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The Exploitation of Raw
Materials in Prehistory

Telmo Pereira
Xavier Terradas
Nuno Bicho

This collection presents state-of-the-art approaches to the use of inorganic raw materials in the period known as prehistory. It focuses on stone-tools, adornments, colorants and pottery from Europe, America and Africa. The chapters intimately merge archaeology, anthropology, geology, geography, physics and chemistry to reconstruct past human behaviour, economy, technology, ecology, cognition, territory and social complexity. The book represents a framework of raw material investigation for those working in science, regardless of the time period, region of the world or materials they are studying.

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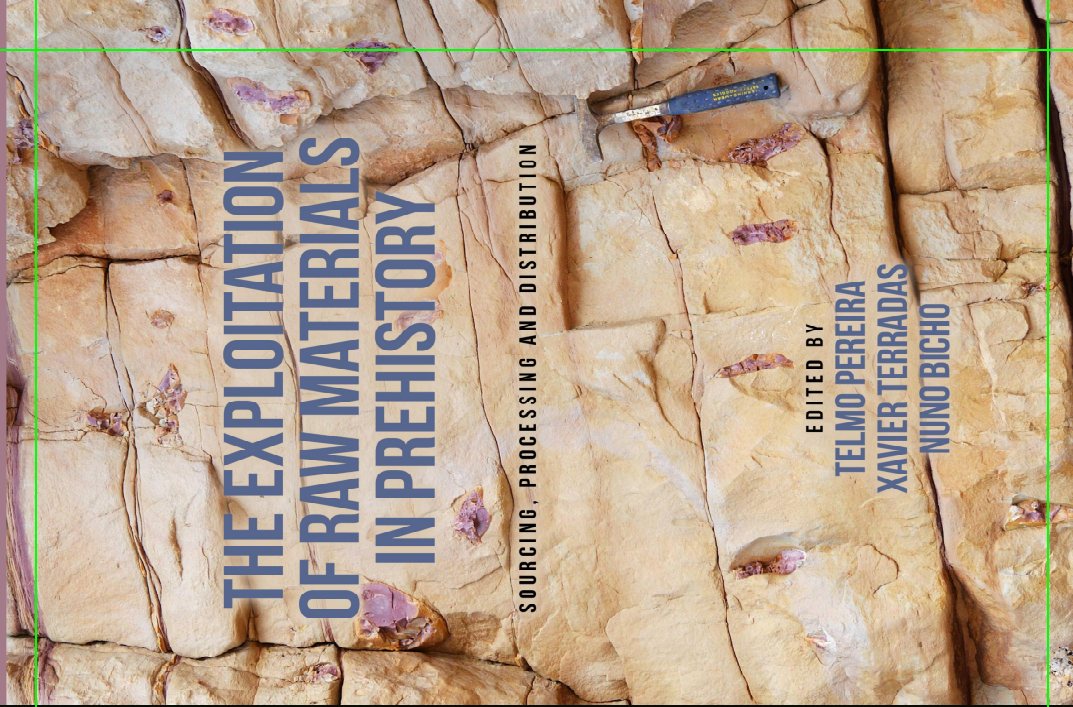
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THE EXPLOITATION OF RAW MATERIALS IN PREHISTORY

SOURCING, PROCESSING AND DISTRIBUTION

EDITED BY
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The Exploitation of Raw Materials in Prehistory

The Exploitation of Raw Materials in Prehistory:

*Sourcing, Processing
and Distribution*

Edited by

Telmo Pereira, Xavier Terradas
and Nuno Bicho

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FOREWORD

The significance of the different raw materials found in the Prehistoric record was recognized very early in the history of archaeological science. A major reason for that was the immediate resemblance between tool-kits seen in modern hunter-gatherers and in early farmer societies. Some of them, often the most exquisite, had symbolic meaning. Others were local, ordinary, coarse and even ugly, but they all had a meaning, a reason to be present in such context and significance in the daily life, traditions, territory and ecology of those communities. As a consequence, their study was considered relevant almost from the start of archaeological investigation and such studies always had a close relation with new technological developments that could help fill gaps, refine the analysis or increase the accuracy of data. Progressively, such research became a branch of archaeological enquiry and used more and more complex equipment according to the development of new techniques.

Presently, a large bulk of good photographs can be taken and seen in real time, automatically associated with accurate coordinates and sent in a second to the other side of the world. All this can be done just by using a telephone that fits in the pocket of your shirt. If one wants, it is possible to add the geochemical spectrum result in seconds with a portable X-ray fluorescence machine carried on a backpack. Yes, we live on what was science fiction just a few decades ago; and that is pretty damn cool!

The investigation of archaeological raw materials uses such top high-resolution methods and such large amount of detailed quantitative data that can estimate with great confidence that the 0,00005% of some element on the rock you just picked from the outcrop is the same that previous human species, living dozens of thousands of years ago, in other geological era, used one day to produce a meal. And if you used a total station in both the rock and the stone tool, you can geospatially relate them to the millimeter. This is so trivial for archaeologists today but so extraordinarily accurate that some people only believe it if you show them all the steps from the process and the individual results of each technological gadget.

This approach has been carried out across regions and the chronology of human occupation therein, merging archaeology with anthropology, geology and geography. The data acquired have been able to help bring

relevant insights to infer traits of human behaviour such as cognition, ecology, ecodynamics, territory, social complexity or technology.

In this scope, the University of Algarve and the Consejo Superior de Investigaciones Científicas (IMF, Barcelona) organized the international meeting *Raw Materials Exploitation in Prehistory: Sourcing, Processing and Distribution* in March 2016, at the University of Algarve, Portugal. The goal was to bring together both younger and senior scientists and their on-going projects focusing on the inorganic raw materials used during Prehistory, regardless the region or the specific time period. This included lithics, pottery, ceramics, metals, glass, beads and colorants. The sessions brought together people from Europe, Africa, Asia and America, and discussed issues such as quarrying and mining, geochemical and mineralogical analysis, archaeometrical characterization, provenance distribution and determination of raw materials, their geological and archaeological context, the raw materials used for making pottery and ceramics, those used in prestige items and as colouring materials, the objectives, changes and procedures of heat treatment and also mechanical experiments to test their physical properties.

This book contains some of the studies presented in the meeting. They represent the state-of-the-art of on-going research across the world in what concerns to sourcing, processing and distribution of Prehistoric raw materials.

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CHAPTER TWENTY SEVEN

A SPATIAL APPROACH TO THE STUDY OF COMPETITION BETWEEN TOOLSTONES IN SPECIFIC REGIONAL CONTEXTS

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Abstract

By “competition” between toolstones we understand the differential probability of such elements being used by humans as a function of their intrinsic properties plus the cultural preferences and strategic/tactical/operational decision rules applied by people on a situational basis. Despite the fact that the concept of competition applied to the relationships between knappable rocks and/or sources is not novel, it has had little theoretical and methodological development. This contribution represents an initial attempt to set a standard approach to the problem of recognizing and describing competitive relationships between toolstones on a regional scale, using spatial analysis performed with GIS tools. Our approach is based on the comparative analysis of paired distance-decay curves, taking into account four simple parameters that can be considered as gross measures of the relative competitive fitness of each raw material or source. The approach is exemplified with data from east-central Argentina.

Keywords: Competition; lithic raw materials; spatial analysis; fall-off curves, east-central Argentina.

Introduction

When we speak of “competition” between toolstones, we are using a figurative expression to depict a situation in which two or more knappable materials have a differential probability of being used by humans. Such a probability depends on the intrinsic properties of the rocks themselves and those of their sources and on the cultural preferences and strategic/tactical/operational decision rules applied by people in different situations and contexts (Barrientos et al. 2015). With the same or nearly the same meaning, the expression has already been used by several authors (e.g. Biró and Regenye 1991; Laylander 2006; Tripcevich 2007; Wilson 2007). One way to discuss competition between raw materials and sources is through the deployment of gravity models (Chappel 1986; Renfrew 1977; Wilson 2007). Another way is through the comparative analysis of paired distance-decay or fall-off curves (Barrientos et al. 2015; Fulford and Hodder 1974; Hodder and Orton 1976). Both approaches are not mutually exclusive, but the latter—the one that we advocate here—does not depend on subjective or difficult-to-quantify variables like the raw material quality, difficulty of terrain or cost of extraction (see the “attractiveness equation” in Wilson 2007: 397) nor is it based on inferences or estimations about past population size or other group-specific variables often included in gravity or interaction models (see Haynes and Fotheringham 1984; Johnson 1977).

The method that we will describe in this paper is not completely novel to the extent that it represents the application, in the GIS era, of principles and criteria established in the mid-1970s by I. Hodder and colleagues (Fulford and Hodder 1974; Hodder 1974; Hodder and Orton 1976) who, in turn, drew on ideas previously developed in the field of studies on geography and market economy (e.g. Berry 1967; Olsson 1967; Reilly 1931). Taking this into account, the aim of this paper is twofold: on the one hand, to present a series of criteria useful for the study of competition between toolstones by using fall-off curves built with GIS tools; on the other hand, to illustrate the approach with examples from a concrete region (east-central Argentina, southern South America).

Studying Competition between Toolstones using Spatial Models: Theoretical and Methodological Considerations

Our approach to the archaeological discussion of competition between toolstones is based, in a proximate way, on the concept of the “lithic landscape” (Barrientos et al. 2015, 2016) and, in an ultimate way, on the theoretical stance called time perspectivism (Bailey 1981; 2007). A lithic landscape is understood as the co-occurrence, in a given geographic space, of different structural units each composed of two principal elements: a) a raw material source, either primary or secondary; and b) an associated scatter or strewn area comprising the spatial distribution of the entire set of unmodified and human-modified pieces of rocks procured from that source. The basic premise lying behind the concept is that the operation of any system based on the exploitation of lithic resources will produce, in the long run and in a regional scale of analysis, a cumulative spatial rearrangement of lithics either in the form of raw materials (i.e. unmodified chunks/hunks/sheets/chips) or artefacts (i.e. cores, tools, and debitage) due to the differential spatial location of activities related with tool production, use, reworking, reuse, and discard. This implies that there is always a spatial transfer of rocks—whatever the distance involved—from an exploited source to one or many other locations across the landscape as the result of the operation of such a system. Building on insights from a) the ecological analysis of organismal movement (especially stochastic modelling; Cox and Miller 1965; Gautestad 2011; Smouse et al. 2010); b) some aspects of lithic technology (particularly the fact that it entails a reductive process influenced, among other things, by transport cost considerations; Surovell 2009; Wilson 2007); and c) the results of archaeological simulative modelling (e.g. derivations of the neutral model; Brantingham 2003, 2006; Pop 2016), it is expected that a random—from the perspective of an external observer—discard behaviour around a source will allow, in the long run and on an ideal featureless isotropic surface, a symmetric and concentric distribution of artefacts (i.e. a scatter or strewn area) with a decreasing gradient of density, size, weight, or frequency from the source to the outer limits of the distribution (Barrientos et al. 2015).¹ In most real situations, however, there are a

¹ It should be noted that this assumption is likely valid only for lithic landscapes generated by hunter-gatherers with a low degree of internal differentiation, a forager-like mobility strategy, and a relatively simple technological organization mostly relying on direct and embedded procurement and with null or negligible levels of exchange as a mechanism for lithic transfer (Barrientos et al. 2016).

number of factors that may create deviations from such an ideal symmetrical pattern, like the presence of competing or alternative raw material sources and of landscape features that modify, either by increasing (e.g. upland areas of difficult terrain) or diminishing (e.g. navigable rivers, corridor areas), transport costs (Barrientos et al. 2015).

By virtue of its formation process, a lithic landscape is a patterned palimpsest that needs to be approached with appropriate theoretical and methodological tools, not aimed at dissecting or disentangling it but at extracting meaningful information in terms of the effects of long-term processes involving the accumulation, at different temporal and spatial scales (Delcourt and Delcourt 1988; Dincauze 2000), of the material correlates of human behaviour. It is in this connection that our approach adopts the theoretical underpinnings of time perspectivism as a general conceptual framework. Unlike other theoretical approaches to lithic technology (e.g. the organization of technology model), time perspectivism is centred on the interpretation and explanation of the archaeological record rather than on the inferential reconstruction of ancient dynamics (Holdaway et al. 2008: 111). In proceeding in this way, this theoretical stance does not deny the importance of past individual and collective behaviours in shaping a great deal of the material and relational aspects of the archaeological record but attributes to them an explanatory role rather than the role of subject matter of archaeological inquiry (Barrientos et al. 2015). From such a perspective, we are particularly interested in defining an ontology based on objects (e.g. lithic landscapes, structural units) and interactions (e.g. competition) that manifest themselves at different spatial and temporal scales, particularly at the larger ones.

The morphology of a single structural unit or of an entire lithic landscape can be modelled with data coming from spatially discrete sampling units (i.e. toolstone relative frequencies from lithic assemblages recovered at distinct locations like archaeological sites or localities) (Barrientos et al. 2015, 2016). This can be accomplished with GIS using different interpolation techniques (e.g. kriging, IDW, splines; Barrientos et al. 2015, 2016; Biró 1998; Biró and Regenye 1991; Catella et al. 2017; Clarkson and Bellas 2014; Ericson 1977). Interpolation is a method of constructing new data from a discrete set of known data points (e.g. relative frequency values of the raw materials represented in different archaeological sites across a region), enabling the translation of sampled point data into continuous surfaces. The building of continuous surfaces—a procedure that has a long history in archaeology (e.g. Ericson 1977; Hodder and Orton 1976)—has the advantage of making intelligible the

spatial information recovered at relatively few, scattered, and unevenly distributed sampling locations, thus contributing to pattern recognition.

Across the modelled surfaces it is possible to trace virtual transects and then to represent, in 2D or 3D graphics, the profile of the investigated variable (e.g. the relative frequency of a toolstone). If the transects intersect the location of one or more source areas (*sensu* Clarkson and Bellas 2014), then it is possible to analyse the properties of the fall-off curves (i.e. the curves that show the variations in the value of the investigated variable in relation with the increasing distance to the source) in multiple directions. These can be smooth or steep depending on factors like mobility patterns, the quality of the investigated raw material, and the spatial proximity and/or competition between two or more raw material sources.

Competitive relationships between two raw materials or sources can be evaluated by examining the shape of each fall-off curve and their reciprocal relationships, as defined by a series of simple parameters: a) the steepness of the slope facing the other source; b) the height of the curve at its respective source; c) the height of the curve at the opposed source; d) the degree of coincidence between the point where the two curves cross (i.e. where the percentages from each raw material are equal) and the mid-point between the sources (Fulford and Hodder 1974). These four parameters can be considered gross measures of the differences in competitive fitness of each raw material or source. In cases where the curve representing the lineal spatial distribution of the relative frequencies of a toolstone is less steep and higher at both its source and at the opposed source, and where the distance between its source and the cross-point is longer, it can be said that such a rock completely outcompetes the other (Fig. 27.1). To the extent that not all parameters vary together in the same direction, it is advisable to assign a comparative score (1/0) to each curve for each parameter and then add them together to get a final composite score characterizing the whole competitive relationship (i.e. 4:0= 1; 3:1= 0.5; 2:2= 0; where 1 and 0.5 are factors that define the degree of competitive success of one toolstone over the other and 0 defines an equilibrated competition). In the following section we will exemplify the approach with data from east-central Argentina by considering three raw materials and two pairs of fall-off curves.

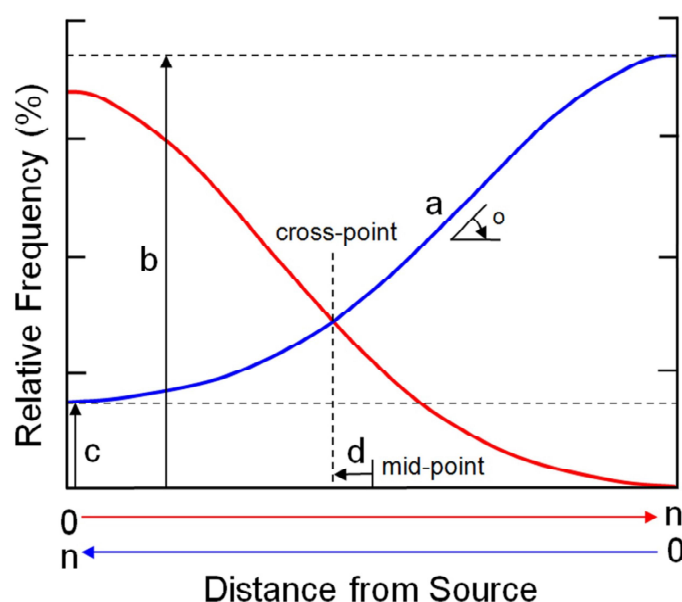


Fig. 27.1. Proposed parameters to measure competitive relationships between two raw materials considering the shape of its corresponding fall-off curves (blue and red lines; in both cases, 0 indicates the position of the respective sources): a) the steepness of the slope facing the other source; b) the height of the curve at its respective source; c) the height of the curve at the opposed source; d) the degree of coincidence between the point where the two curves cross (i.e. where the percentages from each raw material are equal) and the mid-point between the sources.

The Lithic Landscape of East-Central Argentina as a Case Study

The portion of the Argentine territory that we call east-central Argentina ($36.6^{\circ}/40.0^{\circ}$ S; $58.3^{\circ}/66.8^{\circ}$ W; $\approx 290,000$ km²) includes a significant section of the Pampas and the northeast of Patagonia, inhabited by hunter-gatherers from the late Pleistocene to historical times. The Pampas, a grassland/steppe biome, comprises a vast flat to slightly undulating surface landscape only interrupted by two major orographic systems, Tandilia and Ventania, and a number of minor hilly ranges, isolated hills, and scattered rocky outcrops. North-eastern Patagonia is a semi-arid region that comprises

the lower valleys of the Colorado and Negro rivers, the intermediate plateau, and the coastal area. In this latter region, rocky outcrops are scarce and isolated, with the Patagonian Shingle Formation (Rodados Patagónicos) being the most archaeologically relevant geologic feature, composed of gravel deposits of extra-regional provenance (Fidalgo and Riggi 1970; Martínez et al. 2009). In east-central Argentina, there were two main kinds of raw materials used by prehistoric hunter-gatherers for tool-making: quartzite and sedimentary microcrystalline/cryptocrystalline silicates. In order to facilitate our descriptions, we operatively divided these rocks into two subgroups: chalcedony and opaque siliceous rocks or OSR, the latter comprising different kinds of non-translucent cherts (*sensu* Luedtke 1979: 745) (Barrientos et al. 2015, 2016). Other igneous, metamorphic and sedimentary rocks were also available (Harrington 1947; Linares et al. 1980), but they seem to have been of second-order importance for subsistence activities and will not be considered here.

The sources of OSR are very diffuse (Bakken 2011; Barrientos et al. 2015), in the sense of being extensive and difficult to delimit. These rocks appear, in relatively low proportions, intermixed with igneous and metamorphic rocks as well as other stones within the extended gravel mantles of the Patagonian Shingle Formation (Martínez et al. 2009) and in secondary seashore deposits distributed along the Atlantic coast of the Pampas (Bonomo 2005). From a geological standpoint, quartzite is present in different lithologic units, most of them cropping out in Ventania and Tandilia (Dalla Salda et al. 2006; Harrington 1947; Linares et al. 1980). They present very different qualities for flintknapping and their primary and secondary sources—which have a different degree of availability, accessibility, and exploitability—are heterogeneously distributed across the landscape (Bayón et al. 1999; Catella 2014; Catella et al. 2010; Flegenheimer and Bayón 2002). The sources of high-quality quartzite are extremely localized (i.e., point sources; Barrientos et al. 2015), some of them with clear evidence of quarrying activity (Catella 2014; Catella et al. 2013; Colombo 2013). The sources of chalcedony, finally, are much less conspicuous than those of quartzite but they are also highly localized, particularly the primary ones with clear evidence of quarrying work (Barros 2009; Barros and Messineo 2004; Berón 2006; Cardillo and Scartascini 2007).

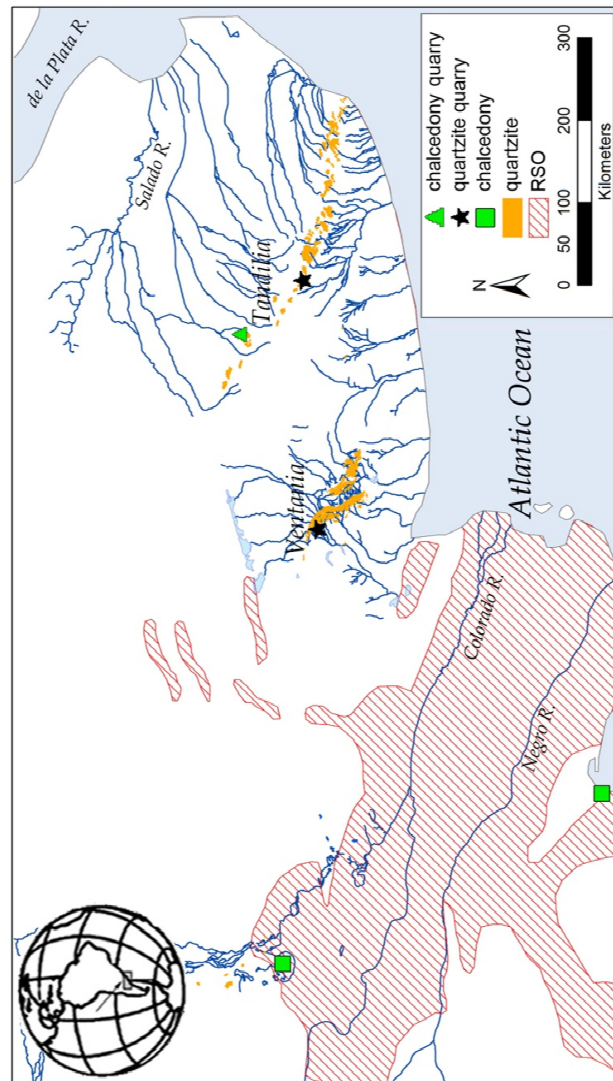


Fig. 27.2. Map of the study area showing the location of the main potential and documented sources of the three raw materials considered in this study: chalcodony, quartzite, and opaque siliceous rocks (OSR).

In this paper we will limit our analysis to just three broadly defined raw materials, namely OSR, quartzite and chalcedony. These rocks have source zones, which are reasonably well known, albeit in a general rather than specific sense (Barrientos et al. 2015, 2016; Catella et al. 2017) (Fig. 27.2). The first step in our analysis was to build a model of the lithic landscape of each toolstone class by using relative frequency data from 124 georeferenced lithic assemblages. The continuous surface models were created by interpolation with ordinary kriging (spherical model) in ArcGis 9.3.² The second step was to identify the zones of highest competition between OSR and quartzite and between chalcedony and quartzite by detecting the areas with the steepest slopes (40°+) of the corresponding distribution of frequencies (slope/surface analysis in ArcGis 9.3) (Fig. 27.3). The third step was to build 3D models for the three raw materials and then to trace two virtual transects (a-b and c-d) across the highest competition zones, intersecting the corresponding source zones (3D Analyst in ArcGis 9.3) (Fig. 27.3). The fourth and final step was to construct, with data from the two transects, a pair of 2D graphics each representing the profiles of the investigated variable (Fig. 27.4).

In the case of quartzite vs. OSR (Fig. 27.4A), the first rock tends to outcompete the second on the basis of three of the four previously described parameters: the height of the curve at its own source and at the other rock source and the distance of the cross-point relative to the mid-point between sources (the slope of the fall-off curve of quartzite is steeper than that of OSR). The resulting composite score is 3:1 in favour of quartzite so it can be said that, on the whole, this rock outcompetes OSR by a factor of 0.5. In the case of quartzite vs. chalcedony (Fig. 27.4B), quartzite tends to outcompete chalcedony in three of the four parameters, namely the height of the curve at the source zone of the latter, the steepness of the curve's slope and the distance of the cross-point relative to the mid-point between sources (chalcedony presents a slightly higher relative frequency at its own source zone). Also in this case, quartzite outcompetes the other toolstone by a factor of 0.5.

² As a technical note it should be mentioned that the use of different interpolators and parameter values may produce different results, so it would be advisable to control this factor; for the sake of simplicity and due to space limitations, in this paper we omit the presentation of information regarding this problem (for further considerations about this issue, see Barrientos et al. 2016).

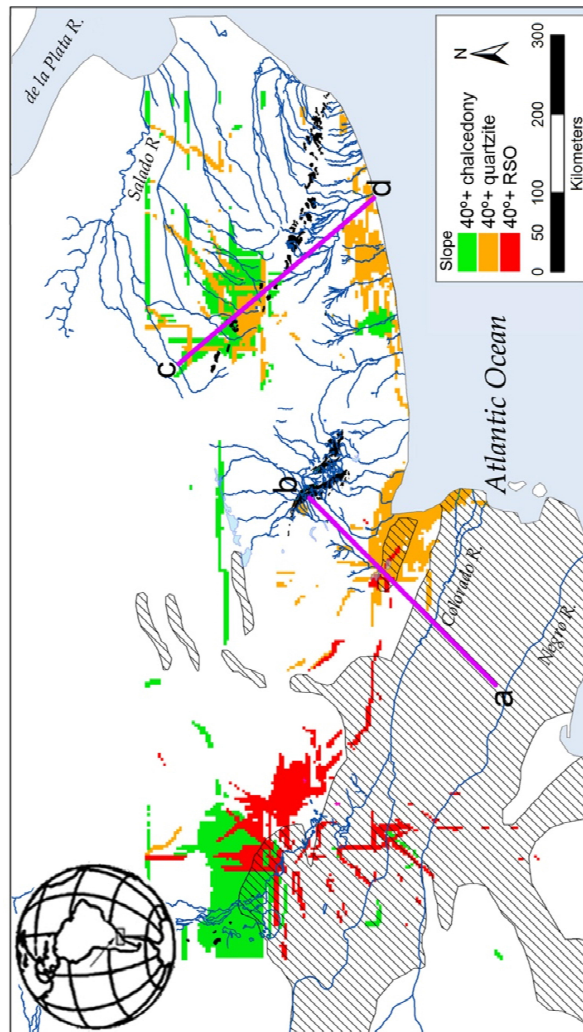


Fig. 27. 3. Map of the study area showing the position of the areas in which the slope of the modelled distribution of relative frequencies of each of the three raw materials considered in this study is equal or higher than 40°. Superimposed are the two virtual transects (violet lines) traced to compare the fall-off curves of the three rocks (a-b: quartzite vs. OSR; c-d: quartzite vs. chalcedony).

What then are the determinants of the observed differences between the investigated toolstones in terms of their relative contribution to the composition of lithic assemblages? Quartzite and sedimentary microcrystalline/cryptocrystalline silicates like chalcedony and OSR are of a quite variable quality (Barros et al. 2015; Bayón et al. 1999; Catella et al. 2013) but, in general terms, are equally good for tool-making. In our study area, the main differences between both kinds of rocks and the ones that may explain their differential competitive success are overall abundance (including the areal extent of the sources and the amount of usable pieces at the sources), the size of the pieces available at the deposits, and multi-task performance. Indeed, quartzites are globally more abundant than sedimentary microcrystalline and cryptocrystalline silicates (Bayón et al. 1999; Catella 2014), the average size of the nodules or pieces obtainable at quartzite sources is probably bigger than that at OSR or chalcedony sources (e.g. Barros et al. 2015; Catella 2014; Catella et al. 2017; Colombo 2013), and the variety of tasks and materials worked with quartzite tools is, in general, wider than that carried out with OSR and chalcedony (Leipus 2006; Pal 2012). All these factors, that seem to explain the reasons why quartzite outcompetes other rocks in different situations, should be nevertheless investigated with greater qualitative and quantitative detail in the future, considering both archaeological and experimental (including simulative) data.

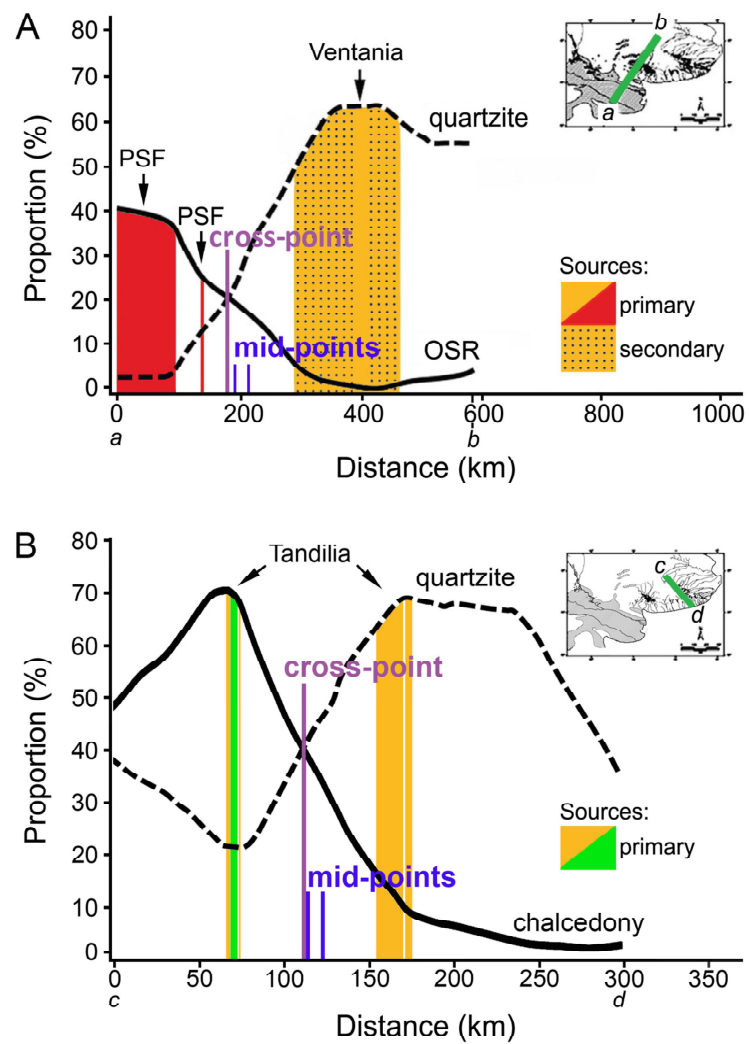


Fig. 27.4 A) fall-off curves of quartzite and OSR along the virtual transect a-b. B) fall-off curves of quartzite and chalcedony along the virtual transect c-d.

Concluding Remarks

This paper represents an initial attempt to set a standard approach to the problem of recognizing and describing competitive relationships between rocks on a regional scale, using spatial modelling of lithic landscapes performed with GIS tools. The examples discussed in this contribution illustrate the effectiveness, simplicity, and relative ease of application of the proposed methodology. When considered on a paired comparative basis, fall-off curves inform about the degree of competitive success of one toolstone over another in spatially explicit contexts. This is useful information when dealing with toolstones and sources that exist in relatively heterogeneous environments with plenty of alternative lithic raw materials and sources.³ It must be noted that the explanation of the detected patterns of interaction between rocks and sources should consider the properties of the investigated resources that probably contributed to their differential competitive fitness, as well as the most enduring and less idiosyncratic aspects of the organization of technology likely involved in their respective modes of exploitation and consumption. Due to the problem of equifinality (Driesch 1929; von Bertalanffy 1950), the explanation should be probabilistic and plural, based on observational and experimental (simulative) data (Barrientos et al. 2015).

It is expected that this brief presentation will encourage the revival—within an updated conceptual and methodological framework—of a largely forgotten line of research initiated by some scholars in the 1970s (Fulford and Hodder 1974; Hodder 1974; Hodder and Orton 1976), thus promoting further explorations on the subject in varied archaeological contexts involving different past environmental and socioecological settings.

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³ Moreover, it seems that the very intelligibility of the fall-off curves based on relative frequency data depends on whether the latter condition is met (see Barrientos et al. 2016: 8).

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