

# Least Cost Paths analysis to reconstruct mobility patterns and procurement strategies for lithic resources in Corsica and Sardinia

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**Abstract** – Is it possible to reconstruct the patterns of territorial mobility and the procurement strategies of early humans in island environment based on the supply of abiotic resources?

This paper tackles the outcomes of a route simulation with GIS open-source technology for chert and obsidian procurement in prehistoric Corsica-Sardinia based on the principle of minimum energy cost. Particular focus is placed on research problems, as the method is applied for the first time on this geographical and chronological scale.

The aim is to highlight both the shortcomings and the potential of Least Cost Path Analyses for small-scale studies of raw material procurement and circulation. It is argued that the model can be strengthened by improving the availability and reliability of the data used as variables for the analysis.

## I. INTRODUCTION

The Least Cost Path Analysis (LCPA) is a tool aimed at studying the relationship among humans and environment that is becoming increasingly popular in archaeological research [1]. It assumes that human groups tend to economize their behaviour in terms of energetic cost [2], thus choosing to conduct their activities with as little energy as possible for achieving their expected results.

The principle of the lowest energy cost is applied to the interactions among humans and landscape during displacements: it is assumed that they will adjust their movements following the most easily accessible paths rather than proceeding in a straight line if this meant encountering obstacles—i.e., natural, or cultural features that impede movement [1, 3]. The least cost path would thus be the most energy-efficient route, in which there is minimal accumulation of these impediments increasing the energy expenditure required to cover the distance [4].

This paper explores the methods of a research aimed at investigating the relationship between the early settlers of Corsica-Sardinia and the environment, addressing both territorial mobility and procurement strategies based on the procurement of abiotic resources. Chert and obsidian, two lithotypes widely used to produce stone tools due to their good knapping qualities, were chosen as proxies to trace the least cost paths bracketing the displacements to the raw material sources. The chronological range encompasses the Pre-Neolithic, whose onset in the islands is debated, and the Early Neolithic—that is, up to the 6th millennium BCE.

Here we will focus on exploring the potential and limits of the Least Cost Path analysis to address both resource management and landscape knowledge of early human groups colonizing insular environments, based on the outcomes and shortfalls of the research.

## II. MATERIALS AND METHODS

The research has first focused on the revision of existing publications on chert and obsidian as raw materials for manufacturing stone tools in Sardinian-Corsican sites. Published data on 26 Pre-Neolithic (PN) and 109 Early Neolithic (EN) archaeological sites were considered, of which 12 PN + 27 EN in Corsica and 14 PN + 82 EN in Sardinia.

A cartographic base of both Corsica and Sardinia was then constructed using QGIS 3.20, the latest released version of the Geospatial Foundation's (OSGeo) Open-Source Geographic Information System. The map was created using available Digital Terrain Models (DTMs) to represent the morphology of the terrain, combined with a vector layer of natural watercourses, a bathymetric chart of the Western Mediterranean and the vectorization of palaeo coastlines for the relevant periods based on isobaths.

Both archaeological sites and raw material sources were

then georeferenced. For the archaeological sites for which sources of obsidian or chert were known, analyses were applied to reconstruct the lowest energy cost routes for procuring the raw material. To do so, the “Least Cost Path” command of QGIS was used. Land slope was taken as the only variable to trace the routes from the ancient settlements (start-points) to the outcrops where lithotypes were probably collected (endpoints).

#### A. Raw material sources

As far as the sources are concerned, obsidian presents different geochemical compositions at several primary and secondary outcrops located on Mount Arci, a relief near the central-western coast of Sardinia [5, 6]—which is also one of the only four obsidian sources existing in the entire Western Mediterranean with an archaeological interest for the era considered in this study.

Unlike obsidian, several potential sources are known for chert or silicified lithotypes, scattered throughout the territory of the sole Sardinia, whereas no chert nor obsidian outcrops are located in Corsica [7, 8]. Nevertheless, the only source to which archaeological chert has been traced back in these chronologies is the Perfugas basin in northern Sardinia.

### III. RESULTS

The result of the Least Cost Analysis is a general pattern of routes that always follow the coastline wherever possible—which was to be expected, having slope as the only variable.

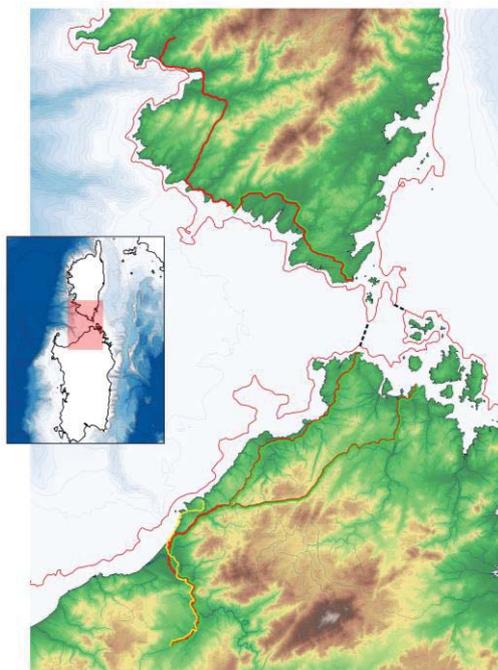


Fig. 1. Overview of least-cost routes (in red and green) for the supply of chert in Pre-Neolithic Corsica-Sardinia. Constructed with QGIS 3.20.

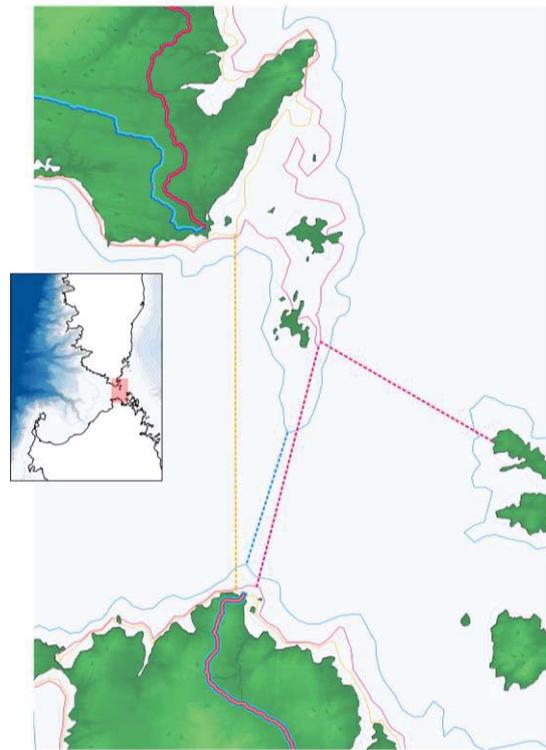


Fig. 2. Detail of the shortest routes as-the-crow-flies across the Bonifacio strait in the Early Neolithic. Constructed with QGIS 3.20.

Whenever the morphology of the coastline consists of inlets and headlands or when it moves away from the desired destination, the routes tend to deviate inland following the course of rivers. Only very rarely, the climbing of a relief or the crossing of a plateau is shown to be less expensive than circumventing it at lower elevations.

Assuming that the distance covered by sea to reach Sardinia from Corsica was the shortest one at the Bonifacio Strait, Southern Corsica was chosen as the arrival point to take the sea in the direction of Sardinia, at its closest proximity to the Sardinian dock (See Fig. 1 and 2).

Thus, all routes from Corsican settlements head southwards to the same location, following the course of several rivers, sometimes upstream, and skirting the coast for some part of the path. Routes beginning in sites located around the Cap Corse follow an itinerary along the entire eastern coast at a very close proximity to the sea and zero slope, moving away from the seashore only at present lagoons or at slight elevations.

Human groups living in Corsica should have had to face a minimum overland journey of 370 km and a maximum of 577 km to get to procure obsidian directly from Mount Arci (See Fig. 3 and 4); while about 177/185 km as a minimum and 123/131 km as a maximum to reach the outcrop of chert at the Perfugas basin (See Fig. 5).



*Fig. 3. Overview of least-cost routes for the supply of obsidian from Early Neolithic Corsica, map 1/2. Constructed with QGIS 3.20.*



*Fig. 5. Overview of least-cost routes for the supply of chert from Early Neolithic Corsica. Constructed with QGIS 3.20.*



*Fig. 4. Overview of least-cost routes for the supply of obsidian from Early Neolithic Corsica, map 2/2. Constructed with QGIS 3.20.*

The least expensive routes through Sardinia also occurred along river valleys, but were clearly shorter than those from Corsica, having the sources at closer distance. Some follow the same path, as it is the most cost-effective from northern locations; others reach the sources from the south. Given the rationale of the energy cost, some outcrops are discarded in favour of others of the same geochemical type at lower elevations.

The routes within Sardinia for the procurement of obsidian do not exceed 294 km in length; but, except for few settlements nearby Mount Arci which could access outcrops within a strictly local range, require to cover a distance of at least 63 km in order to reach the nearest source (See Fig. 6).

Instead, most Sardinian archaeological chert, both Pre-Neolithic and Early Neolithic, is of strictly local origin, pointing to a routinely exploitation of the available resources in the vicinities of the settlement, apart from few occurrences which have been traced back to the Perfugas basin.



*Fig. 6. Overview of least-cost routes for the supply of obsidian within Early Neolithic Sardinia. Constructed with QGIS 3.20.*

#### IV. RESEARCH ISSUES

Several problems were encountered during the development of the research, mostly regarding the paucity of data provided in the literature and their poor reliability, spanning from: insecure archaeological and stratigraphic context; little to no local paleoenvironmental evidence; use of relative or unreliable chronologies combined with lack of published absolute dates; and virtual absence of precise coordinates of both archaeological sites and geological outcrops.

As regards provenance studies, few have examined significant numbers of artifacts to be statistically relevant. Furthermore, although the use of different methods apart from simple visual characterization is recorded for obsidian (SEM-EDS, PIXE, EMP, XRF, INAA), the same is not true for chert which is rarely, if ever, geo-chemically analysed. Its high variability not only hinders its identification based on the sole chemical composition, but also results in a lack of universally agreed terminology among researchers regarding the very definition of “chert”.

These shortfalls greatly affected the outcomes of the Least Cost modelling. As a matter of fact, slope is the only variable related to human-environment interactions for which complete data were available. The LCPA was thus entirely based on this single variable, although many other physical factors might have been considered: hydrology, vegetation, availability of resources, climate [1].

In particular, no relevant information was available on watercourses, such as the width and possible presence of fords, the flow rate and regime, the navigability. These factors can drastically change the interpretation of the role of waterways as a variable in the calculation of cost. In fact, it is still subject to debate among researchers whether rivers are to be considered as obstacles [9] or facilitators of movement [10, 11]. This depends on the characteristics of the stream, e.g., its navigability and the time of the year according to seasonal variations in its flow.

Technological capabilities of human groups must also be considered, in particular navigation skills and boat production technology. In the case of Corsica and Sardinia, navigation skills are assumed in both the Pre-Neolithic and Early Neolithic, at least for the maritime cabotage that would have been necessary to reach the islands in the first place, but no other comprehensive data are available.

Potential sea routes were also excluded from the LCPA; again, this was due to a lack of data that would have been necessary to formulate a reliable proposal—such as sea level; sea conditions and currents; sailing routes; prevailing seasonal and diurnal wind patterns [12]; the identification of low slopes on the coastline to locate the most suitable spot for landing a boat; the intervisibility and the location of protected waters [3], etcetera. It was thus decided to take the shortest route as the crow flies from the Corsican palaeo-coast to the nearest Sardinian dock as the most probable path, drawing a simple straight line (See again Fig. 1 and 2). However, this also means excluding maritime cabotage around Sardinia to reach the same endpoints by boat.

In fact, the sole inland routes were traced in this research. Yet, their itinerary could change significantly if waterways were considered as variables. As the presence of watercourses was not calculated in the analysis, in several cases the routes not only follow the rivers by overlapping the flow channel but also cross them horizontally following the lower gradient terrain—which would probably not be possible if the permanent presence of water was taken into account.

Finally, it should be borne in mind that, although only natural features were taken into account at this stage of the research, cultural barriers also existed and operated (at least in the VI millennium when population density increased in both islands). As a matter of fact, it is not always true that humans act efficiently, as their culture might influence route selection [9]. Movement in some hunter-gatherers’ communities is mostly influenced by the desire to visit or avoid certain places than by energetic efficiency [11]. Yet, detailed landscape-related variables regarding habits, behaviour and symbolism are virtually unknown in these chronologies.

#### V. CONCLUSIONS

Despite the shortcomings, several achievements were accomplished with the application of Least Cost Path

Analysis in this research. Although the results must not be understood as exact physical routes but as simulations of past human mobility in relation to topographical barriers, the existence of several sites in their vicinities might strengthen the model, as it is accepted that humans tend to establish their settlements within reach of communication networks [13]. Furthermore, knowing the approximate length in km has allowed to infer whether these displacements are likely to have occurred, at least for the supply of the sole abiotic resource or as single round trips. Cautious interpretations could thus be made regarding the mode of procurement, be it down-the-line or embedded instead of direct.

As other authors have highlighted, the more variables that can be incorporated, the more realistic the model will be; nevertheless, one must take care in the construction of variables, which have to be robust [1]. Prior to developing new investigations on raw material procurement strategies and mobility patterns in early Corsica and Sardinia, it is first necessary to reinforce the basic data that will be processed with the GIS software, addressing the research gaps that were highlighted above.

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