tally marks total 28, which is the number of days the moon is visible each month (Aveni 1997).

5.5 Discussion

Sun watching along the horizon tied the celestial sphere to the spatial environment. The travel of the sun is so regular that it enabled cultures to define temporal cycles, which became rudimentary calendars. Zeilik (1985) states that horizon calendars have some of the best ethnographic descriptions of astronomical practices.

These horizon calendars are well known in many cultures in the American Southwest and worldwide. The number of identified horizon calendars in the American Southwest provide numerous analogies, strongly suggesting that sun watching would have reached Paint Rock. My observations indicate that solar markers are a portable technology. McCluskey (1977) indicates that the Hopi used portable astronomical knowledge.

The use of rock cairns in sun watching is widespread as they are found operative in horizon calendars in Chaco Canyon (Munro 2011), Cusco, Peru (Dearborn et al. 1998, Dearborn & Schreiber 2008), and Big Horn Medicine Wheel (Eddy 1978). The method of counting in sun watching varies, as many cultures did not have true mathematical knowledge in their culture. The use of a calendar stick (Marshack 1985, Closs 1986), rocks in a basket (Zeilik 1985), wooden counting sticks (Hudson 1979, Turpin 1990), and many other examples are available. The use of tally marks in rock art has a nearby example in northern Mexico (Murray 1986) will be discussed in section 11.1.

Discovering the notch was the first critical step in furthering the research at Paint Rock. Although by coincidence, the fact that both the east and western horizon notches work with the celestial declinations of the rising and setting sun, and the star Sirius had to be known to the cultures who scribed the solar markers. The discovery of the horizon astronomy at Paint Rock is a significant step in confirming the operations of the solar markers as intentional.

6.0 RESULTS AND DISCUSSION-RESEARCH QUESTION 2.

'Determine the observing position(s) used to watch the sun, moon, and stars.'

Identifying the horizon feature, the "notch," gave the sun-watcher a defined rise point of the sun. What became clear as the field surveys were performed to determine the horizon astronomy is that the place of observation must be fixed with relative certainty.

6.1 Detail the Process of Identifying the Place of Observation

The "notch" is created visually by the vertical cliff intersecting the far horizon, as was examined in the last section. Now that a point of relief was identified, the place of observation needed to be located. Three potential areas were selected as possible places of observation. The first was on top of the cliff, as this is where the first indication of the horizon "notch" was found. This area was eliminated as it offered no weather protection, and no markings or other material remains found to indicate its use. The beginning of a "notch" on the horizon from the west end was the only positive characteristic. There were no other features to create a point of anticipation or confirmation, and the horizon was flat otherwise.

The second was at the bottom of the cliff on the floor of the alluvial plain caused by the Concho river flooding. This floodplain has silted up to the base of the cliff debris slope. Standing on the river terrace, the sun watcher would see the same visual notch created by the cliff meeting the far horizon. This area is an open living area but does not have the amenities of the place selected. The lack of living amenities will become evident as the features of the last area are described. The third area was somewhere along the base of the cliff, at the top of the debris fall. This third area produced three of the most likely candidates.

The 300-meter section of the cliff is the only section with pictographs. It is the tallest section of the cliff, and it provides many panels that are weather protected. To either side of this area, the uplift was not as great and as a result, the debris slope is almost to the top of the uplift, hence, there are no exposed areas for pictographs or a place of observation. As each field survey proceeded, I climbed along the base of the cliff at the top of the debris fall and identified three areas along the cliff that provided possibilities for sun-watcher observations. One was located at the west end of the cliff, Figure 26.

Figure 26. Potential place of observation towards the west end of the cliff.

There are multiple characteristics that eliminate this as the place of observation. The most important is that the viewshield is blocked from seeing any part of the horizon that the sun travels. The blocked viewshield means that even when the sun reaches its maximum southerly position on the Winter Solstice (WS), the sunrise along the horizon cannot be viewed from this location. It also has a low ceiling that consists of broken limestone layers. The broken rock roof means that there is a good chance that during a heavy rainstorm, water would accumulate in the living space. The living space is limited in size, and there is no place to stand. This area was eliminated as the potential place of observation.

The second place of observation is connected to the final place chosen, Figure 27. It is separated by several rock layers sticking out to the edge of the debris fall.

Figure 27. The second location selected as the potential place of observation.

This area is to the left or west of the chosen place of observation shown in Figure 28. The chosen place of observation has all the qualities that make it a great location. This location has a single continuous rock slab covering the entire living area, which provides excellent weather protection from rain running down the rocks.

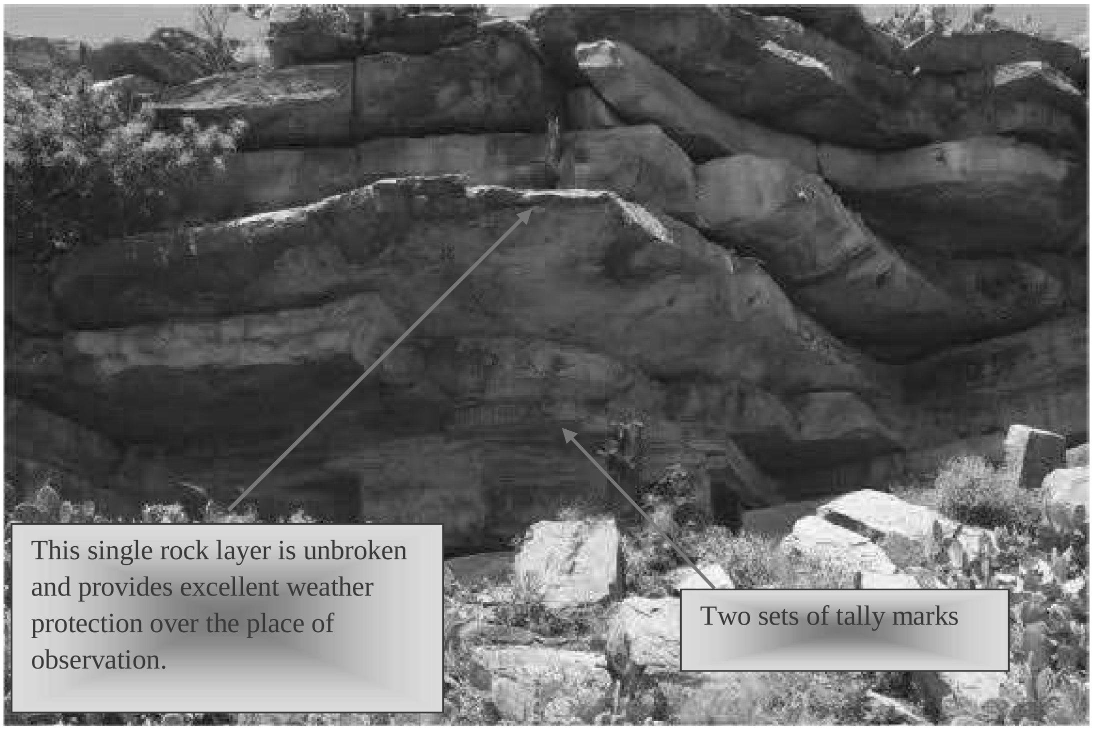


Figure 28. The chosen place of observation has a continuous slab roof.

The chosen place of observation has a large living area and a convenient large rock slab for seating purposes, shown in Figure 29. The final characteristic that solidified the choice was the tally marks on the rock slabs as discussed in the results section on question 1, shown in Figure 25. Tying the material culture to the astronomy provides strong contextual evidence supporting this as the place of observation. The fact that there are multiple sets of tally marks and active solar markers in this area argue strongly for this as the place of observation.

Figure 29. Selected place of observation with rock slab seat.

6.2 Discussion

Identifying the place of observation is significant in establishing the validity of the horizon astronomy (Aylesworth 2004). Observing from a "fixed" position adds to the accuracy of the observations (Vogt 1993). It is further stated that it cannot be based on the fact that it works astronomically but must be supported by other evidence. The tally marks tie the material culture to the place of observation and astronomically. It can be stated confidently that the horizon observations were made from this place. Zeilik

(1989) indicated that a site must also work "culturally" and not just astronomically. His meaning is another way of indicating that other archaeological evidence must support the astronomical premise.

The accuracy of the solar markers is a result of a combination of the sun-watchers skill in observing the sun along the horizon, observing from the same location, and the ability to determine the solar points within a day or two. The significance of the place of observation is critical for one central reason. Observing from the same spot eliminates and change in the rise and set points of the sun. Ruggles (1999) details the changes that can occur, which is an inverse relationship with the distance to the horizon and movement or change in the place of observation. When the horizon is only a few kilometers away, a short lateral movement of the observer can cause a significant shift of the rise/set point of the sun. The more distant the horizon, the less the effect a change in the position of the observer has on the rise/set points. For example, in Arizona, some of the horizons are over 100 km away from the Zuni observer. The specific place of observation can be a large area giving the same result. These facts support the selected place of observation.

7.0 RESULTS AND DISCUSSION-RESEARCH QUESTION THREE.

> **'Observe the calendric light and shadow mechanics on the pictographs already identified, for verification of their operation at the stated times and on major solar points.'**

There were eight reported solar markers prior to the beginning of my study of the Paint Rock site. It is only appropriate that the first set to be examined for the validity of the interactions are these eight. The first and most prominent is the Winter Solstice (WS) marker.

7.1 Winter Solstice Marker (WS)

The Winter Solstice Marker is a shield design glyph that is situated at almost the exact midpoint of the 300-meter section of the cliff. A sunlit patch of light forms a triangular wedge that culminates with the intersecting of the center (from now on referred to as the *focal point*) of the glyph at local solar noon. Locally the wedge is called a 'sun dagger.' The sequence starts in Figure 30 and starts when the dagger touches the inner turtle design. It is interesting to note that Native Americans associate the slow movement of the turtle with the slow movement of the sun at the solstices. It is

Figure 30. Start of the Winter Solstice (WS) sequence at 12:27:40 CST.

Figure 31. The sun dagger intersects the focal point at solar noon, 12:38:05 CST.

Figure 32. The sun dagger touches the outside of the turtle at 12:48:00 CST.

followed by the dagger intersecting the *focal point* at solar noon, 12:38:05 CST. Figure 32 shows the final frame of the sequence when the dagger is touching the other side of the turtle at 12:48:00 CST. The interactive sequence takes just over 20 minutes, which would be considered a rapid interaction, with the dagger in the focal point only for several minutes. The MICA program calculates solar noon on December 21, 2012 as 12:38 CDT. The interaction occurring on the WS and at solar noon, confirms the operation of the solar marker. The interaction at solar noon is strong support for intentionality. The Matrix score for the WS marker is 20 as follows: 1) 5 Points for operations on a *solstice*, 2) 5 points for operating at *solar noon*, 3) 5 points for *focal point* interaction, and 4) 5 points for the *horizon astronomy*. This score is the highest without a second category being scored in section 4. The WS marker is confirmed.

7.2 Winter Solstice Marker Round Shield

The WS interaction of this glyph starts as a sun line that appears at 10:12 CST Figure 33. The sun line expands to a complete line across the glyph splitting the circle in half at 10:20 CST, Figure 34. Over the next 55 minutes, the line expands into a wide light shaft that frames the circular shield on the WS at 11:15 am CST, Figure 35. This interaction occurs in this fashion only around the WS. The geometric conditions set the stage for this as well as the sun's altitude. Scoring this with the

Figure 33. Start of the WS interaction East round shield at 10:12:49 CST.

Figure 34. Light shaft splits the round shield at 10:20:12 CST.

Figure 35. Shaft widens to frame the shield tangentially 11:15:21 CST.

Matrix the interaction scores a 14 as follows: 1) 5 Points for operations on a *solstice*, 2) 2 points for *random morning*, 3) 2 points for *tangent alignments*, and 4) 5 points for the *horizon astronomy*. The scoring means that this WS marker just meets the point threshold to be considered a solar marker. However, as will be shown in Section 8, Research question 4, the discovery of new solar markers, another interaction on this glyph may have been the primary intentions of the sun-watcher.

7.3 Round Shield with Register Lines

Claim of this as a WS marker is based on the sunlight interaction illuminating the

Figure 36. WS light shaft aligns along upper register line at 10:36:33 CST.

shield and aligning to the top line of two lines which project from outside of the upper right quadrant of the circle. This sequence is difficult to monitor, as you have to climb up and look behind some fallen slabs. At 10:24 CST, the glyph is completely shadowed, with only the beginning of at sun patch well below the round shield. Figure 36 shows the beginning of the sequence, as according to Yeates & Campbell, the upper light shaft appears very quickly. It is only 12 minutes from completely shadowed to this first photo. Then, the light shaft begins to narrow and the pointer end aligned with the upper register line, Figure 37. The light pointer gets smaller and recedes from alignment along the upper register mark, Figure 38. In several more minutes, when the light reaches the edge of the rock pointed out in the arrow, the light immediately fills the upper section of the shield for the second time. At this point the reported interaction was considered

Figure 37. The shaft narrows and the pointer tip is aligned to register mark at 10:42:23 CST.

completed. As will be shown in Section 8, there is a second alignment to the lower register line, which begins minutes after the completion of this interaction.

Figure 38. The light pointer has receded from the register line at 10:44:24 CST.

Scoring this with the Matrix the interaction scores a 16 as follows: 1) 5 Points for operations on a solstice, 2) 2 points for random morning, 3) 4 points for register mark alignments, and 4) 5 points for the horizon astronomy. The scoring places the intentionality in the middle of the Probable range, which would confirm this as an intentional solar marker.

7.4 Four Horned Buffalo

The Four-Horned Buffalo has been referred to as a shaman's headdress. There is no ethnohistorical, archaeological, or ethnographic data to confirm this claim. The glyph is unique as it is a buffalo with four horns, but also has a 'speech' bubble from the mouth off to the left side, which is filled in with color. A light shaft pointer begins on the adjacent rock face, which has an angle of about 10-15° wider than a 90° angle. This pointer proceeds to intersect the glyph, and then move down to illuminate the 'speech' bubble and upper right horn, and becomes a wider shaft. It continues to widen, moving down, and then moves off to the right. The speech bubble in this instance is the *focal point*, and the shaft crosses the center of the buffalos head. This sequence is shown in Figures 39-41.

Figure 39. Pointer starts on the adjacent panel next to the four Horned Buffalo head.

Figure 40. The pointer moves down and becomes a shaft across the top of the head.

Figure 41. Shaft illuminates the 'speech' bubble and upper right horn.

Scoring this solar marker with the Matrix, the interaction scores a 17 as follows: 1) 5 Points for operations on a *solstice*, 2) 2 points for *random morning*, 3) 5 points for *register mark alignments*, and 4) 5 points for the *horizon astronomy*. The scoring places the intentionality in the upper end of the Probable range, which would confirm this as an intentional solar marker.

7.5 East Double Circle Sun WS Marker

The glyph was reported as WS marker in Yeates & Campbell (2002). In that paper, there are three photos in a sequence showing the potential interaction of the line with the focal point of the sun symbol. The line has two separate jogs or crooked spots. The first photo shows a crook in the line just to the left of the outer ring. In the second photo, the crook is in the outer ring. In the third photo, the crook is in the center ring, and the trailing crook is in the outer ring. The last crook certainly intersects the focal point of the glyph, but the design or shape of the crook does not line up with the elements in the glyph itself. The lack of alignment is also true for the outer ring and the trailing crook. In attempting to verify the interaction, I have taken eleven photographs at random times on two different trips with similar results. None of my pictures shows a hint of design elements aligning with the shape of the crooked line. As discussed in the section on the Matrix on Geometric Alignments (3.1), this configuration requires a reasonably close alignment of the design elements and the shape of the interacting line. On that basis, the Matrix scoring for this glyph would be 12, well below the solar marker confirmation threshold. However, this glyph may require future dedicated observation. Figure 42 shows the crooked line interaction.

Figure 42. East Double Sun glyph with crooked line, there is no design alignment.

7.6 Mortuary Figure Equinox Marker

This solar marker is a result of a moving sun line, which matches up with a mortuary walking figure's feet on the equinoxes. The sun does not rise exactly at the topographic azimuth on the equinoxes, and since the days are roughly equal in length, after 12 hours the sun will not set due west of the sunrise point, as the ecliptic has cycled through 12 hours. The following photographs sequence the alignment of the moving sun line with the feet of the walking mortuary figure, Figures 43-45. They represent pictures taken the day before the AEQ, the day of the AEQ, and the day after the AEQ. You can see how the misalignment in Figure 43 shows the sun line touching the rear foot heal, but

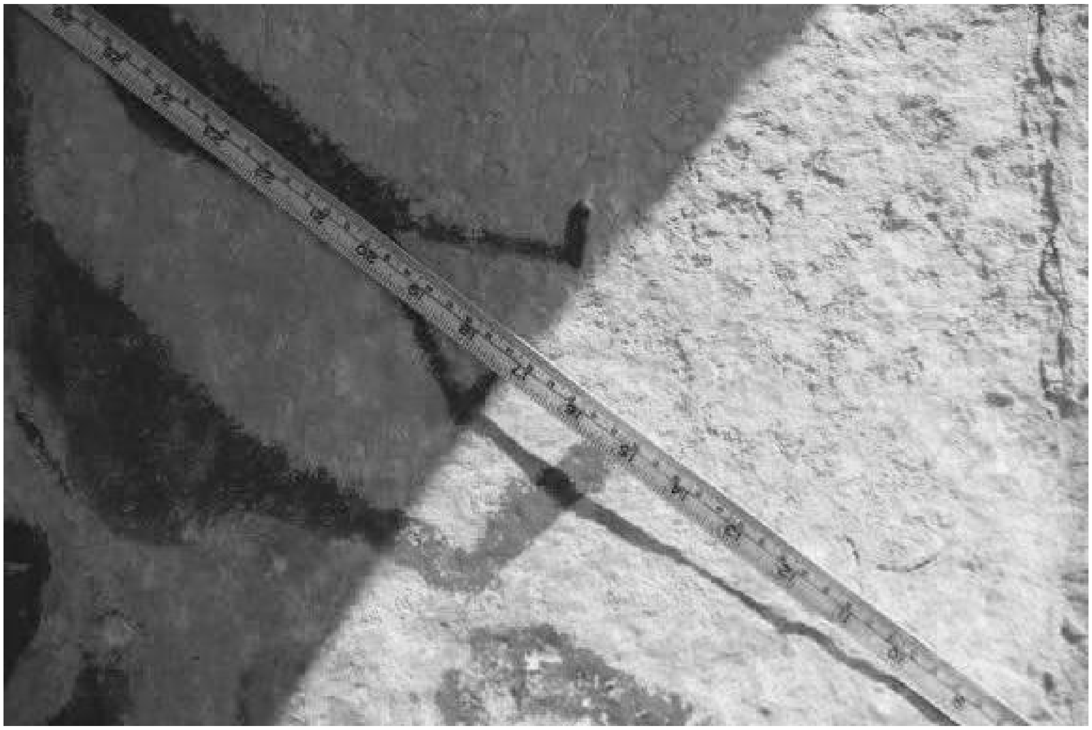


Figure 43. AEQ solar marker the day before the equinox. The alignment is on the rear foot but below the upper or forward foot.

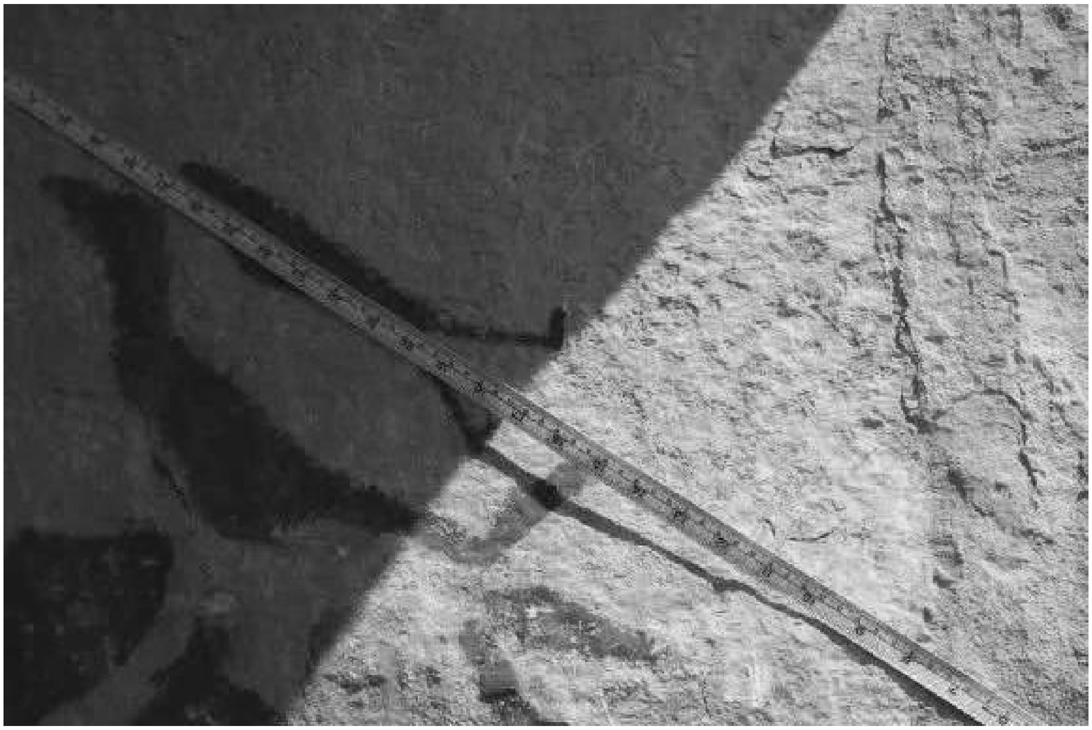


Figure 44. The sunline is aligned equally to both feet on the day of the equinox.

not to the upper foot. Figure 44 shows the sun line aligned to the bottom of both feet on the day of the equinox, and Figure 45, the sun line is clearly up on ankle of the rear foot on the day after the AEQ. The sun is moving south at this moment along the horizon, and it causes the angle of the line to rotate clockwise.

Figure 45. The sun line is up on the ankle of the rear foot the day after AEQ.

Scoring this solar marker with the Matrix, the interaction scores a 15 as follows: 1) 4 Points for operations on the *equinox*, 2) 1 points for *random afternoon*, 3) 5 points for *geometric alignment*, and 4) 5 points for the *horizon astronomy*. The scoring places the intentionality in the middle of the Probable range, which would confirm this as an intentional solar marker. The interaction as presented in the photographs builds a strong case for the intentional placement and operation as an equinox solar marker.

7.7 Double Ellipse Equinox Marker

The double ellipse equinox marker is about 30 feet to the left of the Equinox marker just described above. Mrs. Campbell pointed it out to me while waiting for the equinox alignment on the mortuary figure. The interaction is quick and simple. A pointer begins to the lower right of a small double ellipse, moves up, touches the focal point, and then moves up and away. The sequence is shown in Figures 46-48. The pointer is touching an upright oval spot fully filled-in below the double ellipse. In Figure 47, the pointer touches the inner ellipse at 3:42:13 CST. Then, it moves to the right and loses its shape as a pointer, which is shown in Figure 48. The sequence is 20


Figure 46. Sun pointer touching an oval below the double ellipse at 3:32:13 CST.

minutes long.


Figure 47. The pointer touches the inner ellipse at 3:42:13 CST.

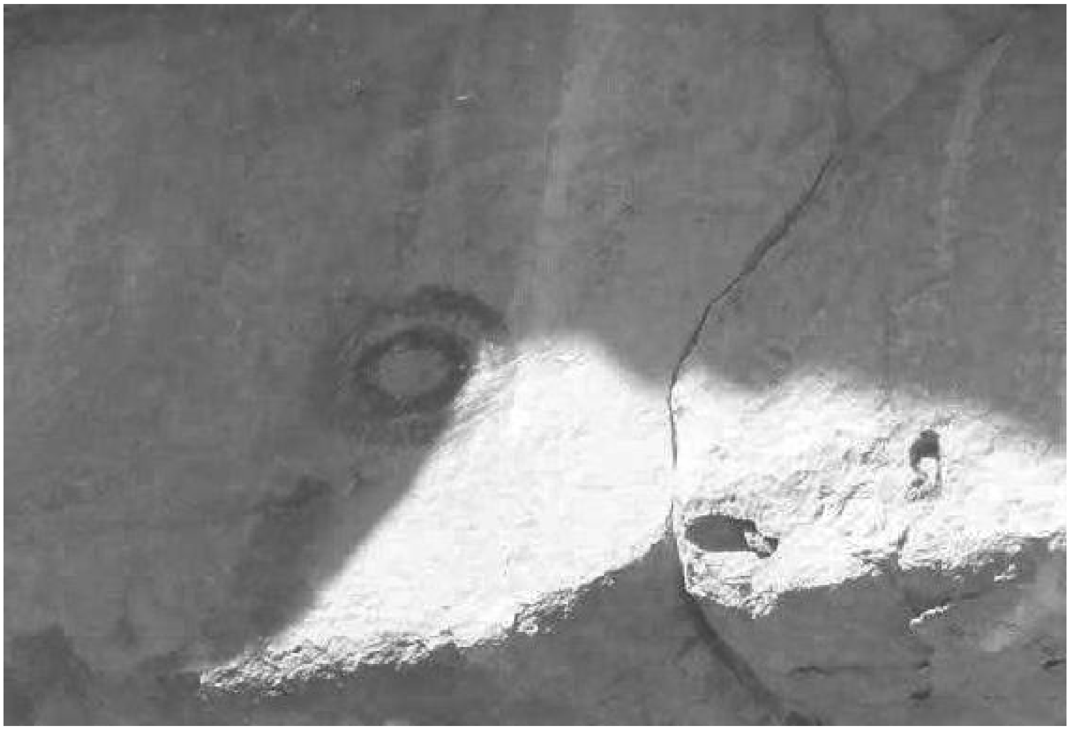


Figure 48. The pointer has moved to the right and lost its shape at 3:53:33 CST.

Scoring this solar marker with the Matrix, the interaction scores a 15 as follows: 1) 4 Points for operations on the *equinox*, 2) 1 points for *random afternoon*, 3) 5 points for *focal point* interaction, and 4) 5 points for the *horizon astronomy*. The scoring places the intentionality in the middle of the Probable range, which would confirm this as an intentional solar marker. The interaction as presented in the photographs builds a strong case for the intentional placement.

7.8 Summer Solstice Solar Marker

This is the final solar marker identified before my study of the site. Dr. R. Robert Robbins (1999) reportedly identified this marker. A narrow light shaft shoots downward towards a shield style glyph that has a central turtle design at solar noon. The turtle is similar to the Winter Solstice glyph, which also has a turtle. The shaft of light passes over the glyph, and about 15 minutes later, a second shaft of light appears on the rock layer below in line with the upper shaft and the turtle. Therefore, in this instance, there is no direct interaction of the sunlight with the glyph. Figure 49 and 50 illustrate these solar mechanics.

Scoring the glyph become problematic, as there is no direct sunlight or shadow that interacts with the glyph itself. The timing of the upper shaft is at a significant time, and the turtle design speaks to Native American mythology of the solstice and the slow movement of the sun along the horizon. The appearance of the lower shaft creates a shaft, turtle, and shaft alignment.

Scoring this solar marker with the Matrix, the interaction scores a 16 as follows: 1) 5 Points for operations on the *solstice*, 2) 5 points for *solar noon*, 3) 0 points for *no direct interaction*, 4) 5 points for the *horizon astronomy,* 5) 1 point for *symbolism.* The scoring places the intentionality in the middle of the Probable range, which would confirm this as an intentional solar marker. The interaction as presented in the photographs suggests an intentional interaction, however, this may be a case that needs to be evaluated, and may cause revisions to the matrix in the future.

Figure 49. A light shaft appears at solar noon aimed at the SS glyph.

Figure 50. A second light shaft forms on the rock layer below the SS glyph.

7.9 Discussion

There are interactions occurring in the morning, at solar noon, and the afternoon, but no claims of sunset solar markers. The pictographs were observed at every chance near sunset over the course of my fieldwork. These observations were limited as in the heat of the afternoon, thunderstorms obscured the western horizon and sunsets on many occasions. I had observed some potential interactions that I thought would occur on specific solar points. I made it a point to check these, and in each case, there was no interaction even suggesting a solar marker. Fountain (2005) reports that the most common time for solar interaction is 'midday' involving rock art. Malville (2008) states that sunrise is the most important time for sun watching. These statements are consistent with what I found at Paint Rock in evaluating the eight claimed solar markers just discussed. It is also true for the new solar markers I identified.

The examination of these solar markers and the scoring with the Matrix has identified potential areas and interactions that may require minor revisions in the Matrix. The intentional placement of these glyphs to create solar markers still meets with some resistance in the scholastic community. The primary and only argument has been that these are coincidental interactions. The sheer numbers of operative solar markers at this site alone argue for intentionality. The newly identified solar markers are examined in the next section.

8.0 RESULTS AND DISCUSSION-RESEARCH QUESTION 4.

'Identify Any New Solar Markers and Determine if There Are Pictographs That Exhibit Calendrical Operations Throughout the Year.'

There have not been any newly discovered solar markers at Paint Rock since the Yeates & Campbell paper of 2002. There have been reports of how to monitor and observe the cliff, which has over 1500 pictographs spread along the 300-meter section of the cliff. One idea was to get teams of people and station them along the cliff on various days, which I believe was done at one time without success. I spent many hours over the 20 field survey trips watching the cliff and the potential solar interactions. Almost 4000 photographs were taken during these observations.

The Paint Rock site is unique in its accessibility to the cliff by vehicle. I would estimate that 90% of the pictographs are visible from the road in front of the cliff. Once the sun begins its northward journey along the horizon, after the WXQ day around the first days of February, many pictographs begin to be in complete shadow until the AXQ day in November. On many occasions, I walked the length of the cliff and back, observing and photographing. This evolved from walking the cliff, to riding in my vehicle, which allowed quicker observation of the interactions. Driving down the cliff starting from the west, I photographed pictographs over and over, especially ones with some solar interactions occurring. It would take 4-6 minutes to proceed down the cliff and drive the outer loop road back to the starting point. I would do these at all times of the day, but about 30 minutes before solar noon, I would repeat the process none stop for an hour. The photographs have been reviewed, and new solar markers were discovered in this manner, which will be presented in the following section.

The development of the Matrix was instrumental in helping identify new interactions in this section. Because of all the observations, I can report the discovery of four completely new solar markers, the discovery of the complete sequence of one previously reported solar marker, and interaction on one of the solar markers at a different solar point, which may have been the primary interaction. I will also discuss possible calendrical operations on several panels. Once a glyph has been placed to interact with sunlight or shadow, a sun-watcher or shaman would most probably continue to observe the pictograph and identify interactions that occur at other times of the year. Once the primary interaction was known, it could serve as a confirmation of the calendrical day, but even more important is the potential for anticipatory interactions. As I will show on the Winter Solstice (WS) solar marker, the dagger begins to form and strike the glyph in early November.

8.1 Winter Solstice Feather Shield-Headdress Solar Marker

This glyph is situated in the area of the second potential place of observation, and it would be easily accessible to the sun-watcher. The interaction is a compound interaction with two pointers. It begins within 30 minutes of sunrise at 8:03 and by 8:17, a sharp pointer is intersecting the *focal point* of the feather shield glyph. Nine minutes later the pointer has disappeared, and the shadow closely mimics the outer half of the round center portion of the shield. At this point, the interaction seems to be over, but around 20 minutes later a second pointer develops from the same sun line and proceeds to intersect a small black pictograph, which appears to be a headdress design. The pointer then moves off and spills onto the adjacent rock face, and the interaction is complete. The sequences are shown in the following figures 51 to 56.

Figure 51. Pointer is formed within 30 minutes of sunrise on the WS.


Figure 52. Fourteen minutes later a sharp pointer is touching the focal point.

Figure 53. End of the sequence with the shadow outlining the shield.

Figure 54. Fifteen minutes later second pointer forms.

Figure 55. Ten minutes after pointer is formed, it strikes a black headdress.

Figure 56. Seven minutes later the pointer strikes the adjacent rock face.

The sequences that occur are both about 20 minutes start to finish. The pointers strike the pictograph in the prime area and then are off, and the pointer disappears. The Matrix score for the Feathered Shield marker is 19 as follows: 1) 5 Points for operations on a solstice, 2) 4 points for operating within an hour of sunrise, 3) 5 points for focal point interaction, and 4) 5 points for the horizon astronomy. The Feather Shield WS solar marker would be confirmed. The Matrix score for the Headdress marker is 15 as follows: 1) 5 Points for operations on a solstice, 2) 2 points for operating at random morning time, 3) 3 points for rapid interaction, and 4) 5 points for the horizon astronomy. The Headdress interaction is a compound continuation of the sun line that first intersects the Feather Shield, but is being scored individually. The Headdress glyph would be confirmed as a solar marker on its own merit.

8.2 The Canoe Winter Solstice Marker

This marker was discovered on the morning of the Winter Solstice 2012. The angle of the sun's rays in the morning line up with many lines incorporated into the glyph. These alignments were first noticed around 8:30 AM CST on the 2012 Winter Solstice (WS). At that time, the moving sun line was at or just below midway, so the following year 2013, I made it a point to begin observations and to photograph the entire sequence from top to bottom. The next three figures show the alignment, top, middle, and bottom, Figures 57-59. The glyph was observed three weeks later in January 2013 and photos were taken, and the lines are at an angle that prevents exact alignments as seen at the solstice. Figure 60 is two photographs, one at the solstice and one on January 16, 2013, with 3 points showing the change in angle and the lack of alignments.

Figure 57. The sun line aligns with the top ladder rung, and a line at the top.

Figure 58. The sun line aligns along the top of three dashes.

Figure 59. Sun line aligns on top of a horizontal line and dash mark at WS.

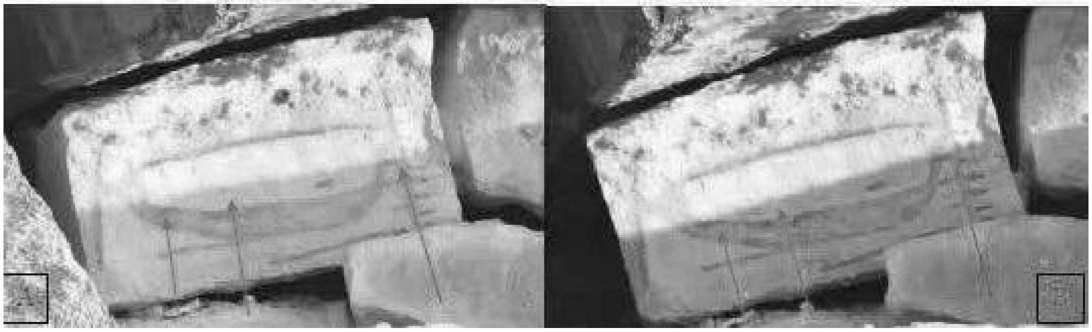


Figure 60. A taken at WS, B was taken January 16, 2013. Note change in angle.

The Matrix score for the Canoe solar marker is 17 as follows: 1) 5 Points for operations on a solstice, 2) 2 points for operating random morning, 3) 5 points for geometric alignment interaction, and 4) 5 points for the horizon astronomy. The Canoe WS solar marker would be confirmed.

8.3 Place of Observation Star Burst Shield

This shield is tucked in corner only feet from the place of observation. The glyph receives a solar interaction that can only occur at the Winter Solstice (WS). Pictures taken 26 days later showed the sun designs operating above the glyph and by the Winter cross-quarter day (WXQ), the sun was nowhere near the rock layer or glyph. The glyph faces east and receives no sunlight for ten months out of the year. A fallen slab splits a rounded finger of sunlight into a light patch, which then illuminates the focal point of the glyph and rapidly disintegrates. The following figures 61 to 63 detail the interaction. This interaction is swift lasting approximately 9 minutes start to finish. The primary interaction shown in the figures is only 5 minutes.

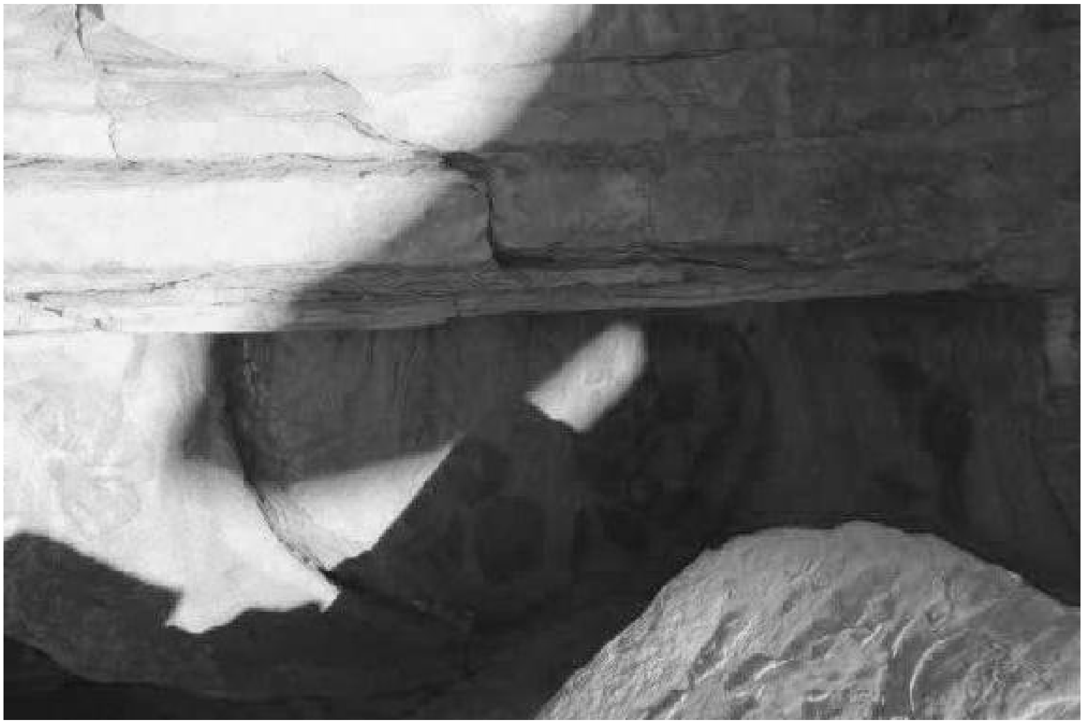


Figure 61. The rounded finger of light becomes a patch of light.

Figure 62. The patch of light illuminates the focal point of the glyph.

Figure 63. In less than 2 minutes, the patch has almost disappeared.

In less than a minute from Figure 63, the sunlit patch is gone, completing the interaction. This interaction is rapid and shows how a researcher at sites may merely miss an interaction doing another task at that moment. The Matrix score for the Star Burst solar marker is 17 as follows: 1) 5 Points for operations on a *solstice*, 2) 4 points for operating within the hour of *sunrise*, 3) 5 points for *focal point* interaction, and 4) 5 points for the *horizon astronomy*. The Star Burst WS glyph is confirmed as a solar marker.

8.4 Rayed Sun Solar Marker

This solar marker operates on the VXQ and SXQ days. The interaction is quick and last about 33 minutes from the tip of the wedge touching the bottom left of the outer ring of the rayed sun glyph, to the tip touching the upper right of the outer ring. This wedge is broader than the WS solar marker dagger, but the interaction is almost the same except for the *random afternoon* (2.5) operation. The sequence is detailed in Figures 64 to 66. The first contact is the lower right outer ring at 2:44:22 CDT. The leading tip intersects the *focal point* (3.1) at 2:57:25 CDT, and the tip hits the upper right outer ring completing the interaction at 3:20:10 CDT. The full sequence lasts 35 minutes and 48 seconds.


Figure 64. First contact of the lower right outer ring at the tip of the arrow.

Figure 65. Light wedge intersects the focal point of the rayed sun.

Figure 66. Leading tip of wedge touches the outer ring of the rayed sun.

The Matrix score for the Rayed Sun solar marker is 14 as follows: 1) 3 Points for operations on a *cross-quarter day*, 2) 1 points for operating at *a random afternoon time,* 3) 5 points for *focal point* interaction, and 4) 5 points for the *horizon astronomy*. The Rayed Sun SXQ day glyph is confirmed as a solar marker, but scored at the threshold of the probable range. This interaction is very similar to the Winter Solstice Solar Marker interaction. The fact that it operates twice a year as the sun travels north for the summer, and then south heading to fall, suggest that further consideration should be made in the matrix for multiple interaction on this glyph.

\8.5 Round Shield with Register Lines-Part 2

This solar marker was examined in section 7.3, as it was one of the claimed solar markers prior to the beginning of my study of the site. The description of the interaction stopped once the pointer disappeared and there was no alignment with the top register line. My continued observation identified that this is a true compound interaction, as once the first pointer disappears the next stage begins. The sun is gaining altitude, which allows light to spill over the top half of the glyph, and below the protrusion acting as the casting device. This produces a large shadow wedge, with the top line then aligning to the lower register line. The initial sequence can be reviewed in Figures 36, 37, and 38, which ends at 10:44:24 CST.

To observe this solar marker a hazardous climb up the debris slope must be made each time. As has been demonstrated, many of the operative solar markers occur at Winter Solstice (WS). In this instance, there is a time gap between the start of the second interaction and what would be considered the end of the first interaction. There are only two pictures with a time gap of 28 minutes to document this sequence. The first photo, Figure 68, shows the second alignment at 11:01:47 or about 17 minutes after the end of the first sequence. I believe that this second alignment occurred well before this stated time. The second photo, Figure 68, shows the shadows top line well below the second register line. The sequence times, therefore, would probably be much closer if I had only this glyph interaction to observe and photograph. In the interim period, other glyphs were being observed and shot before getting back to this one. Since the original description of the interaction describes the sequence as complete after the first alignment finished, it could have been that I did not return to this glyph, but the fact is I did to discover interaction with the second line, which is what I suspected. Figures 67 and 68 show the sequence just described.

Figure 67. The shadow wedge is aligned to the bottom register line.

Figure 68. The shadow wedge has retracted below the register line.

The first sequence has already been scored using the Matrix in section 7.3, scoring a total of 16. Treating this secondary interaction on its own merit using the Matrix the interaction scores a 16 as follows: 1) 5 Points for operations on a *solstice*, 2) 2 points for *random morning*, 3) 4 points for *register mark* alignments, and 4) 5 points for the *horizon astronomy*. This is the same score as the first part. This places the intentionality in the middle of the Probable range, which would confirm this as an intentional solar marker on its own merit.

8.6 Calendrical Interactions of Observed Solar Marker Panels.

The second half of this research question is to identify any potential calendrical operations with the pictographs. There are no solid ethnographic, ethno-historical, or even solid historical records, so the following may be considered speculation as to whether cultures were aware of the interactions to be described. The high level of sun-watching skill observed at this site, and the recording of significant parts of the cultures astronomical knowledge, there is a high probability that daily observations would have noted these additional calendrical interactions.

8.6.1 Winter Solstice Panel

The Winter Solstice solar marker was the first solar marker discovered at Paint Rock. This panel exhibits several calendrical interactions, some that have been known and one new one I discovered in the review of photographs taken. The first interaction is shown in Figure 69, which is the first sunlight to hit the panel after the summer season on the autumnal equinox, or the last patch of light to strike the panel on the vernal equinox. Between the two equinoxes in the spring and summer, the winter solstice panel during the day is in permanent shadow. The momentary sun patch on the corner of the panel may

Figure 69. Spot on far right corner of Winter Solstice panel.[2]

be coincidental. There is a vertical line just to the right of the Winter Solstice solar marker. It is the same color as all the other monochrome pictographs, and it had to be intentionally placed. On the equinoxes, a light streak aligns with this line, as shown in Figure 70. This interaction is essentially a newly discovered solar marker on its own accord. Like most of the other newly discovered solar markers, this was discovered during review of the photographs taken.

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[2] Adapted from Yeates & Campbell (2002)

Figure 70. Light streak aligns with vertical line on the Autumnal equinox.

On the AXQ and VXQ days, the sun dagger forms at the base of the Winter solstice glyph, touching the fifth lobe from the left. It grows larger and proceeds up and to the right, just glancing the corner of the turtle's head before moving further up and to the right. Figures 71, 72, 73, and 74 detail the sequence that starts at 1:06:49 CST and ends at 1:55:05 CST. After this sequence, Figures 75, 76, and 77 show the interaction just two weeks before on the October 23, 2012 trip. This is one of the 12 months in a row trips, which as has been previously stated, that going every month for a year to observe, helps eliminate the claim of coincidence. These October photos show the interaction and design to be completely different from the AXQ day in November.

Figure 71. November AXQ day, the tip of the dagger begins at 1:06:49 CST.

Figure 72. The dagger tip in the middle lobe at 1:11:46 on the AXQ day.

Figure 73. The dagger has expanded and now touches the corner of the turtles head.

Figure 74. Large dagger aligned to the right side before moving off.

Figure 75. Start of a light patch, October 23, 2012, 1:31:42 CDT.

Figure 76. The double pointed dagger to the right, October 23, 2012, 1:52:48 CDT.

Figure 77. Double tip dagger off the glyph, October 23, 2012 at 2:15:09 CDT.

The September-October-November sequence shows the movement of the interaction leading up to the Winter Solstice (WS). Each sequence is shaped differently and moves to the left and gets higher on the panel as the sun moves to the extreme south solstice position. A sun-watcher would no doubt observe these over time and would be able to notice the position of the interaction on the glyph two-three weeks before the Winter Solstice. In other words, this shows a calendrical activity that could then be used as anticipatory notification.

8.6.2 East Round Shield Calendrical operation.

This glyph was examined as a Winter Solstice (WS) marker in section 7.2. The interaction was a light streak that first split the circular glyph down the middle, which widened to a shaft that framed the round shield tangentially. This interaction occurred at a random time in the morning on the WS. The cliff was inspected over and over around solar noon photographing the interactions every 5- 10 minutes. On the Autumnal cross-quarter day 2013, just one minute after solar noon, the round shield was bisected in half by the trailing edge of the light shaft, Figure 78. A review of the photographs would indicate that this

Figure 78. The shield is bisected 1 minute after solar noon on the AXQ day.

glyph is in permanent shadow just after the VEQ and just before the AEQ. As this occurs at solar noon, bisects the focal point of the glyph, this interaction would score higher on the Matrix than the WS tangent interaction. Figure 79 shows the change in the angle from the AXQ day to the WS day interaction when the round shield is bisected.

Figure 79. A is AXQ day and B is WS, note the change in angle.

The Matrix score for the AXQ day interaction on the Round Shield is 18 as follows: 1) 3 points for operations on a *cross-quarter* day, 2) 5 points for operating at *solar noon*, 3) 5 points for *focal point* interaction, and 4) 5 points for the *horizon astronomy*. This score places the glyph in the highest intentionality probability and scores 4 points higher than the WS interaction (Section 7.2). It could be argued since the bisection is at solar noon, that this was the primary interaction and the tangent interaction first claimed is simply coincidental due to the geometric conditions.

8.6.3 The Corn Seasonal Calendar

This potential calendar is made up of two rock layers that seem to be tied together. These two panels include the newly discovered VXQ/SXQ day solar marker examined above in section 8.5. What ties the panels together are two corn plant glyphs, with the lower plant on the bottom rock layer, a wilted or dead corn plant, and the upper corn plant a live corn plant with ears of corn. The large wedge pointer operative in the rayed sun VXQ/SXQ solar marker is the operative sun light on these panels throughout the year. The first thing that was noticed on the first survey visit was the point of the wedge touching the bottom of the stalk of the upper corn plant. The wedge pointer continues up with a curved path the same shape as the upper stalk and ends touching a circular glyph design. This occurs on both VE and AE days. This sequence is shown in Figures 80, 81, and 82. Since the two cross-quarter days have been examined, only photographs detailing the other interactions will be addressed below.

Figure 80. The wedge grows from the left and the tip is between the layers on the AE.

Figure 81. The point follows the path of the stalk up to the right on the AE.

Figure 82. The pointer stops when it touches the branch on the AE.

After AE, the wedge reaches to the left side of the topmost branch of the cornstalk, which would be the same for the WXQ day, Figure 83. In the winter (WS), the wedge is farther to the left end of that same branch from the AXQ point of the corn stalk branch, Figure 84. Compare the location of the tip of the pointer between Figures 83 and 84.

Figure 83. The wedge stops at the branch just to the left of the stalk VXQ.

After the VXQ, the glyph goes into permanent shadow until just before the SXQ day. Between the VE and VXQ days, the wedge is between the rayed sun and the corn plant in April 2012, Figure 85. This movement to the right signifies the approach of summer, and a skillful sun watcher may know when this pointer hits a certain spot that it is time to plant or move north for the summer.

Figure 84. The pointer stops on outer branch tip left of the stalk on the WS.

Figure 85. Corn Calendar wedge is between the rayed sun and the corn plant in April.

8.7 Discussion

As a result of this research question, four new solar markers have been discovered. Counting the Headdress interaction from the Feathered Shield, asserting the solar noon interaction on the Round Shield on the AXQ day as the primary solar marker, and the vertical line alignment on the Winter Solstice panel, a total of seven new solar markers have been identified. Three potential seasonal calendars have been examined.

The Rayed Sun Solar Marker that operates on the VXQ and SXQ days scored just at the threshold of the range to be considered a solar marker using the Matrix. This interaction and the solar marker are more precise than the Winter Solar marker, as the sun is moving quickly along the horizon at the cross-quarter days. The study of this interaction may require some adjustment to the Matrix. One consideration is having certain characteristics score the same point values or higher, meaning the cross-quarter days may be equal to or greater than equinoxes and equal to solstices. The evidence is mounting that the astronomical knowledge on cross-quarter days at Paint Rock has equal importance as the solstices.

9.0 RESULTS AND DISCUSSION-RESEARCH QUESTION 5.

> **'Determine any other bright celestial objects, including bright stars, planets, the moon, and constellations that may have potential calendrical significance.'**

9.1 Helical rise of Sirius in August.

The identification of the place of observation and the 'notch' in the horizon opened up the possibility of checking for stellar objects that may interact with the "notch." The first celestial objects after the sun, which have fixed declinations are the stars. Stars on the celestial sphere are relatively fixed. Stars have a change in position from what is known as proper motion, which is very slight for most distant stars. The change is an apparent change in relation to our sun and other stars. There are only 16 stars with an apparent visual magnitude of one or less.

A list of the bright star produced only one star that came close to the declination of the 'notch.' Sirius, the brightest star in the sky, has a declination almost matching the "notch." Sirius' magnitude and declination are -1.4 and -16° 43' 44" respectively. The declination of the notch was determined to be -16° 3' 48". The difference would be about 40' arc minutes. The 'notch' declination was determined subtracting for atmospheric refraction. Hence, subtracting atmospheric refraction, which for the notch is 35' based on a 0° horizon elevation, from the declination of Sirius, the declination becomes -16° 8' 44." The difference becomes only 5' arc minutes. Hence, Sirius will rise in the notch around its helical rise date.

Determining the helical rise date becomes easier stated in a range. I was unable to secure a ground truth confirmation for the August SXQ day. On the mornings of August 6, 2012, and 2013, low cloudbanks at the eastern horizon obscured the visibility. According to Aveni (2001), a first magnitude star's helical rise requires the sun to be below the horizon at least 10°, which means the star and the sun must have at least a 10° separation. It is also stated that a first magnitude star must be above the horizon at least 1° for visibility.

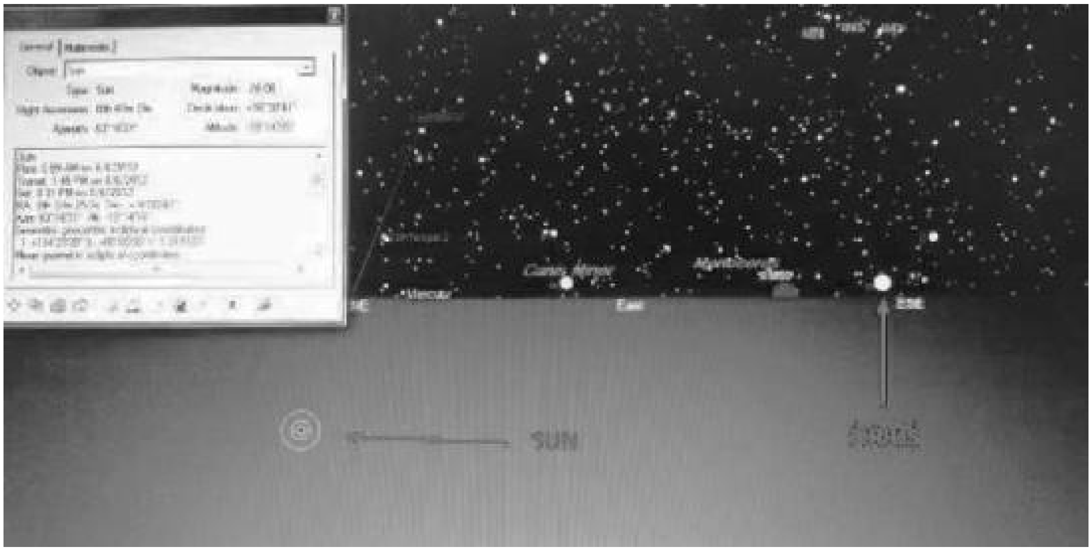


Figure 86. SkyWatch program is showing the helical rise of the star Sirius.

Using the SkyWatch program and doing some astronomical modeling, on August 6, 2012, at 6:11 AM CST, the sun is below the horizon -10° 14' 55" and Sirius has an altitude of +1° 00' 20", Figure 86. These coordinates give them a vertical angular separation of over 11°, and when using the angular separation function, they are physically separated by 48° 12' 49". This physical relationship should make a helical rise visible. Backing up the Skywatch program two days to August 4, 2012, the sun is below the horizon only 8° 26' 01", which means the sky brightness would obscure the helical rise of Sirius. This check suggests that August 6th is the correct date for the helical rise of Sirius. A ground truth photograph was not possible due to obscuring atmospheric conditions on both trips.

9.2 Lunar Tally Marks

Aveni (1997) states in the American Southwest, "the Native Americans only counted the days the moon was visible, so 28 is the most important number." The moon was and still is the basis today of many Native American calendars. I know this first hand, as I have visited at least five different Pueblos in the state of New Mexico, USA, and have always asked about their calendar. The answer has always been that it is a lunar calendar. I photographed two different sets of 28 tally marks at Paint Rock. One set was in the place of observation, noted in Figures 25 and 28, and the second set is displayed here in Figure 87. On the basis of two sets of 28 tally marks, I am confident that the Native American cultures at Paint Rock utilized the moon in a calendrical fashion.

Figure 87. The west end living area has 28 tally marks. This is a possible lunar count.

9.3 Cliff Celestial clock

The cliff has a visible height of over 23°, and the visual effect reduces the number of circumpolar stars down to only the North Star and the first stars of the handle of the dipper of Ursa Minor. Hence, the celestial north pole and Polaris are only 7° above the horizon created by the edge of the cliff. The cliff creates a unique astronomical time clock, one involving Ursa Major or the Big Dipper and the constellation Cassiopeia. These constellations hold distinct positions based on the seasons. Many examples in the literature show that North American native cultures were observers of the celestial sphere, and they were aware of the constellations and their appearance in different seasons, (Marshack 1985:45. Kidwell 1985:220, Williamson 1987:51). The following four figures, 88, 89, 90, and 91, are screenshots from the astronomical software Stellarium. Each of the four shots is shown on the four principal solar points, SS, AE, WS, VE.

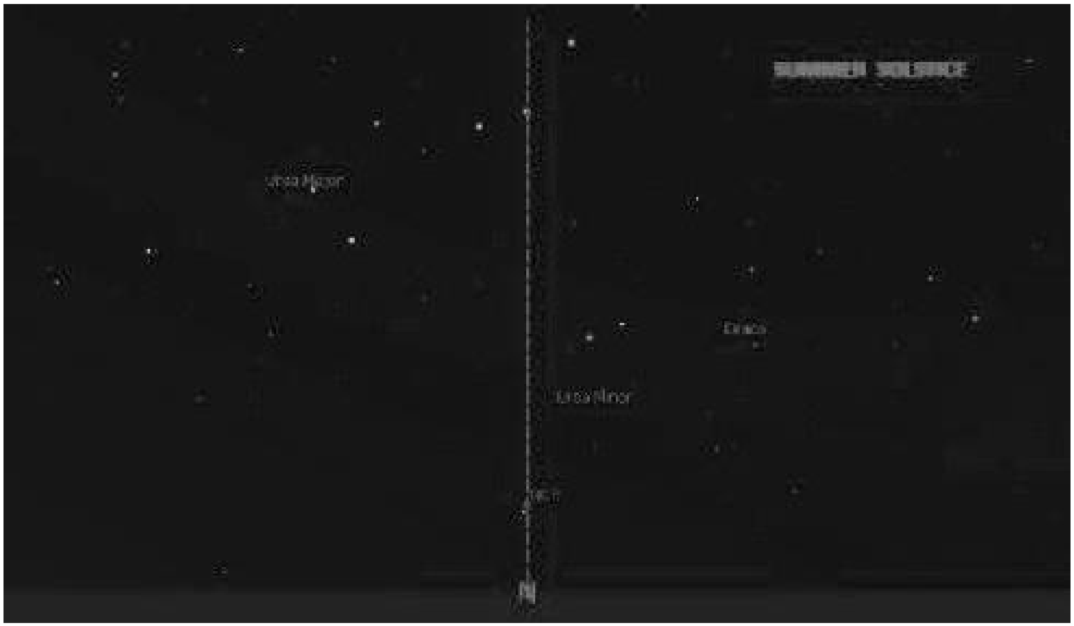


Figure 88. The SS with the Ursa Major (Big Dipper) directly above the CNP.

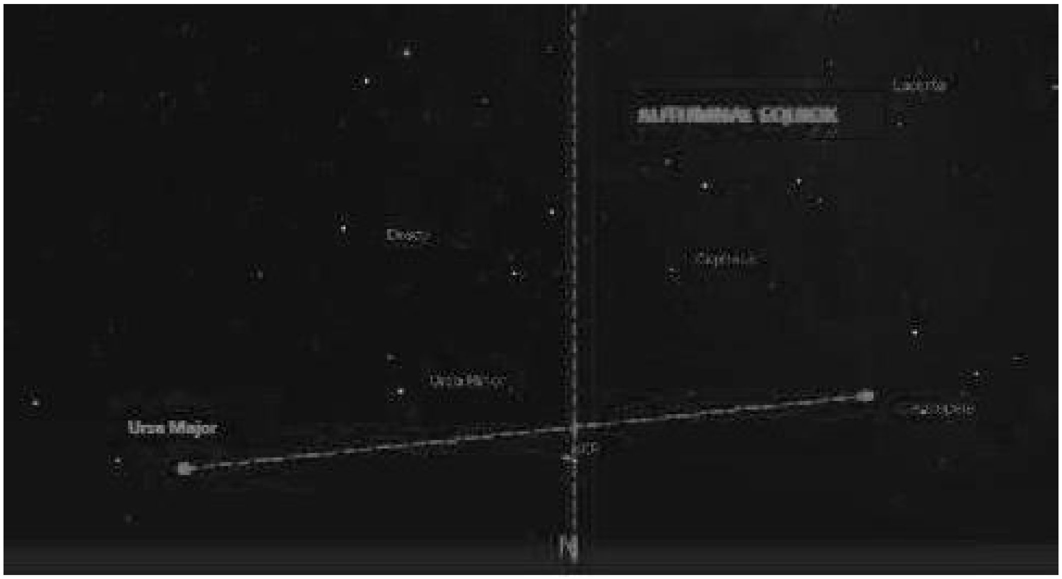


Figure 89. The AE, Ursa Major, is setting opposite Cassiopeia's rising.

Figure 90. Cassiopeia is directly overhead of the CNP.

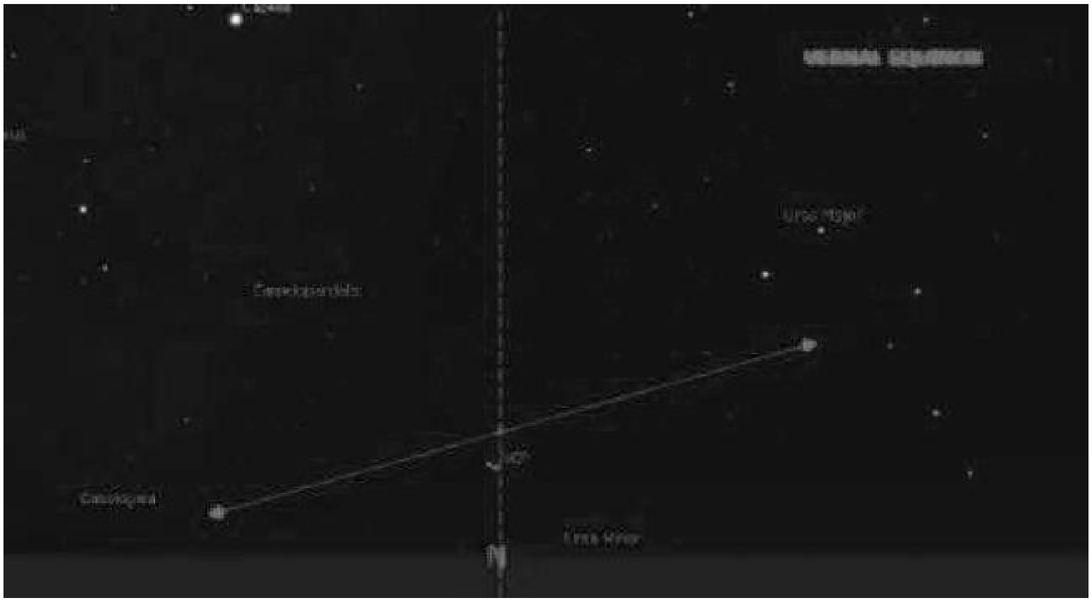


Figure 91. Ursa Major rising in the east, Cassiopeia setting opposite in the west.

The two constellations, Ursa Major and Cassiopeia, act as hands on a clock rotating around the celestial north pole. In the next section, a discussion of a pictograph that appears to be a representation of SN1572 is direct material evidence of this clock at work. Briefly, SN1572 reached maximum on November 6, 1572. This date also happens to be the AXQ day, the day the sun rises in the 'notch.' In the early evening just after dark, Cassiopeia is rising east of the CNP. The supernova exploded across from the upper portion of the W formed by Cassiopeia. The pictograph is constructed with the same configuration as would have been seen that night. This will be examined in detail in Section 10.

9.4 Discussion

The rising of the sun in the "notch" on the AXQ day is purely coincidental, but a significant time marker. The heliacal rise of the star Sirius in the "notch" is even more coincidental, but still another significant seasonal marker that works. Many cultures use Sirius for calendrical purposes. The most well known is by the Egyptians, as the helical rise of Sirius signaled the time when the Nile River begins to flood each year. The newly discovered Rayed Sun SXQ day solar marker would act as a confirmation of the helical rise of Sirius, or a backup if the horizon were obscured from low morning clouds.

The set of 28 tally marks and the observable days of the moon tend to verify the possible interpretation of these tallies. As will be seen in section 11, there are other rock art tally marks in use in northern Mexico. In prehistoric times, the Native American cultures did not have formal mathematics. Tallies of many life situations were kept in many different forms. Sun watchers used rocks, notches in sticks, knots in a rope, and rock art tally marks to record sunrises or sunsets.

The use of the celestial sphere for calendrical purposes and timekeeping is ubiquitous around the world. The celestial clock at Paint Rock is just one example. McCluskey (2005) discusses the use of stars by cultures through time. He mentions the Greek Hesiod who states the appearance of certain stars were seasonal indicators, the Native American tribe, the Pawnee, used the motion of the stars to tell time at night, and most importantly, these required no landmarks to operate. Hence, these activities were very portable.

Ellis (1975) states that the Pleiades, Orion's belt stars, and the Big Dipper were all uses as timekeepers by Native Americans. Williamson (1987) states that the Pawnee used the helical rise of constellations to set their solar calendar. He gives as examples that part of Scorpio, called the First Big One, has a helical rise in December. The heliacal rise of Corvus in November signifies the time to start hunting and winter preparations. The celestial clock at Paint Rock would indeed work the same way.

10.0 RESULTS AND DISCUSSION-RESEARCH QUESTION 6.

'Can any of the iconography of the pictographs match any significant astronomical phenomenon, i.e., comets, supernovas, eclipses?'

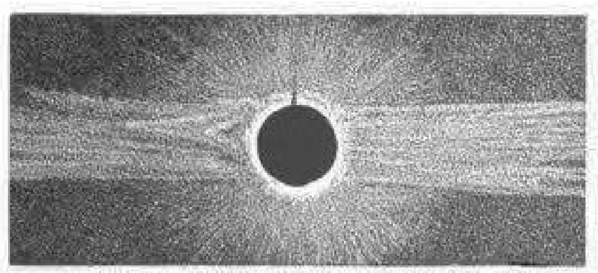
10.1 Eclipses

There have been two claims of significant astronomical phenomenon at Paint Rock. Yeates & Campbell (2002) make two claims in the paper of these events. One is a claim for a possible eclipse and the other a claim of SN1054. The eclipse claim will be examined in this section, and the supernovae claim in the following section. Interpreting rock art in general based solely on the iconography is very problematic, which is interpreting the design of a glyph based on matching similar designs of celestial objects. The most common being a crescent is claimed to be a crescent moon. This association is known as a Rorschach test. To avoid these claims, one must have reliable ethnographic, ethnohistorical, or solid analogy from other sites to make such claims, or the glyph or design must be so compelling as to make its case for the interpretation.

Figure 92 shows the pictograph panel that is reported to be a possible record of a solar eclipse in 1878. The association is made with the sketch made by astronomer Samuel P. Langley of the Allegany Observatory, Walcott (1912). His observations were made from the top of Pikes Peak near Colorado Springs, Colorado. The path of the eclipse does clip the far northeast corner of Texas, but it would have only been a partial eclipse at Paint Rock. Additionally, the earliest historical graffiti that are scratched over

Figure 92. The possible total eclipse panel.

the top of existing pictographs dates to 1856. The best estimates for the age of the pictographs as outlined in the introduction was the period encompassing the Toyah archaeological phase in Texas, which ran from approximately 1300-1600/1700 A. D. The Toyah Phase ended 178 years before the eclipse. Figure 93 is an image from the web of Samuel Langley's sketch. This eclipse occurred well into the historical period, thus after European contact. It is easy to see how an association of the glyph could be made with the sketch. Beyond that, the date is clearly out of context with what appears to be the dates of the pictographs. This form of interpretation is very representative of a Rorschach association, i.e. one figure is very close in appearance to the other.



THE CORONAL STREAMERS OF 1878 (LANGLEY)

Figure 93. Langley's sketch of the 1878 total eclipse. Wikimedia Commons.

Hence, it must be that item. These interpretations are problematic and are the result of observer bias. There are no reliable ethnographic, ethnohistorical, or other analogies to support this as a possible eclipse record.

10.2 Supernova Representations at Paint Rock

The concept of supernova representations in rock art began in 1955 when William C. Miller interpreted two different rock art sites to be possible images of the Crab supernova of AD 1054 (Koenig 1979, Krupp, et al. 2010). Yeates & Campbell (2002) make a circumstantial case for a panel at Paint Rock as a potential representation of SN1054. The panel contains a star and a crescent, which is representative of many other supernovae claims in the American Southwest, Figure 94. It is stated that in addition to the star and crescent, that a triangular shape potentially represents the head of the bull, in the constellation Taurus. The star glyph would then be in the approximate correct location of SN1054, which is at the tip of the bull's horns. Doing an astronomical modeling check with Stellarium, the path of the crescent moon takes it above the head of the bull and not below. Thus, the position of the design elements do not match with the celestial phenomenon as it would have been seen on the date of occurrence.

Figure 94. Possible SN1054 representation.

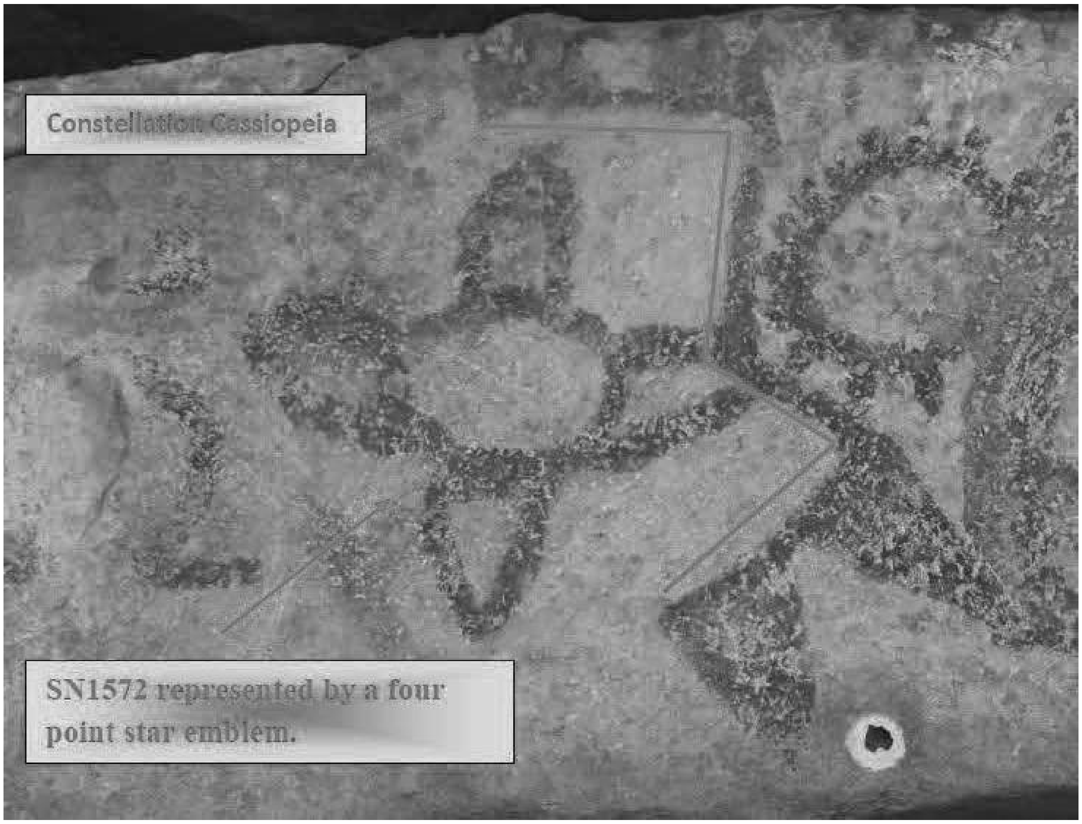


Figure 95. SN1572 representation on the Summer Solstice panel.

A second pictograph is a potential supernova representation is located on the panel next to the Summer Solstice solar marker. The representation contains several glyphs that I hypothesize record Tycho Brahe's supernova, SN1572, Figure 95. The configuration of the supernova and the constellation Cassiopeia are correct for the date of maximum brightness.

10.2.1 Significance of Supernovae

Historical records of supernovae have important astrophysical implications, as they are used to interpret the supernovae remnants (SNR) of the events (Green 2002). The records of these events correlate to two important factors. First, these records provide the age of the event, which make them one of the few celestial objects where the age of formation is known with relative certainty. Secondly, having been observed, they were nearby the Sun in the galaxy, and the luminosity estimates help constrain their distances. A few of these events were visible in the daytime and lasted for months, with several having been reported to be seen for several years.

A supernova, the explosive ending of a star, is the most energetic event known in the universe. The luminosity of supernovae can be so great, that it can outshine all of the other stars in a galaxy (Eldridge 2008). Events of this magnitude are the rarest celestial event that can be observed with the naked eye and without the aid of a telescope. Cultures around the world recorded observations of these events, but the record is spotty and incomplete, before the advent of the telescope in 1608. Even with the telescope, SN1680 has unreliable observation records. Supernovae are designated by the initials SN and the year of occurrence. Hence the supernova observed by Tycho Brahe in 1572 is designated SN1572.

A second stellar event is called a nova, which is less energetic than a supernova. The luminosity of a nova would make most appear stellar in nature, and dim enough that they may go unnoticed to the less literate cultures. In fact, except for the Chinese observations of novae, there does not appear to be other records of these events. There are no known daytime sightings of novae, and for this reason, we will concentrate only on the supernovae events.

10.2.2 Supernovae Mechanism

There are two types of supernova, Types I and II, which are identified by the spectra (Fix 2004). Type I have no hydrogen lines in the spectra, whereas, Type II show hydrogen lines in the spectra. The increase in the luminosity is extraordinary and caused by the release of energy up to $\sim 10^{44}$ J (Green 2002). It is further stated that the energy released interacts with the interstellar medium to produce a supernova remnant. Extragalactic supernova typically outshine their host galaxies, making them easily observable telescopically. A concise discussion of supernovae can be found in Eldridge (2008).

Core collapse is the primary mechanism of all supernovae, except Type Ia. Type Ia supernova occurs in binary star systems, consisting of a larger star and a companion white dwarf. Type I are supernovae from less massive stars than Type II. Type II supernova involves massive stars typically <8 solar masses. Green (2002) indicates Type I supernovae occur in elliptical and spiral galaxies, whereas Type II supernovae only occur in spiral galaxies. Type Ia supernovae have light curves that show the same relationship of luminosity over time. This fact was first investigated by Baade & Zwicky

(1938). This relationship is the characteristic that makes Type Ia supernovae a class of *standard candles* used to measure distances in the universe. Figure 96 shows the light curves of two historical supernovae, SN 1572, top curve, SN1604 middle curve, and the bottom curve is the brightest supernova up to its date of discovery SN1937. The bottom curve and the scale on the right are for SN1937. Note the similar shape of the curves.

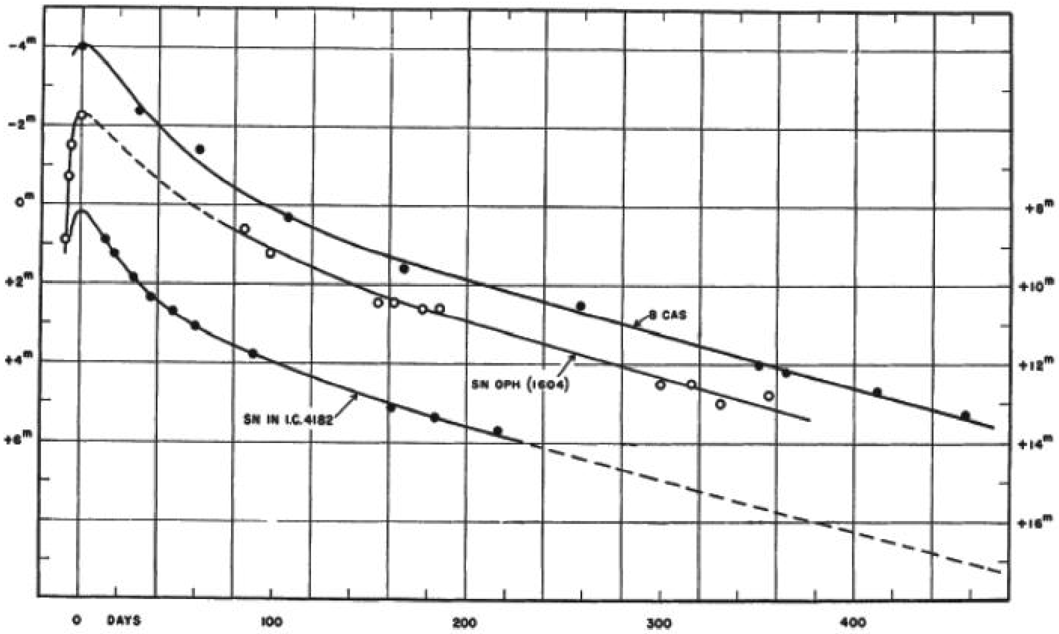


Figure 96. Light curves of Type 1a supernovae. (Mayall 1948, van den Bergh 1973).

10.2.3 Location of Supernovae

The location is the main factor affecting whether a supernova is visible from earth. The location in the galaxy relative to our solar system is critical. Table 4 lists the location information of the historical supernovae since the start of the Common Era, the galactic coordinates of their supernova remnant, and those who left a record of potentially observing the supernova. Many supernovae occur in the Milky Way, but due to their location, they are never seen from earth. Another factor having a direct effect on the number of historically recorded supernovae is that most literate cultures are found in the Northern hemisphere. Hence, observations of the densest part of the Milky Way and the Large and Small Magellanic clouds were not observed by literate cultures (Hamacher 2014).

The second factor is extinction, which is the absorption and scattering of the light by interstellar dust particles and interstellar gas, as light travels through the universe. The earth's atmosphere also affects the amount of light received. Looking at Table 4, the distance column, two of the first three supernovae in the first millennium are at great distances. There is substantial uncertainty of these observations. Evidence of this is the listing of two different years of observations, and only by Chinese observers.

TABLE 4. HISTORICAL SUPERNOVAE OF THE COMMON ERA, LOCATIONS, AND OBSERVERS

SN	CONST.	R.A.	DEC.	D (ly)	TYPE	SNR Galactic Coor.	OBSERVED BY*
185	Centaurus	14:43.1	-62:28	8200	Ia?	SNR: G315.4-2.3	Chinese
385/386	Sagittarius	18:11.5	-19:25	14700	II	SNR: G11.2-0.3	Chinese
393/396	Scorpio	17:14	-39.8	34000	--	SNR: G347.3-0.5	Chinese
1006	Lupus	15:02.8	-41:57	7200	Ia	SNR: G327.6+14.5	Arabic; also Chinese, Japanese, European
1054	Taurus	05:34.5	+22:01	6500	I?	Crab Nebula G.184.6–5.8	Chinese, North American (?); also Arab, Japan
1181	Cassiopeia	02:05.6	+64:49	8500	--	SNR: G130.7+03.1 3C58	Chinese and Japanese
1572	Cassiopeia	00:25.3	+64:09	8000	Ia	SNR:G.120.1+1.4	Tycho Brahe's SN
1604	Ophiuchus	17:30.6	-21:29	14000	Ia	SNR: G4.5+6.8	Johannes Kepler's SN

Table 4. The eight observed historical supernovae of the Common Era. Data shown in decending order of age, the primary constellation, equatorial coordinates, distance, type, galactic coordinates of the supernovae remnant (SNR), and observers who left records of the event. Data acquired from Simbad astronomical data base, Green (2002), IAUweb, SEDSweb*, and Stellarium astronomical software. Table credit Gordon L. Houston.

Figures 97 and 98 show the relative location of supernovae in relation to our solar system and the Milky Way galaxy. The difference in the two is the sun is at the center in the older Chinese record, Figure 97, and the galactic center is at the center of Figure 98. The locations are based on galactic longitude, and the reference point is the galactic center, which has a galactic longitude of 0°. Coordinates increase counterclockwise around the galactic plane. Galactic latitude is the angle measured above or below the galactic plane, with north being positive and south negative. The observable supernovae charted in Figure 97 are all in our quadrant of the Milky Way. Hence, the evidence supports location as a primary requirement for a SN to be observable. The amount of galactic extinction is delimited by the position, as will be noted in Figure 97, there have been no supernovae observed beyond the galactic center, which is 25,000 ly from our sun.

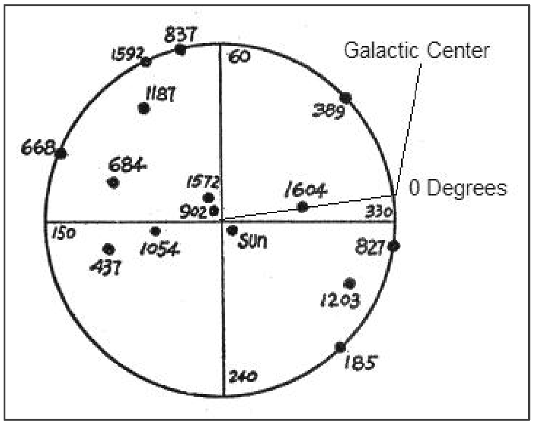


Figure 97. Galactic locations of historical supernovae from Oriental records, based on galactic longitude. Adapted from Ze-zong, X. & Shu-jen (1966).

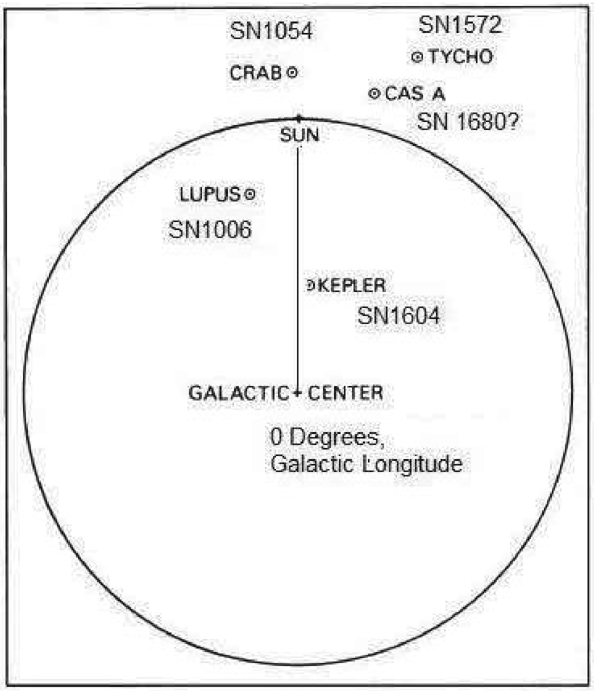


Figure 98. Galactic locations of historical supernovae of the second millennium based on a galactic view. Adapted from van den Bergh (1973).

10.2.4 Observational Characteristics of Supernovae

The explosiveness of supernovae to produce an observable event has many characteristics to be considered, especially one that preliterate cultures would record. Table 5 details characteristics that would enable cultures to become aware of the event. The m_v is the visual magnitude of the event as seen from earth. The visual magnitude is a celestial objects apparent magnitude. which is the amount of energy reaching the earth based on the magnitude scale (Moore 2003a). SN1006 had the highest calculated magnitude of all the historical supernovae. The visual magnitude (m_v) threshold for observations during the day is -4 (Schaefer 1991). The last column, TIME, is the duration the SN was visible. For example, the time of visibility for SN1006 was over two years. Looking back at Figure 96, the light curve of three SN, the luminosity, the amount of energy emitted in all wavelengths (Moore 2003b), declines rapidly over the first 80 to 100 days. Once the luminosity reaches a m_v of +2, the SN simply becomes another stellar object in the star field. Observers must be experienced to maintain observations after this point.

TABLE 5. OBSERVATIONAL CHARACTERISTICS OF HISTORICAL SUPERNOVAE OF THE COMMON ERA

SN	DATE	1ST V.*	AZ 1ST V.*	ALT 1ST V.*	CUMIN.*	m_v	DAYTIME	TIME
SN185	?	?	--	--	--	-2/-8?	N	20 m.
SN385/386	?	?	--	--	--	+1?	N	3 m.
SN393/396	?	?	--	--	--	-1/-3?	N	8 m.
SN1006	Apr. 30	~18:35	129°44'30"	05°47'00"	23:44	-9/-8?	Y	+2 yr.
SN1054	Jul. 4	~04:00	69°10′55"	03°25'21"	NA	-4/-6	Y	22 m.
SN1181	Aug. 6	~21:45	29°10'59"	03°21'42"	04:19	-1	N	6 m.
SN1572	Nov. 6	~18:21	19°40'43"	28°08'40"	21:01	-4/-4.7	Y	6-16m
SN1604	Oct. 9	~18:40	227°46'00"	47°31'11"	NA	-2.5/-3	N	12m.

Table 5. Observational Characteristics of historical supernovae of the Common Era. The dates of the 3 supernovae of the first millennium are unknown, hence visual data cannot be determined. * Data acquired from Stellarium for columns 1st Visibility, Az/Alt of 1st Visibility, and nighttime culmination on the local meridian.

A distinction should be made about naked eye observations: those bright enough to be Supernovae seen during the day suggest the greater possibility of being recorded by multiple observers/cultures around the world than those only visible at night. There are only 3 SN that meet this threshold, which are SN1006, SN1054, and SN1572.

The astronomical software Stellarium data was used to generate the data in columns 3, 4, 5, and 6, and the following figures showing the location of the individual events. Stellarium has a plugin of the historical supernovaes, which was enabled to take the screenshots in the following evaluations. It was also used to determine the approximate moment a SN was first visible. The date in the second column is the day of the maximum luminosity of the light curve, represented by "day 0." The position of 1st Visibility is important, along with V-MAG, in consideration of potential observations by preliterate cultures. These characteristics will be considered, along with criteria established in the following section, to evaluate the different supernovae as potential candidates recorded in the Paint Rock pictographs in Figures 94 and 95.

10.3 Establishing a Criteria for Historical Evaluation

After Miller's interpretation, there were more reported supernovae representations in rock art glyphs made in the American Southwest. These various claims were labeled as Miller's Hypothesis (Mayer 1979). Brandt & Williamson (1979) paper listed 21 throughout this area, including Baja California. They each had similarities claiming the motifs or panels represented a "star" and a "crescent" shape as shown in Figure 99. Two of these images were used by Miller in his claim of SN1054 representations in the American Southwest.

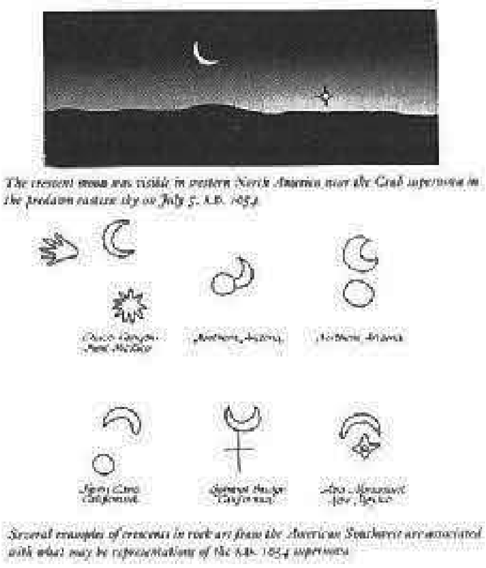


Figure 99. Six representations of SN1054 in the American Southwest.
Image: Public domain.

Ze-zong & Shu-Jen(1966) evaluated historical records of nova and supernova from China, Japan, and Korea. They used six criteria to evaluate these observational records to determine if the records reflected the sighting of novae or supernovae (these terms appear to be used interchangeably in the paper), and were not comet sightings. The criteria helped reduce 1000 potential supernova sightings down to 90. They then checked these against variable stars and comet data, reducing the list down to 53 entries of *A New Catalogue of Ancient Novae.*

A brief description of the six criteria used by Ze-zong & Shu-Jen (1996) follows 1) Those that had position changes or tails. 2) Those recorded only by direction and not a defined position in the celestial sphere. 3) Those located far from the Milky Way, but close to the ecliptic. 4) Those that had descriptions indicating they were comets: examples elongated or fuzzy stars. 5) Those reported as comets were closely examined. 6) Those appearing within six months of a reported comet, either before or after, were rigorously checked.

Hamacher (2014) established a set of criteria to use in attempting to verify evidence of sightings in oral (O) traditions and material culture (M). These criteria are:

(1) O: There is a description of a “new star” appearing in the sky.
(2) OM: The location on Earth from which the “new star” was seen.
(3) OM: The period in time when the “new star” appeared.
(4) OM: The location of the “new star” in the sky.
(5) M: Evidence that the motif represents a star.
(6) OM: Novae/supernova remnant located where “new star” was visible.

Hamacher (2014) then used these to evaluate potential sighting of nova and supernova in Australian Indigenous cultures oral traditions. These six criteria can be loosely correlated to the six established by Ze-zong & Shu-Jen(1966) discussed above. Hamacher (2014) relates criteria (1) only to oral (O) evidence, but the written records of these events from the Orient are material culture (M) describing "new stars." Hence, criteria 1, 2, 3, 4, and 6 can be tied to the oriental classifications.

Mayer (1979) investigates potential rock art glyphs or panels as possible examples of SN1054 in California and Nevada. Mayer (1979) states that Miller and other researchers' established three criteria that a glyph must meet to be a possible depiction of SN1054. Briefly, these are 1) a crescent and star shape involved in the glyph near a large circle, a pit, or star-like image, 2) facing the direction of the event, and 3) supported by archaeological evidence. More importantly, Mayer (1979) goes on to establish a set of criteria to support any astronomical hypothesis.

Two qualifying restrictions must be met by the rock art first. The first restriction is that the astronomical object is one that is "perceived to be distinct, limited, and non-random." Examples given of this restriction included very definite star patterns, the ecliptic, the Milky Way, and the rotation of the stars around the poles. The second restriction is that the rock art panel or glyph "must have well-defined forms and must be complex." Given these restrictions, the two criteria that "distinguish those glyphs which meet the astronomical hypothesis" are:

> (1) The individual figures on the petroglyph must correlate in form with distinct astronomical entities: and, most importantly,
> (2) the relationships among these figures must be shown to correspond to the relationships among the astronomical entities.

Both criteria must be met, but then this only establishes possible "astronomical" reference for the glyph, acknowledging that they still may have occurred by chance. Showing that the glyph meets these criteria, substantially reduces the chance occurrence.

10.4 Evaluating the Supernovae Candidates

The evidence indicates that the monochrome pictographs at Paint Rock were scribed during the Toyah Phase, which dates the pictographs to 1300CE to 1700CE. This fact alone eliminates the first six historical supernovae in Tables 4 and 5, which would include the claim of SN1054 at Paint Rock, Figure 2. Based on the Toyah Phase dates, we will not consider the historical supernovae of the first millennium. However, all historical supernovae starting with SN1006 will be tested as possible candidates represented by the supernova representation of Figures 94 and 95.

Each supernova will be evaluated using the criteria established by Ze-zong & Shu-Jen(1966), Hamacher (2014), and Mayer (1979) and the observational characteristics of Table 4. Stellarium has been utilized to provide visuals of the celestial sphere at the time of 1st visibility and will be used to identify any conjunctions or alignments of the supernovae with the moon or other celestial objects on the reported dates of occurrence. The reason for this is that the astronomical program has all the historical supernovae as a graphic representation and additional labeling has been added where necessary. The program will help correlate the design of the pictograph to actual astronomical objects and will be set to the Paint Rock location to display what would have been seen by the native cultures. The examination will start with SN1572 as it is the primary object of my hypothesis related to the glyph depicting the constellation Cassiopeia and a star design. I will explore the remaining supernovae to rule them as out possible candidates responsible for the inscription of the glyph.

10.4.1 SN1572 Pictograph At Paint Rock

A bright supernova occurred in the fall of 1572 CE reaching maximum luminosity on November 6th. In section 9.3 it was discussed how the cliff creates a celestial clock. Figure 100 depicts the view of the early evening sky of November 6, 1572, that would have been observed by the native cultures. This date corresponds to the AXQ day.

Figure 100. Shows the SN1572 location on November 6, 1572.

The date of SN1572 is within the Toyah Phase archaeological period of the pictographs. The pictograph consists of a sideways W, which is open to the west and matches closely the asterism/constellation known as Cassiopeia. To the left or west of the upper larger opening of the W is a star symbol, which is located in the correct position for SN1572, Figure 95. As additional support, Figure 101 is a drawing from *De Nova Stella,* Tycho Brahe's book, which details the constellation Cassiopeia and SN1572. The similarities to the Paint Rock Pictograph are remarkable.

The pictograph appears to meet 5 of the 6 criteria established by Hamacher (2014), and the glyph is not excluded based on the criteria set by Ze-zong & Shu-Jen(1966). The most substantial support comes from the restrictions and criteria reported by Mayer (1979), not only does the panel meet the restrictions set out, but meets both criteria, Cassiopeia is a distinct constellation, and the location of the supernovae matches

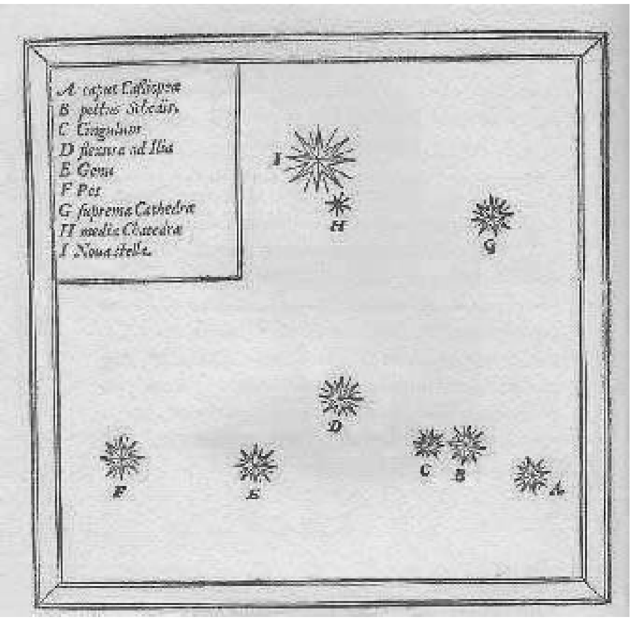


Figure 101. Drawing of SN1572 by Tycho Brahe in his book *De Nova Stella*, 1573.
The image is in the public domain.

the glyph. Hence, a strong case for this glyph as a record of SN1572 is supported by the data and would reduce the chance of coincidence.

10.4.2 SN 1006

This supernova was the brightest of all the historical supernovae. It would have been visible during the day, and the duration of visibility was over two years. It appears to have the most complete list of observers, yet it is outside the Toyah Phase period for the Paint Rock pictographs. The time of 1st Visibility and culmination places it favorably for recording by different cultures.

SN1006 occurred in the constellation Lupus, and the declination makes it a southern hemisphere object, yet all the records are from literate cultures north of the equator. Looking at Figure 102, Lupus is a loose configuration of stars, all of which have magnitudes of +2 or higher, that make no distinct pattern. The location of SN1006 is approximately 24° degrees from the ecliptic, so there is no conjunction with the moon or other celestial objects. The configuration does not match the shape of the pictograph in Figure 94 or 95. Hence, there are too many factors that indicate that this SN was not recorded at Paint Rock.

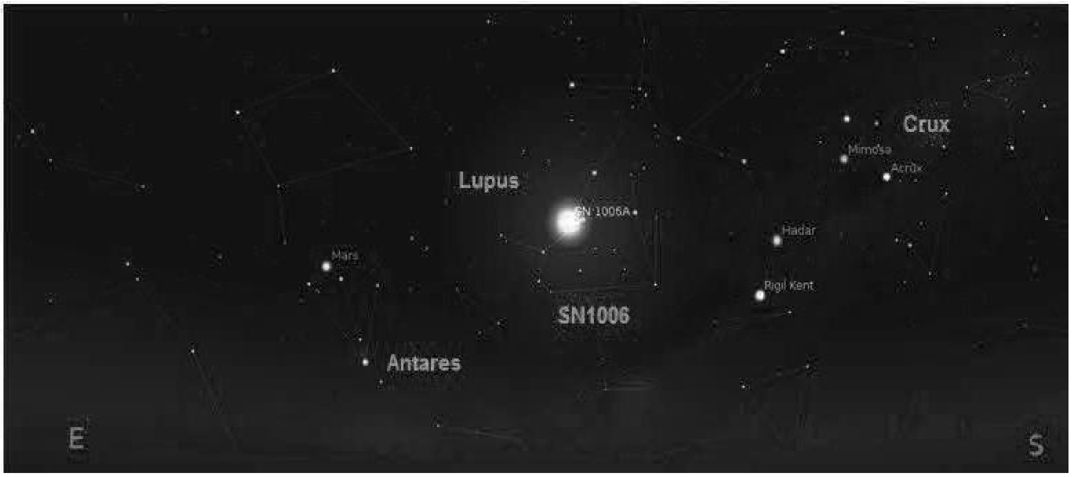


Figure 102. SN1006 is in Lupus, far from the ecliptic, so there is no chance for a Lunar conjunction.

10.4.3 SN 1054

SN1054 was the central object claimed to have been recorded in rock art in multiple locations in the American Southwest. It was Edwin Hubble who first associated the SNR (supernova remnant) with the record of the supernovae in the Chinese text, Sung Shih. He estimated the time frame due to expansion to be around 900 years old, for the SNR to reach its present size (Brandt & Williamson, 1979). One of the brightest supernova, with records around the globe, but interestingly, European records do not reflect observation of SN1054 (Brecher 1983:107, Collins et al. 1999). SN1054 is the supernova claimed to be recorded at Paint Rock in figure 94. The date is well outside the Toyah Phase dates.

The Stellarium celestial chart for SN1054 shows that the crescent moon and the Crab Nebula would have been in conjunction in the eastern sky on the morning of July

5th, 1054, Figure 103. They were in the constellation Taurus, and had an angular separation of 3°50'56". The moon would have been a waning crescent with a total illumination of 9% and would have been to the north of the crab nebula. The day before the angular separation was 10°49'11, " and the moon's illumination was 16%, and the day after the angular separation was 18°40'05", and the moon's illumination was 3.32%. Hence, the conjunction of SN1054 and the moon was a very transient occurrence. If the visibility on July 5th were obscured at a given location, this conjunction would have been missed.

Table 5 indicated the 1st Visibility at 4 am, which is about 1 hour before twilight begins. The V-MAG was bright enough for sun watching cultures to take note, as the visibility extended into the daytime. The location on the celestial sphere of SN1054 was not in association with any distinct celestial object. The closest distinct star pattern, the Hyades open cluster, is almost 11° away. This cluster is considered to be the head of Taurus the bull and has a very definite V shape, which is visible in the celestial chart in Figure 103. The deciding factor in the pictograph configuration is the location of the crescent moon, which would have been above the head, not below. Hence, SN1054 does not appear to have been recorded at Paint Rock by either rock art panel and fails to meet the criteria set by Mayer (1979), no other rock art panel appears to be convincing as a record of the 1054 supernova.

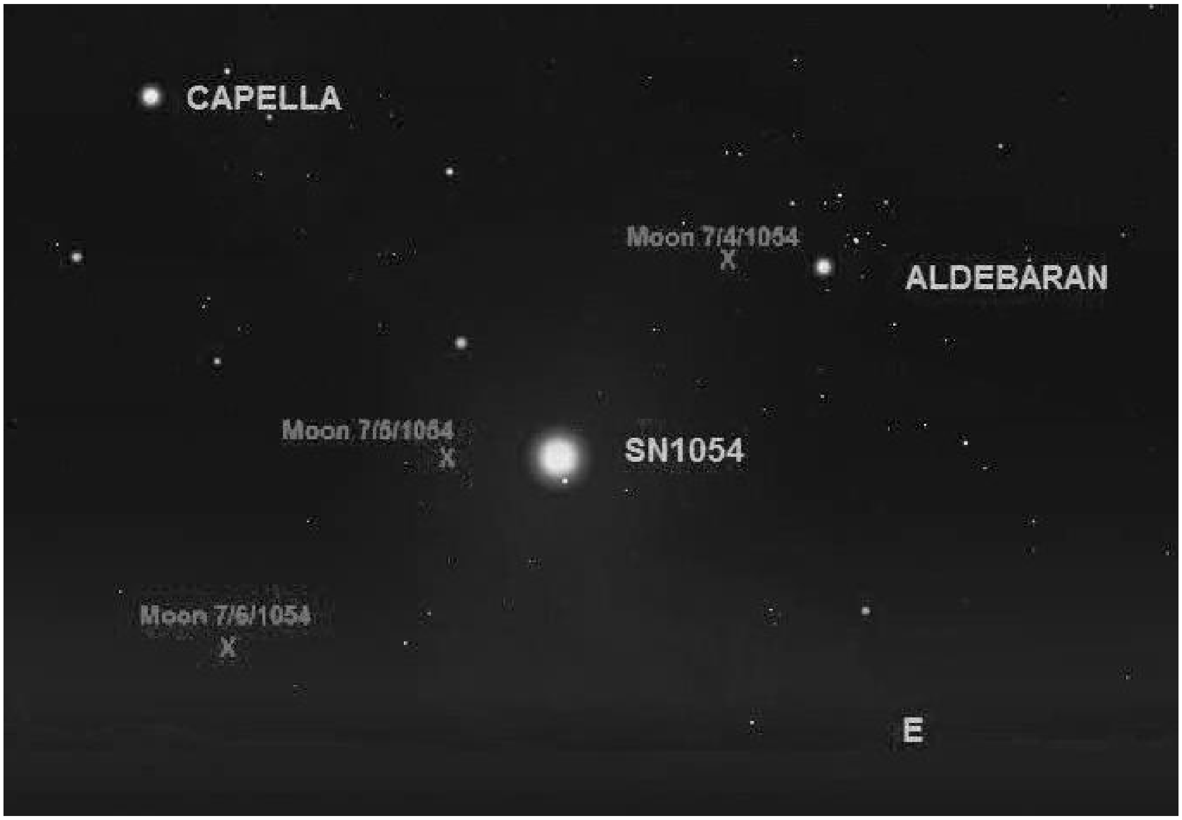


Figure 103. SN1054's maximum luminosity on July 4th, 1054 and the lunar crescent.

10.4.4 SN1181

SN1181 occurred in the constellation Cassiopeia; it is important to rule it out as a candidate recorded by the Paint Rock panel Figure 4. The records of this supernova are questionable enough that the International Astronomical Union (IAU) does not show it on their list of supernovae on the IAU website (IAUweb). It does appear on other lists. The location in relation to the constellation Cassiopeia, as illustrated in figure 12, was at the bottom of the open W.

SN1181 occurred August 6th, which is three months before the calendar date of SN1572 of November 6. From Table 5, we see that the 1st V is at 21:45, where Cassiopeia rises to approximately the same position as that observed for SN1572, but three hours later. The V-MAG of -1 at peak luminosity does not make this supernova as conspicuous as other supernovae, and the rapid fading based on the light curve means that after 20-30 days, SN1181 would only appear stellar with a similar visual magnitude as other stars in Cassiopeia. The date of SN1181 is outside the Toyah Phase dates and the location relative to the constellation Cassiopeia, does not match the design of the rock art panel. Based on these two considerations, SN1181 is ruled out as having been recorded at Paint Rock.

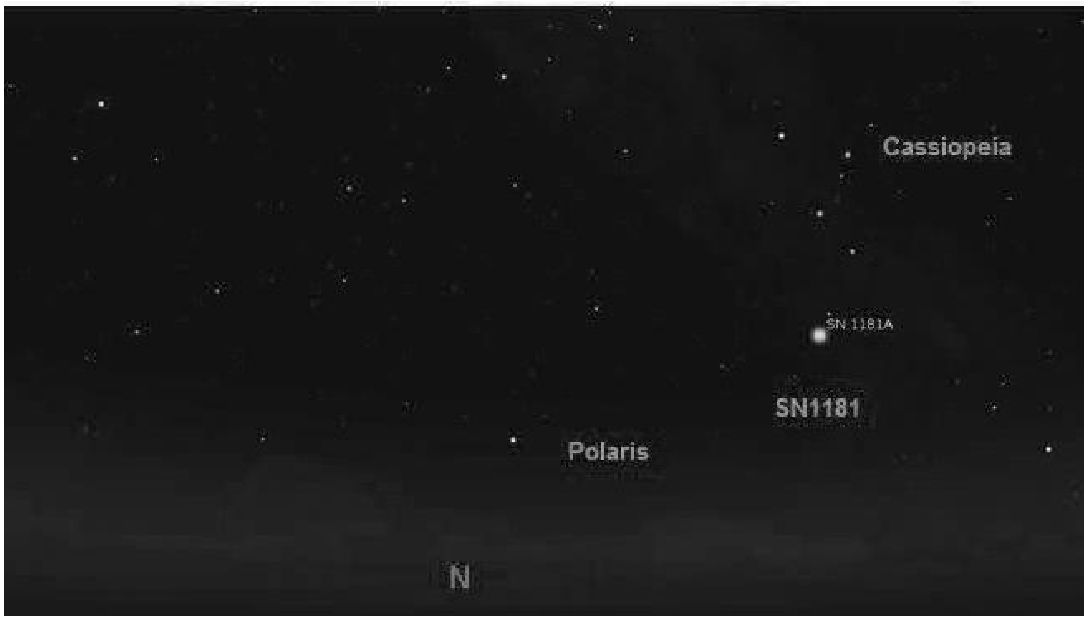


Figure 104. SN1181 Shown at the bottom of the open W of Cassiopeia.

10.4.5 SN 1604

SN1604 is the only other historical supernova that fits within the Toyah Phase archaeological period dates. It becomes visible after sunset in the southwestern sky on October 9, 1604, the date of reaching peak luminosity. It is only visible for about 3 hours after sunset before it too sets below the horizon. This 3-hour window of observation becomes shorter each evening. It was not bright enough to be visible during the day reaching -2.2 according to the light curve in Figure 5. From the time of its peak luminosity on October 9th, it would heliacally set about 45 days later and have a period of invisibility for at least 60 days before its helical rise would again make it visible at night.

Figure 105 displays a significant conjunction with three of the brightest planets, and the full sky chart would have also shown Mercury to be visible after sunset. Although it was brighter than these other planets, the apparent brightness may not have been enough for some sky watchers to notice it right off. Located in one of the largest constellations, Ophiuchus, it is in the lower left corner in an area of the constellation with no significant stars or patterns. After the helical rise, it would be at least another two weeks before SN1604 was high enough above the horizon to be observed for any length

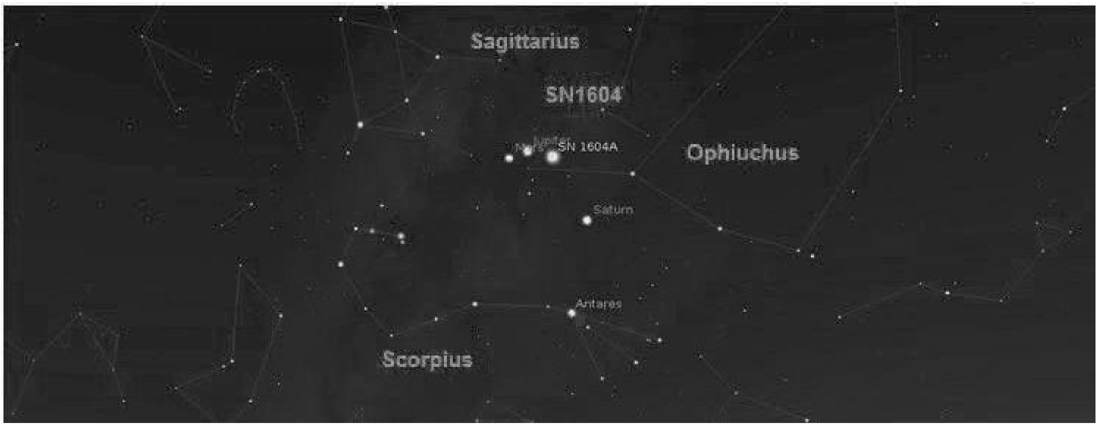


Figure 105. October 9, 1604, conjunction of SN1604 on the day of maximum luminosity.

of time. By this time, 120 days have passed since peak luminosity, and thus, the light curve shows that it would have faded to +1.5 visual magnitude. SN1604 occurred in the lower left corner of Ophiuchus, which is not a distinct portion of the constellation. These facts alone make it doubtful SN1604 was recorded by either panel at Paint Rock.

10.5 Comets and Other Possible Celestial Events

There are as many as 13 different star shape pictographs scattered along the cliff. Some are in groups, and most are single glyphs. As with any other interpretation of rock art, without solid information from reliable sources, the interpretations become speculative. One set of star images, Figure 106, has been suggested to be the signature of a famous Native American Asa Harvey, whose name meant "starry pathway," as stated in the tour brochure, Appendix 2. This grouping of star symbols could be a representation of the conjunction of SN1604 with three other bright planets, Mars, Saturn, and Jupiter, as seen in Figure 105. These analogies make

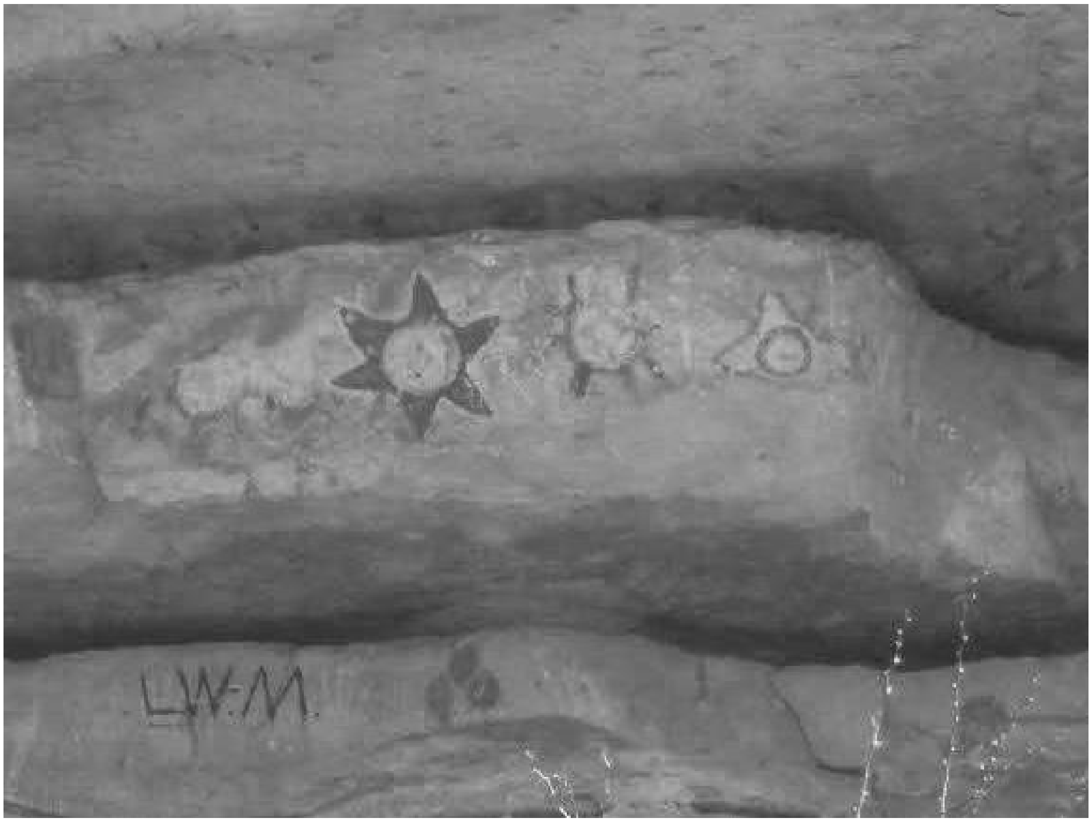


Figure 106. A grouping of 4 star symbols below the WS solar marker.

good points for possible interpretation, but yet are only speculation without supporting evidence.

10.6 Discussion

Total eclipses are unique natural phenomenon, which occur only at new moon. The total eclipse is caused by the conjunction of the new moon and sun, as observed from the surface of the earth. The alignment configuration of three celestial bodies is known as syzygy. The Great Eclipse's path of 1878 appears to clip the northeast corner of Texas, which would mean the eclipse would be roughly 85% at Paint Rock. Naked eye observations of the eclipse are difficult even when the sun is 99% covered. At 85% the landscape would look no different than when the sun is covered by a passing cloud, such that it may not have been noticed at all. If someone suspected it to be an eclipse, were these native cultures even aware of what was causing the eclipse. The date is well into the historical period and the year after the Sims family purchased the property. There is no record of continued scribing of the pictographs by the native cultures after this time.

The rarest of naked-eye celestial events, historical records of supernovae extend back to the beginning of the Common Era and beyond. The Chinese observers appear to have been the most consistent in the recording of these events. Some of these records are confused with possible comet sightings, and or nova sightings. These observational records all have been from cultures in the northern hemisphere, which were also literate cultures. Hamacher (2014) indicates the observation and incorporation by the Boorong culture of Western Australia of the 1840 Eta Carinae supernovae, but this appears to have been after contact with Western cultures. Otherwise, there is a void in the records from preliterate cultures of this supernova, including the preliterate cultures of the American Southwest.

The supernova claims in the American Southwest all involved rock art. The design of the alleged panels all included a star and a crescent symbol. The most common challenge to these is the regular conjunction of the moon and Venus. Venus has one conjunction a month with a crescent moon, either waxing or waning. These conjunctions are transient events that only last one day, as the moon moves approximately 12.5° a day. The transient nature would also be true if the conjunction involved supernovae and the moon. These conjunctions may occur with the moon being in a fuller phase than a crescent. These facts, along with the tests of the supernovae based on the criteria presented, fail to establish a confirmation that these records are a record of any supernova observation.

Data has been presented that support the potential record of SN1572 at Paint Rock. Unlike a conjunction with the moon, the alignment of the SN1572 with the constellation Cassiopeia was fixed and remained so until the supernova faded from visibility. The data presented for SN1572 and the analysis of the other historical supernovae eliminates other historical supernovae as possible candidates. The design of the glyph is in the same configuration as would have been seen at the moment of peak luminosity of SN1572 and its position in relation to Cassiopeia. Cassiopeia is a distinct astronomical object, and the position of the supernova is in the correct position for SN1572. Hence, all the criteria support this as a record of SN1572 and would rule out the panel as a chance design.

There are stellar images scattered around the cliff of different star shapes, but the meaning behind the event that caused these to be scribed has been lost in time.

11.0 RESULTS AND DISCUSSION-RESEARCH QUESTION 7

'What evidence is there for the cultural transmission of astronomical knowledge either from or to cultures in adjacent areas?'

11.1 Paint Rock as a cultural crossroads.

Paint Rock is known as a nomadic site and is situated in a position with significantly different cultures in every direction. Starting from the cardinal direction north, Paint Rock sits at the southern tip of the Great Plains of North America. To the east lies a Mississippian Mound complex of the Caddo Indians. To the south are Mexico and the great Aztec and Maya cultures with rich astronomical traditions. Finally, to the west sits the American Southwest, with the Pueblos and the multitude of rock art solar markers. There is astronomical activity in some form in each of these adjacent cultures.

It is interesting to note that the latitude of Paint Rock 31° 31' 21" is almost due west of the Caddo Mound complex, whose latitude is 31° 35' 49". To the west, the Hot Wells Pueblo, site 41EP15, lies at approximately 31° 55', but is on a military reservation, so public access is limited. Measuring on a map, Paint Rock lies very near equal distance from each of these two sites. Almost due south, but further than the east/west sites is Presa de La Mula, near Monterrey, Mexico. Murray (1986) investigates the tallies on a large stone, thought to be a lunar count. Almost due north is the Buried City site, which is at almost an equal distance north. The pueblo houses are reported to be aligned due north/south and east/west with most having openings to nearly due east.

The archaeological evidence of a cultural crossroads begins with Turpin et al. (2002). They did a petrographic analysis of pottery sherds, and the results showed pieces of Caddoan pottery present. Completing the circle of exchange, Jackson (1938) indicates that designs on Caddoan pottery in east Texas found in graves had identical designs matching the rayed-sun emblem and the hatched concentric circles pictographs at Paint Rock. As the two motifs are related to pictographs that record astronomical knowledge, I am confident of the exchange of cultural practices, including astronomy. The astronomy of the Caddo Mounds site will be explored further in section 11.6.

There is direct evidence of cultural exchange with Paint Rock and the Rio Grande pueblos of north-central New Mexico. The Concho River has a large freshwater mussel. Speilmann (1983) indicates that mussel shell ornaments were found at Gran Quivira. Gran Quivira is the southernmost pueblo of the northern Rio Grande Pueblos, situated southeast towards Paint Rock. Since the trading of foodstuffs rarely survives, Speilmann (1983) had to rely on the exchange of trade goods. The mussel is not found west of the Rocky Mountains, and it is stated that the closest source is the headwaters of the Concho and Colorado Rivers. The Concho runs into the Colorado River downstream from Paint Rock. The headwaters of the Colorado River are only fifteen miles north of Paint Rock. In my walking surveys to the east and west horizon, there were many of these mussel shells on the ground, Figure 107. The shell ornament is a significant indicator of cultural exchange between the two areas.


Figure 107. Freshwater mussel shells are scattered around the Paint Rock landscape.

The Hueco Tanks site, a Texas State Park, has many pictographs scattered over three mountains. In the American Southwest, the site is inside the boundary for the Jornada Mogollon cultural group (Stewart et al. 1990). There are no reports of solar markers at the location, but the imagery of the pictographs and petroglyphs indicate contact with the cultures of Mexico. There are reports of Aztec and Maya deity designs. Although there is no indication of contact with Paint Rock, the proximity of the 2 sites and the known cross-boundary interaction of cultures, it can be stated with confidence that it probably occurred.

Depending on the literature one reads, the American Southwest is defined as parts of four states. The complete states of Arizona and New Mexico form the heart of the cultural area, with southern Utah and Colorado making up the rest. However, some resources include western Texas, and deep into northern Mexico. The Pueblo cultures extended up and down the state of New Mexico following the Rio Grande River, but also spreading east and west of this natural trade route. It is known that there is a multitude of rock art sites with numerous solar markers throughout the American Southwest.

Murray (1986) discusses a rock art site near the city of Monterey, Mexico. The stone rock face is covered in a grid with tally marks. They are thought to be a recording of lunar activity. He states that in a personal communication with Anthony Aveni, Aveni noted that the tally of 206 is almost equal to 7 lunar months. The large slab has several variants of counts, and the lunar count hypothesis is evident in each area. This use of tally type marks is raised as the tally marks at Paint Rock may arise from a cultural contact to the south.

11.2 Caddoan Mississippian Mound site.

As a secondary site with a completely different culture than the hunter-gathers of the plains of North America, the Caddo Mounds complex in east Texas has had a cultural exchange with the Paint Rock site, as was just discussed. The site is formally called the

George C. Davis site in Cherokee County, Texas (41 CE19). The site consists of three principal mounds, the burial mound, the central temple mound, and the high temple mound to the south. The culture is part of the Mississippian Mound culture in eastern America. The largest city in the Mississippian culture is Cahokia, which is located just east of the Mississippi River, across from the modern day city of St. Louis. There are various reports that both complexes have potential astronomical activity.

At Cahokia, evidence of wood log structures, with post holes in cardinal directions were found. As the largest city in the whole Mississippian culture, the main mound, Monks Mound, had a larger base than the Great Pyramid at Khufu in Egypt, and larger than the Pyramid of the Sun at Teotihuacan, Mexico (Young & Fowler 2000). Ground penetrating radar studies at Caddo Mounds have identified multiple postholes in front of the low temple mound (Creel 2001). Hence, the possibility of a henge-like structure similar to the one potentially at Cahokia. There has never been any follow up to this investigation.

The Low Temple mound is oriented north to south. From the south side of the mound to the north side, the longitude is identical, W 95.15199°. The Burial Mound and the High Temple mound are virtually aligned north to south. Longitude readings were taken at the point of the survey only changed by 0.00073 thousandths of a degree. As the cultural exchange between Paint Rock and the Caddoans is documented, and since there are indications of astronomy at the site, I decided to pursue a horizon survey at the site.

I went four times to do field surveys and investigate the horizon topography. I went two more times to do ground truth photography, being clouded out on the first occasion. The trips are documented in Appendix 1. The area is considered to be in the East Texas Piney woods ecoregion. Thus, the site is surrounded by forest in most directions. To add to the challenge at the site is the incursion of modern society, houses, farms, and planted hedges of large trees blocking sight lines to the horizon. The solar arc was calculated using Formula 1.1. The east solar arc at Caddo Mounds ranges from 62° 21' 29" to 117° 38' 31", which is close to Paint Rock's, as they are at almost the same latitude. Preliminary online work was done, as outlined in the methodology section. A topographical map was printed, and potential site lines were drawn from the three mounds to the horizon. Field survey's and study of the topographical map suggested the only topographical relief was in the northeast direction, consistent with an SS sunrise. Figure 108 is the result of the topographic map web-based survey. A satellite view was studied, printed, and labels added, Figure 109.

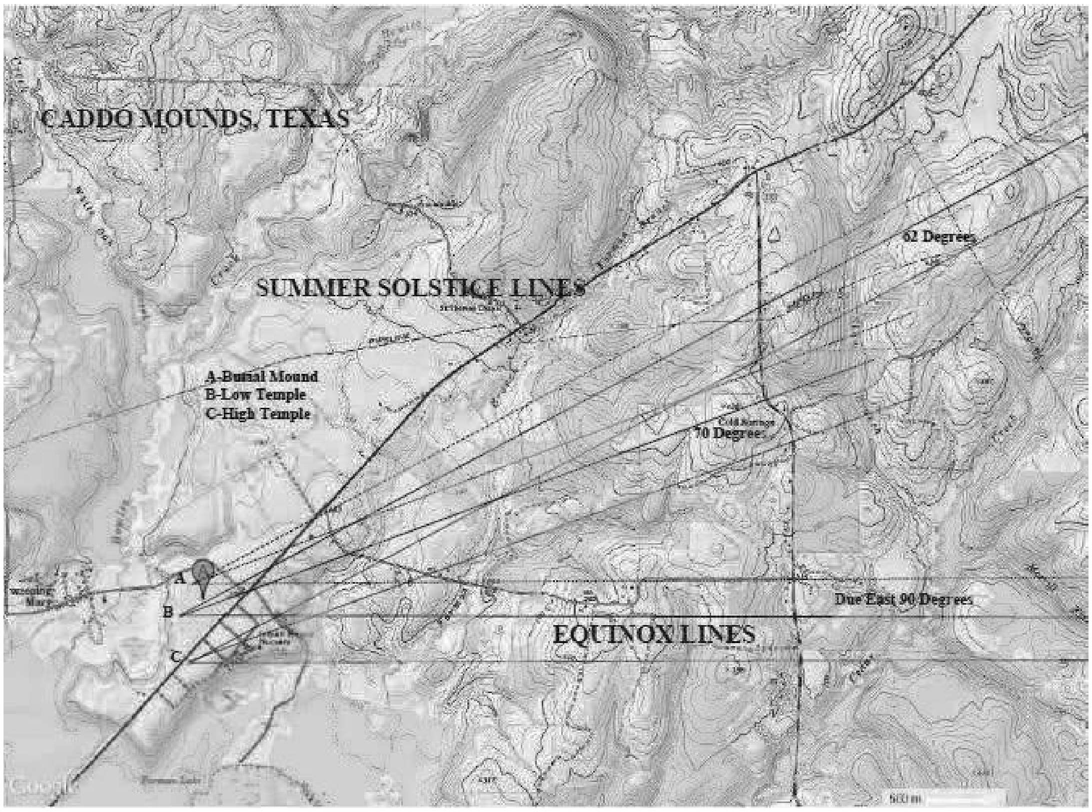


Figure 108. Horizon lines extending from the three mounds. (map from ACMEweb)

Many photographs were taken of the horizon within the east and west solar arcs. The visual sight lines are obstructed in some views by trees. The trip in March 2014, was to secure the best photos with the foliage off the trees. These photos produced the best visuals for sunrise/set dramatic relief. Inspecting the topography and the photos, the horizon to the northeast rises up to a bluff, which then has a quick drop in altitude of about 75 feet, or equivalent to a 7-story building. Figure 110 is the horizon astronomy survey produced from the horizon survey.

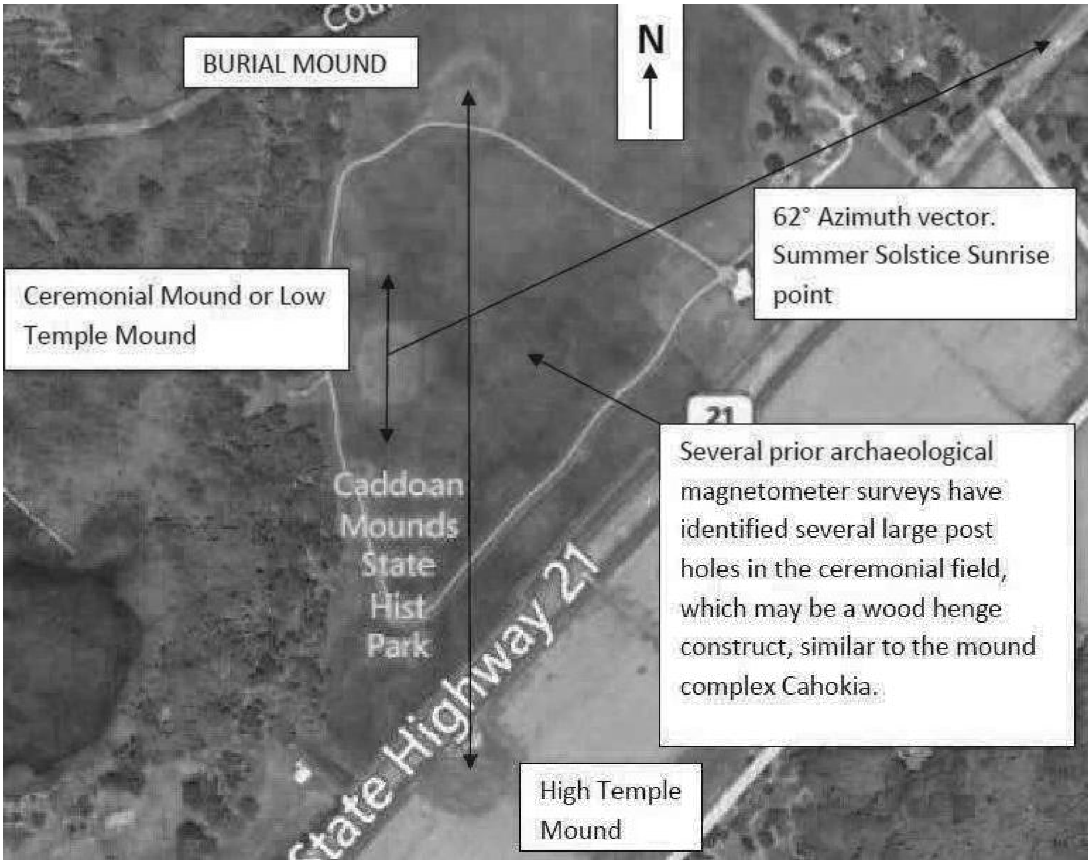
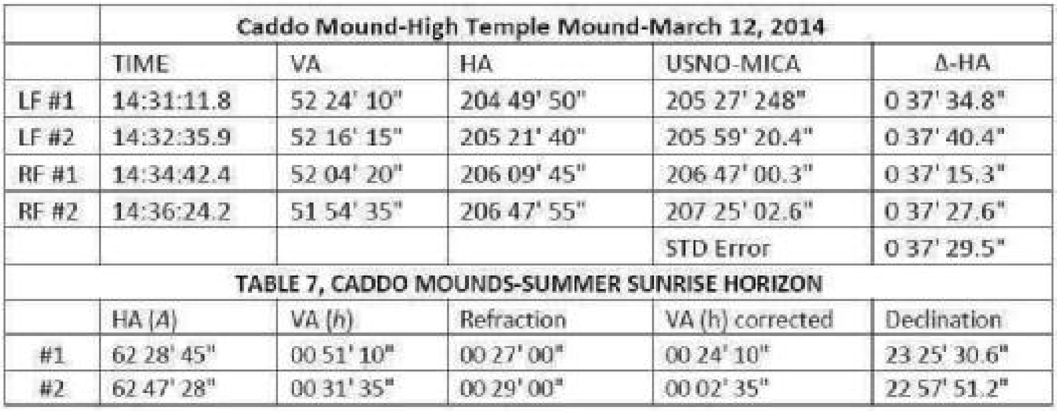


Figure 109. Satellite view of Caddo Mounds. (ACMEweb)

The final step is to do ground truthing. Figure 111 is a summer solstice (SS) sunrise photograph. It rises from the view of the High Temple mound at the peak of the high bluff (Point #1 on Figure 110). You can see how the topography drops off to the right or south of the point from the illumination of the sun. The view from the Low Temple Mound would probably put it squarely on top of the bluff. The distance between Point #2 and Point #1 is 0° 27' 39.4". Using Skywatch software to model daily rise declinations, this separtion occurs at about 12 days. In other words, the sun would rise at the base of the cliff, in the notch, 12 days before the Summer Solstice (SS). The sun's rise at the top of the bluff would give the sunwatcher a confirmation. Twelve days would allow for preparations for ritual celebrations of the Summer Solstice (SS).



Caddo Mound-High Temple Mound-March 12, 2014

	TIME	VA	HA	USNO-MICA	Δ-HA
LF #1	14:31:11.8	52 24' 10"	204 49' 50"	205 27' 248"	0 37' 34.8"
LF #2	14:32:35.9	52 16' 15"	205 21' 40"	205 59' 20.4"	0 37' 40.4"
RF #1	14:34:42.4	52 04' 20"	206 09' 45"	206 47' 00.3"	0 37' 15.3"
RF #2	14:36:24.2	51 54' 35"	206 47' 55"	207 25' 02.6"	0 37' 27.6"
				STD Error	0 37' 29.5"

TABLE 7, CADDO MOUNDS-SUMMER SUNRISE HORIZON

	HA (*A*)	VA (*h*)	Refraction	VA (h) corrected	Declination
#1	62 28' 45"	00 51' 10"	00 27' 00"	00 24' 10"	23 25' 30.6"
#2	62 47' 28"	00 31' 35"	00 29' 00"	00 02' 35"	22 57' 51.2"

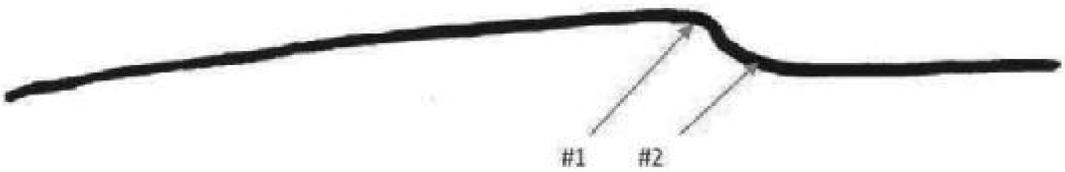


Figure 110. Horizon survey of the northeast SS sunrise points.

Figure 111. SS sunrise confirmation photo showing the sun at the top of the bluff.

The evidence for astronomy at Caddo Mounds includes north-south alignments of the Burial Mound and High Temple mound, the north/south orientation of the low temple mound, the evidence of a possible woodhenge, and the potential horizon astronomy.

11.3 Discussion

The spatial definition of the American Southwest is the four states of New Mexico, Colorado, Arizona, and Utah. Some definitions include the western part of Texas, which would place Paint Rock in or very near the edge of this region. Although, proving that the solar markers at Paint Rock are a direct result of cultural exchange will never be known. Rock art solar markers are a transportable technology, as are the methods of sun-watching along the horizon. In this section, the surrounding cultural exchange has been documented. Each of the cultures in question has astronomical attributes, so the possibility of this knowledge passing between sites is high.

12.0 CONCLUSIONS

The positive outcome of the seven research questions strongly confirms the hypothesis that Paint Rock was a major sun watching station. Paint Rock has been shown to be one of the most active solar marker sites in the world. Adding the six newly identified solar markers to the eight previously claimed makes a total of fourteen active solar markers in the confined space of the exposed 300-meter section of the geologic uplift. Compare this number to the numbers reported by the following two rock art researchers in the American Southwest. Fountain (2005) reported 219 solar markers at 45 sites, which is 4.9 solar markers per site. Preston & Preston (1983) reported 109 solar markers at 46 sites or 2.4 solar markers per site. In the literature, most researchers state that solar markers sites are small and typically only have one or two solar markers. These facts found in the literature adds additional support that Paint Rock was a major sun-watching station.

The results came about in sequence of the proposed research questions. Starting with question number one, discovering the horizon astronomy was paramount to answering the question, "How the glyphs were placed so accurately to record this astronomical knowledge?" Horizon calendars are known worldwide, using the horizon to mark and track the yearly travel of the sun. There was no apparent dramatic relief along the horizon at any point. It was the "ah ha" moment when it was realized that a visual "notch" was created by the vertical part of the cliff meeting the far horizon.

Discovering the "notch" led to the search for the place of observation. Having a fixed place of observation is required to make precise observations and to verify them with repeated sightings year to year. Vogt (1993) showed that the Native American hunter-gather cultures of the Great Plains watched the sun from "fixed positions." Paint Rock is at the end of the Great Plains. The process of identifying and selecting the place of observation led to a selection that included material culture that tied the sun watching to the landscape. Zeilik (1985) asked the question, what would a sun-watching station look like? At Paint Rock, it has a weather-protected roof, large living area, rock layers to scribe solar markers and tally marks, with a commanding view of the horizon. In addition to the "notch," a possible horizon rock cairn was identified, which may be an anticipatory aid.

Hours of observations were conducted along the cliff of sunlight and shadow interactions with the pictographs. I had plenty of time to contemplate what characteristics make up a solar marker and what qualities they would possess. The idea of the Matrix was born. The Matrix has some revision to be incorporated, which became apparent when scoring the existing and newly discovered solar markers. The Matrix was presented at three different conferences. It was improved after each. The final presentation was at the annual meeting of the Society of American Archaeology, which received the most positive feedback. Most applauded the effort to quantify the characteristics of a solar marker.

The observations and recording of the interactions, coupled with the Matrix, provided a quantitative and objective method of analysis to confirm the eight reported solar markers. It was then used to evaluate the six newly discovered solar markers. It is thought that, as an objective tool such as the Matrix will help overcome the most common objection about the solar markers, that the interaction is simply coincidental.

There are still those in the academic community who are not convinced of their validity. The sheer numbers of operative solar markers led Schaefer (2006) to state,

> *"With other identical examples, the probability of the null hypothesis ("random" coincidences of shadow and (on[1]) 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."*

This quote confirms the underlying premise of the Matrix that all solar markers are intentional. Solar markers are one of the most objective interpretations of rock art. Eddy (1978) supported this premise when he stated, "that the cliff writings are objective and more compelling evidence than repeated tales, however sincerely told." The Matrix provides a scientific basis to interpret rock art. The celestial sphere is virtually the same as it was when the cultures made their observations, and as Murray (1998) stated, "rock art is in situ" and exist today virtually as when the ancient cultures scribed the glyphs.

Astronomical modeling provided further evidence of the potential astronomy at the site, which are the heliacal rise of Sirius in the "notch," and the celestial clock with the Big Dipper and Cassiopeia as hands on the clock. The two sets of 28 tally marks added additional evidence of astronomical recording at the site. Several glyphs were examined that had been associated with astronomical events of the past. The facts did not support these claims. Another glyph was proposed as a recording of the supernova called Tycho's supernova, SN1572. The astronomical modeling, the location in the galaxy, the time of visibility, and the observational characteristics all supported the hypothesis of this glyph as a record of SN1572. The final research question examined the cultures who bordered the area around Paint Rock. A horizon astronomy survey was conducted at Caddo Mounds. The topography suggested that the Mississippian culture could have used the horizon for calendrical purposes. They could adequately anticipate and confirm the SS sunrise. Facts were presented showing strong indications of contact with these bordering cultures, and that each culture possessed different forms of astronomical knowledge.

In summation, the positive research results for each of the seven research questions strongly supports the main research hypothesis, that Paint Rock was a major sun watching station. It is believed that with further study, more solar markers will be discovered at Paint Rock. The significance of the research to the third area of archaeoastronmical research cannot be overstated. It has been shown that establishing the horizon astronomy and place of observation at all rock art sites with reported solar markers should be standard methodology. These two steps are paramount to overcoming the argument that the solar interactions are simply coincidental. It is believed that with further refinement, the Solar Marker Matrix of Intentionality will be a standard tool used by all rock art researchers. The ultimate goal of the Matrix is to establish standard methodology and terminology, so that a data base of solar markers worldwide can be established. The data base will open a new window of research in archaeoastronomy. It is believed that this study has and will add significantly in the future to the body of knowledge of archaeoastronomy and cultural astronomy.

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APPENDIX 1

REPORT OF FIELDWORK AT PAINT ROCK, TEXAS

PHD Candidate: Gordon L. Houston Supervisor: Prof. Irakli Simonia

Report Exact Time of Fieldwork (how many hours/days you spent there).

The field work consisted of two sites, the primary research site, Paint Rock Pictographs, and the Caddo Mounds site. Combined, the total field work amounted to 62+ full days of effort. I drove a combined total of 26,654 km, which is the equivalent of driving from my home in Houston, Texas USA to Tbilisi, Georgia and back. Total cost for gas, food, and lodging $3,635.

FIELDWORK PAINT ROCK-Consisted of a total of 52 days, made up of the following dates: March 19, 20, 2012, April 19, 20**,** 2012, May 3, 4, 2012, June 19, 20, 21, 2012, July 2, 3, 2012, August 6, 7, 2012, September 20, 21, 22, 2012, October 22, 23, 2012, November 5, 6, 2012, December 19, 20, 21, 2012, January 15, 16, 17, 2013, February 2, 3, 2013, March 20, 21, 22, 2013, May 5, 6, 7, 2013, June 20, 21,2013, August 6, 7, 2013, September 22, 23, 24, 2013, November 6, 7, 2013, December 18, 19, 2013, February 4, 5, 2014. This totals 52 field days, plus a minimum of 10 days added or a half day preparation for each of the 20 trips.
Paint Rock 368 miles (592 km) one way (6 hours drive time) 726 miles round trip (Total distance 14,520 miles) (1184 km x 20=23,680 km total distance) total drive time 12 hours x 20-=240 hours driving time.

Total cost: gas $2550, lodging $240, food $460=$3,250.

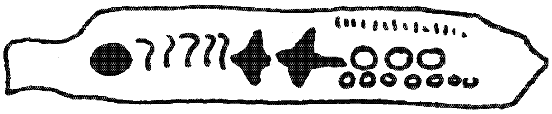
FIELDWORK CADDO MOUNDS - Six total trips consisting of the following dates: September 10, 2013, December 16, 2013, (December 23, 2013 photos taken by Tony), February 13, 2014, March 12, 2014, June 19, 2014 (Attempted sunrise photo, but was clouded out, June 25, 2015 Distance is 154 (248 km) miles one way 308 (496 km) miles round trip. (3 hour drive one way). Six (6) trips total miles 1,848 (2974 km). Total drive time 36 hours. Total cost: gas $325, and food $60, equals $385.00.

Along the Trail

STOP 1

A group of characters possibly relating to a hunt from left to right: A sun or moon followed by crooked lines thought to be throwing sticks or atlatls, two birds, several circles which could be suns, moons or tipi rings. Above these are a number of count marks. Note the lines are about the width of a person's finger.

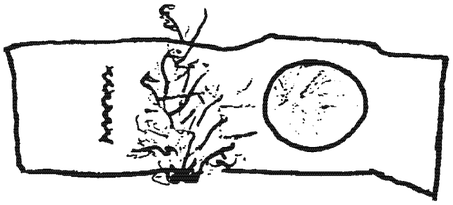
Pictographs are thought to have been used in the same manner in which we use words—that is they relate incidents, leave messages or merely are a person's sign.

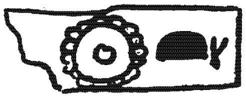


STOP 2

The large painting near the top of the bluff is an example of an instrument-made circle. The Indian apparently used a strip of hide tied to a piece of pigment and made a circle as we would with a string and chalk at the blackboard.

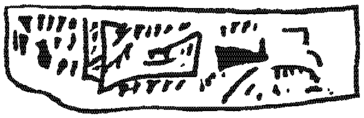
At the left is another set of tally marks. Lower and to the left on another rock is a free hand circle which seems to be a sun symbol. On the same rock is a picture of a buffalo. It is interesting to note the large number of buffalo paintings which appear on the bluff. This would seem to indicate that buffalo were abundant in this region.





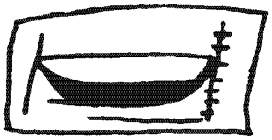
STOP 3

There are two significant groups of paintings at this stop. On both the rocks there are dozens of detailed geometric designs which have no apparent meaning to modern observers. Possibly the drawings refer to trails or rivers, thereby presenting a map-like meaning. These intricate drawings are made with both black and red pigment.



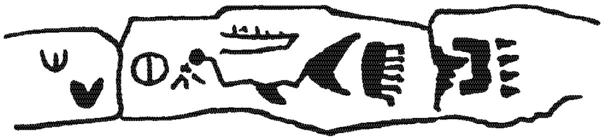
STOP 4

An impressive design which resembles a boat could represent the artist's impression of a boat seen along the coast or one of the larger rivers. Possible enumeration marks are seen to the right. Another conception is that it represents a canoe burial as was practiced by some tribes with the ladder used to ascend to the heavens. A third theory is that it represents a cave along the canyon wall of one of the southern rivers—Pecos, Devil's or Rio Grande—to which these Indians are said to have migrated during winter months.



STOP 5

The most outstanding drawing at this stop appears to have a fish-like tail. This is thought to be the "Plumed Serpent" which was a very significant deity of Southwestern Indian culture. Note the snakelike body attached to the tail. To the right of the tail is an interesting painting which appears to be an insect or animal which has six legs.



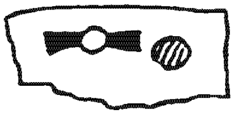
STOP 6

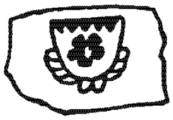
From this point, several memorable paintings may be viewed. One of these, which resembles a shield, is probably the most photographed and famous pictograph on the bluff. At midday, December 22, 1996, a sun dagger was discovered pointing to the center of the painting. This suggests that certain tribes gathered here to join in winter solstice rituals.

To the right note the stick figure with arms extended. It appears to have an arrow through its head.

To the left of the solstice marker one can see a spear-point and a tally stick with four scalps attached.

Above this painting are two pictographs near the top of the bluff. The shaded circle at the right is believed to be the eclipsed sun and the circle with wings is the emerging sun.

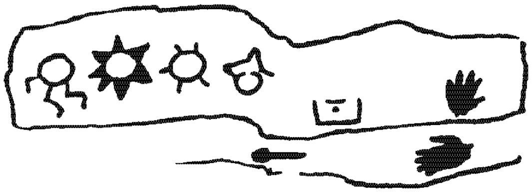




STOP 7

This sequence of prominent stars is said to represent the signature of a famous Indian named Asa Havey, a contemporary and companion of Quanna Parker. It has been documented that Asa Havey left his mark among the paintings at this site. His name meant "starry pathway" or "milky way."

To the right of the stars is a vertical hand print and immediately below it is a horizontal hand print. Note that these are both left hands, indicating that the artists were right-handed.



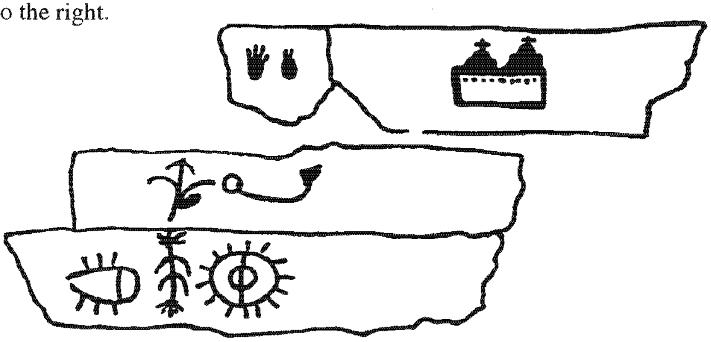
STOP 8

The rectangle with dots across the top is believed to be a mission wall. Two domes of a church project above the wall—each dome has a Christian cross. Early missions in the area were San Clemente, San Saba and several in San Antonio.

On the rock to the left are two dim, rust-colored hand paintings.

Further to the left is an encircled hourglass.

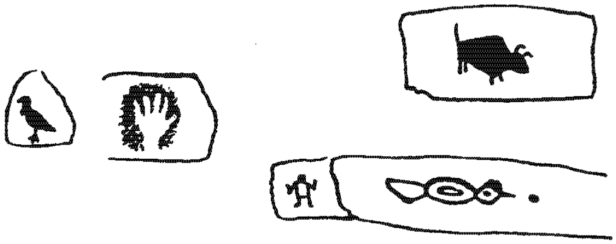
A favorite painting among modern-day farmers and ranchers is the sun, wilted corn and grasshopper indicating a hot summer and plague of grasshoppers, common to the area. Above the wilted stalk of corn is a healthy plant with a full-grown ear. To the right of the healthy corn stalk is a distinct sun symbol with a long, snake-like element extending to the right.



STOP 9

On a small yellow surface near the top of the bluff is seen a buffalo with his tail up. It has been said that buffalo with tails up were running while those with tails down were grazing. Three ledges below and slighty to the right is seen a roadrunner chasing a bug. Directly to the left a small painting of a man with black arms and legs and a red torso. Below the roadrunner's tail is a dim outline of a man astride a horse. Directly below that can be seen the upper part of a body appearing to be a soldier wearing epaulets.

To the left is seen a five-pointed star, and still further on the point of a rock is a turkey above a sun symbol. To the right of the sun is an interesting spatter painting of a left hand which appears as a negative print.



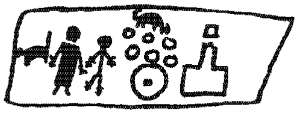
STOP 10

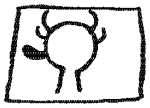
At this stop are seen many red and black counting marks which could tally days of camping, animals killed or people.

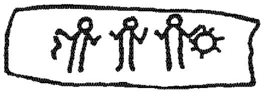
Above the red tally marks are three ceremonial figures having vertical black lines as bodies with upraised arms. The person on the right appears to be holding a shield while the one on the left is holding a snake.

The large, four-horned figure is believed to be an important leader entitled to wear four buffalo horns as his headdress. The baloon-shaped element could be a talk symbol or ceremonial pipe.

Around the rock to the left is one of the most impressive drawings at the bluff. This painting is believed to represent Mission San Clemente, built in 1685 by the Franciscans to Christianize the Lipan Apaches. In this group are seen a stick man representing the Indian, a robed figure depicting the Father, two animals—one a cow and another a horse. A wheel or cart and building help us interpret their meaning.







STOP 11

This striking group is one of the best-preserved of those at the site. It is highly stylized and an artistic representation. It is thought to show a tomahawk in the lower right, two heart-shaped objects to the left—possibly representing meat. On the left is a rodent—perhaps a beaver. Above the tomahawk is a bird and to the right is the symbol of a man whose body has been wrapped for burial. His position would indicate he is ascending to the Happy Hunting Grounds. Each equinox, sunlight on the rock makes a trail for his ascension.

Preservation of this painting is so good that one can still see where the artist wiped his fingers across the handle of the tomahawk.

STOP 12

On the right-hand side of this long, yellow rock is the drawing of a horizontal woman. Her position indicates capture. Her hooped skirt identifies her as a white woman and would date the painting about Civil War time. To the left is a shield with crossed lances—a symbol of a war party. Beneath the spear on the left are two scalps.

It is recorded that near Mason in 1865 a woman, her daughter and their maid were traveling by wagon and were attacked by Comanches. The mother and maid were killed and 15-year-old Alice Todd was carried away by the Indians never to be heard from again.

Observers and students of this site believe this group of paintings to be among the last placed here.

Further to the left one will see a turtle within a circle, a solstice symbol. At midday on June 21, 1998, Dr. Bob Robbins discovered lines of light pointing to the turtle, creating a summer solstice marker. As in Stop 6, it suggests that certain tribes gathered to celebrate rituals marking the first day of summer.

STOP 13

This is the last group of paintings on the West end of the site.

At the lowest level of paintings is a group of human figures. One of these is a robed figure and the others have an hourglass shape. One of these is inverted, symbolizing death.

Above and to the right is a bear-track, within which is shown other robed and hourglass figures.

On the right hand side of the large rock above is a stick figure with bow and arrow. Several different styles of figures are shown to the left indicating that various tribes painted here. A crude painting of a man on a horse is shown and the person is wearing a big sombrero—all in black.