Supplementary Information III: Mobility, Terrain Susceptibility, and Resources in the Eresma-Riaza interfluve

Development and calibration of a spatial model for the analysis of Paleolithic archaeological potential in the Duero basin of the Iberian Peninsula

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The compilation of material sources, their digitization, and the acquisition of new data through analyses resulted in a total of 16 final cartographies (Appendices 4-16): slope, aspect, territorial mobility, fords, insolation, territorial viewshed, lithological resources, physiography (geodiversity), active geomorphological dynamics during the Pleistocene, karstic forms, hydrological resources, slope movements, and degree of anthropization of the territory.

The value of these cartographies lies not only in their use as input for the multicriteria analysis but also as an atlas that deeply describes the study area, its composition, resources, and accessibility, with applications beyond assessing the archaeological potential of the region. Below is a brief analysis of some maps considered relevant in themselves.

1. Mobility analysis

The mobility analysis carried out to detect population circulation routes in the study area reveals significant differences between the results obtained using two cost surfaces: slope in radians (Fig. 1) and Tobler's (1993) algorithm (Fig. 2). Tobler's algorithm produced a density surface identifying routes at the Guadarrama and Somosierra passes, as well as an exit via Limera pass, highlighting the horizontal path connecting Navafría pass with Somosierra as a key crossing of the Central System. The Eresma and Duero valleys, along with the sandy and rolling plains region, show high mobility potential on the northern slope of the Central System. Expected gaps appear mainly on the slopes and summits. Likewise, the Pradales ridge and Sepúlveda massif act as geographic obstacles to north-south and east-west movement, though the analysis detects some routes crossing the ridge northwest-southeast and the massif east-west.

The second, more conservative model detects only the Guadarrama and Somosierra passes. In this mobility model, route density concentrates in the Duero valley, especially near Aranda del Duero and around Valladolid and Ávila on the study area's periphery. Less dense but notable routes follow the Adaja, Voltoya, Moros, and Eresma river valleys west to east, though important rivers like Cega, San Juan, Duratón, or Riaza are overlooked.

One key question is whether anthropogenic terrain modification influenced detected routes. A 50 m^2 digital elevation model (DEM) was selected precisely to avoid such biases. These biases have been explored in Paleolithic mobility analyses (Becker et al., 2017), showing DEM resolution affects distance estimates: higher resolution yields steeper slopes and lower velocity. High resolutions of 5 and 10 m^2 are ideal for detailed scale studies (e.g., canyons), but increase anthropogenic noise (roads, constructions). Many studies use 25x25 m DEMs (Fábrega Álvarez and Parcero Oubiña, 2007); for large areas, 90 m SRTM DEMs have been applied (Aceituno Bocanegra and Uriarte González, 2019). Here, a 50 m^2 DEM was chosen as a balance to blur major road effects and cover the study area in detail. The slope-in-radians cost surface suggested only two mountain passes coinciding with A-1 and AP-6 roads. Tobler's algorithm detected additional passes not aligned with major roads, suggesting limited anthropogenic influence.

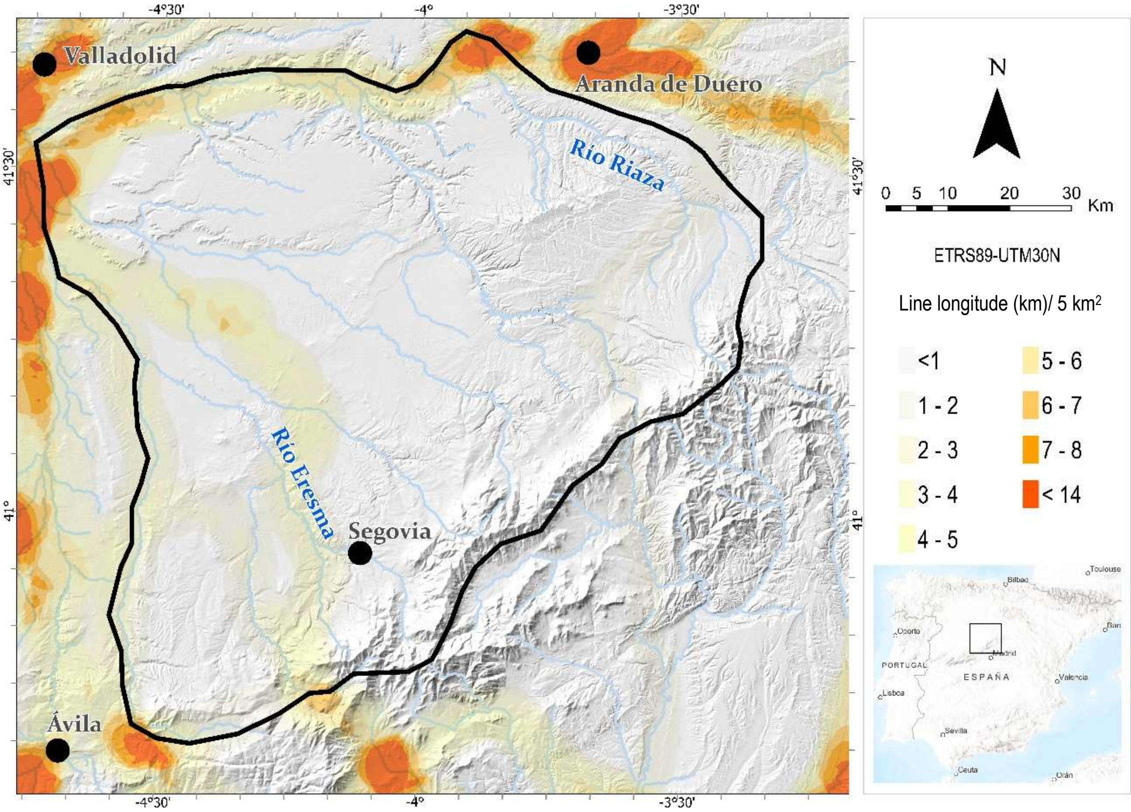

Fig. 1: routes estimation by calculating the surface cost with the slope in radians.

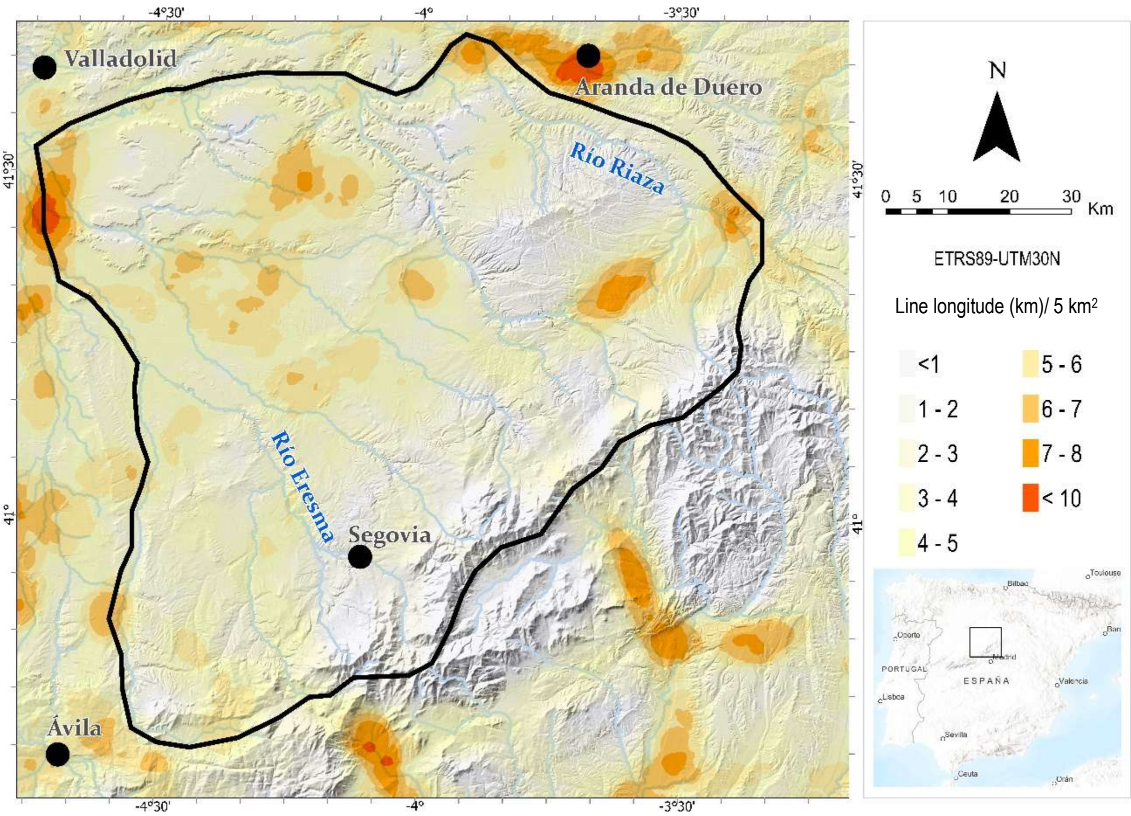

Fig. 2: routes estimation by calculating the surface cost with the Tobler's algorithm (1993).

Although the conservative slope-in-radians results might seem preferable for the multicriteria analysis, Tobler's algorithm was ultimately selected as providing a more robust and territory-consistent model of human population movement.

Regarding fords, it is important to note that those represented in the cartography are approximations using a rudimentary methodology to address a difficult question. They do not precisely indicate the capacity to cross main watercourses but represent the number of routes, paths, or rural tracks currently crossing them. Moreover, river courses in the past likely differed, so these data only vaguely approximate the Paleolithic environment.

Few fords or crossing zones were identified along the Duero, Duratón, and Cega rivers, as well as some stretches of the Eresma and Pirón rivers. Nevertheless, most main rivers such as Adaja, Voltoya, and Riaza appear largely passable, facilitating mobility. Indeed, high route densities were detected along the first two rivers, crossing watercourses rather than following their banks, supporting the hypothesis that these rivers were not necessarily obstacles.

2. Slope Movements and Site Destruction Susceptibility

The multicriteria analysis assessing terrain movement susceptibility identified low susceptibility zones associated with physiographic units like riverbanks, rañas, or the rolling plains of Tierra de Pinares (Fig. 3). Susceptibility rises in campiñas and páramos, especially their highest areas where steeper slopes and alternating compact and erodible lithologies occur. High susceptibility zones include the Central Iberian Range summits and canyons such as the Duratón gorges. Despite using a simplified method based only on slope and lithology, results align with expectations (Ferrer Gijón and Ayala Carcedo, 1987).

Since riverbanks often host archaeological sites—due to water proximity for settlement and their capacity to transport or bury archaeological remains—and have low movement susceptibility, they present high potential for site preservation. The opposite applies to canyons: modeled areas often contain shelters and overhangs that might have served as temporary refuges. However, their high susceptibility to landslides (Tanarro and Muñoz, 2012) reduces preservation potential, as archaeological deposits may have been destroyed or displaced, not to mention frequent cave roof collapses that bury and sometimes destroy assemblages under blocks.

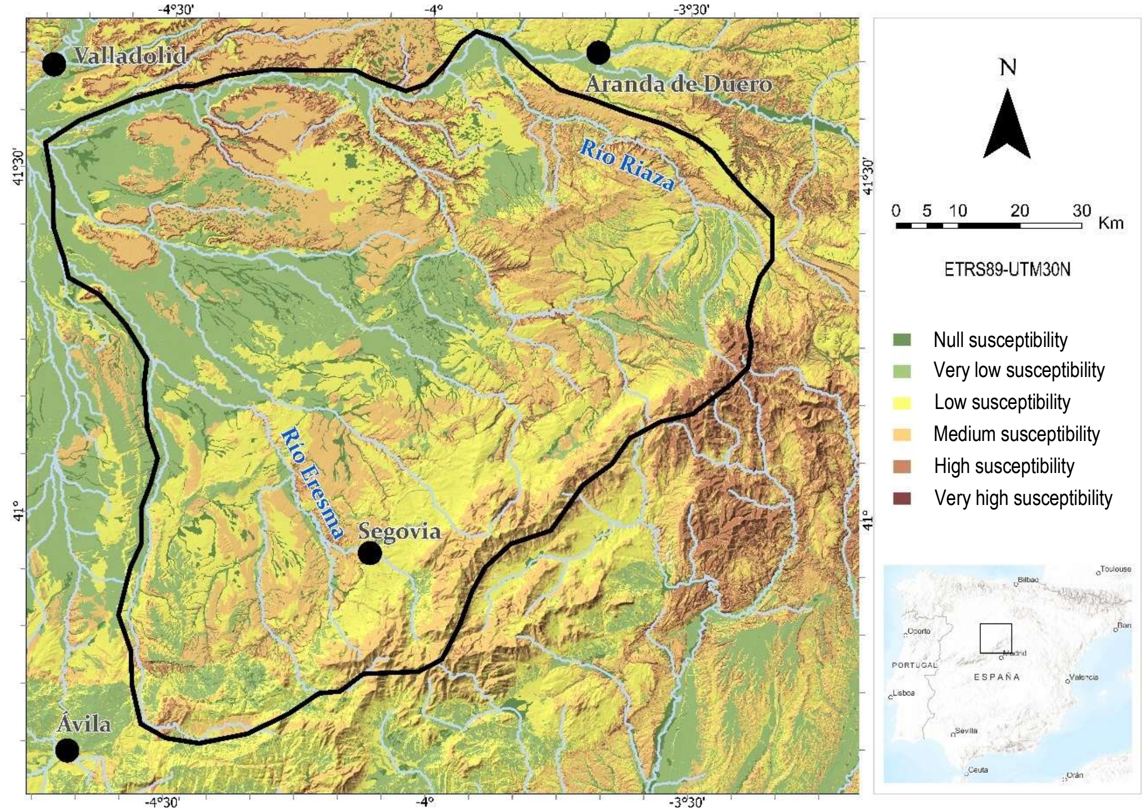

Fig. 3: slope movement susceptibility estimated by means of multicriteria analysis.

3. Relationship between Lithological Resources and Karstic Formations

Resource procurement and strategic territorial use for refuge selection are key behavioral and ecological variables to understand archaeological site location. Most lithic industry studies in sites from the study area report locally sourced raw materials (Díez Martín, 1996; Cacho Quesada et al., 2007; Martos et al., 2013; Álvarez-Alonso et al., 2018), making raw material location a primary factor in the multicriteria analysis. Long-distance transport occurs mostly for rare, high-quality materials, providing valuable information on Paleolithic mobility, but typically the procurement area lies near the site.

Relating karstifiable lithologies—indicators of possible caves and shelters—with the distribution of raw materials of potential Paleolithic interest offers a preliminary view of potentially habitable zones or areas with favorable conditions (Fig. 4). A concentration of varied raw materials (flint, quartz, quartzite) occurs in the northeast near the Duratón and Riaza rivers, where several surveys identified flint procurement zones (Cacho Quesada et al., 2007; Martos et al., 2013). This sector, including the Sepúlveda massif and Pradales ridge, hosts the most developed karstified Mesozoic lithologies known as the Duratón karst (Díez Herrero and Martín Duque, 2005). Several caves have been identified nearby, making this a promising area for prospecting. Similarly, the Segovia karst region shows flint outcrops and sources of quartz and quartzite cobbles.

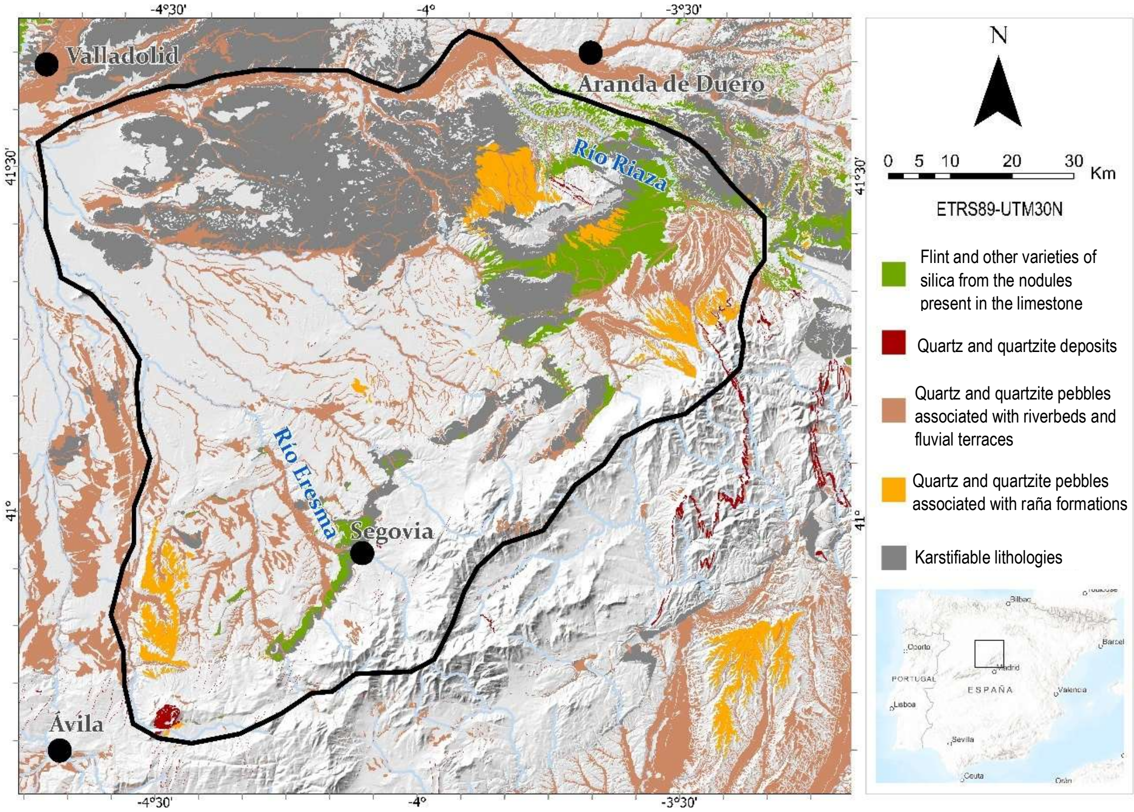

Fig. 4: Relationship between karstifiable lithologies and lithic resources.

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