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In search of homelands: using strontium isotopes to identify biological markers of mobility in late prehistoric Portugal

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A B S T R A C T

This study uses strontium isotopes ($^{87}Sr/^{86}Sr$) in dental enamel from burial populations related to the fortified Chalcolithic settlement site of Zambujal (c. 2800–1800 BC) to distinguish the presence of non-local individuals. Zambujal is located in the Estremadura region of Portugal near the Atlantic coast and has long been considered a central location of population aggregation, craft production, and trade during a time of increasing political centralization and social stratification until its eventually abandonment during the Bronze Age. While it is assumed that population migration and long distance trade played an important role in the region's development, little is known about the migration patterns of individuals or groups. The results of this study find that nine percent (5 out of 55) of the total surveyed individuals can be classified as non-local (based on $^{87}Sr/^{86}Sr$ values distinct from the local bioavailable range of 0.7090–0.7115 as defined by 2sd of the sampled human mean), the majority of which come from one burial site, Cova da Moura. Comparisons with other regional data suggest the possibility that some of these non-locals come from the Alentejo region of the Portuguese interior, corresponding with known exchange patterns.

1. Introduction

The archaeological record of the Late Neolithic through Early Bronze Age in the Estremadura region of Portugal (Fig. 1) provides clear evidence of the rise of a socially-complex, chiefdom-scale non-state society (Cardoso, 2007; Gonçalves, 1999; Lillios, 1995). While several settlement sites in this area have been discovered (including Fórnea, Pico Aguda, and Boiaca), the most prominent and well-excavated is the walled fortification of Zambujal (c. 2800–1800 BC), which has long been considered a center of trade, population aggregation, craft production, and metallurgy in this region until its eventual abandonment during the Bronze Age (Kunst, 1995; Sangmeister and Schubart, 1981; Uerpmann and Uerpmann, 2003). While it is assumed that population mobility and long distance trade played an important role in the development of social complexity in the region, very little is known about the migration patterns of individuals or groups. Therefore, this study uses strontium isotope ratios ($^{87}Sr/^{86}Sr$) in dental enamel to distinguish non-local individuals from seven Late Neolithic-Early Bronze Age (3500–1800 BC) burial populations related to Late Neolithic and Copper Age settlement sites, in particular Zambujal, near the municipality of Torres Vedras in the Estremadura region (Fig. 1).

$^{87}Sr/^{86}Sr$ isotope ratio ranges are available for some geological formations and groundwater samples in the Iberian Peninsula (e.g. Freitas et al., 2003; Moita et al., 2009; Schneider et al., 2009; Villaseca et al., 2009; Voerkelius et al., 2010), and predictions can be made based on the lithologies and ages of different geological units. However, with the exceptions of preliminary studies by Ortega et al. (2012), Prevedorou et al. (2010) and Boaventura et al. (2010), specific measurements of bioavailable $^{87}Sr/^{86}Sr$ isotope ratios are unavailable for most of Portugal and Spain. Thus, this study marks a crucial first step in connecting past peoples and animals with particular geographic regions using $^{87}Sr/^{86}Sr$ isotope ratios in the Iberian Peninsula.

2. Strontium isotope ratios and landscapes

In archaeological research, the measurement of radiogenic strontium isotope ratios ($^{87}Sr/^{86}Sr$) in biological tissues can be used

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Fig. 1. Map of the Estremadura and Alentejo regions of Portugal.

to identify human and animal migration patterns (see Beard and Johnson, 2000; Bentley, 2006; Price et al., 2002, 2012). This is possible because the strontium isotope signature of each particular geographic area permeates the landscape and local groundwater and is absorbed into the local plants and residing animals. Strontium is incorporated into teeth and bone through water and food intake. Due to its close chemical affinity, it substitutes for calcium in the mineral component (hydroxyapatite) of hard tissues (Bentley, 2006; Ericson, 1985; Nelson et al., 1986; Schroeder et al., 1972:496). Radiogenic strontium isotopes ($^{87}Sr/^{86}Sr$) do not fractionate when absorbed into human and animal tissues, and thus an organism's strontium isotope signature directly reflects the bioavailable strontium in its environmental range. Therefore, animals and humans occupying the same territorial ranges and ingesting only local plants, animals, and water, should bear similar strontium isotope signatures. Conversely, between regions that are geologically distinctive, humans and animals should exhibit differences in strontium isotope ratios according to the local lithology. When significant geologic heterogeneity exists in larger regional landscapes it is possible for humans and/or animals to migrate into areas in which the local bioavailable $^{87}Sr/^{86}Sr$ ratio deviates enough from that of the home range for this difference to be clearly identifiable in analyses of hard tissues. This approach requires geologic diversity over transversable distances, and thus our study area in central Portugal should be amenable to strontium isotope fingerprinting of human migration given the wide range of rock types of different ages present in the region (Fig. 2). However it is important to clarify that this methodology is unable to distinguish between individuals who originate from different locations that share similar bioavailable $^{87}Sr/^{86}Sr$ values, and therefore the number of migrants recognized will provide only a minimum estimate of mobility.

2.1. Geology of the Estremadura

The Estremadura region of southwestern Portugal borders the Atlantic coast and encompasses both the Lisbon and Setúbal peninsulas (Fig. 1). Geologically the region is quite diverse, occupying part of the Lusitanian Basin, a northern Atlantic basin formed during a rifting phase of the late Triassic. This basin, which is mainly composed of Cretaceous and Jurassic sediments with pockets of Triassic sediments in the north, connects to the Alentejo and the Algarve Basins in the southeast, and is delineated in the north and east by the Late Paleozoic Hercynian basement rocks of the Iberian Meseta (Cunha and dos Reis, 1995; Wilson, 1988) (Fig. 2). The landforms of the Lusitanian Basin are geologically younger than other parts of the Iberian Peninsula and are mainly composed of heterogenous lithologies including limestones, sandstones, clays, marls, basalts and volcanic rocks (Azerêdo et al., 2002; Wilson, 1988). In general the Lusitanian Basin lacks many of the igneous granites and metamorphic schists found in the Portuguese interior, although some intrusive massifs of granites are found west of Lisbon near the municipality of Sintra (Sparks and Wadge, 1975). The Lusitanian Basin is further divided by faults into the Northern Lusitanian Basin, the Central Lusitanian Basin, and the Southern Lusitanian Basin (Schneider et al., 2009). In the northeast of the Central Basin the landscape is dominated by Jurassic marine limestone massifs, while in the inland west and south, Jurassic limestones are interspersed with large areas of Cretaceous sandstones and conglomerates (Schneider et al., 2009). Basalts are prevalent in the volcanic complexes around Lisbon and in the southeast of the region the lowlands of the lower Tagus basin are mainly composed of Triassic sandstones. Rivers, including the Almonda and the Nabão originate in the northern highlands and cut through the southeastern Tagus Tertiary Basin where Miocene