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ANDEAN SUMMER-BREAK: ROCK ART INSIGHTS ON INFORMATION NETWORKS AND SOCIAL INTERACTION IN A DESERT-HIGHLAND INTERFACE IN NORTHERN PATAGONIA (SOUTH AMERICA)

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Abstract

The Andes mountain range is one key physiographic feature of South America. Since the highlands are a very productive ecosystem only accessible in the summer, they may have been likely occupied during this season by human groups coming from different low-altitude areas in both slopes. The goal of this paper is to delve into trans-Andean social interaction and high-altitude human occupation strategies during the last 3000 years, which is a key period witnessing the inscription of the southern Andean landscape trough the execution of rock art. We develop a regional case study focused on a desert-highland interface in northwestern Patagonia (Argentina and Chile, 36-37ºS), which shows striking biogeographic and archaeological differences between both slopes. This case is based on the combination of two main lines of research: a) GIS landscape-modeling integrating seasonality and least cost paths to address connectivity between Andean highlands and lowlands and b) rock art macroregional trends to assess the materialization of information networks over the landscape. The results of our spatial analysis show that northwestern Patagonia has a high degree of environmental variability that entails changing connectivity profiles along the annual cycle, creating different scenarios in terms of insularity and risk for human populations. On this basis, the analysis of human informational networks as encoded in rock art suggests the existence of visually hierarchized environments that may have played a key role at a macro-regional scale. Overall, these results contribute to expand the discussion on human social networks and information exchange strategies deployed between highlands and their surrounding lowlands considering the role of landscape connectivity.

Keywords

Andean highlands – GIS spatial analysis – Rock art – Landscape connectivity – Social interaction
Information networks

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Introduction and Goals

The Andes mountain range is a ubiquitous physiographic feature of South America, extending 7500 km along the western margin of the continent[1]. On its southern portion, corresponding to Patagonia, the Andes present mean altitudes around 2500-3000 masl.

These high elevations combined with macro-regional climate patterns favor a climate characterized by a marked seasonality. On one hand, the lowlands located in both sides of the Patagonian Andes are available for human occupation year-round.

On the other, the highlands can only be accessed for a few months during the summer season when, due to the local water availability, they turn into a very productive ecosystem[2]. During winter, these high-altitude spaces are covered with snow affecting their productivity, habitability and potential for trans-Andean circulation. Taking this into account, the highlands may have been likely accessed and occupied during the summer by human groups coming from different areas in both slopes.

The great complexity of the Andean landscape has been a central topic of archaeological inquiry, which has focused on understanding the patterns of human use and articulation of its different environments for decades[3].

Considering the existence of striking biogeographic and seasonal differences between these environments, the issue of social interaction and information flow among human groups occupying the Andes and its surroundings becomes significant.

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[1] C. Clapperton, Quaternary Geology and Geomorphology of South America (Amsterdam: Elsevier, 1993).

[2] R. Barberena et al., "Espacios internodales en Patagonia septentrional: biogeografía, información y mecanismos sociales de interacción", Estudios Atacameños num 56 (2017a): 57-75.

[3] M. Aldenderfer, "Altitude Environments in Archaeology", in Encyclopedia of Global Archaeology, eds. C. Smith (New York: Springer-Verlag, 2014), 163-168; R. Barberena *et al*., Espacios internodales… 57-75; R. Barberena et al, "Scale of human mobility in the southern Andes (Argentina and Chile): a new framework based on strontium isotopes", American Journal of Physical Anthropology num 164 (2017b): 305-320; J. M. Capriles et al., "High altitude adaptation and late Pleistocene foraging in the Bolivian Andes", Journal of Archaeological Science Reports num 6 (2016): 463-474; V. Durán et al., "Arqueología del Área Natural Protegida Laguna del Diamante (Mendoza, Argentina)", Anales de Arqueología y Etnología num 61 (2006): 81-134; V. A. Durán et al., "To and fro: the southern Andean highlands (Argentina and Chile): Archaeometric insights on geographic vectors of mobility", Journal of Archaeological Science Reports num 18 (2018): 668-678; H. Lagiglia, Arqueología de Cazadores-Recolectores Cordilleranos de Altura (San Rafael: ICN Ediciones Ciencias y Arte, 1997); G. Lucero, "Biogeografía y paleoecología humana de tierras altas: subsistencia y tecnología en el Valle del Río de las Taguas (Departamento de Iglesia, Provincia de San Juan)" (Tesis de Doctorado en Geografía, Universidad Nacional de Cuyo), 2015, MS; G. Lucero et al, "Rutas Prehistóricas en el NO de San Juan: una propuesta macrorregional desde los Sistemas de Información Geográfica". En V. Cortegoso and V. Durán (eds.), Arqueología de ambientes de altura de Mendoza y San Juan (Argentina). Colección Encuentros num 3 Ediunc (Mendoza: EDIUNC, 2014), 275-305; J. Murra, El 'control vertical' de un máximo de pisos ecológicos en la economía de las sociedades andinas (Huánuco: Universidad Nacional Hermilio Valdizán, 1972), 427-468; G. Neme, "El Indígeno and high-altitude human occupation in the southern Andes, Mendoza (Argentina)", Latin American Antiquity num 27 (2016): 96-114; Rademaker, K., Hodgins, G., Moore, K., Zarrillo, S., Miller, C., Bromley, G. R., Leach, P., Reid, D. A., Álvarez, W. Y. and Sandweiss, D. H., "Paleoindian settlement of the high altitude Peruvian Andes", Science num 346 (2014): 466-469; G. Romero Villanueva, "Biogeografía humana y circulación de información en el norte del Neuquén. Un análisis arqueológico sobre la comunicación visual en grupos cazadores-recolectores del noroeste de Patagonia" (Tesis Doctorado en Arqueología, Facultad de Filosofía y Letras, Universidad de Buenos Aires) 2019, MS; among others.

In this context, the general aim of this paper is to delve into high-altitude human occupation strategies and trans-Andean social interaction in a desert-highland interface in northwestern Patagonia (Argentina and Chile, 36-37ºS) during the last 3000 years, which is a key period witnessing the inscription of the southern Andean landscape trough the execution of rock art, among other significant organizational changes[4]. To tackle this issue, we combine two lines of research.

First, we develop a reconstruction of seasonality and least cost paths through Geographic Information Systems (GIS) to address *landscape connectivity* among Andean highlands and surrounding lowlands. Second, we analyze the macroregional distribution of rock art in this geographic framework as a proxy of the materialization of *information networks* over the landscape[5].

We argue that these networks can inform about human strategies regarding *social interaction* and *information exchange* in high-altitude environments, and also about the complementary use of ecologically diverse environments, including the highlands[6].

1. Environmental setting and archaeological background

1.1. Environmental setting

The macro-region of study is located in northwestern Patagonia (South America, 36-37°S) (Figure 1). It includes lowlands located in both sides of the Andes as well as a segment of the Andean mountain range of Argentina and Chile with a west-east width of *ca*. 250 km. The interaction of the westerly storm-tracks with the Andes and the Cordillera del Viento range results in an orographic rain-shadow effect that produces a strong west-east decrease in precipitation[7]. Rainfall decreases with altitude in both sides of the Andes and vegetation distribution follows this gradient[8].

[4] G. Romero Villanueva, Biogeografía humana y circulación de información…

[5] R. Barberena et al., Espacios internodales… 57-75; G. Romero Villanueva, Biogeografía humana y circulación de información…

[6] M. Aldenderfer, Altitude Environments in Archaeology… 163-168.

[7] R. D. Garreaud et al, "Present-day South America climate", Palaeogeography. Palaeoclimatology. Palaeoecology num 281 (2009): 180-195.

[8] E. Abraham et al., "Overview of the geography of the Monte Desert biome (Argentina)", Journal of Arid Environments num 73 (2009): 144-153; F. A. Roig et al., "Biogeography of the Monte Desert", Journal of Arid Environments num 73 (2009): 164-172; C. I. Ruiz Silva, "Propuesta de Planificación Ecológica para el sector Laguna Del Maule y el Corredor Pehuenche en relación a la Ruta Internacional 115-CH. Comuna de San Clemente, Región del Maule", (Memoria para Geógrafo, Escuela de Geografía, Facultad de Arquitectura y Urbanismo, Universidad de Chile) 2010.

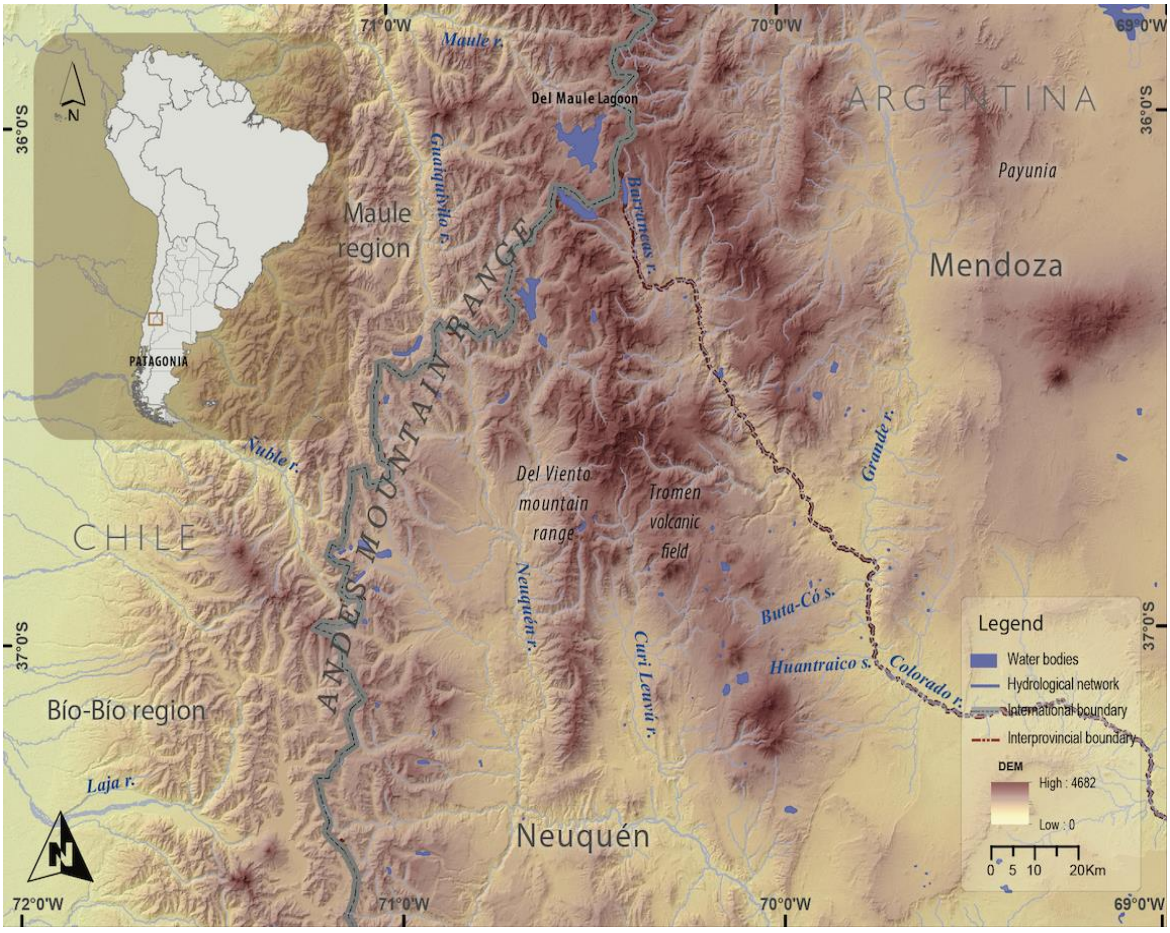

Figure 1
Northwestern Patagonia study region (South America, 36-37°S).
References: r = river and s = stream

The Andean highlands are characterized by large amounts of winter precipitation and by the presence of localized wetlands with high quality summer pastures that attract mammal species and bird communities seasonally (Figures 1 and 2)[9]. This is the case of Laguna del Maule, a location that coincides with the primary outcrops of a primary obsidian source (Figure 2, references A and B)[10]. The western Andean slope is mainly characterized by a temperate Mediterranean climate influenced by the Pacific Ocean (Csb *sensu* Sarricolea *et al*., 2017[11] based on modified Köppen-Geiger system) (Figure 2C), while the eastern slope is dominated by arid climates with lower precipitations (bsk and bwk types *sensu* Kottek *et al*., 2006[12]) (Figure 2, references D and E).

[9] R. Barberena et al., Espacios internodales… 57-75; C. I. Ruiz Silva, Propuesta de Planificación Ecológica…

[10] R. Barberena et al, "Deconstructing a Complex Obsidian Landscape in Northwestern Patagonia: A Geoarchaeological and Geochemical Approach", Geoarchaeology num 34 (2019): 30-41; A. Seelenfreund et al, "Trace element analysis of obsidian sources and artifacts of central Chile (Maule River basin) and western Argentina (Colorado River)", Latin American Antiquity num 7 (1996): 7-20.

[11] P. Sarricolea, M. J. Herrera-Ossandon and Ó. Meseguer-Ruiz, "Climatic regionalisation of continental Chile", Journal of Maps num 13-2 (2017), 66-73.

[12] M. Kottek et al., "World Map of the Köppen-Geiger climate classification updated", Meteorologische Zeitschrift num 15-3 (2006): 259-263.

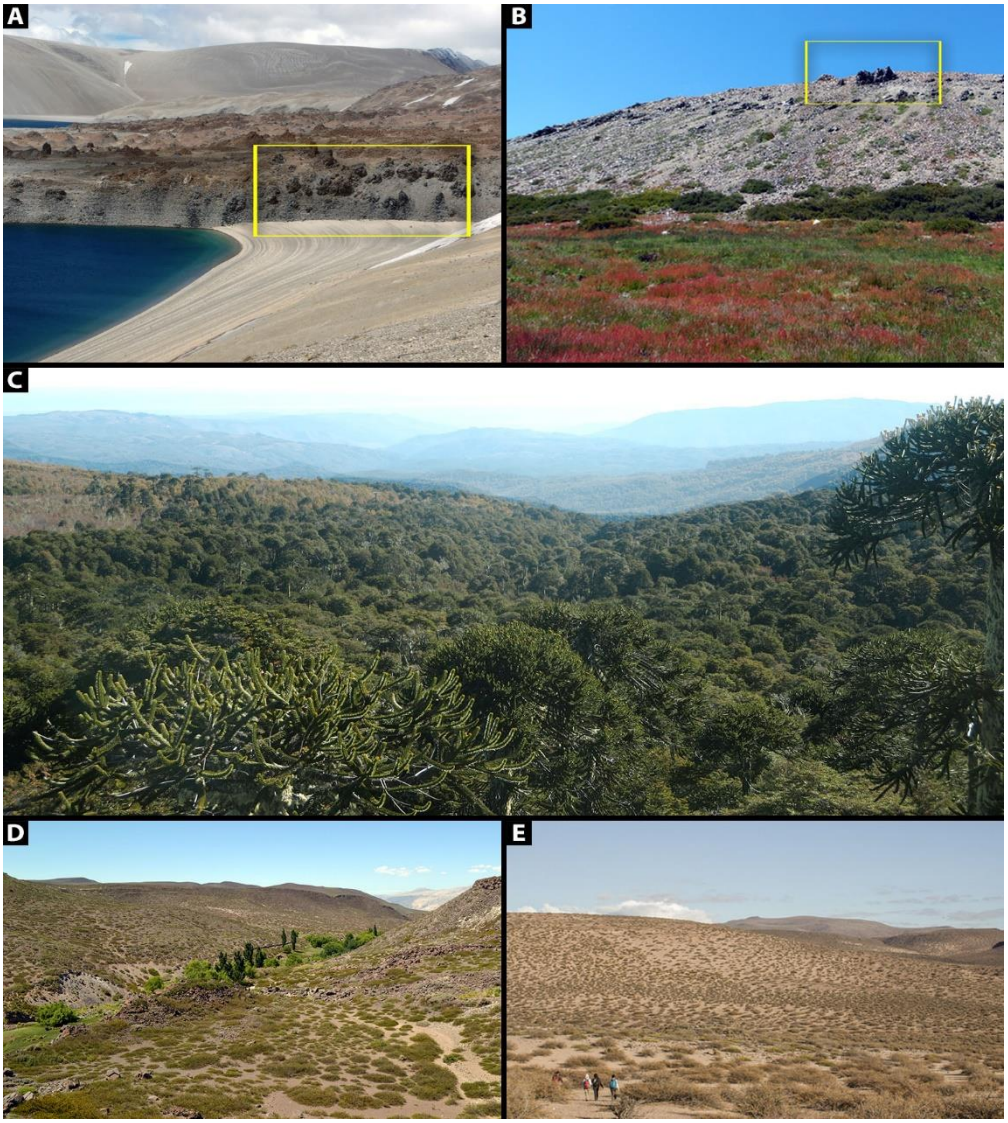

Figure 2
Environmental setting of northwestern Patagonia. A and B: Laguna del Maule, located in a high-altitude environment, is visible on the image with associated obsidian sources and wetlands; C: typical landscape of the western Andean slope in current Chilean territory; D and E: views of eastern Andean steppe and desert landscape, in currently Argentinean territory
Credits A and B: Ángela Peñaloza

1.2. Archaeological background

We have been carrying out research to assess the scale of human paleomobility and ecological complementarity across southern Andean deserts and highlands, particularly during the last 3000 years[13]. Following a human biogeography approach[14], we are interested in

[13] R. Barberena, "Biogeografía, competencia y demarcación simbólica del espacio: modelo arqueológico para el norte de Neuquén", Intersecciones en Antropología num 14 (2013): 367-381; R. Barberena, "Cueva Huenul 1 Archaeological Site (Northwestern Patagonia, Argentina): Initial Colonization and mid-Holocene Demographic Retraction", Latin American Antiquity num 26 (2015): 304-318; R. Barberena et al., Espacios internodales… 57-75; R. Barberena et al., Deconstructing a Complex Obsidian Landscape...,

studying the past spatial-temporal distribution of human populations in relation to the structure of the Patagonian landscape, and in assessing its influence on long-term historical processes.

The region under study witnessed a number of key historical processes beginning with the initial human colonization during the Pleistocene-Holocene transition[15], mid-Holocene occupational plateaus[16], and the systematic marking of the landscape trough the execution of rock art, mainly during the late Holocene[17].

Overall, the archaeological record shows an acceleration of behavioral changes during the last 3000 years, including aspects of technological and economic organization. Since this time there is an evident divergence in the archaeological record of the Pacific and Atlantic sheds. While societies from the eastern side remained largely mobile and based on a hunter-gatherer economy[18], the archaeological record from the western lowlands suggest more settled societies where horticulture was increasingly important through time and investment in diverse technologies such as ceramics and metallurgy increased as well[19]. However, it is important to emphasize that since the Maule region in Chile remains largely unexplored archaeologically, we base these comments on information available for contexts immediately southwards from this region[20]. Radiocarbon dating trends and DNA suggest a higher population density[21]. These late

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2019, 30-41; G. Romero and A. Re, "Representaciones rupestres del noreste de Neuquén (Patagonia septentrional). Primeras tendencias espaciales y temporales", Comechingonia Revista de Arqueología num 18-1 (2014): 73-92; G. Romero Villanueva, Biogeografía humana y circulación de información…; A. Rughini et al., "Arqueología distribucional, biogeografía y organización espacial humana: la localidad Barrancas-Buta Ranquil (provincia del Neuquén, Argentina)", Under review in: Latin American Antiquity (2019).

[14] M. M. Lahr and R. Foley, "Towards a Theory of Modern Human Origins: Geography, Demography, and Diversity in Recent Human Evolution", Yearbook of Physical Anthropology num 41 (1998): 137-176; M. V. Lomolino et al., Biogeography. Fourth Edition (Massachusetts: Sinauer Associates Inc. Sunderland, 2010); Millington, A. C., S. Walsh y P. Osborne, GIS and remote sensing applications in biogeography and ecology-2nd print (Boston, MA: Kluwer Academic Publishers, 2001).

[15] R. Barberena, Cueva Huenul 1 Archaeological Site… 304-318; G. Neme and A. Gil, "El registro arqueológico del sur de Mendoza en perspectiva biogeográfica". In G. Neme and A. Gil (comps.), Paleoecología humana en el sur de Mendoza: perspectivas arqueológicas (Mendoza: SAA, 2012), 255-279.

[16] R. Barberena, Cueva Huenul 1 Archaeological Site… 304-318; R. Barberena et al, The human occupation of northwestern Patagonia (Argentina): Paleoecological and chronological trends, Quaternary International num 356 (2015): 111-126; G. Neme and A. Gil, "Human occupation and increasing Mid-Holocene Aridity. Southern Andean perspectives", Current Anthropology num 50-1 (2009): 149-163.

[17] R. Barberena et al., Espacios internodales… 57-75; J. Fernández, "Estudios sobre el arte rupestre de la provincia del Neuquén", Anales de Arqueología y Etnología num 29-31 (1974-1976), 5-36; J. Fernández, "Las piedras con marcas de la cordillera del Viento. Arte rupestre en el departamento Minas, Neuquén, Argentina", (Buenos Aires: Sociedad Argentina de Antropología, 2000 [1979]); C. Gradin, "El arte rupestre del sur mendocino entre los siglos VIII y XV de la era ¿Un área de conflicto o de convivencia?", Relaciones de la Sociedad Argentina de Antropología num XXII-XXIII (1997-1998): 7-23; H. Niemeyer and L. Weisner, "Los petroglifos de la cordillera andina de Linares (Provincias de Talca y Linares, Chile)", in Actas del VI Congreso de Arqueología Chilena II (Santiago de Chile, 1972-1973), 405-470; G. Romero Villanueva, Biogeografía humana y circulación de información…; among others.

[18] R. Barberena et al., Espacios internodales… 57-75; R. Barberena et al., Scale of human mobility… 305-320.

[19] Adán et al., "Historia prehispánica en la región...; Campbell et al., "Obsidianas, turquesas y metales...", in press; see also Falabella et al., "Diversidad y heterogeneidad cultural...

[20] R. Barberena, Cueva Huenul 1 Archaeological Site…, 2015, 304-318; R. Barberena et al, The human occupation of northwestern Patagonia…, 2015, 111-126; R. Barberena et al., Espacios internodales…, 57-75; E. J. Marsh, "La fecha de la cerámica más temprana en los Andes sur. Una perspectiva

Holocene contexts resemble a first instance of 'effective occupation'[22] of the northwestern Patagonian landscape, which seems to have had an impact on mobility and the exploitation of resources. This is particularly evident when comparing the archaeological record from the two Andean slopes, which differ not only in terms of climate, but also in key physiographic properties including amount of available space and terrain ruggedness (Figures 1 and 2).

On a local scale, human use of the highlands is demonstrated by the presence of several artifacts made on Laguna del Maule 1-Laguna Negra obsidian, which so far has only been recorded geologically in the highlands of the Barrancas river[23] (Figure 1). Overall, this obsidian has been recorded archaeologically in the lowlands of the Barrancas-Colorado river basin[24]. Regarding rock art, the archaeological evidence registered in the highlands consists mainly in engravings, but also a few paintings that have been chronologically framed within the last 3000 years[25]. This lapse coincides with a marked increase in the number of archaeological sites across the Andes, as well as a regional pulse in the use of obsidian types from the highlands at this latitude (37°S) (unpublished data) and in adjacent Andean contexts to the north (34-36°S)[26] and south (40-41°S)[27], as well as in Chile[28].

We have previously developed a reconstruction of seasonality patterns for northwestern Patagonia through GIS[29] (Figure 3). The information from the area analyzed was averaged and, based on the resulting raster, we segmented the landscape into three altitudinal sectors. We estimated that the higher sectors of the study region located above 2000masl could only be occupied during four or five months per year, so they would not be appropriate to sustain year-round occupation (Figure 3, spaces colored in red). On the contrary, sectors below 1800masl allow year-round occupation (colored in wheat in Figure 3). Finally, the intermediate sectors (1800-2000masl) would function as ecotonal zones that can also be occupied annually but with a high-energy cost in winter (Figure 3, spaces colored in orange).

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macrorregional mediante modelos bayesianos", Revista del Museo de Antropología. Suplemento Especial 1 (2017): 83-94; G. Romero Villanueva, Biogeografía humana y circulación de información…; Rughini et al., Arqueología distribucional…; among others.

[21] R. Barberena et al, The human occupation of northwestern Patagonia… 111-126; S. I. Perez, P. N. Gonzalez and V. Bernal, "Past population dynamics in Northwest Patagonia: An estimation using molecular and radiocarbon data", Journal of Archaeological Science num 65 (2016): 154-160.

[22] L. A. Borrero, "Arqueología de la Patagonia", Palimpsesto. Revista de Arqueología num 4 (1994-1995): 9-56.

[23] R. Barberena et al, Deconstructing a Complex Obsidian Landscape … 30-41.

[24] R. Barberena et al, Deconstructing a Complex Obsidian Landscape … 30-41; D. D. Rindel et al., "Sources of obsidian artefacts, exchange networks and landscape use in Auca Mahuida (Neuquén, northwestern Patagonia)", Archaeometry (2019). In press:

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[26] R. Barberena et al., Scale of human mobility… 305-320; V. Cortegoso et al, "Geographic vectors of human mobility in the Andes (34-36°S): comparative analysis of 'minor' obsidian sources", Quaternary International num 422 (2016): 81-92.

[27] S. I. Perez et al., Past population dynamics in Northwest Patagonia… 154-160.

[28] R. Campbell et al., "Obsidian in archaeological sites on Mocha Island, southern Chile: Implications of its provenience", Journal of Archaeological Science Reports num 13 (2017): 617-624.

[29] R. Barberena et al., Espacios internodales… 57-75.

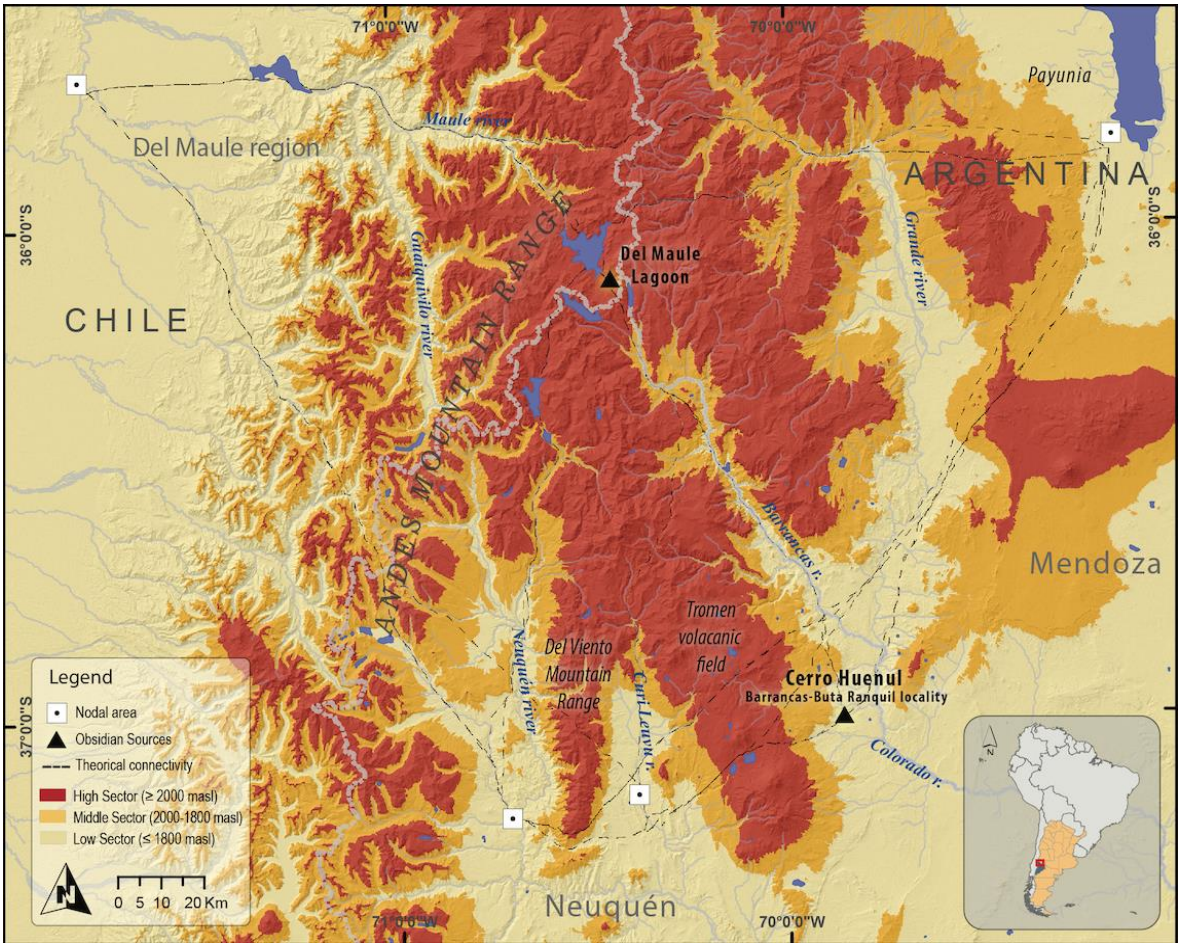

Figure 3
GIS seasonality reconstruction and probable nodal areas and internodal spaces in northwestern Patagonia during the late Holocene (taken from Barberena *et al*. 2017a[30])

From the perspective of human biogeography, the low-altitude settings of the study region (<1800masl) could have functioned as demographic *nodes* utilized more permanently for residential occupation[31]. On the other hand, the Andean highlands (>2000masl) could have worked as *internodal spaces*, occupied less permanently and basically during the summer season for multiple activities like intermountain mobility, hunting activities in highly productive summer ecosystems and lithic provisioning (spaces colored in red in Figure 3)[32]. These ecological and geographical attributes make those environments particularly adequate as loci for social interaction and information exchange. However, the previously observed seasonality patterns carry implications for the *geographical connectivity*[33] between probable nodal areas of northwestern Patagonia located in both Andean slopes. By considering new proxies, we are interested in exploring how this landscape fragmentation might have influenced long-term social interaction and information networks.

[30] R. Barberena et al., Espacios internodales… 57-75.
[31] R. Barberena et al., Espacios internodales… 57-75.
[32] R. Barberena et al., Espacios internodales… 57-75.
[33] B. Fitzhugh et al., "Modeling Variability in Hunter-Gatherer Information Networks: An Archaeological Case Study from the Kuril Islands". In R. Whallon, W. Lovis and R. Hitchcock (eds.), Ideas, Debates, and Perspectives 5. Information and its Role in Hunter-Gatherer Bands (Los Ángeles: Cotsen Institute of Archaeology Press, University of California Press, 2011), 85-115.

2. Materials and methods

2.1. Materials

We have analyzed more than 9000 rock art motifs recorded in over 100 sites from northwestern Patagonia (Figure 1 and Tables 2 and 3). Some of them were recorded by us while others were documented by colleagues (see Table 2 for references). The analytical variables considered were number of rock art sites and their altitude, number of rock art motifs, techniques, morphological categories, and motifs type. We also assessed the presence of other indicators that could provide temporal context, such as superimpositions and degrees of weathering and patina formation. For those areas for which there are no total counts of motifs, we based our analysis only on the sites that present the most appropriate and complete information.

The areas with rock art considered are, to the north of the study region, the upper basin of the Maule River (Maule region, Chile) and the Payunia volcanic field (southern Mendoza province, Argentina), while southwards of our research area they include the upper and middle basins of the Neuquén and Curi Leuvú river basins, as well as the Barrancas-Buta Ranquil locality, all of them located in northern Neuquén province, in Argentina (Figure 1). Since research in these areas is in different degrees of advance, the frequencies reported should be considered as minimum numbers. However, the main trends are strong and unlikely to be altered by an expansion of the database. Regarding its chronology, for comparative purposes at a macroregional scale, we assume a late Holocene chronology for most of them, as proposed by several authors mainly through relative dating methods (Table 3). However, recent evidence provided by absolute methods (AMS radiocarbon dating of four rock art motifs) showed that the execution of rock art in northwestern Patagonia started during middle Holocene times, when black comb-shaped motifs were painted in separate but recurrent episodes at Cueva Huenul 1 site, located in the Barrancas-Buta Ranquil locality[34].

2.2. Social interaction, information networks and rock art

Social networks are a key element in the constitution and social reproduction of human groups in general and mobile hunter-gatherers in particular[35]. Basically, they allow

[34] G. Romero Villanueva, Biogeografía humana y circulación de información…

[35] T. Aubry et al., "We will be known by the tracks we leave behind: exotic lithic raw materials, mobility and social networking among the Coa valley foragers (Portugal)", Journal of Anthropological Archaeology num 31 (2012): 528-550; M. Conkey, "The identification of prehistoric hunter-gatherer aggregation site: the case of Altamira", Current Anthropology num 21-5 (1980), 609-630; C. Gamble, "Interaction and Alliance in Paleolithic Society", Man New Series num 17-1 (1982), 92-107; M. Jochim, Hunter-Gatherer Subsistence and Settlement: A Predictive Model (New York: Academic Press, 1976); J. McDonald and P. Veth, "Information exchange amongst hunter-gatherers of the Western desert of Australia". In R. Whallon, W. Lovis and R. Hitchcock (eds.), Information and Its Role in Hunter-gatherer Bands. (Los Angeles: Cotsen Institute of Archaeology Press, 2011), 221-234; V. Scheinsohn, "Rock art information among hunter-gatherers in Northwest Patagonia: an assessment of environmental and territorial models In R. Whallon, W. Lovis and R. Hitchcock (eds.), Information and Its Role in Hunter-gatherer Bands. (Los Angeles: Cotsen Institute of Archaeology Press, 2011), 235-248; A. Troncoso et al., "Rock art and social networks among hunter gatherers of north-central Chile", Journal of Anthropological Archaeology num 42 (2016): 154-168; R. Whallon, "Social networks and information: non utilitarian mobility among hunter-gatherers", Journal of Anthropological Archaeology num 25 (2006): 259-270; R. Whallon, "An introduction to information and its role in hunter-gatherer bands In R. Whallon, W. Lovis and R.

to establish bonds of communication, information exchange, cooperation, integration, and segregation at different scales among different social units dwelling in a particular landscape. In some cases, as Whallon[36] has suggested, these bonds can act as *safety nets*, crucial for the social endurance.

From a biogeographic perspective, we explore the role that landscape structure played in the long-term constitution of these networks by considering the variable degrees of connectivity among its different environmental regions[37]. In relation to this, some authors have proposed a close relationship between environmental uncertainty and the intensity of network connectivity[38]. Particularly, they have argued that potentially risky environments favor more open and connected networks, favoring cooperation and associativity between different mobile groups[39]. Importantly here, risk may operate in different temporal scales. For instance, it can be argued that the seasonal unavailability of the highlands due to snow cover is a risk factor by reducing the possible paths of human circulation and communication. While this may certainly be so, this constitutes a predictable phenomenon that occurs on an annual basis and can thus be considered as less risky. However, there is climatic information for the last centuries showing that snow precipitation in the southern Andes is determined by multiple forcing factors with different cycles, making it difficult to predict years with unexpectedly high or low snow cover, as well as the possible occurrence of early snow precipitation events during the annual cycle[40]. The years characterized by unusually high and/or early occurring winter precipitation may represent an uncertainty, in terms of the difficulty to predict it. The mobile and low demography groups inhabiting the eastern Andean shed would have been particularly sensitive to these events.

To begin to unravel the complexity of this relationship, in this paper we discuss differences in the degree and intensity of hunter-gatherer information networking between the Patagonian highlands and lowlands as strategic responses to environmental variability and interaction costs[41].

Hitchcock (eds.), Information and Its Role in Hunter-gatherer Bands (Los Angeles: Cotsen Institute of Archaeology Press, 2011), 1-28.

[36] R. Whallon, Social networks and information…, 2006, 259-270; R. Whallon, An introduction to information… 1-28.

[37] R. Barberena et al., Espacios internodales… 57-75; G. Romero Villanueva, Biogeografía humana y circulación de información…

[38] C. Gamble, Interaction and Alliance in Paleolithic Society… 92-107; V. Scheinsohn, Rock art information among hunter-gatherers in Northwest Patagonia… 235-248; R. Whallon, Social networks and information… 259-270; R. Whallon, An introduction to information… 1-28.

[39] D. Nettle, "Explaining global patterns of language diversity", Journal of Anthropological Archaeology num 17 (1998): 354-374.

[40] M. H. Masiokas et al., "Snowpack Variations since AD 1150 in the Andes of Chile and Argentina (30°–37°S) Inferred from Rainfall, Tree-Ring and Documentary Records. Journal of Geophysical Research: Atmospheres num 117-5 (2012): R. B. Urrutia et al., "Multicentury Tree Ring Reconstruction of Annual Streamflow for the Maule River Watershed in South Central Chile: tree ring reconstruction of the Maule watershed". Water Resources Research num 47-6 (2011): I. A. Mundo et al., "Multi-Century Tree-Ring Based Reconstruction of the Neuquén River Streamflow, Northern Patagonia, Argentina". Climate of the Past num 8-2 (2012): 815-829.

[41] B. Fitzhugh et al, Modeling Variability in Hunter-Gatherer Information Networks… 85-115.

2.3. Least cost path analysis (LCP) and landscape connectivity

Modeling of human routes using GIS based on topography has been applied in different South American environments[42]. In the region under study, characterized by striking topographic and seasonal differences, other variables such as temperature, rainfall, and extreme or limiting factors are also relevant[43]. LCP analysis is a methodology suitable to model and study mobility patterns in heterogeneous landscapes, since they can identify the optimal transit alternative from a place of origin to one or multiple destinations based on several variables[44].

We employed multiple origin/destination LCP to model travel costs among probable nodal areas of northwestern Patagonia[45]. The nodal areas considered are the lower basin of Maule river (Maule region, Chile), the lower altitude spaces of the Payunia volcanic field (southern Mendoza province, Argentina), and the lower and middle basins of the Neuquén and Curi Leuvú river (Neuquén province, Argentina) (Figure 1). We also mapped regionally available obsidian sources such as Laguna del Maule and Cerro Huenul. In this analysis, each cell has a resistance value related to the difficulty of moving across the cell, which is related with the topographic characteristics of the environment modeled from digital elevation models (DEM). Based on the resistance map, this tool builds a network and calculates cost-weighted distances and least-cost paths.

The digitalized movement simulations imply a variable cost that can be expressed in distance, time or energy. In our case study, we produced an anisotropic cost/friction surface through the ArcGIS 10.4. The anisotropic cost relates energy consumed with the degree of slope, considering that energy expenditure varies according to the degree of slope in an irregular and non-constant way[46]. The resulting LCPs were corrected on the basis of geographical and geomorphological conditions (*i.e.* abrupt reliefs and geoforms complicated to travel) of the areas traversed by the LCP. Afterwards, we added isochrones equivalent to seven hours of walk[47]. Finally, considering the pervasive role of seasonality in northern Patagonia, we model the impact of snow cover on the LCPs in order to assess annual variation in landscape structure and human circulation.

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[42] R. Barberena et al., Espacios internodales… 57-75; V. Cortegoso et al., Geographic vectors of human mobility… 81-92; N. Franco et al., "Human dispersal in the Atlantic slope of Patagonia and the role of lithic availability"; PaleoAmerica num 5-1 (2019): 88-104; G. Lucero et al., Rutas Prehistóricas en el NO de San Juan… 275-305; K. Rademaker et al, "Connecting the Dots: Least Cost Analysis, Paleogeography, and the Search for Paleoindian Sites in Southern Highland Peru". In D. White and S. Surface-Evans (eds.), Least Cost Analysis of Social Landscapes: Archaeological Case Studies (Utah: The University of Utah Press, 2012), 32-45; N. Tripcevich, "Estimating Llama Caravan Travel Speeds: Ethno-archaeological fieldwork with a Peruvian salt caravan", Center for Spatial Studies Meeting (Santa Barbara: University of California, 2008).

[43] L. A. Borrero, "Evolución cultural divergente en la Patagonia austral", Anales del Instituto de la Patagonia, Serie Ciencias. Humanas num 19 (1989-1990): 133-139; K. Butzer, Arqueología, una ecología del hombre: método y teoría para un enfoque contextual (Barcelona: Bellaterra, 1989); G. Lucero, Biogeografía y paleoecología humana de tierras altas…

[44] G. Lucero et al, Rutas Prehistóricas en el NO de San Juan… 275-305; K. Rademaker et al., Connecting the Dots… 32-45.

[45] R. Barberena et al., Espacios internodales… 57-75.

[46] J. Conolly and M. Lake, Sistemas de Información Geográfica aplicados a la Arqueología (Barcelona: Bellaterra, 2009); R. López Romero, "Cálculo de rutas óptimas mediante SIG en el territorio de la ciudad Celtibérica de Segeda: Propuesta metodológica", Saldvie num 5 (2005): 95-111.

[47] G. Lucero, Biogeografía y paleoecología humana de tierras altas…

3. Results

We begin presenting a GIS spatial analysis integrating LCP and seasonality to build geographic connectivity profiles between the Andean highlands and lowlands during the annual cycle. Then, we discuss rock art's macro-regional variability to assess the materialization of information networks over the constructed landscapes, considering the role that these profiles might have played in their constitution.

3.1. LCPs and landscape connectivity in northwestern Patagonia

The results of the multiple LCPs show different spatial blocks associated with variable travel costs (Figure 4 and Table 1). From the location of previously identified nodal areas, we modelled two main trans-Andean corridors that follow fluvial basins. The northern path connects the Grande river and the Pehuenche stream, both located in Mendoza province (Argentina), with the Maule river, in Chile. The southern corridor involves, on the one hand, a path coinciding with the Neuquén and Curi Leuvú river basins, which traverse the Andes through currently used mountain paths. In addition, we modelled three vertical paths with a north-south axis that coincide with the Neuquén, Curi Leuvú and Barrancas river basins, which could have functioned as corridors giving access to the highlands.

Our results suggest that, during the austral summer, northwestern Patagonia is characterized by a *high geographic connectivity* between nodal areas located east and west of the Andes, but also between these areas and the main local sources of high quality obsidian: Laguna del Maule, in the north, and Cerro Huenul, in the south (Figure 4 and Table 1). These different environments are connected through multiple east-west and north-south paths that facilitate inter-regional and trans-Andean circulation during this season, as well as access to resources from the highlands.

The multiple LCPs also show that some nodal areas present better connectivity among them than with others (Figure 4 and Table 1). The route connecting the Neuquén river and the Maule basin presents the best conditions for trans-Andean circulation, since it is characterized by low mobility costs and little topographical restriction. The model includes the Neuquén-Nahueve rivers and the Lumabia creek in the eastern watershed, and the Loncomilla, Achibueno and Longaví rivers, which feed the Maule basin, in the western Andean (Figure 4). The nodal areas of the Neuquén and Curi Leuvú rivers appear as the most connected, while the Payunia and the Laguna del Maule source are characterized by large topographical restrictions and high movement costs. The Barrancas-Buta Ranquil region is well-connected towards the east and north, presenting low topographic resistance to movement.

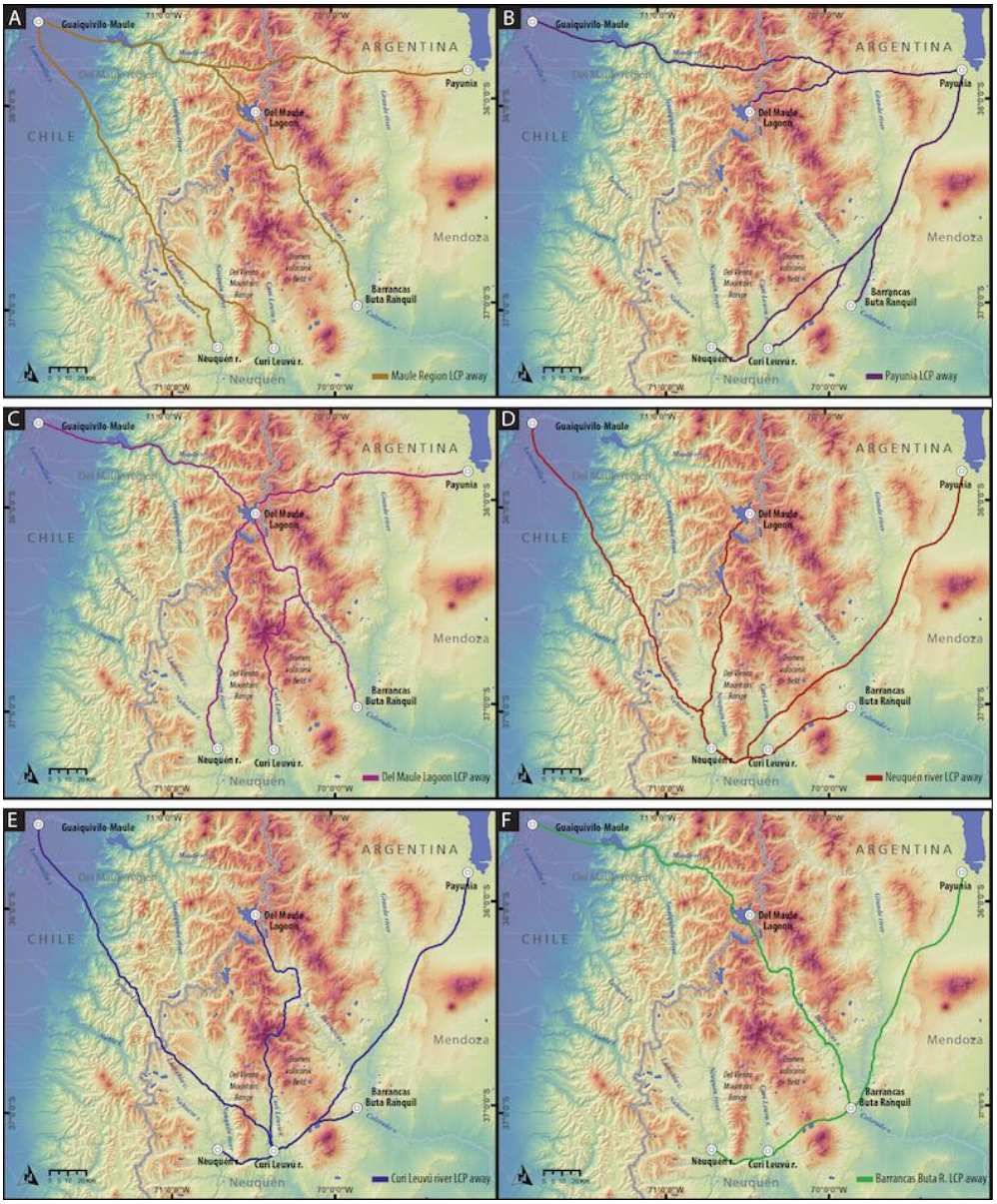

Figure 4
LCP and landscape connectivity among lowlands and highlands from northwestern Patagonia during the Austral summer season. Each map shows the LCP among proposed nodal areas.

Figure 5 shows the results of modelling the incidence of seasonality (as reconstructed in Figure 3) over the LCPs. Thus, the winter snow coverage (colored in red in Figure 3) not only reduces the available space for occupation by more than half, but also disrupts connectivity between nodal areas in both Andean slopes as shown in Figure 5. Regarding the northern corridor, the connections are drastically restricted during winter. On the other hand, at the southern portion of the study region, the Neuquén, Curi Leuvú and Barrancas upper river basins can only be accessed from the south, thus constituting real *Andean dead-ends*[48] (Figure 5). The

[48] L. A. Borrero, "The Archaeozoology of Andean "Dead Ends" in Patagonia: Living near the Continental Ice Cap". In M. S. Mondini, A. S. Muñoz and S. Wickler (eds,), Colonisation, Migration and Marginal Areas. A zooarchaeological approach (Oakville: Oxbow Books, 2004), 55-61.

fragmentation of the landscape produced by the snow cover limits circulation and communication to a very small set of available low-lying paths. We do not expect that this situation represented a risk by itself, since it is predictable on an annual basis. However, recorded cycles of increased snow cover, as well as events of early precipitation, may have represented situation of uncertainty for small mobile groups[49]. Overall, these discontinuities prevent free access to the highlands and associated resources, imposing a *low geographic connectivity* and high fragmentation to the winter Patagonian landscape, entailing geographical insularity and high risk for human populations[50].

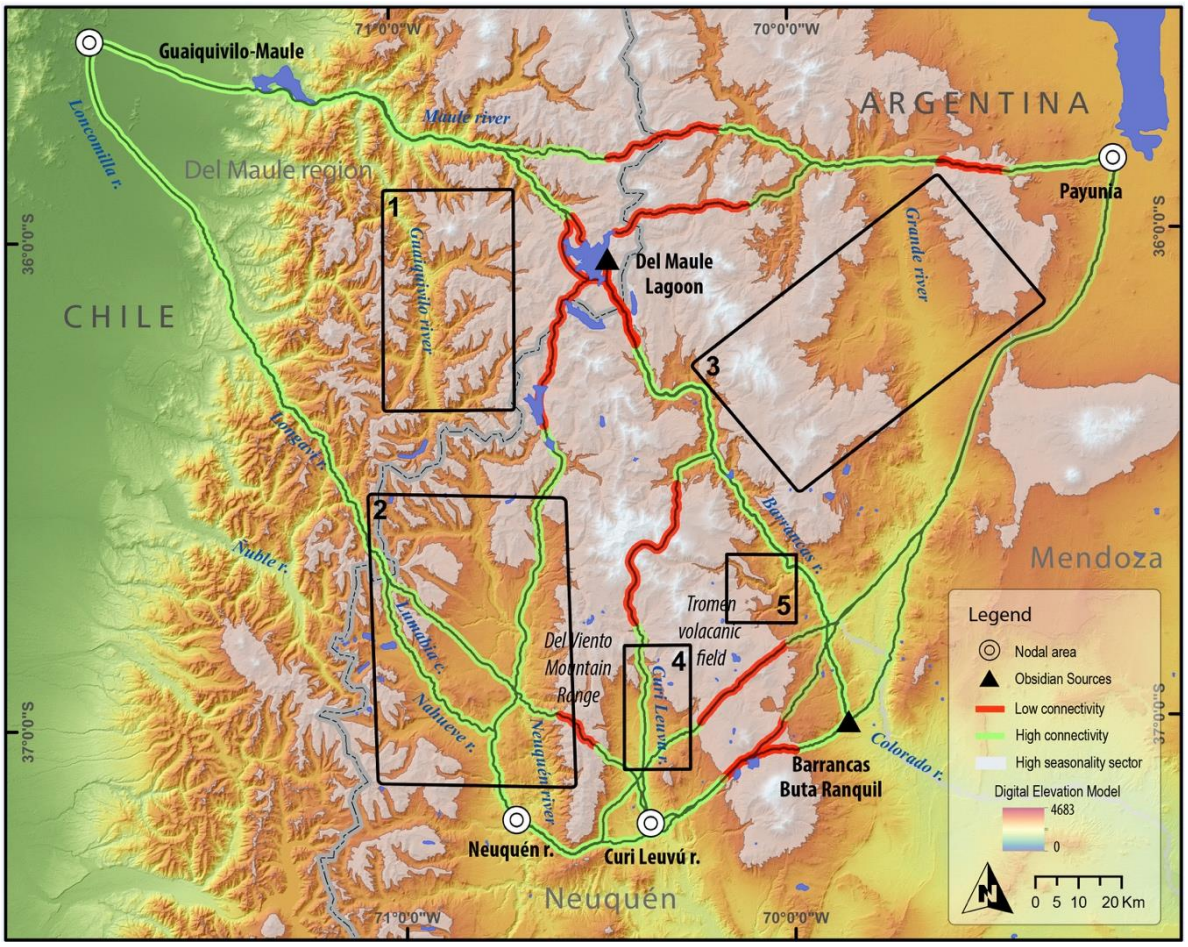

Figure 5
LCP and landscape connectivity among lowlands and highlands from northwestern Patagonia during the Austral winter season. References of approximate location of rock art sites: 1: Maule river upper basin (Maule region, Chile); 2: Neuquén river upper and middle basin (Neuquén province, Argentina); 3: Curi Leuvú river upper and middle basin (Neuquén province, Argentina); 4: Barrancas-Buta Ranquil locality (Neuquén province, Argentina); 5: Payunia (Mendoza province, Argentina)

[49] M. H. Masiokas et al., "Snowpack Variations since AD 1150 in the Andes of Chile and Argentina… 117-5; R. B. Urrutia et al., "Multicentury Tree Ring Reconstruction of Annual Streamflow for the Maule River Watershed in South Central Chile… 47-6; I. A. Mundo et al., "Multi-Century Tree-Ring Based Reconstruction of the Neuquén River Streamflow… 815-829.

[50] C. A. S. Mandryk, "Hunter-gatherers social costs and the nonviability of submarginal environments", Journal of Anthropological Research num 49 (1993): 39-71.

LCP MAULE-GUAIQUIVILO						**LCP PAYUNIA**					
Destination	Distance	Hours	Days	Km/h	Connectivity	Destination	Distance	Hours	Days	Km/h	Connectivity
M	136	30	4,3	4,5	Low	M	126	28	4,0	4,5	Low
RN	213	44	6,3	4,8	High	BBR	154	32	4,6	4,8	High
RCL	229	52	7,4	4,4	Low	RCL	198	43	6,1	4,6	Low
BBR	284	57	8,1	5,0	Low	RN	232	50	7,1	4,6	Low
P	257	55	7,9	4,7	Low	G	257	55	7,9	4,7	Low
Average	/	47,6	6,8	4,7	/	Average	/	41,6	5,9	4,6	/
LCP LAGUNA DEL MAULE						**LCP BARRANCAS-BUTA RANQUIL**					
Destination	Distance	Hours	Days	Km/h	Connectivity	Destination	Distance	Hours	Days	Km/h	Connectivity
G	136	30	4,3	4,5	Low	RCL	54	12	1,7	4,5	Low
RN	213	44	6,3	4,8	Low	RN	91	21	3,0	4,3	Low
RCL	229	52	7,4	4,4	Low	M	137	29	4,1	4,7	Low
BBR	284	57	8,1	5,0	Low	P	154	32	4,6	4,8	High
P	257	55	7,9	4,7	Low	G	284	57	8,1	5,0	Low
Average	/	47,6	6,8	4,7	/	Average	/	30,2	4,3	4,7	/
LCP NEUQUÉN RIVER						**LCP CURI LEUVÚ RIVER**					
Destination	Distance	Hours	Days	Km/h	Connectivity	Destination	Distance	Hours	Days	Km/h	Connectivity
RCL	37	9	1,3	4,1	High	RN	37	9	1,3	4,1	High
BBR	91	21	3,0	4,3	Low	BBR	54	12	1,7	4,5	Low
M	146	34	4,9	4,3	High	M	164	35	5,0	4,7	Low
G	213	44	6,3	4,8	High	P	198	43	6,1	4,6	High
P	232	50	7,1	4,6	Low	G	229	52	7,4	4,4	Low
Average	/	31,6	4,5	4,4	/	Average	/	30,2	4,3	4,5	/

Table 1

LCP travel costs and probable connectivity. References: M: Maule; G: Guaiquivilo; RN: Neuquén river; RCL: Curi Leuvú river; BBR: Barrancas-Buta Ranquil locality; P: Payunia and /: no data.

3. 2. Landscape inscription and information networks in northwestern Patagonia

Tables 2 and 3 summarize the information on rock art macroregional trends. In the first place, taking into account motifs density and distribution, as well as the altitude of the sites, it becomes clear that Andean highlands concentrate nearly 80% of the motifs sample (research areas 1 and 2 in Table 2 and Figure 6). Among them, the upper Maule river basin -research area 1-, located in Chile, concentrates *ca*. 47%. Secondly, we observe the predominance and wide spatial distribution of engraved designs over painted ones (Table 3 and Figure 6). Approximately more than 80% of the total motifs sample were executed by this technique, which is present in all the research areas. Likewise, abstract or geometric designs dominate widely in the analyzed sample, although there is inter-regional variation (Table 3 and Figure 6). In the upper Neuquén river basin, the upper-middle Curi Leuvú river and the Barrancas-Buta Ranquil locality these motifs constitute more than 80% of the total sample (research areas 2, 3 and 4 in Table 3). In addition, and despite the lack of complete motif repertories for many research areas, we observe the existence of a wide range of shared motif types that include not only simple geometric forms

like strokes, circles, dots and various types of lines -straight, broken, zigzag, sinuous-, but also other designs with diagnostic morphologies, such as parallel lines, chained rhombus and triangles, figures of axial symmetry and cruciform figures (Figures 7 and 8).

Research area	N rock art sites	Sites altitude (masl)	N rock art motifs
1. Maule river upper basin (Maule region, Chile)[51]	30 to 40	High (most of them 2100 to 2600)	5000
2. Neuquén river upper and middle basin (Neuquén province, Argentina)[52]	32	High to Intermediate (most *ca*. 2000)	2800
3. Curi Leuvú river upper and middle basin (Neuquén province, Argentina)[53]	15	most of them: Intermediate to High	336 (1 site: Molulco-Mogotillos)
4. Barrancas-Buta Ranquil locality (Neuquén province, Argentina)[54]	12	most of them: Low	1128 (total count)

[51] L. Albornoz Ramos et al., "Mitificación y sacralización de montañas y lagunas como estrategia de control territorial de los antiguos grabadores de arte rupestre Guaiquivilo de la provincia de Linares. Centro sur de Chile", ArqueoWeb num 15 (2014): 18-24; P. S. Kelly and H. Carrión, "Estilo Guaiquivilo: reevaluación de sus características desde una zona limítrofe", XX Congreso Nacional de Arqueología Chilena (Concepción, Chile, 2015); A. Morales et al., Arte rupestre en el Maule. Huellas de un pasado desconocido (Chile: FONDART, 2015); H. Niemeyer and L. Weisner, Los petroglifos de la cordillera andina de Linares… 405-470; N. Sanguinetti, Petroglifos del Cerro Quiñe (provincia de Linares) (Linares: Dirección de Bibliotecas, Archivos y Museos, Museo de Linares,1970); C. Vergara Duplaquet, Petroglifos de las piedras de las marcas. In Actas del VI Congreso de Arqueología Chilena II (Santiago de Chile: Universidad de Chile, 1972-1973), 471-485.

[52] E. M. Cúneo, "Sitio Buraleo: representaciones rupestres del "estilo Guaiquivilo" en el noroeste neuquino, departamento Minas, República Argentina". In F. Gordón, R. Barberena and V. Bernal (eds.), El poblamiento humano del norte de Neuquén. Estado actual del conocimiento y perspectivas. (Ciudad Autónoma de Buenos Aires: Aspha Ediciones, 2017), 75-99; J. Fernández, Estudios sobre el arte rupestre de Neuquén… 5-36; J. Fernández, "Corpus de arte rupestre neuquino. 1º parte", Revista del Museo Provincial Vol: 1 (1978): 17-93; J. Fernández, Las piedras con marcas de la cordillera del Viento…; O. Menghin, Estilos del arte rupestre de Patagonia… 57-87; J. Schobinger, "El arte rupestre de la Provincia del Neuquén", Anales de Arqueología y Etnología num 22 (1956): 115-227; F. E. Vargas and A. Hajduk, "Grabados imperceptibles. Pisadas y paralelas del sitio Piedra Auque. Departamento Minas. Noroeste de la Provincia de Neuquén", Arqueología num 25:1 (2019): 245-257; T. Vega, "El arte rupestre del norte neuquino. Las formas y sus valores". In A. M. Rocchietti et al., (eds.), Libro de Resúmenes Segundo Congreso Nacional de Arte Rupestre. (Rosario: Laboratorio de Arqueología y Etnohistoria, Departamento de Historia, Facultad de Ciencias Humanas, Universidad Nacional de Río Cuarto, 2016), 13-14; T. Vega, M. Martínez, M. Piombo, P. Bestard, M. Gelós and C. Seró, "Profundización de los aspectos estéticos de petroglifos y pictografías de la provincia del Neuquén. 1º parte", Chungará Vol: 28-1 (1996): 365-379; T. Vega, M. B. Gelós and P. Bestard, "Gestión del arte rupestre neuquino. Caso Parque Arqueológico Colomichicó", In Imágenes Rupestres lugares y regiones, eds. F. Oliva, A. M. Rocchietti and F. S. Banfi (Rosario: 2016), 415-422.

[53] A. Hajduk and E. M. Cúneo, "Representaciones rupestres en la Cuenca del río Curi Leuvú (departamento Chos Malal, Provincia del Neuquén, República Argentina). Informe preliminar". In M. Salemme, F. Santiago, M. Álvarez, E. Piana, M. Vázquez and E. Mansur (eds.), Arqueología de la Patagonia. Una mirada desde el último confín (Ushuaia: Editorial Utopías, 2009), 515-526; J. Schobinger, El arte rupestre de la Provincia del Neuquén…, 11956, 15-227; F. E. Vargas, "Petroglifos del Norte Neuquino en la cuenca del Curi-Leuvú. Un abordaje desde la Arqueología del Paisaje" (Tesis de Licenciatura en Antropología, Universidad Nacional de Rosario, 2015), MS.

5. Payunia volcanic field (southern Mendoza province, Argentina)[55]	18	most of them: Low to Intermediate	No data

Table 2
Overview of the information about northwestern Patagonian rock art. Part 1

Research area	Techniques	Motifs morphology	Temporal indicators	Proposed chronology
1. Upper basin Maule river (Maule region, Chile)	engravings	ABS: 54,07% FIG: 44,5% ANT: 35% ZOO: 9,5% -1 site-	Superimpositions and patina differentiation	late Holocene
2. Upper basin Neuquén river (Neuquén province, Argentina)	mostly engravings (few paintings)	ABS: 95% FIG: 5% -ANT y ZOO- (study case: Colo Michi Có site)	Superimpositions and patina differentiation	late Holocene
3. Middle-Upper basin Curi Leuvú river (Neuquén province, Argentina)	mostly engravings (few paintings)	mostly ABS fewer FIG (ZOO & ANT) ABS: 87% FIG: 13% (study case:	patina differentiation	late Holocene

[54] R. Barberena et al., Espacios internodales… 57-75; J. B. Belardi et al., "The Development of a Legacy: Evolution, Biogeography and Archaeological Landscapes". In M. Cardillo and H. Muscio (eds.), Darwin´s Legacy: The Status of Evolutionary Archaeology in Argentina. Tribute to the 200th anniversary of the birth of Charles Darwin and the 150th anniversary of the publication of The Origin of Species (Buenos Aires: IMHICIHU-CONICET, 2016), 89-98; G. Romero Villanueva, "La clasificación de las pinturas rupestres del noreste de Neuquén, Patagonia septentrional". In F. Oliva, A. M. Rocchietti and F. S. Banfi (eds.), Imágenes rupestres, lugares y regiones. (Rosario: Universidad Nacional de Rosario, 2016), 441-452; G. Romero Villanueva, Biogeografía humana y circulación de información…; G. Romero and A. Re, "Representaciones rupestres del noreste de Neuquén (Patagonia septentrional). Primeras tendencias espaciales y temporales", Comechingonia. Revista de Arqueología num 18-1 (2014): 73-92.

[55] V. Durán, Poblaciones indígenas de Malargue. Su arqueología e historia (Mendoza: CEIDER, Serie Libros Nº1. Universidad Nacional de Cuyo, 2000); A. Gil, Arqueología de La Payunia, Mendoza, Argentina. El poblamiento humano en los márgenes de la agricultura (Oxford: Archaeopress, BAR International Series 1477, 2006); C. Gradin, "El arte rupestre del sur mendocino...", 1997-1998;
L. Hart, Arte de la Prehistoria. Diseños rupestres de Cuyo (Mendoza: Zeta Editores, 2016); H. Lagiglia, "Los petroglifos de Ponontrehue". In Actas del IX Congreso Nacional de Arqueología Argentina II, 1994, 91-93; G. Neme et al., "Arte rupestre de la prehistoria del sur de Mendoza". In L. Hart (comp.), Arte de la Prehistoria: diseños rupestres de Cuyo (Mendoza: Zeta Editores, 2016), 13-19; J. Schobinger, "Nuevos sitios de arte rupestre en el Departamento Malargue de Mendoza", Relaciones de la Sociedad Argentina de Antropología num XII (1978): 175-182; J. Schobinger, "Áreas intermedias o marginales". In J. Schobinger and C. J. Gradin (eds.), Cazadores de la Patagonia y agricultores andinos. Arte rupestre de la Argentina. (Madrid: Encuentro Ediciones, 1985), 80-91; J. Schobinger, "Arte rupestre del Departamento de Malargue". In A. Gil and G. Neme (eds.), Entre montañas y desiertos. Arqueología del sur de Mendoza. (Buenos Aires: Sociedad Argentina de Antropología, 2002), 103-118; H. Tucker and A. Risi, "El registro simbólico como codificación del paisaje. Aproximaciones al estudio del arte rupestre del departamento de Malargue, Mendoza, Argentina". In Libro de resúmenes VIII Simposio Internacional de Arte Rupestre (San Miguel de Tucumán: ISES, Universidad Nacional de Tucumán, 2010), 117-120.

		Molulco-Mogotillos site)		
4. Barrancas-Buta Ranquil locality (Neuquén province, Argentina)	Mostly paintings (99,82%) (very few engravings: 0,18%)	ABS: 85,02% FIG: 3,01% ZOO: 1,15% ANT: 1,86% UNDET: 11,97%	Superimpositions (N: 141); differential weathering on paintings; similar designs on dated mobiliar art; motifs dated by AMS	mostly late Holocene (very few: middle Holocene)
5. Payunia (Mendoza province, Argentina)	engravings but also paintings	mostly ABS fewer FIG (ZOO & ANT)	Differential weathering on paintings	late Holocene

Table 3
Overview of the information about northwestern Patagonian rock art. Part 2. References: ABS: abstract motifs, FIG: figurative motifs, ANT: anthropomorphic motifs, ZOO: zoomorphic motifs and UNDET = undetermined due to preservation issues.

As mentioned, our results also show noticeable differences in the abundance of rock art motifs between regions (Tables 2 and 3 and Figures 7 and 8), since the Andean highlands -research areas 1 and 2 in Table 2)- concentrate the largest number of motifs, particularly in the upper Maule river basin, in Chile. There are also regional differences in the proportions of motif categories (Table 3). Again, the upper Maule basin -research area 1 in Table 3 and reference A in Figure 6- stands out for presenting relative high proportions of figurative motifs, in general, and of anthropomorphic designs (more than 35%), in particular. Finally, the regions located in the highlands -research areas 1 and 2- present a higher density of the macro-regional diagnostic motifs previously referred (Figure 6).

We consider the case of the parallel-lines type as a leading example, which for operational reasons, in this analysis includes several types of lines -straight, broken, zigzag, sinuous-. This motif type reaches proportions greater than 30% in some sites of the upper Neuquén river basin -research area 2 and reference B in Figure 6-[56] while in other regions, such as the Barrancas-Buta Ranquil locality, it barely represents 6% of the total -research area 4 and reference B in Figure 7-[57].

[56] J. Fernández, Las piedras con marcas de la cordillera del Viento…
[57] G. Romero Villanueva, Biogeografía humana y circulación de información…

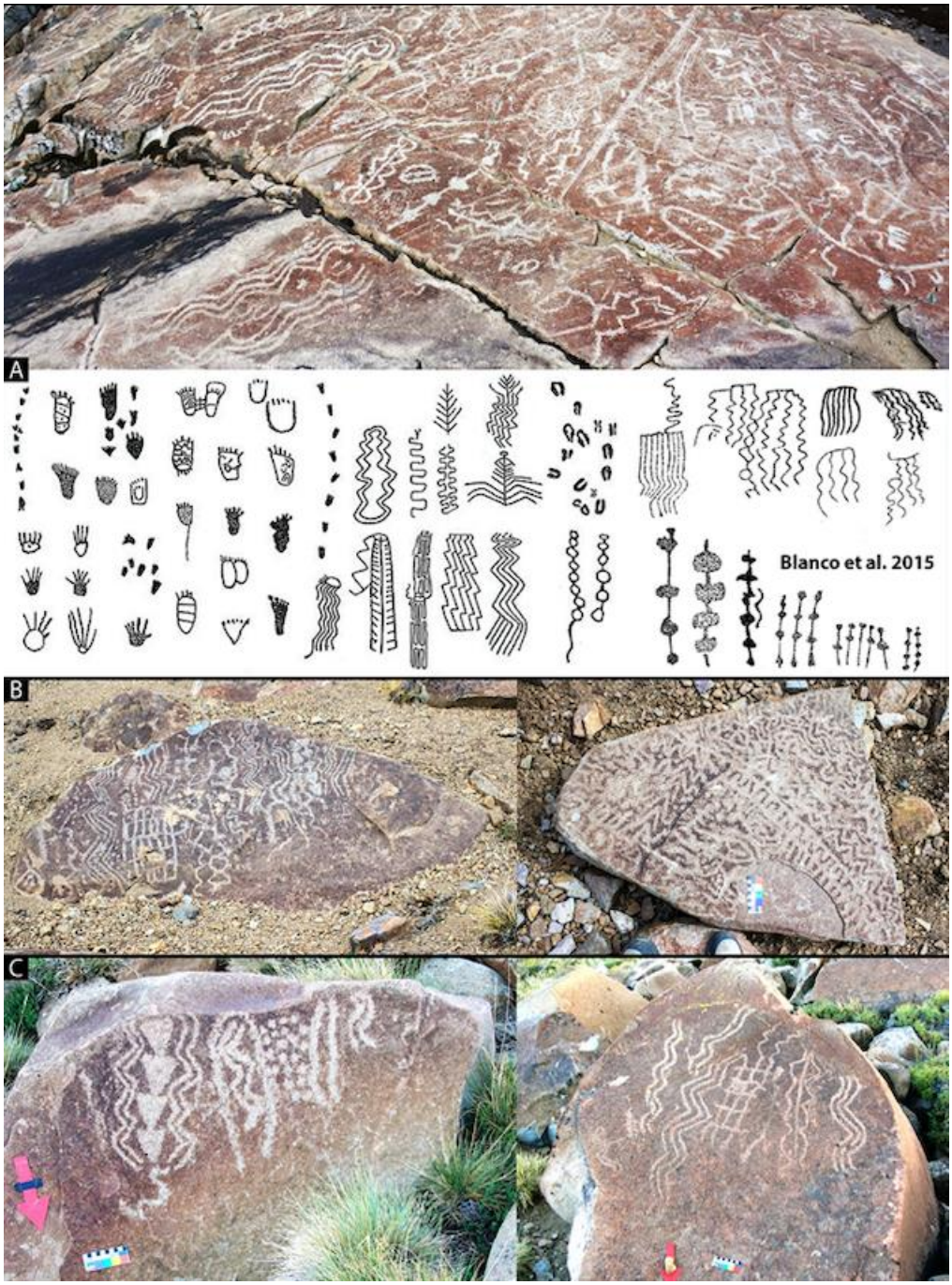

Figure 6
Rock art of northwestern Patagonia. A: Engravings from Calabozos site, upper Maule river basin (Maule region, Chile). Digital tracings of diagnostic motifs taken from Blanco *et al*., 2015[58]. B: Engravings from Colo Michi Có site, upper Neuquén river basin (northern Neuquén province, Argentina). C: Engravings from Molulco-Mogotillos site, upper-middle Curi Leuvú river basin (northern Neuquén province, Argentina)
Credits: A: Renata Gutiérrez and C: Emmanuel Vargas

[58] J. F. Blanco, M. de la Maza and M. A. Peñaloza, "Memoria inscrita. Arte rupestre de contacto, integración y dominación en el Centro-Sur de Chile", Boletín del Museo Chileno de Arte Precolombino num 20-2 (2015): 89-110.

Figure 7
Rock art of northwestern Patagonia. A: Paintings from Gruta del Indio (left) and Alero Las Tinajas (right) sites (southern Mendoza province, Argentina)
B: Paintings from Cueva Huenul 1 site, Barrancas-Buta Ranquil locality (northern Neuquén province, Argentina). Credits: A: Laura Hart. C: image digitally enhanced with Dstretch[59]

4. Discussion

Northwestern Patagonia is characterized by a heterogeneous landscape strongly affected by seasonality and, hence, experiencing different connectivity constraints along the annual cycle. The results of the LCPs showed that low-altitude and annually available areas have good inter-regional and trans-Andean connectivity during most of the year, with lower movement costs. However, winter snow coverage creates a scenario of geographical insularity. While humans would have been strategically equipped to deal with annual and predictable cycles, the existing climatic record shows the existence of unpredictable anomalies in the southern Andes of extremely high snowpack cover in the

[59] J. Harman, "Using Decorrelation Stretch to Enhance Rock Art Images", http://www.dstretch.com/AlgorithmDescription.html (accessed may 2018).

highlands. Since alternative climate forcing conditions these events[60], these situations would be unpredictable, hence constituting a situation of uncertainty. The impact of these unusual events may have been particularly intense in small and mobile human groups inhabiting northwestern Patagonia. These cycles may have favored the development of more open and connected information networks with the purpose of enhancing cooperation and associativity in a context where the costs of maintaining networks are high and network connections become particularly vulnerable in winter in general, and in years with heavy snowpack in particular[61]. Following Fitzhugh and colleagues (2011)[62], it is expected that, under these conditions, human groups will develop a *specialized* type of information network, investing a greater amount of energy in networking through the generation of specialized traders, subsidized to serve the essential function of connecting dispersed human groups in predictable and unpredictable years.

Since information networks can be addressed archaeologically trough the analysis of the spatial distribution of rock art motifs, we suggest that the observed similarities in northwestern Patagonian rock art may suggest the use of a shared visual code among mobile human groups that reside for long periods in annually available nodal areas located east and west of the Andes, but also used the highlands during the summer. From an information exchange approach, these similarities can be conceived as a pool of shared information that allowed human groups to socialize and organize the use of the highlands at a macro-regional scale.

The materialization of this strategy trough rock art becomes systematic during the late Holocene, when significant behavioral and technological changes occur in relation to an increase in population density as inferred from radiocarbon databases and mitochondrial DNA[63]. The scenario described for northwestern Patagonia's rock art during the late Holocene is consistent with that expected by other authors who suggested that, during an 'effective occupation' stage (*sensu* Borrero 1989-1990[64]) associated with the redundant use of space by groups with small and circumscribed home ranges around critical resources located in different environments, it is highly probable to observe an increase in the intensity of rock art production compared to previous moments[65]. Thus, we suggest that this demographic scenario promoted changes in social interaction and information exchange.

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[60] M. H. Masiokas et al., "Snowpack Variations since AD 1150 in the Andes of Chile and Argentina… 117-5.

[61] M. H. Easdale et al., "A social–ecological network analysis of Argentinean Andes transhumant pastoralism", Regional Environmental Change num 16 (2016): 2243-2252.

[62] B. Fitzhugh et al., Modeling Variability in Hunter-Gatherer Information Networks… 85-115.

[63] R. Barberena et al., "The human occupation of northwestern Patagonia… 111-126; M. A. Berón, Patrones de violencia en sociedades preestatales: tipificación de eventos a partir de diferentes casos entre cazadores-recolectores de la Pampa Occidental argentina. Una propuesta. In J. M. Lopez Mazz and M. Berón (eds.), Indicadores arqueológicos de violencia, guerra y conflicto en Sudamérica. Montevideo, Comisión Sectorial de Investigación Científica, Universidad de la República Uruguay, 2014, 81-116; G. Martínez, "Arqueología del curso inferior del río Colorado: estado actual del conocimiento e implicaciones para la dinámica poblacional de cazadores-recolectores pampeano-patagónicos". Cazadores Recolectores del Cono Sur 3 (2008-2009): 71-92; S. I. Perez et al., Past population dynamics in Northwest Patagonia… 154-160.

[64] L. A. Borrero, Evolución cultural divergente … 133-139.

[65] D. Fiore, Poblamiento de imágenes: arte rupestre y colonización de la Patagonia. Variabilidad y ritmos de cambio en tiempo y espacio. In D. Fiore and M. M. Podestá (eds.), Tramas en la Piedra. Producción y usos del arte rupestre. Buenos Aires, WAC, SAA, AINA, 2006, 43-61.

Furthermore, the identified macroregional connections established trough rock art during the late Holocene may have functioned as *'safety* nets'[66] of great adaptive value in unpredictable and geographically constrained environments, like the dryland-highland interface of northwestern Patagonia. As Whallon[67] stated, looking for and procuring food and other essential materials are not the only reasons for hunter-gatherer movement. The archaeological and ethnographic records are full of examples of people moving in the landscape, individually or in groups, to promote social contact, among other reasons such as exchange, ritual and ceremonial pursuits[68]. These interactions enhance information available about a territory and its resources, as well as on neighbor groups on different spatial scales[69].

Favorable areas within the Andean highlands may have played a key role for information networking in northwestern Patagonia as suggested by the greater amount and diversity of rock art motifs recorded. Since these spots present strategic factors that attract human groups, such as high summer productivity, access to high quality obsidian and potential for trans-Andean circulation, they are also appropriate for social interaction and exchange of information between different human groups, even though communication may or may not have not been face-to-face[70]. Thus, we suggest that the Andean highlands functioned as seasonal *visual communication hubs* of the information network unfolded over the northwestern Patagonian landscape. This idea builds on the proposal of Belardi and Goñi[71] and Re[72] that suggested that seasonally available environments of Southern Patagonia functioned as population convergence zones adequate for social interaction and information exchange.

In sum, we suggest that rock art was a key visual communication media in northwestern Patagonia during the late Holocene, embedded within mobility and informational strategies unfolded over a highly variable and risky environment. In this context, high levels of investment in networking are necessary through the generation of specialized networks aimed at maintaining connectivity between generally dispersed groups. This was materialized by equipping the landscape with information signaling least cost circulation corridors and paths[73], as well as visually hierarchized high-altitude environments which were key spaces for human groups for biogeographic, social and informational reasons[74].

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[66] R. Whallon, Social networks and information… 259-270.
[67] R. Whallon, Social networks and information… 259-270.
[68] M. Smith, The Archaeology of Australia's Deserts (Cambridge: Cambridge University OPress, 2013); R. Campbell et al., Obsidian in archaeological sites on Mocha Island… 617-624.
[69] K. A. Spielmann and J. F. Eder, "Hunters and Farmers: Then and Now", Annual Review of Anthropology Vol: 2 (1994): 303-323; R. Whallon, An introduction to information… 1-28.
[70] J. B. Belardi and R. A. Goñi, "Representaciones rupestres y convergencia poblacional durante momentos tardíos en Santa Cruz (Patagonia argentina). El caso de la meseta del Strobel". In D. Fiore and M. M. Podestá (eds.), Tramas en la piedra. Producción y usos del arte rupestre (Buenos Aires: World Archaeological Congress, SAA-INAPL, 2006), 85-94.
[71] J. B. Belardi and R. A. Goñi, Representaciones rupestres y convergencia poblacional … 85-94.
[72] A. Re, "Representaciones rupestres en mesetas altas de la Provincia de Santa Cruz. Circulación de información en espacios de uso estacional" (Tesis de Doctorado en Arqueología, Facultad de Filosofía y Letras, Universidad de Buenos Aires), 2010.
[73] C. Bellelli et al., "Arqueología de pasos cordilleranos: un caso de estudio en Patagonia norte durante el Holoceno tardío", Boletín del Museo Chileno de Arte Precolombino num 13-2 (2008): 37-55.
[74] A. Hajduk, A. M. Albornoz and M. J. Lezcano, Espacio, cultura y tiempo: el corredor bioceánico desde la perspectiva arqueológica. In P. N. Floria and W. Delrio (comps.), Cultura y espacio. Araucanía-Norpatagonia (Bariloche: Universidad Nacional de Río Negro, 2011), 262-292.

5. Final remarks and future agenda

How past human groups use Andean highlands and their surrounding lowlands remains as a fundamental research question. We have presented the results of a project assessing trans-Andean social interaction and high-altitude human occupation strategies during the last 3000 years. We have combined a biogeographical approach developed by GIS tools and the analysis of human informational networks as encoded in rock art. On this basis, we have suggested that while the highlands overall would have worked as winter temporary barriers[75], some parts of these lands would have also operated as convergence zones and visual communication hubs in the summer.

While Andean high-altitude environments were certainly accessed and occupied from diverse demographic nodes located in lower-altitude settings, in the future we want to explore the potential existence of dominant geographic vectors of human access to the Andes[76]. At the latitude of 36-37º S, the Andes mountain range is characterized by lower mean altitudes. Among other biogeographic considerations, this condition may have favored a balanced access from both slopes in comparison to other Andean regions. However, we must consider that the framework for human decision-making on mobility may have been widely different for mobile hunter-gatherer societies inhabiting the northern Patagonian drylands and for the more settled human groups with an emphasis on agriculture that inhabited the lowland valleys in the Maule, Bío Bío and Araucanía regions in Chile[77]. We still have to assess the role that the highlands may have played for these economically and socially diverse human groups.

A methodological issue to explore in the future that can contribute to this discussion involves superimposing the results of a new connectivity analysis that involves nodal areas randomly established in the landscape.

Beyond the geographical discussion, this research contributes to evaluate the complexity of human use of Andean environments by acknowledging the highlands as a highly flexible ecological-economic-social ecotone with differences in demography and mobility. Further studies that include obsidian geochemistry and stable isotopes analyses will help us to deepen in the strategies deployed by the complex mosaic of societies that occupied the different environments of this South American mountain range for millennia[78].

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[75] P. M. Veth, Islands in the Interior. The Dynamics of Prehistoric Adaptations within the Arid Zone of Australia (Ann Arbor: International Monographs in Prehistory,1993).

[76] V. Cortegoso et al., Geographic vectors of human mobility… 81-92; V. A. Durán et al., To and fro… 668-678.

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