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Research Article

Sacred Landscape and Cultural Astronomy on the Marcahuasi Plateau, Peru

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Abstract

The Marcahuasi plateau, in the highlands of Huarochirí Province, Peru, is touristed today for its landscape of evocative stone formations and archaeological remains. We present ethnohistorical documentation of the cultural salience of stone features and celestial alignments to the inhabitants of the region and propose that such notions extend to the prehispanic era at Marcahuasi. Although most formations likely are wholly natural features, a preliminary analysis involving Monte Carlo simulation with analysis of statistical significance of astronomical alignments suggest the plateau combines elements of a "natural" landscape and at least partially modified "cultural" monuments that were part of an animated Andean cosmology.

Keywords: Archeoastronomy; Monte Carlo simulation; solar alignments; Pleiades; Huarochirí; Andes

Introduction

The dramatic landscapes of the highland Andes were and continue to be sacralised in the worldviews and ritual practices of Andean peoples. Some landscapes are rendered sacred by virtue of stone, in the form of towering mountain peaks or particular rock outcroppings, whether in their natural states or modified by humans; others provide settings for charting calendrical and mythical time through the passage of celestial bodies; and some sit at the interface of the two, in the celestial alignments of stone buildings or monuments that materialize the cultural astronomies of various groups [1-11]. The Marcahuasi Plateau, in Peru's Huarochirí province, receives thousands of annual tourists because of its landscape of anthropomorphic and zoomorphic rock formations, prehispanic structures, and expansive vistas of the Cordillera Occidental, the westernmost mountain range of the Andes [12-14]. Historical and ethnographic studies document the sacred nature of the plateau's "stone forest," and it seems likely that ancestral Andean peoples would have been similarly compelled by its topography strewn with evocative rock formations.

In this study we provide a preliminary assessment of whether certain of Marcahuasi's rock formations possessed alignments to solar and stellar rising and setting events of known significance to Andean cultural astronomy that may have drawn prehispanic peoples to the plateau and reinforced its status as a sacred landscape. We examine the close concordances between several alignments and rising/setting events and also present a novel method for assessing the statistical significance of a larger array of potential alignments allowing for a range of error in horizon-based azimuth measurements. We do not provide a detailed assessment of the geological origin of the formations and what elements of them may be anthropogenic. Rather, following Schreiber [8,15,16],

we assess whether certain rock formations on the northwestern plateau represent a combination of "natural" landscape and "cultural" monuments that would have been of significance to the prehispanic inhabitants of, and visitors to, the plateau based on their alignment to particular points in the solar calendar and the final appearance of the Pleiades star cluster in the western horizon.

The Marcahuasi Plateau

Sitting high in the Central Andes of Peru, at an altitude of approximately 4,000 m (13,123 ft), the Marcahuasi plateau (also written as Marka Wasi and Markawasi) is located approximately 90 km (56 miles) east of Lima following the Rimac River, near the town of San Pedro de Casta (Figure 1). The surrounding Huarochirí region was traditionally the territory of diverse peoples, including those referred to in various texts as Chaclla, Huanca (Wanka), and Yauyos, who were conquered by the Inca and incorporated into their empire in the mid fifteenth century [17-19]. Following the Spanish invasion of Peru and dismantling of the Inca Empire, the colonial period document known as the Huarochirí Manuscript was compiled by the friar Francisco de Ávila in the town of San Damián de Checa sometime between 1598-1608, marking his first arrival to the region to its most consensus publication date [20-22]. The manuscript is a rarity for the Andes and is of great historical value in detailing elements of Indigenous religion and cosmovision in the native language of Quechua. It was nevertheless recorded in a colonial context and is inflected with the introduction of Christianity to the region in the final third of the sixteenth century, particularly by missionizing Jesuits, as well as by Ávila's editorial filter in overseeing the manuscript's composition [4,18]. With these caveats in mind, the Huarochirí Manuscript was compiled only some 55 km (35 miles) to the southeast of Marcahuasi, and therefore provides rich information on local ritual, religion, and cosmology relevant to assessing sacred landscapes in the region [18].

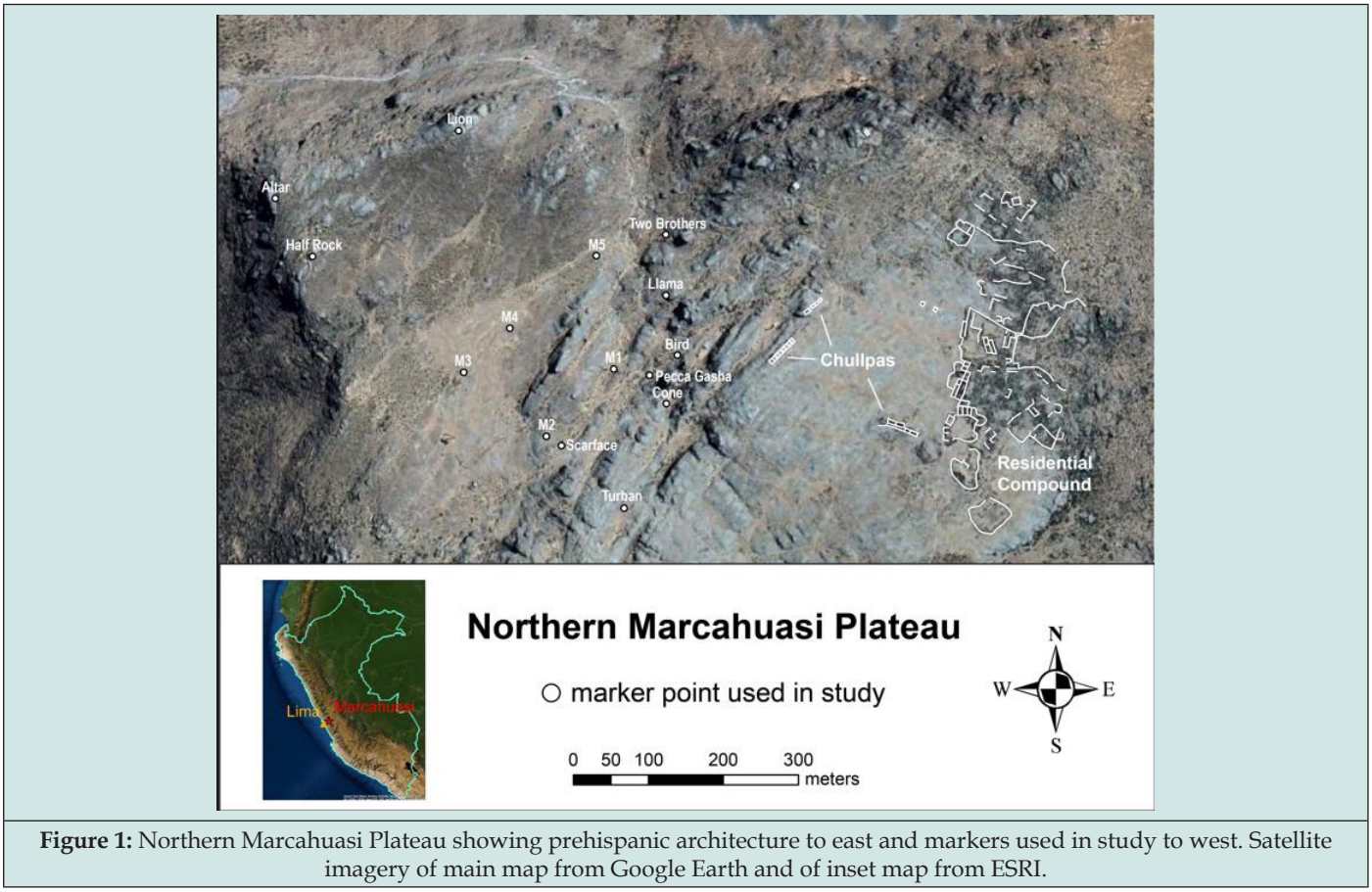

Figure 1: Northern Marcahuasi Plateau showing prehispanic architecture to east and markers used in study to west. Satellite imagery of main map from Google Earth and of inset map from ESRI.

The prehispanic architecture at Marcahuasi is concentrated on approximately 5.5 ha of the northeastern plateau. Building remains consist of a network of residential room-blocks and walls covering some 1.25 ha to the east, interpreted by some as a fortress [13], and four clusters of open sepulchres usually designated chullpas [21,23] located west of the residential area, several of which still retain ancestral remains (Figure 2). None of the structures have been systematically excavated but based on stylistic similarities with others in Huarochirí Province, the chullpas appear diagnostic of the Late Intermediate Period (ca. 1000-1450 CE) prior to the Inca conquest of the region [20,21,23-26]. They are rectangular in form, have small doors located at ground level, and either consist

of a single structure or a line of attached ones-the longest featuring eight aligned chambers with doors. Circular enclosures with low walls, visible particularly to the south of the residential compound, likely served as corrals for flocks of camelids.

Figure 2: Rows of chullpas on ridge separating architectural remains of northeastern plateau from markers of northwestern plateau. Photo by David Carballo.

The pioneering Andean archaeologist and ethnographer Julio C. Tello, who hailed from Huarochirí Province, visited Marcahuasi and San Pedro de Casta a century ago. Together with Próspero Miranda, a resident of Casta, Tello documented the beliefs and ritual practices of the Casteños of the time. These included veneration of the deity Huallallo (also Wallallo), who is also a protagonist in the narrative of the Huarochirí Manuscript and to whom Casteños of the early twentieth century made offerings at a sacred stone located between Casta and Marcahuasi in association with rituals relating to water and irrigation [27,28]. In several passages of the Huarochirí Manuscript, supernatural entities are recounted as having been turned to stone [4,18]. The embodiment of a sacred entity within particular stones or rock outcroppings is consistent with the Andean notion of huanca (also wank'a), representing a concrete, physical manifestation of sacred beings [29]. As a potentially comparable case, at the site of Ampugasa, located some 40 km southeast of Marcahuasi, the ceremonial core of the settlement consists of a rock outcropping with rock formations that Hernández Gravito [17] contends embody elements of the mythic narrative of the Huarochirí Manuscript, creating a sacred landscape combining stone, celestial bodies, and divine actors.

Daniel Ruzo began documenting Marcahuasi's enigmatic stone formations in 1952 as part of a research project that lasted decades [30]. This project has continued to present under Luis Ruzo (Marcahuasi-Ruzo.com). Since certain rock formations have been considered sacred to inhabitants of the region for the last four or five centuries, it seems probable that the same applied in prehispanic times, a proposition we evaluate here. Among a number of interesting formations, we focus on those that spread over some 12 ha of the northwestern plateau and, in particular, monolithic formations that we designate as "markers" (M1-M5) or by names in use at the site that derive from projected formal attributes. The rock formations designated as markers are generally smaller and could be either glacial erratics, likely for some, or purposefully modified by humans, possible for others (Figure 3). They are clustered in the centre of the northwestern plateau, whereas those formations with designations based on some formal similarity to anthropomorphic, zoomorphic, or inanimate entities represent protuberances on the landscape located to the east and west of the markers.

The most famous of the named rock formations is locally known as Peca Gasha ("head in the alley" in Quechua), an impressive outcrop approximately 40 m tall that shows evidence of clear human modification in a gridded petroglyph on its southern face (Figure 4) and uncertain modification for what are interpreted to represent facial features. Other named outcrops reference perceived formal similarities to animals or shapes. Two of the latter, Half Rock and Altar, seem to be wholly natural formations but stand out for their prominence on the western edge of the plateau, where they provide conspicuous horizon markers that could have been used for solar or other stellar setting events (Figure 3 left, Figure 5). Before evaluating this possibility, we review ethnographic, ethnohistoric, and archaeological sources on what horizon observations have salience within Andean cultural astronomy.

Figure 3: Examples of markers on the northwestern Marcahuasi plateau: (left) Marker 4 in foreground with Half Rock, at the plateau horizon, in background and (right) upper protuberance of Marker 5 connected to basal rock layer. Photos by Luis Ruzo.

Figure 4: Pecca Gasha monument with gridded petroglyph under raking light in inset. Photos by David Carballo and Luis Ruzo.

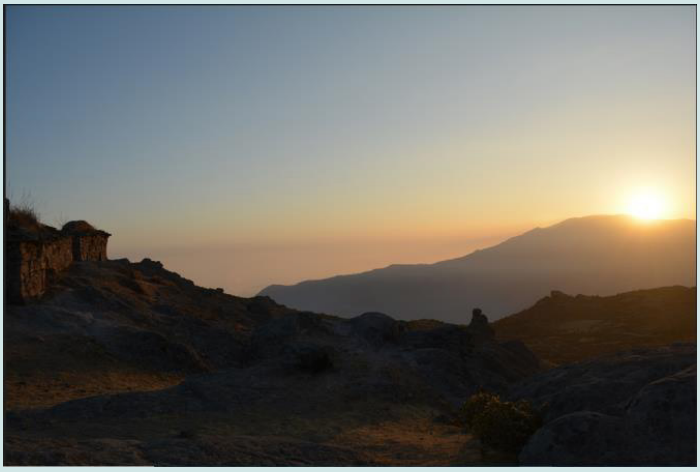

Figure 5: Sunset viewed from northwestern Marcahuasi plateau with chullpas to left and Half Rock visible to right as protuberance at the edge of the plateau. The date (August 27, 2017) is not a likely significant alignment. Photo by David Carballo.

The Sun and Pleiades in Andean Cultural Astronomy

Scholarship on Andean cultural astronomy is rich and spans the study of possible alignments in some of the earliest monumental centers of the ancient Americas, in Supe Valley centers dating to some five millennia ago [31], to a wealth of information on alignments, calendars, and cosmological narratives of the Inca and contemporary descendant communities [2,3,10,11]. Purposeful alignments to events in the solar cycle are particularly well documented for the Inca and their predecessors, and include rising or setting during the solstices, equinoxes, and zenith passage-the phenomenon observable only in tropical latitudes when the sun is positioned directly overhead at noon [5,32]. In addition to the possible astronomical alignments of buildings, the Inca practice of charting solar and astral passages along the horizon using open platforms or other viewing spaces (ushnu) and gnomon-like stone pillars to establish lines of sight is well documented by colonial period chroniclers, though the corresponding dates and celestial phenomena under observation remain points of scholarly debate [3,33]. Such features included milestones along the Inca road system, the Quapaq Ñan, that took the shape of rock-pile cairns or freestanding monoliths, referred to as saywas or tupus, used to chart the solar cycle and conspicuously incorporate it symbols of the imperial realm [6,7].

The solstices were particularly important to the Inca ritual calendar in marking the major festivals of Inti Raymi ("Sun Month") and Capac Raymi ("Royal Month") associated with the June and December solstices, respectively [11,34,35]. Yet other celestial phenomena were also culturally significant to Andean peoples who charted their progress through the night sky, including those involving the Milky Way and the Pleiades. We can again turn to the Huarochirí Manuscript for ethnohistoric details. The manuscript documents the role of priests who tracked solar movements (Chapter 9) and the importance of the Milky Way, and the Pleiades-the latter recorded using the Spanish term Las Cabrillas (Chapter 29)-to the cosmological narratives of the region [18]. Solar priests carried the title yanca, and the manuscript relates that, in order to time rituals to the mountain deity Pariacaca, "This man observes the course of the sun from a wall constructed with perfect alignment" [18]. Regarding stellar observations, Chapter 29 of the Huarochirí Manuscript mentions the llama and other "dark star" constellations perceived in spaces with fewer stars along the celestial axis of the Milky Way, possibly three bright stars of the constellation Orion's Belt in the Western zodiac, and the Pleiades. Of the last, the manuscript notes that if the star cluster was observed to be large it was a harbinger of a bountiful year, whereas if it was small times would be hard [18].

Tello and Miranda [27] documented how the importance of the Pleiades continued well into the twentieth century to the inhabitants of San Pedro de Casta: "Cuentan los mayores de Casta, que oyeron decir a sus antepasados, que a comenzar el año gentílico, esto es, durante el mes de Junio, cuando hacen su aparición las Cabrillas, los habitantes de los hoy arruinados pueblos de Pampa Kocha, Waya Kocha, Kasha, Achin, Waksa K'aka, Opika y otros, dejaban simultáneamente sus residencias, para acudir en grandes romerías a Marka Wasi, a presenciar el terrible espectáculo, del sacrificio de la víctima humana."

(The elders of Casta recount hearing from their ancestors that at that start of the pagan new year, that is, during the month of June, when the Pleiades make their appearance, the inhabitants of the today ruined towns of Pampa Kocha, Waya Kocha, Kasha, Achin, Waksa K'aka, Opika and others, descend simultaneously from their residences to form great pilgrimages to Marka Wasi to witness the terrible spectacle of the sacrifice of a human victim. [Translation by the authors.])

It should be noted that the Huarochirí Manuscript only mentions the sacrifice of llamas not humans in association with the rituals to Pariacaca and does not mention sacrifices in relation to the Pleiades. Nevertheless, the date in June recognized by twentieth

century Casteños is the same as in the Huarochirí Manuscript, occurring around the time of the Christian festival of Corpus Christi. The last evening appearance of the Pleiades in the West at the latitude of Marcahuasi (-11.75 degrees) would occur around June 3 [10,11]. Based on these historical and ethnographic accounts of what celestial cycles were salient to the cultural astronomy of inhabitants of the region, we therefore used this alignment for the Pleiades in addition to those for the rising and setting of important events in the solar year-solstices, equinoxes, zenith passage-for our study of rock outcroppings on the northwestern Marcahuasi Plateau.

Analyses of Potential Alignments

Field methods for the study involved multiple trips to Marcahuasi to map and document rock outcroppings and prehispanic architecture using a portable GPS (Garmin GPSMAP 62sp) that was then overlain on satellite imagery acquired using Google Earth Pro. Rock formations included the 15 monolith-like markers and other distinctive outcroppings in the northwestern plateau labelled on Figure 1: M1, M2, M3, M4, M5, Altar, Bird, Cone, Half Rock, Lion, Llama, Pecca Gasha, Scarface, Turban, Two Brothers. Our analyses included all of these possibilities so as to not bias the sample under study. The coordinates of the 15 features were input into the Omni azimuth calculator (https://www.omnicalculator.com/other/azimuth) to compute azimuth alignments, resulting in a total of 210 potential target alignments between all features (Figure 6). These were then compared to the azimuths of potentially significant solar rise and set events using the NOAA solar calculator (https://gml.noaa.gov/grad/solcalc/) for equinoxes and solstices, the RL.SE calculator for solar zenith dates (https://rl.se/zenith-calendar), and the heliacal set of the Pleiades based on modified calculations for that event viewed from Cuzco, calculated by [1,10].

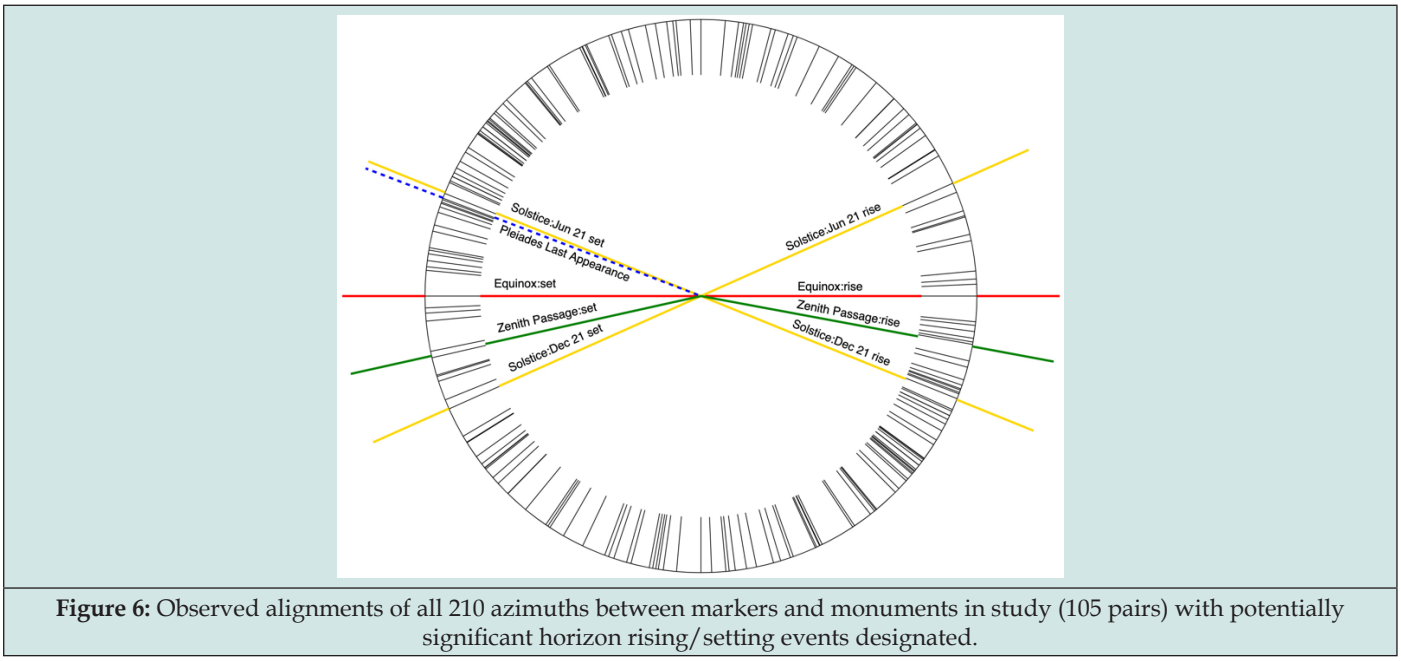

Figure 6: Observed alignments of all 210 azimuths between markers and monuments in study (105 pairs) with potentially significant horizon rising/setting events designated.

A few variables create uncertainty in the dataset including, most importantly, error in coordinate measurement based on satellite accuracy of the GPS and ambiguity in the target date for occupation and observation on the plateau. The latter introduces variability in potential alignment targets due to slight changes in the obliquity of the ecliptic viewed from Earth (affecting solar alignments) and to precession of the equinoxes (affecting heliacal rising and setting of constellations such as the Pleiades) over time [1]. Although the chullpas at the site appear stylistically to date to the Late Intermediate Period, we do not know when, within this 450-year period, the primary occupation of the site dates to nor whether it was the focal period for people first inhabiting the plateau, which could have been earlier. We approached this uncertainty in the dataset by examining both the match in azimuth lines between rock features and potentially significant rising or setting events, using 1000 CE as an approximate date at the onset of the First Intermediate Period (Figure 5), and allowing for incremental ranges of error, from a very tight tolerance of 0.01 degrees up to a loose tolerance of 2.5 degrees in azimuth calculations (Table 1). In other words, for the most inclusive list of possible alignments, if a potential target azimuth were 270 degrees-due West, corresponding to sunset on the equinox-we considered values up to between 267.5 and 272.5, two degrees to the North or South of the target with decimal rounding for the rock feature pairs listed in Table 1. This analysis of tolerance in range of error also accounts for our using only azimuth calculations and not including horizon elevations because corrections for altitude are minimal for any sites so close to the equator, representing a little over 1 degree for a 3 degree elevation [1].

Table 1: List of possible solar alignments and heliacal set for markers and rock formations on northwestern Marcahuasi plateau.

Date/Celestial Event	Rise		Set	
Equinoxes				
March/September 21	Azimuth	90	Azimuth	270
	M3-M1	87.5	M1-M3	267.5
	M3-Pecca	90	M5-Half	270
	Half-M5	90	Pecca-M3	270
Solstices				
21-Jun	Azimuth	66	Azimuth	292
	M3-Llama	68	M1-M4	290.4
	Scarface-Cone	65.9	M1-Half	289.9
			M4-Half	289.6
			Bird-Altar	290.7
			Cone-Half	291.8
			Pecca-Altar	294.2
21-Dec	Azimuth	112	Azimuth	246
	M4-M1	110.4	Cone-Scarface	245.9
	Altar-Bird	110.7	Llama-M3	248
	Altar-Pecca	114.2		
	Half-M1	109.9		
	Half-M4	109.6		
	Half-Cone	111.8		
Zenith Passage				
February 18/October 23	Azimuth	100.5	Azimuth	257.5
	M1-Pecca	99.6	Bird-M1	258.5
	M4-Bird	98.7	Llama-M4	257.1
	Altar-M5	100.1		
Pleiades Last Appearance (Heliacal Set)				
3-Jun	Azimuth	NA	Azimuth	290.8
			M1–M4	290.4
			M1–Half	289.9
			M4–Half	289.6
			Bird–Altar	290.7
			Cone–Half	291.8
			Pecca–Half	288.8

Note: Azimuths in decimal degrees. Tally of possible alignments by marker/formation: M1=10, M2=0, M3=6, M4=8, M5=3, Half=12, Altar=6, Pecca=6, Llama=3, Scarface=2, Cone=5, Bird=5, Lion=0, Turban=0, Two Brothers=0

With the above parameters in mind, our results of the analyses indicate that, of the possible total of 210 alignment targets, four have tight tolerances of <0.01 degrees from the azimuth of a possibly significant rise/set event (Figure 7a); nine are within 0.25 degrees of a target (Figure 7b); 12 are within 0.5 degrees of a target (Figure 7c); and 33 are within 2.5 degrees of a target. The closest matches are all equinox-related alignments of the E-W oriented cluster of four markers and outcroppings: M3, M5, Half Rock, and Pecca Gasha. Rising and setting on both solstices and the heliacal setting of the Pleiades all have at least one alignment that falls within 0.25 degrees of the target, and only the solar Zenith passage dates have their closest match within a larger range of error (0.4 degrees). Other potential alignments stand out for the conspicuousness of the two stone features and western horizon, such as the possible June solstice setting alignment between M4 and Half Rock illustrated in Figure 3, and the fact that Half Rock is involved in the most alignment possibilities (n=12). Half Rock is part of four possible June solstice setting alignments, two of which fall within a degree of error in target azimuth. Alignments relating to this shortest day of the year, for the Southern Hemisphere, are

well known within and around the Inca imperial capital of Cuzco [1,34]. The range of diachronic variability in solar alignments due to obliquity of the ecliptic and other factors is within a degree during the likely prehispanic occupation but could reach several degrees for the final appearance of the Pleiades, due to the effects of precession. For this reason, in addition to the uncertainty due to coordinate measurements via handheld GPS, it is worth considering whether the final group, allowing for a broader range of error, is significant at a statistical level.

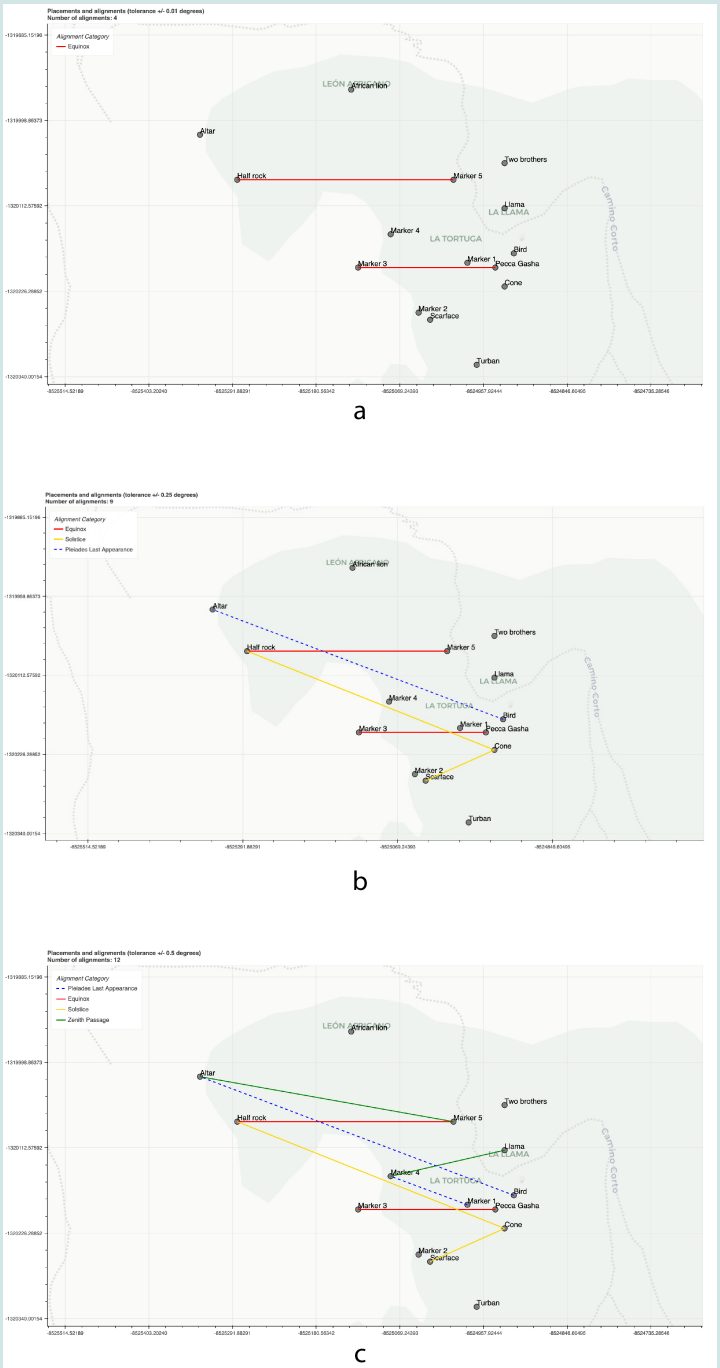

Figure 7: Significant alignments at Marcahuasi ($p < 0.05$) for tolerances of (a) 0.01, (b) 0.25, and (c) 0.5 degrees in azimuth (see also Table 2).

We also enumerated the azimuths associated with each pair of markers for comparison with each target and, again assuming a level of alignment error tolerance, calculated the number of alignments. Because there are 105 pairs associated with 15 markers, it is not surprising to observe many alignments if the tolerance is large. We therefore quantified the level of surprise (or lack thereof) using Monte Carlo statistical methods for p-value estimation [36,37], comparing the numbers of alignments observed in the Marcahuasi data to numbers that would be obtained were the markers randomly distributed across the site. The computer code is written in Python (see supplemental material) and simulates 10,000 random marker configurations for each tolerance level. The number of alignments for each configuration is tallied, providing a Monte Carlo estimate of the distribution of alignments for random markers. The observed numbers of alignments at Marcahuasi (for the given tolerances) are then evaluated with respect to the estimated distributions yielding p-values. (Table 2) shows the p-values as a function of tolerance. Results of this analysis indicate the estimated p-values are significant (less than 0.05) for tolerances of less than +/-1.0 degree, meaning the observed alignments at the site are indeed surprising purely on statistical grounds. For levels of tolerance greater than or equal to one degree, the number of alignments is not surprising.

Table 2: Estimated p-values as function of alignment error tolerance. For tolerances < 1.0 degree, the number of observed alignments at Marcahuasi are surprising ($p < 0.05$, highlighted in green). The number of observed alignments for looser tolerances are not statistically surprising ($p \geq 0.05$, highlighted in red).

Tolerance (+/-deg)	0.01	0.05	0.1	*0.5*	1	1.5	2	*2.5*
Observed at site	4	4	7	12	16	19	25	33
p-value	0.0002	0.011	0.00225	0.03035	0.11525	0.26745	0.2746	0.1993

Conclusion

Given the extensive ethnographic and ethnohistorical documentation of the cultural salience of stone features and celestial alignments in the vicinity of Marcahuasi and the broader Huarochirí Province, it is not surprising that such notions extend further back in time to the prehispanic era. In this study we have provided evidence for potentially significant alignments in the "stone forest" of the northwestern Marcahuasi plateau. While it is clear that some stone features, such as Pecca Gasha, were recognized as meaningful and partially modified by Marcahuasi's inhabitants, the extent of modification for it and the other formations, including whether it impacted any alignments we discuss, remains unclear and requires further geoarchaeological analyses. Nevertheless, we propose that the northwestern plateau combines elements of a "natural" landscape and "cultural" monuments [8] that would have been noted by occupants of the site for the close matches of many of its gnomon-like rock formations and thereby formed part of an ontologically animated and integrated Andean cosmology.

Our analyses document the closest alignment matches associated with solar rising and setting on the equinoxes. The next closest matches are found for the June solstice sunset, December solstice sunrise, and last appearance (heliacal set) of the Pleiades. Alignments to sunrise and sunset on the dates of the solar zenith passage are less strong, but some fall within half a degree of the target, which our Monte Carlo based analysis indicates is a significant departure from a random distribution. Stone features on the western edge of the plateau (Half Rock and Altar) are especially conspicuous when looking towards the western horizon and are involved in over half of the proposed potential alignments, given variable degrees of tolerance. Most or all of these potential alignments may represent natural features, yet that would not detract from our interpretation of the northwestern plateau as an ushnu-like setting for horizon-based astronomical observations that would have been noted by Marcahuasi's inhabitants and woven into their cosmology in a manner similar to elements of the Huarochirí Manuscript and proposed for other archaeological sites in the region [17,18].

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