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Identification of astronomical objects in ancient engravings: Malargüe, Mendoza, Argentina. Methodological contributions in archaeoastronomy

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Abstract. In 2007 a group was formed to study 'Archaeoastronomy of Malargüe'. Its main objective is to contribute to the understanding of rock art records from the study of their variability, in order to understand their functionality in the context of regional archaeological problems. The research is addressed using an interdisciplinary theoretical and methodological model, focusing on the characteristics of the site and location of the engravings, their relationship with the landscape, and the identification of possible representations of astronomical objects. In this paper, we discuss some of the theoretical and methodological tools we have used for the fieldwork and analysis, using as our case study work at the rock art sites of Agua Botada, Valle Hermoso, and Los Toscales del Payén in the south of Mendoza, Argentina.

Keywords. Malargüe, rock art, methodology, landscape

1. Introduction

The southern region of the province of Mendoza (Fig. 1) was inhabited by hunter-gatherers from the late Pleistocene and early Holocene through to historic times (Duran 2004; Neme & Gil 2008). Despite this apparent temporal and spatial continuity there was continual economic, technological and social change. Its dynamics can be seen through the diversity of the archaeological record left behind by the populations who constructed and occupied this landscape. Archaeological research in southern Mendoza over the last two decades has attempted to improve our understanding human adaptation in the region, focusing particularly on technology and subsistence strategies.

Rock art research in southern Mendoza dates back to the 1960s, when Juan Schobinger and Carlos Gradin began to study the area systematically and identified at least 14 rock art sites, featuring both engravings and paintings (Schobinger 2002). From a comparison of motifs and styles in the area with those of other regions, they proposed that the rock art here was created in the latter half of the Late Holocene and is characterized by four styles, one of which developed within the region while the others were strongly influenced by neighboring areas.

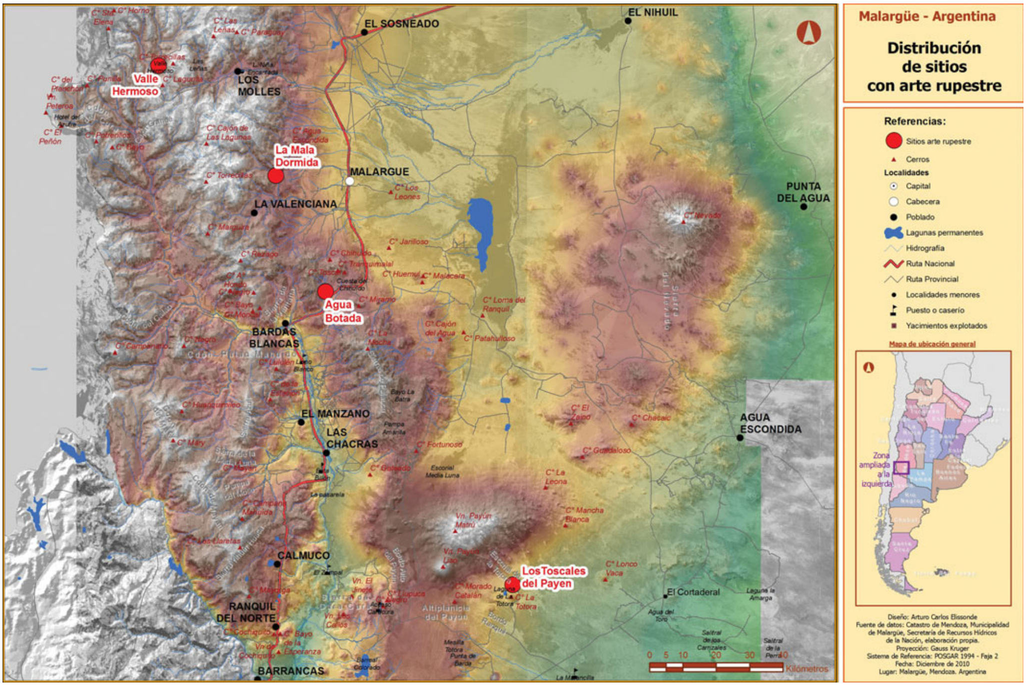

Figure 1. Location of the sites presented in this paper.

The first archaeoastronomical work in the region was undertaken in the 'Cave of the Indian', a key archaeological site. It showed possible representations of astronomical objects and their position in the sky (Risi 2002), suggesting the need for an interdisciplinary approach in order to explore this issue further.

2. Theoretical perspectives

The second half of the Late Holocene Period (2000 BP) provides the first evidence of socio-economic and technological transformation at a regional level: occupation sites are found throughout the entire territory, suggesting an intensification in the exploitation of resources and widespread circulation of goods through exchanges with neighboring regions (Duran 2004; Neme & Gil 2008). The appearance of rock art is related to social practices produced by three interrelated domains—economic, technological and cognitive (Fiore 2009).

Rock art functions as a social communication system that interacts with different actors (Aschero 1996; Fiore 1996; Carden 2007), and this implies that well-defined and preset principles governed the siting of the engravings and paintings in relation to natural and cultural resources, access, and the distribution of people in the environment. In this way cultural phenomena observed in the landscape are related to the production and maintenance of a specific social system (Bradley 1997; Cruz Berrocal 2005).

One would expect social practices to be related to the environmental characteristics of the region and the diversity of ecological conditions, with marked discontinuities in the spatial and temporal distribution of resources triggering social change. Consequently, understanding the functionality of rock art in the Late Holocene will provide insights into the social use of space and how the landscape was built in the past (Criado 1999).

The environment is not only composed of the landscape and topography. The day and night sky are also included within the social sphere. The astronomical knowledge of groups of people in the past could play an important role in locating resources and making the best use of different localities according to seasonal variations in ecological conditions.

Certain questions guide our work. What is the relationship between rock art and its distribution in space and possible places of transit? Could the sites with rock art be used as markers for certain resources and territories? And could astronomical objects be represented, with such representations functioning in the context of the situations described in the previous questions?

3. Methodological approach

3.1. *Fieldwork methodology*

Our fieldwork methodology was based on surface prospection and survey. We recorded the following quantitative variables:

- Relating to context (placement and location etc.): Landform, Hydrography, Topographic Location, Accessibility, Site Visibility, Visibility between sites, Visibility between blocks, Visibility of art panels, and Orientation of panels with engravings.
- Relating to astronomy: Position of Patterns, Form of Pattern, Production Technique, External characteristics (ground, material, technique, etc.), Internal relationships (overall composition, connections between components and their position), and Direct observation of astronomical phenomena, both by day and night.

3.2. *Archaeoastronomical methodology*

We identified certain groups of patterns whose size and position show a high degree of correlation with the appearance (timing and location in the sky) of particular constellations—the Southern Cross throughout the year, Scorpius in the winter, and Orion during the summer. While the designs in question appear among a wider group of representations, the patterns analysed stand out clearly from the rest, because of their location in prominent areas of topographic relief, their distribution within the panels in relation to other patterns, and their high visibility.

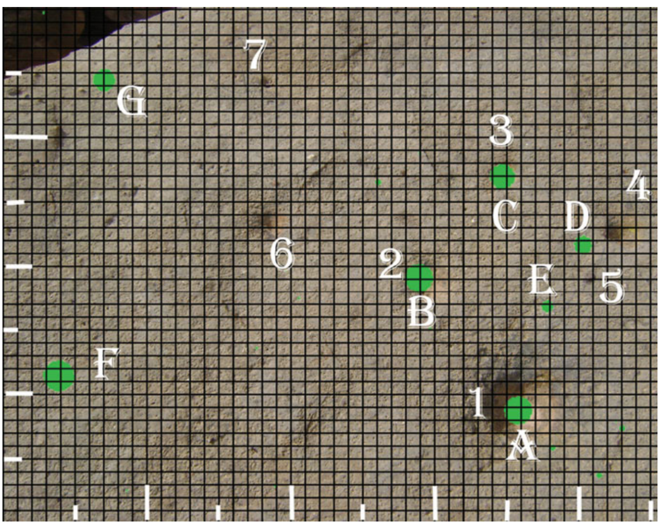

Figure 2. Grid of coordinates to study positions.

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En plano		Constelación Sitio	Bayer	Nombre	Magnitud visual promedio	Mínimo	Máximo	Diámetro en roca	Relación diámetro / magnitud	coeficiente de correlacion de tamaño	Mortero	X1	Y1	Estrella	X2	Y2	coeficientes de correlacion de posición (x e y)
1		Orión Toscales	β	Rigel	0,28			2,84	10,14	-0,686193443							
2		Orión Toscales	α	Betelgeuze	0,65	0	1,3		0,00								
3		Orión Toscales	ζ	Alnitak	1,9			2,77	1,46								
4		Orión Toscales	ε	Alnilam	1,72	1,64	1,74	2,25	1,31								
5		Orión Toscales	δ	Mintaka	2,23	2,14	2,26	1,85	0,83								
1	A	Cruz A. Botada	α	Acrux	0,7			3,02	4,31	-0,732619111	1	35,6	8,8	A	35,6	8,8	0,985
2	B	Cruz A. Botada	β	Mimosa	1,27	1,23	1,31	2,27	1,79		2	29,2	18,5	B	28,9	19,2	0,998
3	C	Cruz A. Botada	γ	Gacrux	1,67			1,09	0,65		3	34,9	27,5	C	34,7	26,9	
4	D	Cruz A. Botada	δ		2,81	2,78	2,84	1,5	0,53		4	43,2	22,2	D	40,2	21,8	
5		Cruz A. Botada	ε		3,58				0,00								
		Cruz A. Botada		Blue Nebula				1,39									
6	E	Cruz A. Botada	β	Beta Cen	0,64			1,41	2,20								
7	F	Cruz A.Botada	ε	Epsilon Cen	2,28			0,82	0,36								
		Cruz V. Hermoso	α	Acrux	0,7			1,64	2,34	-0,945924466	1	0	0	A	0	0	0,996
		Cruz V. Hermoso	β	Mimosa	1,27			1,31	1,03		2	-0,8	6,8	B	-0,8	6,8	0,991
		Cruz V. Hermoso	γ	Gacrux	1,67			1,29	0,77		3	-5,8	7,3	C	-5,4	7,3	
		Cruz V. Hermoso	δ		2,81			1,05	0,37		4	-5,6	2,1	D	-5,9	3,1	
1	A	Escorpio	α	Antares	0,88	1,16	0,28	1,83	2,08	0,271258621	1	0	0	A	0	0,0	0,977
2	B	Escorpio	τ		2,83			1,59	0,56		2	8	0	B	2,9	1,8	0,970
3	C	Escorpio	ε		2,27			1,43	0,63		3	13,2	1	C	11,9	4,3	
4	D	Escorpio	μ1		3,08	2,94	3,22	1,71	0,56		4	19,5	0	D	17,2	3,4	
4	D	Escorpio	μ2		3,56			1,61	0,45		4			D			
5	E	Escorpio	ζ		3,62			1,61	0,44		5	23	4	E	23,1	2,5	
6	F	Escorpio	η		3,32			1,35	0,41		6	28,5	3,5	F	25,5	7,0	
7	G	Escorpio	θ		1,86			1,04	0,56		7	31,5	9	G	36	8,8	
8	H	Escorpio	ι		2,99			1,68	0,56		8	28,5	14	H	27,4	14,0	
9	I	Escorpio	κ		2,41	2,41	2,42	1,25	0,52		9	24	17	I	22,8	17,8	
10	J	Escorpio	λ	Shaula	1,65	1,62	1,68	0,95	0,58		10	19,2	16,7	J	19,2	16,2	
11	K	Escorpio	ν	Lesath	2,7			1,49	0,55		11	19	13,5	K	19,2	15,2	

Figure 3. Statistical data for each site studied.

3.3. *Data analysis*

Our aim was to identify possible similarities between objects or regions of the sky and the rock art patterns through direct observation of daily phenomena. This involved the systematic comparison, using software, of astronomical images corresponding to those regions identified in the sky and similar patterns found in the engravings. The steps in this process (Figs 2 & 3) were:

- The characterization and design of a 'grid of similarities', which compares the rock art design with astronomical images using a suitable system of coordinates.
- Load the data into a spreadsheet and Matlab software.
- In Photoshop, measure the dimensions of the patterns identified that are similar to astronomical objects.
- In the spreadsheet, calculate the relationship between rock art patterns (in this case, the diameter of cup marks) and objects in the sky (apparent visual magnitude of stars). This lets us compare the sizes with the brightness of stars in a clear and direct way.

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• In Matlab, superimpose the rock art and astronomical patterns on the same graph, using error bars in x and y to plot the differences in position.

• Calculate the coefficient of correlation, thus determining statistically if there is a relationship between the two sets of data.

These statistical tools allow us to quantify the evident similarities between visible configurations in the skies and what is depicted on the rock.

4. Case studies

4.1. *Los Toscales del Payén (Scorpius)*

There is an evident similarity between the positions of the cup marks shown in Fig. 4 and the stars of the constellation Scorpius. Antares (α Sco), marked A in the photo, was superimposed on the largest cup mark and this point was set as the origin of the similarity grid. The correlation coefficients for the x- and y-coordinates obtained using Matlab are 0.97 in both cases, so there is a linear correlation between the positions of

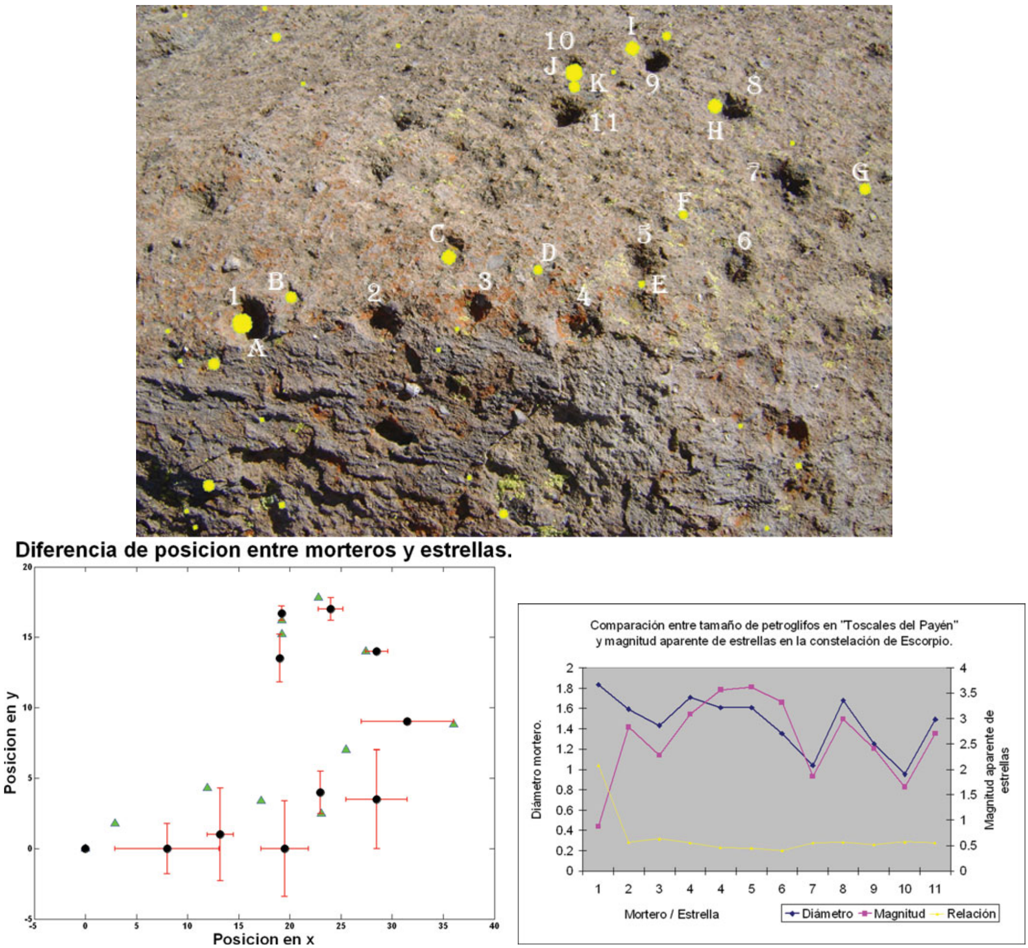

Figure 4. *Top:* Visual comparison of the relative positions of cup marks at Toscales del Payén and the stars of Scorpius. *Bottom left:* Comparison of the x- and y-coordinates of the stars and cup marks in the similarity grid. *Bottom right:* Comparison of the star magnitudes and cup mark sizes.

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the cup marks and stars. There is also a correlation between the size of the cup marks and the brightness of the stars, but the relationship is reversed, i.e. the larger cup marks represent the less bright stars (with the exception of Antares itself). (N.B. This means that the correlation coefficient between cup mark size and stellar magnitude is positive.)

We are confident that the eleven points considered are the most representative of the area identified. All other cup marks in this sector of the panel are much smaller, including some that appear to have been produced naturally by erosion.

4.2. *Valle Hermoso (Southern Cross)*

The position chart here (Fig. 5) shows a high degree of similarity between the pattern represented on the rock panel and the constellation of the Southern Cross. The correlation coefficient between the incisions on the rock and star positions is 0.99, confirming the close relationship between them. The relationship between incision size and star brightness is symmetrical and direct, i.e. larger incisions correspond to brighter stars, unlike in the previous case. This is confirmed by the negative sign in the correlation coefficient (–0.94). Finally, the 'Southern Cross in the rock' points to the south celestial pole in the sky, as does the constellation. There are no other circular incisions in this area of the rock panel.

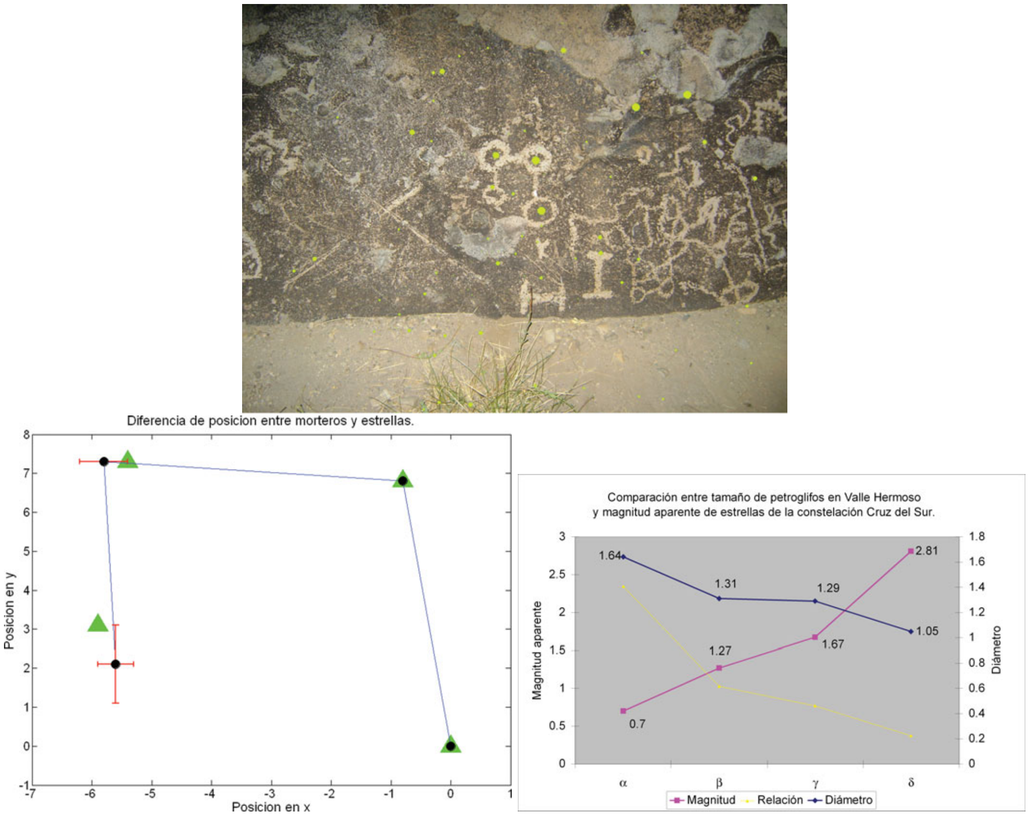

Figure 5. *Top:* Visual comparison of the relative positions of incisions at Valle Hermoso and the stars of the Southern Cross. *Bottom left:* Comparison of the x- and y-coordinates of the stars and cup marks in the similarity grid. *Bottom right:* Comparison of the star magnitudes and cup mark sizes.

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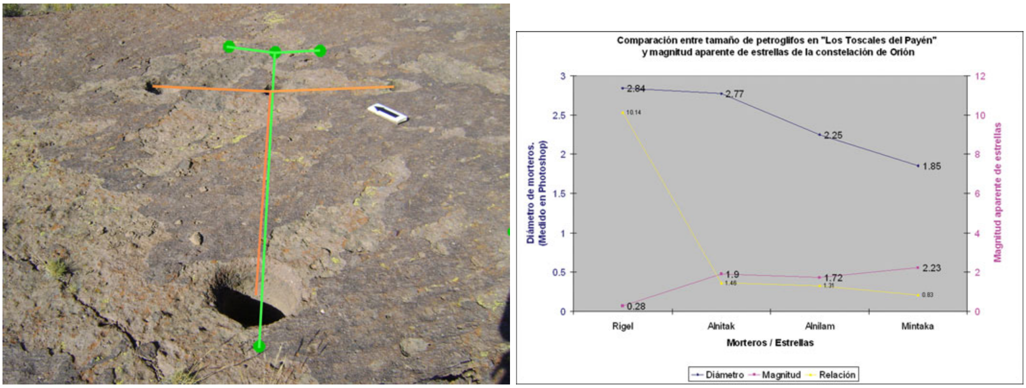

Figure 6. *Left:* Visual comparison of the relative positions of cup marks at Toscales del Payén and the stars of Orion. *Right:* Comparison of the star magnitudes and cup mark sizes.

4.3. *Los Toscales del Payén (Orion)*

In this case (Fig. 6) cup mark size is, once again, positively correlated with star brightness (correlation coefficient –0.68). But while the rock panel correctly represents the perpendicularity between the alignment of 'The Three Marys' (Orion's Belt) and the direction of Rigel, the scale is wrong.

4.4. *Agua Botada (Southern Cross)*

The shape of the largest four cup marks here is, once again, similar to the Southern Cross (Fig. 7). The correlation coefficient between the cup mark and star positions is 0.98 and, as in the last two cases, cup mark size is positively correlated with star brightness (correlation coefficient –0.73). Also, the representation points to the south, as does the actual constellation. However, in this case we find additional cup marks, the closest being to the right of the one that appears to represent δ Crucis. There is no bright star at that location in today's sky, but there is the 'blue' planetary nebula, NGC 3918. Some studies of the rate of expansion of the nebula have suggested that it resulted from a stellar explosion 3000 years ago (Clegg *et al.* 1987). If so, then this might well have been visible to the naked eye. This possible dating matches the archaeological record of the area.

5. Discussion

The preliminary results obtained in the four studies confirm, using statistical tools, what can be seen at a glance: that there is a high degree of similarity between cup mark patterns and certain constellations. The spatial correlation coefficients, resolved along the coordinate axes, consistently show signficant values approaching 1.0. The correlation test to relate the size of the cup marks to the brightness of the stars reveals much greater variability, but one would not expect a perfect relationship, given the difficulty of the work. The possible representation of Scorpius at Los Toscales del Payén is curious in that (with the exception of Antares) cupule size is negatively related to star brightness; yet there is a nearly perfect linear size-brightness relationship among the eleven points shown in Fig. 4.

The representations concerned are consistently found at the top of rock art panels, and the panels themselves are found in prominent topographic locations. This means that the sites in question are highly visible while also offering a broad view outwards,

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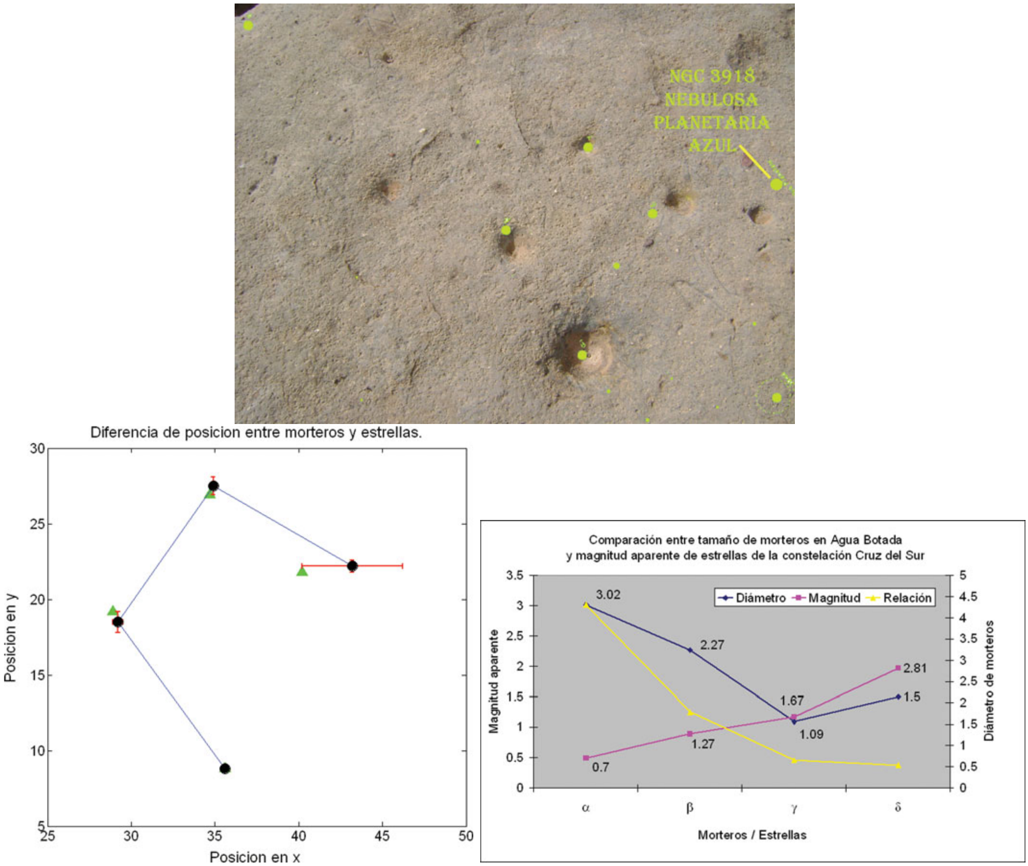

Figure 7. *Top:* Visual comparison of the relative positions of cup marks at Agua Botada and the stars of the Southern Cross. *Bottom left:* Comparison of the x- and y-coordinates of the stars and cup marks in the similarity grid. *Bottom right:* Comparison of the star magnitudes and cup mark sizes.

both of the surrounding landscape and of the day and night sky. On the other hand, there is variability in the techniques used to produce the rock art patterns:

• The Los Toscales del Payén engravings are on ignimbrite. Wind erosion and geomorphological conditions have formed large boulders with flat, level tops. These have a predominantly east-west orientation. The rock art analyzed is on top of these high blocks, and has this same orientation. The designs face up to the sky, and the constellations that are possibly represented in them can be easily seen from those places.

• The Agua Botada engravings are located on a rocky wall with a north-south orientation. They are located on the side facing east. The representation of the Southern Cross is in the top of the wall, looking toward the sky, facing south. It is one of the few engravings with this orientation on the site. The constellation of the Southern Cross can be easily seen throughout the year from this location.

• The Valle Hermoso engravings are located on five parallel walls, all of which have an east-west orientation; the engravings are on the side facing north. Someone looking at the panel is facing south, and during the autumn would see the possible representation of the Southern Cross on the rock, and that constellation in the sky, in the same position. The Southern Cross on the rock points towards geographical south.

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Production techniques also differ. The representation of the Southern Cross at Valle Hermoso is carved by incisions whereas that at Agua Botada consists of cup marks created by abrasion and polishing. Similar techniques to the latter were used at Los Toscales del Payén to represent Orion and Scorpius.

This variability in production techniques and features of the site gives us initial insights into the organization of the work process and the distribution of the rock art containing astronomical patterns. Analysis of the composition of, interconnections between, and distribution of these rock art panels will make it possible to extend the contextual information and evaluate the methodology used.

The material production of rock art depended upon economic, technological and cognitive aspects. Our preliminary results point the way to establishing standardized criteria for recognizing astronomical representations in rock art, and to the integration of archaeoastronomical data into rock art studies on a regional level .

6. Perspectives

The work we have described allows us to start drawing up a set of working hypotheses regarding the functionality of a system of regional rock art. We can assume that astronomical knowledge played an important role in people's orientation and location in, and use of, the environment, for the purpose of ensuring the survival of human groups. Archaeologically, we can identify a transformation at the regional level in the second half of the late Holocene (2500–2000 BP), manifested in socioeconomic and technological changes, and resulting in the occupation of the entire territory, increased population density, intensification in the exploitation of resources, and the widespread circulation of material goods through exchange with neighboring regions. In this context, rock art could have played a key role within hunter-gatherer subsistence patterns as a social information system operating at the regional level, helping to provide access to specific resources.

A possible interpretative scenario suggested by our data is that the astronomical engravings added individuality to the places where they were located. This uniqueness would have operated at a regional level and could have related logistically to—for example—seasonal camps or ceremonial sites. However, if astronomical representations occurred more frequently than we have discovered so far, then this might suggest the demarcation of territories, restricted access to resources, and/or routes of conveyance.

A specific possibility raised by the representation of the Southern Cross in Valle Hermoso and Agua Botada is that a continuum of subjects were actually represented, these representations being produced using a variety of techniques, and strengthening the message content.

Our preliminary results permit us to frame the above arguments and begin to compare ideas in relation to population dynamics, accessibility of resources and territory, problems that had become increasingly complex for Late Holocene human groups. We hope that more answers will be revealed when our results are integrated with contextual information from internal and external relationships relating to other rock art patterns. At the same time, this will allow us to adjust and improve our methodology for identifying celestial representations in rock art.

We realize that this does not exclude other, different levels of analysis of rock art, but we do hope that it will open a new space for debate and the acquisition of knowledge via a more comprehensive approach.

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