Digging the topology of rock art in Northwestern Patagonia

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Abstract

We present a study on the rock art of Northern Patagonia based on network analysis and communities detection. We unveil a significant aggregation of archaeological sites, linked by common rock art motifs that turn out to be consistent with their geographical distribution and archaeological background of hunter-gatherer stages of regional peopling and land use. This exploratory study will allow us to approach more accurately some social strategies of visual communication entailed by rock art motif distribution, in space and time.

Keywords: archaeology; complex networks; Patagonia; rock art; modularity

1 Introduction

The use of analytical methods derived from network science has undeniably hatched over the last decade, bringing together several disciplines as mathematics, physics, computer science, biology and social sciences.
Archaeology is not an exception: the number of projects in this academic field recurring to the analysis of complex networks has been growing at an increasing pace in the last decade. The utility of the networks approach resides in the possibility of abstracting the most relevant features of a case-study and represent them and their connections as a network \cite{1, 4, 2, 3}. In this way, the information can be analyzed globally and locally in a systematic manner by revealing the topological properties of the underlying network and the emerging patterns encoding valuable pieces of information. In fact, the structure associated to any cultural process is organized into networks of nodes and relational links that connect them. As soon as the object under study is organized into unities whose connections trace a framework of relationships, network science turns into a suitable tool to analyze the collection of data.

Once the abstraction exercise has been done, different networks can be constructed from the same archaeological data to explore different aspects of the same phenomena. In turn, there is a collection of topological quantities that serve to characterize the structure of the built network by means of local and global properties.

The present research project is focused on the study and characterization of a set of rock art sites located in the provinces of Neuquén and Río Negro, Northern Patagonia, Argentina \cite{5}. Our work is part of a larger project that aims to discuss the flow of information and mechanisms of cultural transmission in relation to archaeological hunter-gatherer models in Northern Patagonia. In this sense, as a first step we want to elucidate the possible ways in which information flowed in the past via the display of rock art motifs, and also to show how this gave place to the set of archaeological sites with a specific distribution over the landscape \cite{6}. A similar approach has been useful to model the geographical path of information, including but exceeding their topological dimension, which helped to reconstruct ancient hunter-gatherer paths, territories, action ranges, and other archaeological implications \cite{7}. In turn, this information will serve as a comparative parameter to be contrasted with an archaeological model of land occupation and use of space in future research projects.

We carry out an exploratory analysis at two different levels, drawn on shared features at each of the surveyed sites. Firstly, we evaluate the existence of correlations between the geographical distribution of the sites and the prevalence of different rock art motifs among them. This could show possible evidence of common and shared information between them, and can shed light on the possible transmission of different cultural traits in the past. Secondly, we perform a similar analysis but centered around the motifs themselves that appear at each site, in order to analyze the existence of well defined ensembles of motifs, regardless of whether they are engraved or painted.

Each one of the surveyed sites exhibits a set of rock art motifs which have been classified according to their morphology, geometry and production technique. Based on the collected information we built a bipartite network consisting of two different types of nodes: the sites and the motifs. From this network we produced two different projections, a network of sites and a network of motifs. In the first case, the nodes—corresponding to the sites—are connected if they share at least one
motif. In turn, the nodes of the second network represent the motifs, linked between them if they concur at a given site. In both cases the links are weighted according to the number of times two nodes are connected. Given that we want to check whether our network analysis can let us infer some information about the spatial proximity of the sites, the network construction deliberately ignores any previous knowledge about their geographical location. A similar network construction in an archaeological system was carried out in [2].

Once the two networks were built, we proceeded with the analysis of their topological properties in order to: a) detect the existence of highly relevant nodes, b) record how the nodes are organized and c) check for the existence of communities by a modularity analysis. By means of such analysis we aimed to unveil a meaningful aggregation of sites, linked by common cultural features that turns to be consistent with the possibility of cultural transmission backed up by their geographical distribution.

2 Network construction

The database of prehistoric Northern Patagonia rock art consists of georeferenced sites, each of which contains paintings, engravings or both [8]. This relational database includes both published information about rock art sites from Patagonia as well as fieldwork data provided by our own team members and ARPat database [9, 10, 8]. It contains information at the site scale and at the motif scale, which can be used independently or combined, according to digital queries defined by archaeological research questions. Out of this macro-regional database, we have selected for this paper 136 sites which regionally fall within Northwestern Patagonia. The temporal duration of rock art production is not precise, although it has been possible to distinguish temporal blocks for the different repertoires of Patagonian rock art [13, 12, 11]. The production of the set under study covers a temporal range of the last 4000 years BP (before the present) [14, 9, 11], which will be discussed later in light of the results obtained. The quantity of motifs at each site ranges from 1 to 35 (see Fig. 1), totaling 1095 motifs [5]. Examples are shown in Fig. 2. Given the large variety of motifs designs, we classified them into groups, according to their geometric details and other stylistic features. This led to the definition of a total of 148 motif groups (see Appendix II). Examples of the groups are: concentric circles, parallel lines, feline tracks, frets, etc., some of which can be seen in Fig. 2.

The information about each site and the corresponding groups of motifs present in them was used to construct a bipartite network with sites and groups of motifs on each side, as follows. A group of motifs is linked to a site if any of the motifs that belongs to the group is present at the site. From this bipartite network we built two different projections, with their nodes identified with only one of the two parts in each case. An example of the procedure is presented in Fig. 3. In this way we obtained the following two network types:

Network of sites. In this case the nodes of the network are the archaeological sites. Two nodes are connected by a link if they share at least one group of motifs in common. If more than one group is shared, the link is weighted accordingly. It is
important to note that the network thus constructed is an artificial mathematical object, which does not (necessarily) correspond to actual connections between the people that populated the sites and produced the art. This network is even blind with respect to the geographical location of the sites. Any topological structure present in the network will emerge from the complex sharing of groups of motifs between them.

**Network of motifs.** In this case the nodes are the categories to which each motif design corresponds, which as noted above, are called motif groups. Two nodes of this network are linked if the corresponding motif groups appear at the same site. If a pair of groups appear together in more than one site, the link is weighted accordingly. This motifs network is complementary to the network of sites, and provides an insight on the possible relationships between the many motif categories of the set, thus shedding light on their stylistic classification.

These two types of networks were analyzed using standard tools of the theory of complex networks, in order to characterize their topological properties. Of particular interest in this study is the analysis of the partitions of the set of nodes, which define what are called *communities* of the network. Social networks, built on contact between people, naturally break into communities that the mathematical analysis can detect. Bear in mind, however that our networks are not based on any known contact between people, but just by sharing common material culture elements instead.

## 3 Results

Quantitative properties of the networks are summarized in Table 1. It is noticeable that the network of sites is rather dense, with a density of 0.51 of all possible links. The average degree of sites is also large at \( \langle k \rangle \approx 70 \), from a distribution
Figure 2: Examples of typical motifs found in: A) Patagonian forest [15], B) and C) Patagonian steppe [16], D) North of Neuquén province [17]. The motifs correspond to the following group classification referred to in the text: 1) anthropomorphic, 2) zoomorphic guanaco, 3) concentric fret, 4) fret (engraved), 5) footprints, 6) sinuous parallel lines, 7) zig-zag parallel lines, 8) axially symmetric figure.

Table 1: Summary of the topological properties of the networks. The columns show: number of vertices, density of links, mean path length, mean degree, global clustering coefficient, mean local clustering coefficient and mean betweenness centrality. The maximum betweenness centrality in each case corresponds to: site #42 (Huechahue, $\beta = 201.7$), group #22 (anthropomorphic, $\beta = 1161.7$).

| Network | $N$ | $\delta$ | $\langle L \rangle$ | $\langle k \rangle$ | $c$ | $\langle c \rangle$ | $\langle \beta \rangle$ |
|---------|-----|----------|-------------------|-------------------|-----|-------------------|-------------------|
| of sites| 136 | 0.51     | 1.75              | 68.2              | 0.72| 0.77              | 49.8              |
| of motifs| 148 | 0.13     | 2.33              | 19.6              | 0.37| 0.58              | 91.4              |
that, ranging from 1 to 119, is biased towards the right (see Fig. 3). We also see that the average path length of both networks is small, and that both are highly clustered. The higher clustering of the network of sites makes sense in the context of the spatial unity and cultural homogeneity (see Discussion).

The most interesting results are provided by the modularity analysis of both networks. This was done using two algorithms that support weighted graphs and that have proven to be adequate to this kind of social network [18]. The algorithm based on the leading eigenvector of the community matrix [19], as well as the Louvain method [20] were used. The resulting communities of the network of sites are shown in Fig. 5 (and listed in Appendix I), with the sites at their geographical location (which does not play any role in the calculation). The two algorithms give very similar results, with a small but relevant difference. The leading eigenvector method finds three communities of similar size (Fig. 5, left). These will be referred to according to their geographical range: North of Neuquén (black), Forest (green) and Steppe (red). It can be seen that, apart from a few sites between latitudes $-40$ and $-41$, the North of Neuquén community is the most geographically segregated of the three, occupying mainly the namesake region. The other two communities occupy mostly the whole range of the area under study, from the Andes mountain range on the west and over the Patagonian steppe at the center and east. The Steppe community, though, stays mainly east of the Andes.

The Louvain algorithm finds four communities (Fig. 5, right), with the overwhelming difference being the split of the Forest community found by leading eigenvector into two: a Nahuel Huapi community (green, concentrated around the southernmost tip of Neuquén, and corresponding to the Nahuel Huapi lake region), and a Valleys community (blue), extending along several river valleys in the transition region between forest and steppe. The size of the symbols in Fig. 5 corresponds to
the betweenness centrality of the sites, $\beta$. We can see that the Valleys community is dominated by the sites with largest values of $\beta$ of the Forest community found by the leading eigenvector method.

Figure 4 is one of the main results of this paper. It is remarkable that these three (or four) homogeneous sets of sites are well segregated in geographical space, even though the analysis, as mentioned, contains no information on the location of the sites. They show the potential existence of homogeneous blocks, with shared coherent information and visual codes, belonging to each one of this (mathematical) communities, which are based on a stylistic similarity given just by sharing groups of motifs. Indeed, the regions occupied by North of Neuquén province, Nahuel Huapi, Valleys and Steppe were inhabited by hunter-gatherer groups, which gradually occupied the environments in a discontinuous way during the last 4000 years. In this sense the network communities, despite not pondering the temporal variable of the data set, are coherent with some archaeological inferences about the occupation of the environments of Northern Patagonia (see Discussion below).

We also analyzed the modularity structure of the network of groups of motifs. In this case, the communities indicate the existence of ensembles of motifs that tend to appear together, akin to stylistic modalities. In the following we will use the term “module” to refer to these communities of groups of motifs, especially to distinguish them from the “communities” of the network of sites. Again, bear in mind that the analysis is completely blind with respect to any other information about the system. The modules found by the two algorithms are listed in corresponding tables in Appendix II. It is difficult to represent them on a map, because more than one thousand motifs are restricted to 136 sites. Figure 6 is an attempt to do so. Each symbol is colored according to its module, and their size reflects the number of motifs of the corresponding group present at the site.

In this case, the leading eigenvector algorithm shows the existence of 2 modules
Figure 5: Communities of the sites network, found by each algorithm (as indicated). Each color represents a community, and symbol size corresponds to the betweenness centrality of the site.

(2 disconnected nodes, fig H and fig rhombus, were left out of the analysis). It is easy to see that these modules, just like the communities found in the network of sites, are also segregated in space. There is a Module 1 (red), typical of the North of Neuquén, and a Module 2 (orange), typical of the South. Both of them mix, even at single sites, in the central valleys and steppe regions. The Louvain method again identifies subsets of the southern community. In this case the Module 2 of the leading eigenvector algorithm is split in three. The community structure is shown in Fig. 7. Two of them (Modules 3 and 4, purple and green respectively) are smaller, and found mainly in the mixing regions of the steppe. We will discuss this structure and its relevance in the following section.

4 Discussion

Results are discussed here in the context of the actual system that the two identified networks represent. The modularity analysis carried out on the graphs has no information about the cultural, historical or geographical background of the sites and their motifs content. The resulting communities could have been just mathematical artifacts, devoid of anthropological meaning. However, we found that both the sites network’s communities and the motifs network’s modules are full of relevant information.

Starting with the geographical distribution of the sites communities, three (or four) distinct communities have been found: North of Neuquén, Forest (or
Figure 6: Communities of the network of motifs, colored according to the module. Size corresponds to the quantity of motifs found at each site, within each community.

Figure 7: Modules: communities of the motifs network (Louvain method).
Nahuel Huapi plus Valleys) and Steppe. These are easily recognizable as significant archaeological units. Recently, it has been shown by traditional anthropological/archaeological methods [21], that the human groups that inhabited the North of Neuquén province participated actively in a regional dynamic of mobility and interaction together with the Maule region in Chile, at least during the last 1000 years BP [21, 22, 23, 24]. Our modularity analysis was able to detect the context of production and use of rock art images that reinforces the particular identity of archaeological signals of the North of Neuquén apart from the rest of the province.

The human occupation of the ecotone and the steppe, on the other hand, differs from that of the Andean forests, since it has more evidence of early human presence [25, 26, 27, 28, 29, 30, 31, 32] without the discontinuities observed in the forest environment and specifically in the Nahuel Huapi area [22]. These human groups that inhabited the ecotone and steppe centered their economy and subsistence on the guanaco (*Lama guanicoe*) hunting, complemented sporadically with resources from the forest [33]. It is also an extremely different habitat, desertic except in the rivers valleys. The classical stylistic content of its rock art is dominated by animal and human footprints with simple geometrical motifs that are coherent with the archaeological background that postulates a minimum age of this rock art in 4000 years BP, produced with a particular engraving technique [14]. However, although it contains many geometrical patterns, such as frets, they are very different from the similar geometrical patterns found in forests. Again, our analysis was able to identify the steppe as one of the unique communities.

North of Neuquén and Steppe were mostly identified as the same communities by both algorithms (leading eigenvector and Louvain). The Forest community (leading eigenvector) deserves special attention, since it was split by Louvain into two communities (Nahuel Huapi and Valleys): this has archaeological implications. From a biogeographic perspective, the southern half of Neuquén has a phytogeographic transition (ecotone between the Patagonian forest and the steppe). It was revealed by the Louvain method that it has differences in the communities of sites and motifs, as if it were a transitional region. The traditional archaeological studies have shown that the forest and lakes environments of the south of Neuquén and Río Negro provinces, especially from the Manso river to Nahuel Huapi and Lacar lakes, possesses a unique and different fret rock art style, called *Modality of the Forest and Lake Area* [34, 35]. This style was related to hunter-gatherer groups with aquatic mobility, well adapted to lacustrine environments, and it has been used as an archaeological indicator to mark the differences with hunter-gatherer groups with pedestrian mobility that inhabited the ecotone and the neighboring steppe [35]. Even if the fret style is ubiquitous in both environments, there are several differences in terms of the morphology, techniques and colors of their composing motifs. In the former case, the basin of Manso river, Nahuel Huapi and Lacar lakes, fret style motifs are usually monochromatic red and mostly made with painting techniques [36, 37, 38, 39], with a transition to polychromy in the valley of the Traful river [38, 39] (ecotone), and are definite polychromous in the steppe [40]. This difference could be explained not only from a point of view of the availability of raw materials, but also as an intentional cultural choice. It is remarkable that, even though all this cultural and stylistic information was not loaded into the
database used to build the network of sites, the modularity analysis was able to
detect these subtle differences and find these two (sub-)communities.

Another interesting result of the split into two communities of the southern half
of Neuquén is the presence of nodes (sites) with large betweenness centrality (the
size of the symbols in Fig. 5), which also has possible archaeological implications.
In particular, the Huechahue site has the highest centrality and it is located pre-
cisely at the ecotone region in one of the valleys that connects the Andes with the
steppe. As we saw, this is both a biogeographic transition and a boundary between
site communities. This high centrality measure of the Huechahue site could be a
consequence not only of its geographically strategical position but also of its prob-
able role as an aggregation site, or a place were hunter-gatherer sub-groups met at
specific times of the year (e.g. seasonally, annually, etc.).

Regarding the network of motifs, the modularity analysis also produced relevant
communities that can be identified as stylistic entities. This automatic procedure
gives independent support to analyze the existence of different modalities within
the fret style, about which there is an ongoing controversy [11, 41]. In this case, we
were able to distinguish quantitatively and qualitatively the differences expressed
between the motifs found in the forest and those belonging to the ecotone and
steppe environment. In the case of the first (see Appendix II), we verified that
the presence of anthropomorphs and zoomorphs is a clear signal that characterizes
the forest’s rock art. In addition, Module 2 presented more variety of geometrical
motifs than expected for its environment, because the stylistic modality of the forest
was defined as consisting predominantly of figurative motifs [22]. This allows us
to attempt a redefinition of the repertoire of motifs belonging to the traditional
Modality of the Forest and Lake Area. However, it should be noted that this
difference may also be due to a sample bias, not only because we focused on the
west side of Neuquén province, but also because the forest environment has better
records and more publications of archaeological sites. On the latter (see Appendix
II, Module 3), we identified and verified that the fret motifs are more complex and
accompanied by simple geometric and figurative motifs, which implies a greater
diversity, possibly due to the differences observed in terms of the history of human
occupation of the steppe during the last 4000 years BP.

5 Conclusion

The application of network analysis to the rock art database of Northern Patag-
onia brings new insight in two important ways. Firstly, we want to highlight the
methodological aspect of community detection as a formal method to identify possi-
ble anthropological and archaeological processes at different spatial scales. This
methodological innovation allows us to visualize and discriminate clusters of sites
and motifs in a suprarregional scale, which is not a common approach in rock art
studies of Patagonia.

The detection of communities in rock art studies could serve as a first step to
discover in which manner the repertoire of sites and motifs are distributed and
linked through the landscape, and which sites could have particular properties or
roles within the network. In our case, the communities were coherent with the archaeological background of hunter-gatherers of Northern Patagonia. This type of analysis will allow us to generate hypotheses about the relevance of certain sites or sets of sites within the network, to be contrasted with other lines of evidence and archaeological models of land use, mobility and subsistence.

Finally, the most challenging and promising issue that network analysis of rock art can provide is the detection of the variability of the rock art record, which cannot be visualized or identified with traditional archaeological methods. Such is the case of those sites or group of sites which do not fit into the regional styles or repertoires previously established and with traditional consensus in the academic arena. As was mentioned by Taçon [42], we need to pay attention to those sites that are in between two or more well known regional styles, in order to achieve a more accurate interpretation on their role in past hunter-gatherer systems. The relational approach of network analysis and specifically of community detection is a fruitful path to explore, as well as their implication into regional archaeological debates.

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Appendix I

Communities of the network of sites, according to the leading eigenvector and the Louvain methods. The sites are derived from a compilation of bibliography and new surveys performed by one of the authors (F. E. Vargas), and are described in full in [5].

Leading eigenvector method.

North of Neuquén: Abrigo de las Mosquetas, Abrigo de las Torcazas, Agua escondida, Alero Coliguay, Butalón Norte, Cajón de Flores, Cañada de las Minas, Casa de Piedra, Caverna de los Gatos, Cerro de las Brujas, Colomichico (E y G), Corral 1, El Chacay, Estancia Jones, Las Chaquiras, Los Barrales 1, Los Barrales 2, Los Radales, Mata Molle, Mogotillos Arriba, Molulco-Mogotillos, Pampa Linda, Parque Diana, Paso Valdez, Piedra Bonita, Pozo del Loro, Puesto Marchan, Rincón de Las Papas.

Steppe: Arroyo Llano Blanco, Aguada del Carrizal, Alero de la Vizcacha, Alero La Marcelina, Alero La Pava, Alero Larriviere, Cañadón de Santo Domingo,
Cancha Huinganco, Casa de Piedra Ortega, Cerro Nonial, CH1-CNG1-CNG3-CY-PC5-PC6-PdT2-PdT3-PdT4, Chocón Chico, cueva del Cañadón de la Piedra Pintada, Cueva Epullán Chica, Cueva Epullán Grande, Cueva Visconti, El Manantial, La Medialuna, La Oquedad, Los Chenques II, Los Grabados, Los Rastros, Malal Huaca o Arroyo Mala Vaca, Paredón Las Lajitas, Peña Haichol, Piedra Pintada, Piedra Pintada del Manzanito, Planicie Bandera, Portada Covunco, Puerto Tranquilo IX, Puesto Bustingoria, Quili Malal.

**Forest:** Abra Ancha, Abra Grande, Abrigo de las Cruces, Abrigo de Media Falda, Abrigo del Ciervo, Abrigo del Risco, Abrigo Loma Alegre, Agua del Pino, Alero las Mellizas, Alero Los Cupreses, Alero Maqui, Aleta (Puesto Muñoz), Antepuerto (iv 8), Arroyo Seco, Bahía López, Bajada de la Arena, Campamento 2, Casa de Piedra de Curapil, Catritre 1, Cementerio Río Limay, Cerro Abanico, Cerro Carbón, Cerro El Huecu, Cerro Leones, Chacay Melehue I, Chacay Melehue II, Chacay Melehue IV, Chape, Chenque Peluén, Cueva Alihuén, cueva Picañor, Cuevas Gadianas, Curruhuioca 1, El Chenque 1, El Chenque 2, El Chenque M de la Barba Negra, El Crucero, El Monito, El Trébol, Estancia Chacabuco, Extremo SO (iv 10), Gingins, Huechahue, La Ramadilla, Lago Guillelmo, Lago Moreno, Laguna del Pescado (iv 7), Los Rápidos Nariz del Diablo 1, Nichos 1 y 2, Norte de Puerto Pampa (iv 5), Norte de Puerto Pampa (iv 6), Norte de Puerto Vargas (iv 3), Paredón Bello, Paredón con arte (PTA 4), Piedra del Maqui, Piedra Trompul, Potro de la Bahía, Puente de Tierra (iv 9), Puerto Anchorena (iv 8a), Puerto Chaval 2 (Nariz del Diablo II sensu Pedersen), Puerto Tigre, Puerto Tranquilo I (iv 2a), Puerto Tranquilo III (iv 2), Puerto Tranquilo VI, Puerto Tranquilo VII, Puerto Vargas (iv 4), Punta Verde (iv 1), Quebrada de la Piedra Pintada, Queutre-Inalef, Quila Quina 1, Rincón Chico, Río Minero I, Río Minero II, Villa Coihues.

**Louvain method.**

**North of Neuquén:** Abrigo de las Mosquetas, Abrigo de las Torcazas, Abrigo del Risco, Alero Coliguay, Butalón Norte, Cajón de Flores, Cañada de las Minas, Casa de Piedra, Caverna de los Gatos, Cerro de las Brujas, Colomichico (E y G), Corral 1, El Chacay, Estancia Jones, Laguna del Pescado (iv 7), Las Chaquiras, Los Barriales 1, Los Barriales 2, Los Radales, Mogotillos Arriba, Molulco-Mogotillos, Pampa Linda, Paso Valde, Piedra Bonita, Pozo del Loro, Puesto Marchan, Rincón de Las Papas.

**Steppe:** Arroyo Llano Blanco, Aguada del Carrizal, Alero de la Vizcacha, Alero La Marcelina, Alero La Pava, Alero Larrievier, Cañadon de Santo Domingo, Cancha Huinganco, Casa de Piedra Ortega, Cerro Nonial, CH1-CNG1-CNG3-CY-PC5-PC6-PdT2-PdT3-PdT4, Chacay Melehue I, Chocón Chico, cueva del Cañadón de la Piedra Pintada, Cueva Epullán Chica, Cueva Epullán Grande, Cueva Visconti, El Manantial, La Medialuna, La Ramadilla, Los Chenques II, Los Grabados, Los Rastros, Malal Huaca o Arroyo Mala Vaca,
Mata Molle, Paredón Las Lajitas, Parque Diana, Peña Haichol, Piedra Pintada, Piedra Pintada del Manzanito, Planicie Banderita, Portada Covunco, Puerto Tranquilo IX, Puesto Bustingorria, Quili Malal, Rincón Chico, Villa Coihues.

**Nahuel Huapi:** Abra Ancha, Abrigo de las Cruces, Abrigo de Media Falda, Abrigo Loma Alegre, Alero las Mellizas, Aleta (Puesto Muñoz), Antepuerto (iv 8), Bahía López, Campanario 2, Catritre 1, Cementerio Río Limay, Cerro Abanico, Cerro Leones, Chacay Melehue II, Chacay Melehue IV, Chape, Chenaque Pehuén, Cueva Picaflor, Cuevas Gaudianas, Curruhuinca 1, El Chenque M de la Barba Negra, El Cruce, El Monito, El Trébol, Extremo SO (iv 10), Gin-gins, Lago Guillelmo, Lago Moreno, Nariz del Diablo 1, Nichos 1 y 2, Norte de Puerto Pampa (iv 6), Norte de Puerto Vargas (iv 3), Piedra del Maqui, Piedra Trompul, Puente de Tierra (iv 9), Puerto Anchoarena (iv 8a), Puerto Chavol 1, Puerto Chavol 2 (Nariz del Diablo II sensu Pedersen), Puerto Tigre, Puerto Tranquilo I (iv 2a), Puerto Tranquilo VI, Puerto Tranquilo VII, Puerto Vargas (iv 4), Punta Verde (iv 1), Queutre-Inalef, Quila Quina 1, Río Minero I.

**Valleys:** Abra Grande, Abrigo del Ciervo, Agua del Pino, Agua Escondida, Alero Los Cipreses, Alero Maqui, Arroyo Seco, Bajada de la Arena, Casa de Piedra de Curapil, Cerro Carbón, Cerro El Huecu, Cueva Alihuén, El Chenque 1, El Chenque 2, Estancia Chacabuco, Huechahue, La Oquedad, Los Rápidos, Norte de Puerto Pampa (iv 5), Paredón Bello, Paredón con arte (PTA 4), Potrero de la Bahía, Puerto Tranquilo III (iv 2), Quebrada de la Piedra Pintada, Río Minero II.

**Appendix II**

Communities of the network of motifs, called “modules” in this work, according to the leading eigenvector and the Louvain methods. The sites are derived from a compilation of bibliography and new surveys performed by one of the authors (F. E. Vargas), and are described in full in [5].

Leading eigenvector method (fig rhombus and fig H disconnected and unclassified).

**Module 1:** Simple geometric, zoomorph, hand- and footprints. circle, concentric circles, associated circles, complex triangle + circles + rhombi assoc, stairlike, indet combined strokes, fig L, axial sym, phytomorphic, straight line + short trans append, parallel lines, winding parallel lines, zig-zag parallel lines, straight lines, segmented lines, sinuous lines, zig-zag, hands, irreg oval, feline footprint, guanaco footprint, human footprint, points, grouped points, aligned points, reticulate, rhombi, triangles, aligned triangles, tridigit, zoomorphic bird, zoomorphic quadruped, indet zoomorphic.

**Module 2:** Antropomorph, complex geometric. anthropomorphic, anthropo-zoomorphic, finger slide, finger + palm slide, bidigit, circle + lines, circle
+ appendix, side-by-side circles, side-by-side circles + appendix, circles + radial appendices, side-by-side conc circles, conc circles + appendix, conc circles + inside element, joined circles, circle + inside element, clepsydra, clepsydra + inside element, cruciform, cruciform + appendices, cruciform + inside & outside elements, grouped cruciform, conc cruciform, double cruciform, stairlike cruciform, irreg cruciform, triple cruciform, joined cruciform, squares, side-by-side squares, squares + inside element, segmented squares, framed, irreg framed, zig-zag framed, spiral + geometric, star, arc, arc + inside element, square + inside element, concentric squares, fig stalklike, geometric indet, fig I, fig curved lines, fig horiz + vert lines, fig broken lines, fig 8, fig 8 + inside element, fig orthog stalklike, pentagonal, straight line + appendices, straight lines indet, sinuous fig + inside elements, fig T, fig trapezoidal, fig triangular, triangled rhomboidal fig, fig U, fig V, fig invert Y, linear crenelated, linear X-like, linear Y-like, fret, double fret, stalklike fret, irreg fret, irreg fret + inside element, dashes, hole, hole + lines, rider, labyrinth, stalklike labyrinth, irreg labyrinth, square labyrinth, angled lines, curved lines, curved lines + radial appendices, stalklike lines, orthogonal lines, orthogonal + curved lines, broken lines, straight lines + dashes, sinuous lines w appendix, spots, eye-like oval, oval + appendices, oval + inside element, oval + lines, pointlike circular, dots, rectangles, rectangles w appendices, rectangles w inside elements, conc rectangles, filled rectangles, segmented rectangles, rhombi w appendices, stalklike rhombi w inside elements, segmented rhombi, semicircle, triangles + circle, side-by-side triangles, stalklike triangles, cruciform stalklike triangles, opposite triangles, tridigit + circles + appendices, zoomorphic + stalklike, zoomorphic frog, zoomorphic guanaco, zoomorphic snake.

Louvain method (fig rhombus and fig H disconnected and unclassified).

Module 1: Simple geometric, zoomorphic, hand- and footprints circle, stalklike, indet combined strokes, fig L, axial sym, phytomorphic, square labyrinth, straight line + short trans append, orthogonal + curved lines, parallel lines, winding parallel lines, zig-zag parallel lines, straight lines, segmented lines, sinuous lines, zig-zag, hands, oval + appendices, oval + inside element, oval + lines, feline footprint, guanaco footprint, human footprint, points, grouped points, aligned points, rectangles w appendices, reticulate, rhombi, triangles, aligned triangles, tridigit, indet zoomorphic.

Module 2: Antropomorph and complex geometrical. anthropomorphic, anthropozo...
stairlike, sinuous fig + inside elements, fig trapezoidal, fig triangular, tri-
ang rhomboidal fig, fig V, fig invert Y, linear crenelated, linear X-like, frte
key, double fret, irreg fret, dashes, rider, labyrinth, stairlike labyrinth, curved
lines, curved lines + radial appendices, stairlike lines, orthogonal lines, broken
lines, straight lines + dashes, spots, oval, pointlike circular, dots, rectangles,
rectangles w inside elements, filled rectangles, segmented rectangles, stairlike
rhombi w inside elements, triangles + circle, side-by-side triangles, stairlike
triangles, cruciform stairlike triangles, opposite triangles, zoomorphic + stair-
like, zoomorphic bird, zoomorphic quadruped.

Module 3: Complex circles and undulated. bidigit, circle + appendix, side-by-side circles, circles + radial appendices, conc circles + appendix, conc circles + inside element, cruciform + inside&outside elements, joined cruciform, concentric squares, fig stairlike, fig horiz + vert lines, fig broken lines, fig 8 + inside element, pentagonal, straight line + appendices, straight lines indet, fig T, fig U, stairlike fret, irreg fret + inside element, irreg labyrinth, angled lines, sinuous lines w appendix, eye-like irreg oval, rhombi w appendices, seg-
mented rhombi, semicircle, tridigit + circles + appendices, zoomorphic frog, zoomorphic snake.

Module 4. Circle + lines, side-by-side conc circles, joined circles, associated cir-
cles, grouped cruciform, conc cruciform, zig-zag framed, fig curved lines, linear
Y-like, hole, hole + lines, conc rectangles, zoomorphic guanaco.

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