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Isotopic Evidence of Diet and Mobility From the Megalithic Burials of the Rego da Murta Dolmens (Portugal)

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This study uses stable and radiogenic isotopic data from Chalcolithic (c. 3000–1900 BC) humans and animals recovered from the Rego da Murta dolmens (Alvaiázere, Portugal) to understand dietary and mobility patterns in the populations using these monuments. The results suggest diets based primarily on C_3 plants and terrestrial animals, with some possible variation in protein intake by age or status. Analyses of $^{87}Sr/^{86}Sr$ values identify two individuals out of ten from Rego da Murta I and four individuals out of fifteen from Rego da Murta II as migrants. These data were compared to other Chalcolithic burials in south-western Portugal: while diets were found to be similar across the region, the very high $^{87}Sr/^{86}Sr$ values recorded for two migrant humans match no known settlement in the broader region. A recent mapping study of $^{87}Sr/^{86}Sr$ values in Portugal suggests their origins may lie to the north/north-east of the dolmens.

Keywords: Portugal, Chalcolithic, diet, strontium isotopes, migration

Introduction

This study uses stable and radiogenic isotopic data from humans and animals recovered from the Chalcolithic (*c.* 3000–1900 BC) burials of Anta da Rego da Murta I and Anta da Rego da Murta 2 in Alvaiázere (Leira, central Portugal) to understand dietary and mobility patterns in the populations using these monuments. Archaeological evidence from late prehistoric south-western Portugal suggests that it was a time of new population aggregations and more complex social and regional relationships from the Neolithic into the Early Bronze Age (Gonçalves, 1999; Cardoso, 2007; Lillios, 2020). Megalithic building and use were prevalent, and these megalithic

doi:10.1017/eaa.2025.1
Manuscript received 26 May 2024,
accepted 1 January 2025, revised 1 October 2024

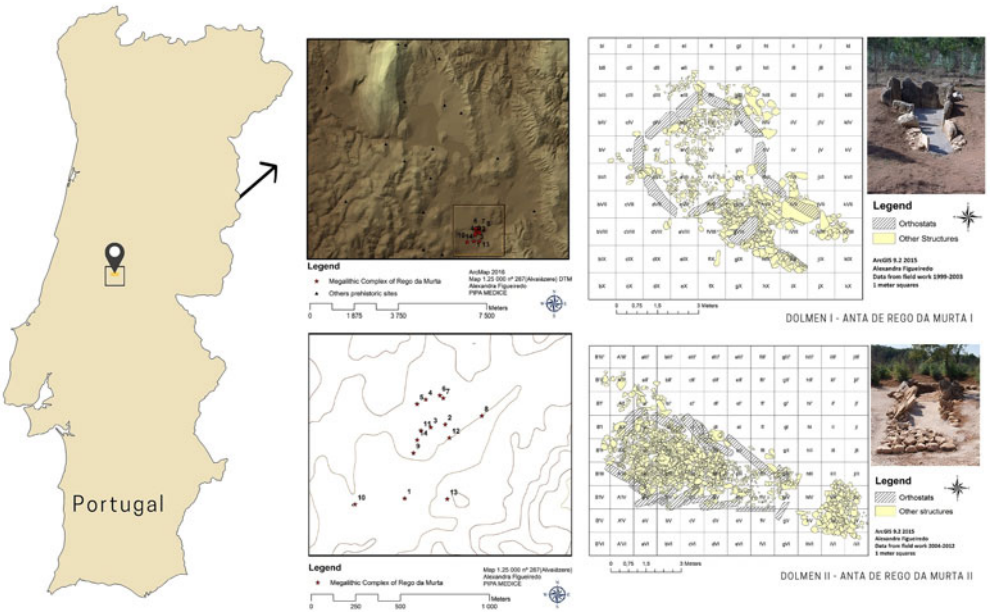

Figure 1. *Location map and plans of Rego da Murta I and II.*

landscapes and the archaeological remains found within them offer an important window into the cultural, economic, and ritual aspects of life during this period, before large-scale abandonment of settlements occurred in the Bronze Age. Preliminary results of the $^{87}Sr/^{86}Sr$ ratios for the twenty-five humans from Rego da Murta I and II discussed here were first reported by Waterman and colleagues (2013). At that time, the limited animal and environmental $^{87}Sr/^{86}Sr$ data available for the area prevented a clear evaluation of human and animal migration patterns at these sites. The newly expanded $^{87}Sr/^{86}Sr$ dataset presented here, in combination with new dietary data, allow us to more fully consider the human lifeways of the people interred in the Rego da Murta monuments.

Rego da Murta

The Rego da Murta megalithic complex consists of fourteen archaeological sites, including two dolmens which provide detailed evidence of funerary rituals (Figure 1). The complex also includes menhirs (Figueiredo, 2008) and prehistoric art (Figueiredo, 2021), further emphasizing its importance as a ritual landscape (Figueiredo, 2008, 2017, 2019b, 2021). The dolmens were excavated between 1997 and 2012 by a team coordinated by the Polytechnic Institute of Tomar (Figueiredo, 2007, 2008, 2010, 2017, 2019a, 2019b, 2021). These excavations recovered a large quantity of human and animal remains and material culture that provide crucial clues for understanding the later prehistory of the Ribatejo region of Portugal.

The first dolmen, Rego da Murta I (RM I), consists of a sub-polygonal chamber with eight orthostats and a corridor of six slabs of varying dimensions (Figure 1). The dimensions of the corridor's two right slabs are similar to those of the chamber's supports. The left wall of the corridor contains a stone that is

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possibly a recycled menhir (it differs morphologically from the other orthostats and is strikingly similar to other menhirs in the complex) and a posthole is also located in the centre of the left wall of the corridor (Figueiredo, 2007, 2017, 2021). A circular structure in the centre of the chamber appears to have supported a structure made of perishable materials (Figueiredo, 2007: 162). Several funerary deposits in highly fragmented and disturbed contexts have been identified at RM I, including in the monument's centre, near a semicircular stone structure, at the corridor entrance, and between the corridor and the chamber (Figueiredo, 2007, 2019b). When compared to the better-preserved deposits of Rego da Murta II, it is hypothesized that these were ossuary-type deposits with a mixture of old and new remains (Figueiredo, 2021: 59).

Artefacts recovered from RM I are morphologically and technologically diverse, and include mostly undecorated ceramics, lithics (flakes and blades, some lamellae, quartzite cores, and arrowheads), and polished stone objects such as necklace beads and zoomorphic adornments. (Figueiredo, 2007). Fragmented faunal remains were recovered from nineteen deposits, including many rabbits or hares, but also domesticated animals, such as pigs, goats/sheep, and dogs (Detry, 2005). Wild species such as fox (*Vulpes vulpes*) and roe deer (*Capreolus capreolus*) were also recovered (Figueiredo, 2007: 242–46, 2021: 42). The human remains were generally derived from inhumations, but some also showed evidence of incineration; one such instance was below the orthostat at the entrance to the chamber, with a bone fragment dated 3360–3090 cal BC (at 95 per cent confidence; 4520±40 BP; Beta 190001)—the oldest date from the site.

Anthropological studies have identified a minimum number of fifty individuals at RM I: thirty-six adults and fourteen non-adults (less than fifteen years old), with at least six female and four male individuals (Silva & Ferreira, 2005). Pathological conditions were uncommon, but include some laminar spikes, enthesopathies, and weak arthrosis (Ferreira & Silva, 2003: 9). Dental examination revealed few cariogenic lesions and only seven teeth had enamel hypoplasia, indicating very low levels of dietary stress or illness during childhood (Silva & Ferreira, 2005: 11–15).

Anta Rego da Murta II (RM II) is better preserved than RM I, as the prehistoric deposits were deliberately sealed by stones during rituals (Figueiredo, 2007, 2021: 43). The ongoing use and maintenance of the dolman are attested by clearing old deposits to construct a stone slab floor, which was later covered by further deposits in the Middle and Final Chalcolithic (Figueiredo, 2019b). Like RM I, the RM II monument consists of a polygonal chamber composed of eight small limestone orthostats and a corridor, in the shape of a slightly elongated horseshoe made of six orthostats. The side areas between the chamber and the corridor have a small buttress, and next to the entrance a small atrium opens to the west-northwest. Here at least eight preserved ossuary contexts were found (Figueiredo, 2017: 50, 2021: 44), along with other depositions disturbed by more recent (but still prehistoric) deposits.

At Rego da Murta II, a greater number of polished stone objects were recovered. The ceramics are generally smaller than at RM I, and usually lack decoration, although fragments of Atlantic Bell Beaker and Spanish Boquique-type ceramics were recovered, some found overturned on top of the stones that covered the bone deposits (Figueiredo, 2007, vol. 2, 270–82). Additionally, a wide variety of necklace beads, flint arrowheads, and halberds were found, but few flakes and blades, when compared to RM I (Figueiredo, 2021: 40).

Compared to RM I, better preservation meant that more complete osteological

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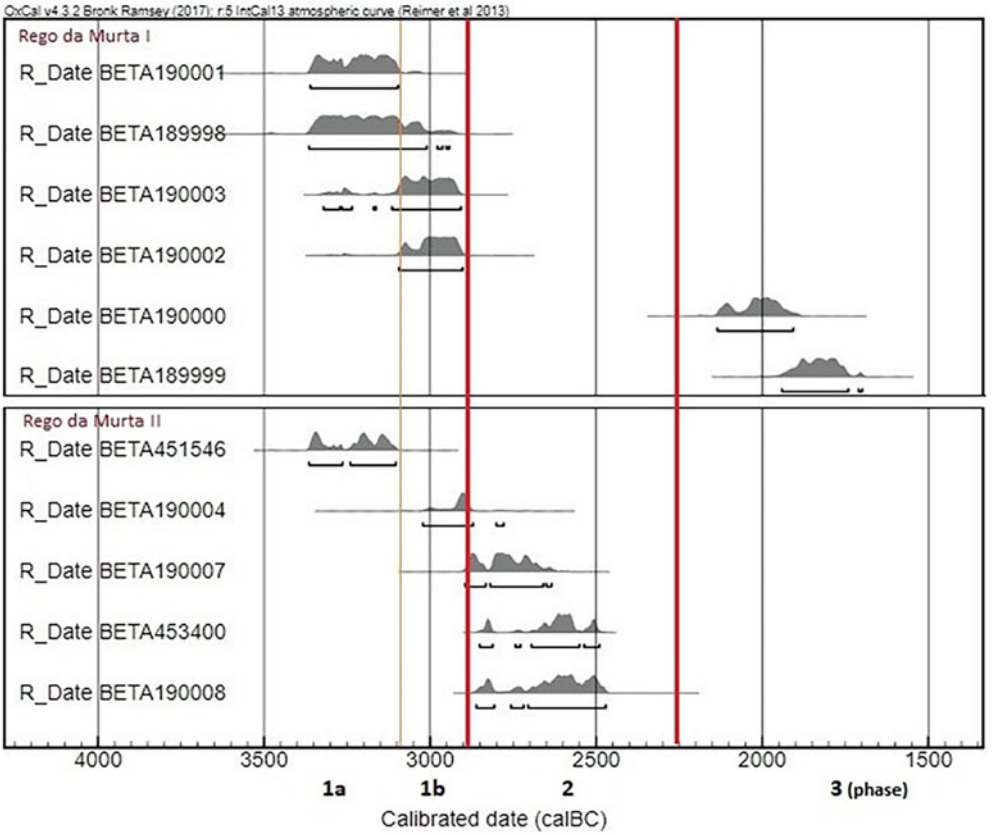

Figure 2. *Radiocarbon ages from Rego da Murta I and II (after Figueiredo, 2021).*

remains were found at RM II. Anthropological analyses identified a minimum of sixty-nine individuals interred at RM II (Silva & Ferreira, 2005; Alves et al., 2022), of both sexes and varying ages. As at RM I, remains of wild and domesticated animals were recovered at RM II. Eight species were identified: deer, rabbit, hare, fox, pig, sheep/goat, cattle, and horse or zebra (Detry, 2005).

Occupation, interpretation, and chronological framework

The radiocarbon dating suggests an earlier origin for RM I than for RM II (Figure 2). When considering all the dates in terms of provenances and contexts, the occupation of the two sites can be divided into three phases. The first phase corresponds to the construction of both monuments and is primarily seen in depositions from 3500 to 3000 BC in RM I. Similar depositions are believed to have happened in RM II but appear to have been cleared away by the beginning of the Chalcolithic period for the construction of the stone floor at the base of the chamber. Traces of ancient depositions were observed *in situ* beneath that floor with dates similar to the early depositions of RM I, i.e. 3370–3100 cal BC (at 95 per cent confidence; 4540±30 BP; Beta 451546).

The second phase of occupation is exclusively documented in RM II and involves the construction of the stone

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floor and the deposition of remains on top of it (Figueiredo, 2007, 2019a, 2019b, 2021). These new deposits appear to be secondary deposits, and combine sediments, and new artefacts, with fragmented skeletal elements that may have originated elsewhere (potentially primary burials). Supporting this interpretation, the sediment on the stone floor mixed with the remains was unlike any layer around it in terms of colour, granularity, and composition (Figueiredo, 2021). The remains on top of the floor were in small mounds later covered with stones to seal the deposit. There is also evidence that previous deposits were sometimes disturbed, possibly when small pits inside the monument were dug in new ritual activities (Figueiredo, 2019b, 2021). In these contexts, the human remains were from different individuals and anatomical regions, without any clear selection criteria. This may suggest that these remains are more representative of ancestral relationships with the living community, rather than known individuals (Figueiredo, 2007, 2021). In the third and last phase, ritual practices in RM II cease, whereas activities continue at RM I. In this third phase, dates from remains recovered from RM I's corridor area align with the early Bronze Age (2140–1900 cal BC at 95 per cent confidence; 3640±40 BP; Beta-190000 and 1950–1700 cal BC at 95 per cent confidence; 3510±40 BP; Beta-189999) (Figueiredo et al., 2018: 210).

The skeletal remains from the Rego da Murta dolmens are highly fragmented due to post-depositional taphonomic processes. Anthropogenic actions, characterized by frequent deposits within the monument and ritualistic practices that altered previous deposits, were the primary disturbing factors (Ferreira & Silva, 2003; Silva & Ferreira, 2005). Among the remains, the teeth are best preserved, and these were used to calculate the minimum number of individuals.

Background to Methods

Gathering stable ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$) and radiogenic ($^{87}Sr/^{86}Sr$) isotope data from the hard tissues of humans and animals has grown to be a vital part of archaeological research, providing evidence of past diet and migration patterns (see e.g. Ambrose & Krigbaum, 2003; Katzenberg & Waters-Rist, 2008; Loftus et al., 2016; Somerville & Beasley, 2023).

Stable isotopic analyses

The values of $\delta^{13}C$ and $\delta^{15}N$ from bone collagen are used to differentiate protein in the diet in relation to the consumption of C_3, C_4, and CAM plants, and marine and terrestrial animal proteins (Smith & Epstein, 1971; Chisholm et al., 1982; Schoeninger & DeNiro, 1984; Ambrose & Norr, 1993; Tykot, 2002, 2004). For bone apatite, $\delta^{13}C$ values can evaluate the inputs of C_3, C_4, and CAM plants, and marine and terrestrial animal consumption within the whole diet, including proteins, carbohydrates, and lipids (Ambrose & Norr, 1993; Schwarcz, 2000; Tykot, 2002, 2004). When both collagen and apatite are analysed, the combination of $\delta^{13}C_{ol}$, $\delta^{13}C_{ap}$, and $\delta^{15}N$ data can provide a more nuanced picture of foodways in past populations. For example, differences in the spacing between $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ may be attributed to differential protein intake (Krueger & Sullivan, 1984; Lee Thorp et al., 1989) or used to evaluate marine versus terrestrial protein and C_3 versus C_4 plant consumption (Kellner & Schoeninger, 2007). The $\delta^{18}O$ values from dental enamel or bone apatite provide data about water sources and can be used to distinguish between plants and animals from different geographic locations (Stuart-Williams et al., 1996; White et al., 2004). In bones and teeth, trophic level adjustments

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in the values of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{18}O$ from consumed to consumer can also inform on the environment, animal foddering systems, fertilizer use, and food consumption patterns (Katzenberg & Waters-Rist, 2008). Cortical bone can remodel at different rates according to numerous physiological factors (Fahy et al., 2017). It is, however, generally thought that isotopic values in adult bone reflect approximately the last ten years of an individual's life (Manolagas, 2000). In enamel, because it does not remodel, apatite values reflect the time of tooth formation.

Radiogenic isotopic analyses

Using radiogenic strontium isotope ratios ($^{87}Sr/^{86}Sr$) from dental enamel (in combination with ratios from environmental samples) provides one way of investigating human and animal migration patterns in prehistory (see Beard & Johnson, 2000; Price et al., 2002, 2012; Bentley, 2006). The ratios of strontium isotopes in a landscape are based on local geology and water sources (Faure & Powell, 1972; Gilli et al., 2009). These ratios move into plants, and then into animals' teeth and bone when consumed, as strontium substitutes for calcium in the building of hydroxyapatite (Schroeder et al., 1972; Ericson, 1985; Nelson et al., 1986; Bentley, 2006). Unlike $\delta^{15}N$, $\delta^{13}C$, and $\delta^{18}O$, strontium isotopes undergo minimal fractionation when moving from plants to animals and then from animal to animal as part of food webs (Lewis et al., 2017). Therefore, $^{87}Sr/^{86}Sr$ values in bone and teeth should directly reflect the bioavailable strontium of the local environment when eating local foods and drinking from local water sources. In turn, animals and humans that live in the same area and ingest only local foods should exhibit similar $^{87}Sr/^{86}Sr$ isotope values (Burton & Hahn, 2016).

Conversely, humans and animals should exhibit differences in radiogenic strontium isotope ratios when from geologically distinct regions. Because landscapes can have similar geological features and therefore similar local bioavailable $^{87}Sr/^{86}Sr$ values even when geographically distinct, it is possible that humans and animals who originate from different locations share similar $^{87}Sr/^{86}Sr$ values. Therefore, this method can only be used to quantify a minimum estimate of mobility. Distinctions between dental enamel values and the bioavailable $^{87}Sr/^{86}Sr$ values from a burial location may indicate migration after tooth formation (Price et al., 1994, 2004). This is because dental enamel does not remodel over time and stores the strontium isotope values from the diet during enamel formation.

Geology of the Ribatejo region

The geological formations of the Iberian Peninsula, composed of a wide variety of rock lithologies of different ages, allow for different locations in Portugal and Spain to be distinguished by their $^{87}Sr/^{86}Sr$ isotope fingerprints. The formations around the Rego da Murta dolmens in the Ribatejo region (Figure 3) are especially diverse and include conglomerates, sandstones, limestones, dolomitic limestones, marly limestones, and marls from the Cretaceous and Jurassic periods, as well as red sandstone from the Triassic (Cunha, 1990: 35–38; Forte et al., 2009). Intercalations of formations from the Precambrian period are also present. To the east and north-east, there are quartzites, dating from the Ordovician to the Devonian period. In these areas, schists, clayey schists, greywackes, mica schists, amphibolites, quartzites, and Precambrian gneisses are also found. The Rego da Murta dolmens are located near Alvaiázere (Leiria), in a depression between the rivers

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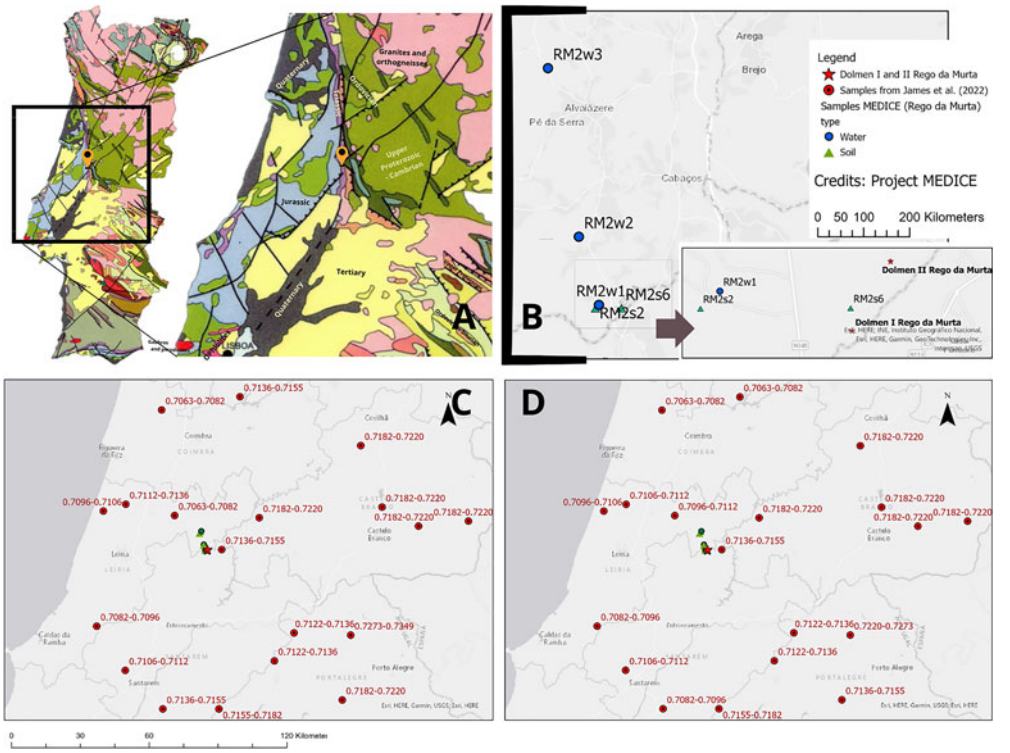

Figure 3. *Map of Portugal with geological and isotopic information. (A) Geological map of Portugal, (B) locations of the dolmens and environmental samples, (C) nearby $^{87}Sr/^{86}Sr$ isotope ratios from plants, (D) nearby $^{87}Sr/^{86}Sr$ isotope ratios from soils (C, D: data from James et al., 2022).*

Nabão and Zêzere, in the eastern part of S. Saturnino and Vale de Rodrigo and south of Serra de Alvaiázere, on the red sandstone of Silves, where conglomerates, marls, and dolomitic limestones predominate, ranging from the Triassic to the Jurassic (Cunha, 1990). Thus, it is expected that $^{87}Sr/^{86}Sr$ isotope values will vary widely across the region.

Methods and Materials

Dental enamel samples for the strontium analysis (first, second, or third molars, depending on availability) were taken from ten adults from RM I and from eleven adults, three adolescents, and one child from RM II (Supplementary Tables S1 and S2). When available, bone samples were also taken from the same individuals for stable isotopes. Those sampled are five out of ten individuals from RM I and fourteen out of fifteen individuals from RM II. Samples were taken from twenty-six animals from the two burial sites. For the strontium analysis, enamel alone was analysed for the large animals and most of the rabbits, but, due to small tooth size, some dentine was used along with the tooth enamel for the rodents and two rabbits. Two soil leachate and three water samples were also analysed to help calculate the local $^{87}Sr/^{86}Sr$ range. Bone samples were also taken from six animals where mandible fragments were available for stable isotopic analysis. Although not directly dated, the human and animals remains

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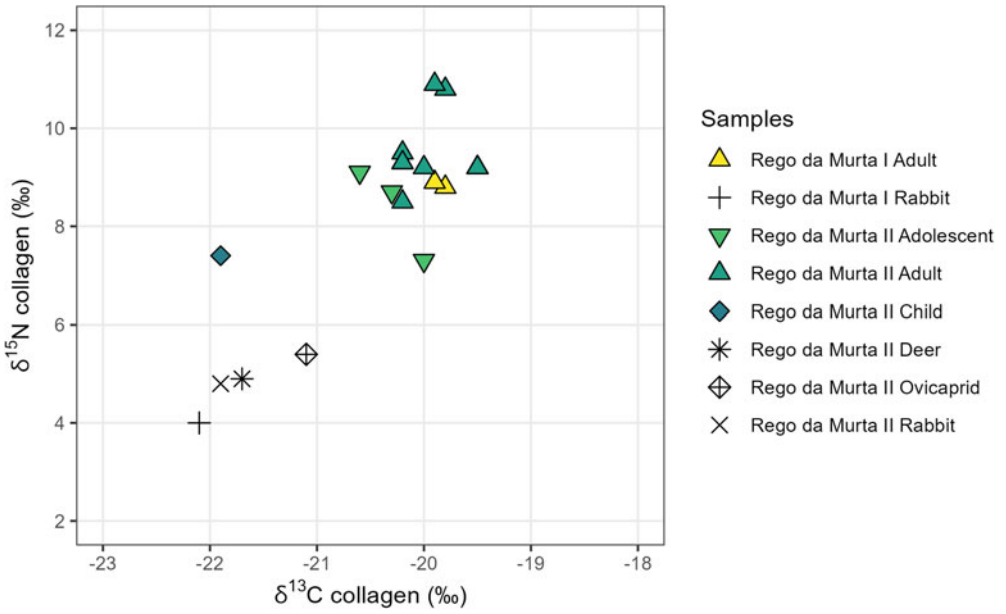

Figure 4. *Scatterplot of stable carbon and nitrogen isotope values for human and animal bone samples from Rego da Murta I and II. Markers are grouped by site and taxon.*

sampled from RM I and II are associated with Chalcolithic burial deposits at each dolmen. For the stable ($\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$) and radiogenic ($^{87}Sr/^{86}Sr$) isotopic analyses, standard laboratory methods were used. A full explanation of these methods is available in the Supplementary Material.

Results and Discussion

$\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ results

Measurements of $\delta^{15}N$ and $\delta^{13}C_{col}$ from bone collagen were obtained from four adults from RM I, and $\delta^{18}O$ and $\delta^{13}C_{ap}$ were obtained from bone apatite from five adult individuals. For RM II, $\delta^{15}N$ and $\delta^{13}C$ from bone collagen samples were obtained from thirteen individuals, including nine adults, three adolescents (*c.* 10–15 years old), and one child (*c.* 6–9 years old), while bone apatite $\delta^{18}O$ and $\delta^{13}C$ values were obtained for ten adults and all the nonadults. For the individuals RMI 26 and RMII 1000, the collagen was too degraded to analyse. Additionally, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values were obtained from six animals recovered from the dolmens for comparative purposes (Supplementary Material Table S1, Table S2; Figures 4–6).

The data show that C_3 plants and terrestrial proteins were the main components of human diets with little evidence of marine dietary inputs. When plotted against regression lines derived from the results of experimental feeding studies (Kellner & Schoeninger, 2007; Froehle et al., 2010), the data suggest that all macronutrient sources came from C_3 foods. Two adults from Rego da Murta II (RMII 631 and RMII 1003) had noticeably higher $\delta^{15}N$ values, over 3‰ higher than the lowest values, which were from an adolescent and a child from RM II. The three adolescent individuals from RM II exhibit lower $\delta^{13}C_{col}$ and $\delta^{15}N$ values than nearly all adult individuals (Figure 4).

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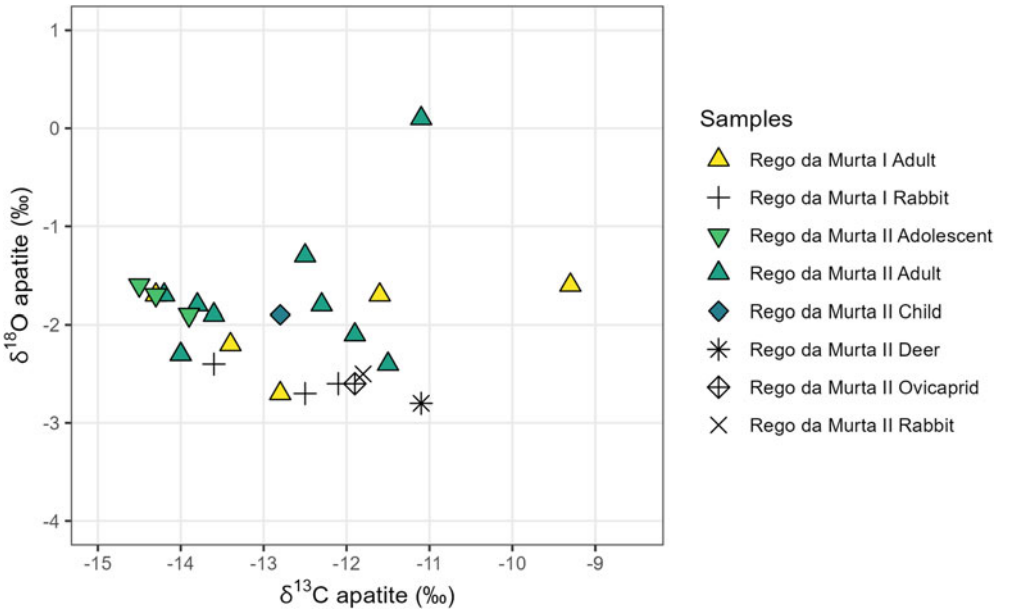

Figure 5. *Scatterplot of stable carbon and oxygen isotope values of human and animal bone samples from Rego da Murta I and II.*

These adolescents also exhibit some of the lowest $\delta^{13}C_{ap}$ values of the population (Figure 5). This could imply dietary differences by age and/or status in this community. Conversely, adults from RM I had almost no variability in $\delta^{15}N$ or $\delta^{13}C$ values, suggesting dietary homogeneity in protein sources. The whole diet for the humans from RM I, as depicted by $\delta^{13}C_{ap}$, was more variable but still offers no suggestion of C_4 plant intake or marine food influence, except for one individual (RMI 267) for which $\delta^{13}C_{ap}$ values were much higher than others in the burial. This value of -9.3 ‰, may suggest that a C_4 or CAM plant was a carbohydrate source in his or her diet. The $\delta^{18}O$ values from both dolmens, and the sampled animals, suggest similar water sources for humans and animals. There is one exception, as one adult (RMII 624) has an outlier $\delta^{18}O$ value (Grubbs' Single Outlier Test, P-value 0.0011), which may suggest a foreign water source and possibly migration (see Figure 8; Figure S1) (Grubbs, 1950).

$^{87}Sr/^{86}Sr$ results

The local bioavailable Sr composition was calculated by taking two standard deviations from the mean of the $^{87}Sr/^{86}Sr$ ratios for small fauna (rabbits and rodents) and soil leachate and water samples resulting in an estimated local range of 0.709–0.714 (Table S3). In the report by Waterman and colleagues (2013) in which the human strontium values for the RM I and II humans were first published, a local range of 0.7107–0.7127 was calculated using three rodents and two rabbits. The authors noted that this was an ill fit for the data and made many humans and domesticated animals non-local. They suggested a more natural fit would be in the 0.7145–0.710 range. The data presented here confirm that the estimated local range is larger

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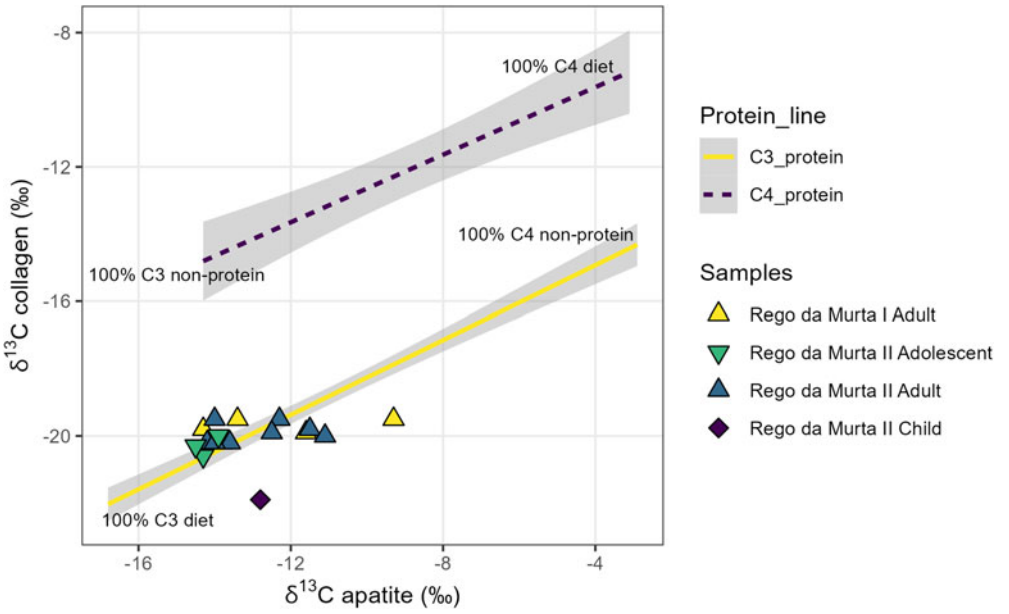

Figure 6. *Scatterplot of stable carbon isotope values of human bone apatite and collagen from Rego da Murta I and II individuals plotted against the simple carbon isotope model (Kellner & Schoeninger, 2007; Froehle et al., 2010).*

than that pilot study calculated. James and colleagues (2022) published a predictive $^{87}Sr/^{86}Sr$ map of Portugal based on the values of soil leachate and plant samples and the use of Empirical Bayesian Kriging. This map has estimated local $^{87}Sr/^{86}Sr$ ratios for the landscape around the dolmens to be 0.7082–0.7096. This seems unsuitable for the Rego da Murta dataset as all the fauna sampled in this project, both domestic and wild, large and small, have values above this. It appears that the Rego da Murta dolmens are at the junction between geologically different areas, with the landscapes to the west, north-west, and south-west matching James and colleagues' (2022) predictions, while landscapes to the east, north-east, and south-east exhibit higher $^{87}Sr/^{86}Sr$ ratios. Indeed, when James and colleagues' (2022) $^{87}Sr/^{86}Sr$ ratios from plants and soil around the larger dolmen area are examined (Figure 3), a clear delineation of lower values to the west and higher values to the east is visible.

Rego da Murta I

The $^{87}Sr/^{86}Sr$ ratios for the Rego da Murta I humans were variable, with a high of 0.7198 and a low of 0.7110. The average for the human samples from this dolmen was 0.7139±0.0032 (Table S1). Based on the calculated local range, individuals RMI 299 (0.7197) and RMI 305 (0.7198) can be considered migrants, with values just under 0.720, far exceeding the local range. This suggests that these adults grew up consuming food and water in a landscape with more radiogenic values. North-east of Rego da Murta, in the Palaeozoic landscapes of the Beira Alta and Beira Baixa regions (*c.* 200 km away), matches for these values can be found, as well as in the Alentejo region to the south-west (James et al., 2022). However, origins for our RM I individuals may be much closer. A soil leachate and plant sample recovered just some 20 km east/north-east of the dolmens had values of

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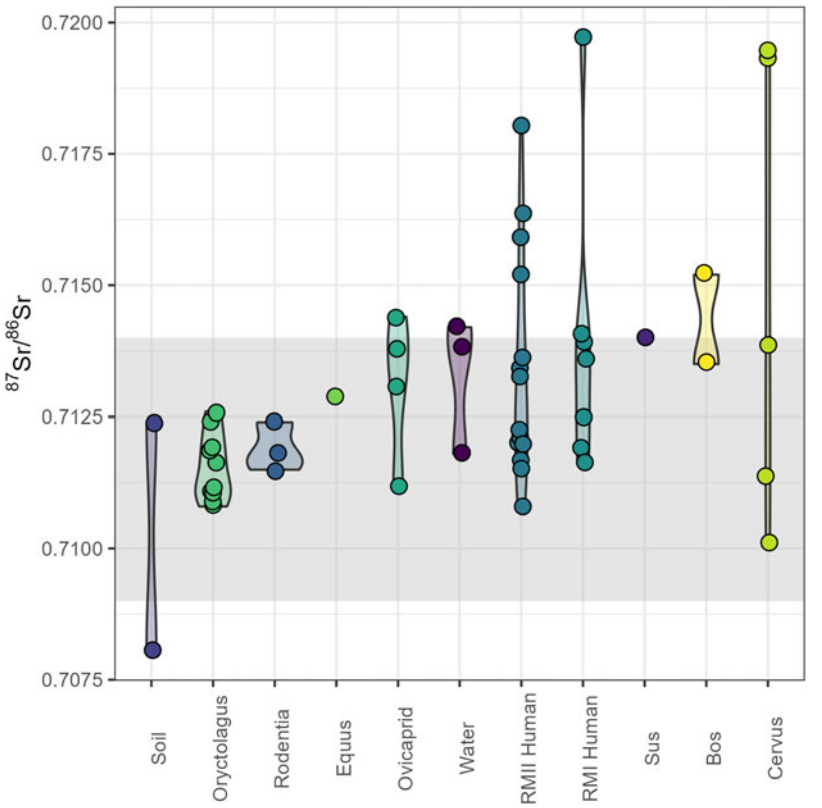

Figure 7. *Violin plots of $^{87}Sr/^{86}Sr$ isotope ratios from Rego da Murta I and II. The shaded grey box indicates the proposed local range of $^{87}Sr/^{86}Sr$ values for the Rego da Murta dolmen area.*

0.7182 and 0.7220 (James et al., 2022), suggesting that our migrants came from this nearby locality (Figure 3).

Rego da Murta II

For the Rego da Murta II humans, the $^{87}Sr/^{86}Sr$ ratios were similarly variable with a high of 0.7180, a low of 0.7108, and an average of 0.7135±0.0021 (Table S1). Here four adults fall outside the upper boundary of the calculated local range, yet none of these have values quite as high as those of the migrants from RM I (Figure 7). Again, landscapes that match these values (0.715–0.718) could be found far to the east, north-east, and south-east, but also within a 60 km range in these directions. One of the RM II migrants, RMII 624, is also the individual with the outlier $\delta^{18}O$ values (Figure 8). This adds strength to the idea that this person grew up in a more distant landscape.

The $^{87}Sr/^{86}Sr$ ratios for the sampled fauna also reveal some interesting patterns and divergences. The small fauna (seven rabbits and three rodents) used to help calculate the local $^{87}Sr/^{86}Sr$ range along with the soil and water, all have values between 0.7109 and 0.7126 (Table S3). The large domestic and wild animals show more variability, with two deer matching the values of the two migrant humans from RM (Table S4). This may suggest that they came from the same landscape

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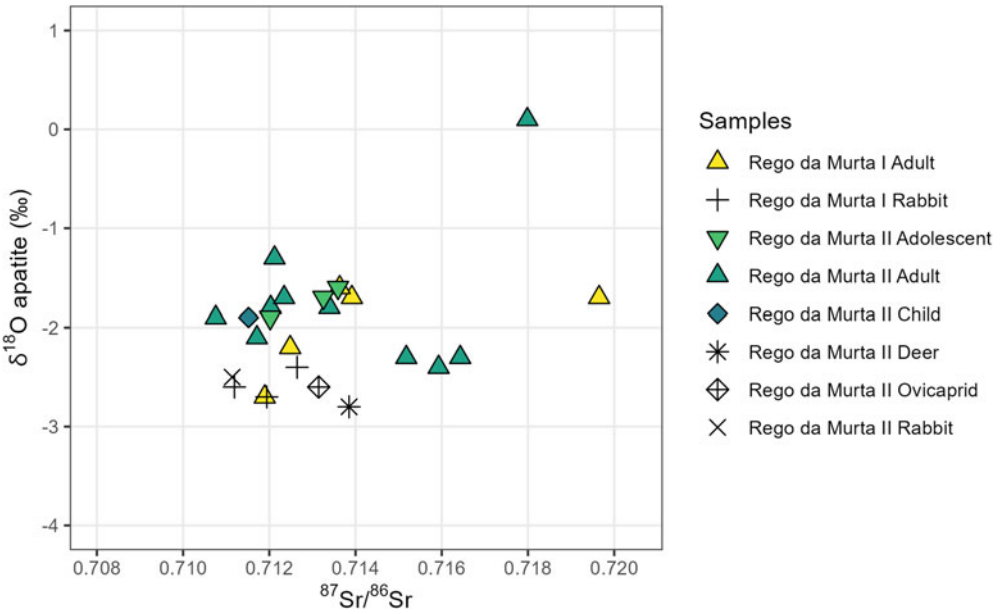

Figure 8. *Scatterplot of strontium isotope ratios and stable oxygen isotope values of human and animal samples from Rego da Murta I and II.*

and that this landscape is close enough for hunting and transport. As the values refer to the bioavailable strontium during dental formation, this may also reflect migratory foraging patterns for the deer rather than the location the deer were hunted. The only other animal that exceeds the local range is a bovine with a value of 0.7152. This may indicate activities related to stock movement, with parts of early cattle life (during the first two years when permanent dentition is forming) spent grazing in more mountainous areas, or it could denote cattle trading.

Broader Regional Comparisons and Conclusions

Much of the cultural and biological data from the Rego da Murta burials match trends seen in contemporaneous populations in Portugal, including collective burials in megaliths, tholoi, and caves, with a similar array of artefacts and a long use-life. Diets here, like elsewhere in the region, were based on C_3 plants and domesticated animals. Local C_4 or CAM plants may have made their way into the diets of some individuals and animals, but generally this signature appears in the apatite and is suspected of being carbohydrate-based. What we see in the $\delta^{13}C_{ap}$ values of the RMI 267 individual is also found in the Estremadura region of Portugal, at burial sites such as Cova da Moura (Waterman et al., 2014b: 124–25). Variations in $\delta^{15}N$ values by age, with adults at times having statistically significant differences in protein type/intake when compared with subadults, are also found in other burials in the region (Waterman et al., 2014b) and may relate to age-related food restriction or preferences, or to the physiological processes of bone growth.

As previously stated, the use of $^{87}Sr/^{86}Sr$ ratios from biological tissues to identify non-local animals and humans can only provide a minimum estimation of

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mobility. The calculated local $^{87}Sr/^{86}Sr$ range at RM I and II (0.709–0.714) overlaps slightly at the lower end with the local range of the Chalcolithic settlement of Zambujal (0.7085–0.7115) (*c.* 130 km away) (Wright et al., 2019; Waterman, 2023), and more fully with the Chalcolithic settlement of Vila Nova de São Pedro (0.709–0.714) (*c.* 120 km away) (Waterman et al., 2024) and partially at the higher end with the landscape around the Chalcolithic settlement of Perdigões (0.712–0.718) (200 km away) (Valera et al., 2020; James et al., 2022). Therefore, there could be people or animals in our sample from these places that cannot be discerned with this methodology. We can, however, say that our analysis shows no evidence of people or animals moving from places in the Lisbon peninsula, such as the Chalcolithic settlement of Leceia, which has a local $^{87}Sr/^{86}Sr$ range of 0.706–0.708 (Wright et al., 2019). The most intriguing finding in our strontium dataset is the two individuals and two deer with very high $^{87}Sr/^{86}Sr$ values (all over 0.719). For these we are not yet able to pinpoint a place of origin, but there may be nearby landscapes to the east that match these values. Based on the energy inputs into long-distance migration, the most parsimonious approach would be to assume that our migrants are from the closest area matching these values (Waterman, 2023). Waterman and colleagues (2014a) found one individual from the Cova da Moura burial site located some 120 km to the south-west of the Rego da Murta dolmens that exhibited the same very high $^{87}Sr/^{86}Sr$ values (0.721) as found at RM I. It is possible that this individual came from the same area as some of the humans and animals identified in this study.

In sum, the stable and radiogenic isotopic data from humans and animals recovered from the Chalcolithic burials of Anta da Rego da Murta I and II indicate diets based primarily on C_3 plants and terrestrial animals, as is the case throughout the region at this time. Some variation in protein type and intake suggests some dietary heterogeneity in the Rego da Murta community, perhaps by age or status. Analyses of $^{87}Sr/^{86}Sr$ values have identified two individuals from RM I and four individuals from RM II as migrants. Additionally, $^{87}Sr/^{86}Sr$ values from animals recovered from the burials also identified two deer from RM I that match the values of the human migrants and may suggest a relationship between them. Mapping studies of $^{87}Sr/^{86}Sr$ values in Portugal suggest the origins may be to the east/north-east/south-east of the site, perhaps as close as 20 km away, however more research into this possibility is warranted. These findings broaden our understanding of the dietary and mobility patterns of humans and animals in late prehistoric Portugal and provide evidence of possible origins for humans and animals with particularly high $^{87}Sr/^{86}Sr$ isotope ratios—origins which may be applied to other datasets in the Iberina Peninsula.

Acknowledgements

We would like to thank Craig Lundstrom, Tom Johnson, and Josh Smith of the University of Illinois Department of Earth Science and Environmental Change for help with the MC-ICP-MS work for this project. Funds were provided by the Archaeological Institute of America Archaeology of Portugal Fellowship, the Research Centre for Historical Sciences at the Autonomous University of Lisbon, the Polytechnic Institute of Tomar, and Mount Mercy University.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/eaa.2025.1.

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https://doi.org/10.1017/eaa.2025.1 Published online by Cambridge University Press

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Données isotopiques sur l'alimentation et la mobilité des occupants des dolmens de Rego da Murta (Portugal)

Cette étude, réalisée pour mieux comprendre l'alimentation et la mobilité de la population ensevelie dans les dolmens chalcolithiques (c. 3000–1900 av. J.-C.) de Rego da Murta (Alvaiázere, Portugal), concerne les données obtenues sur les isotopes stables et radiogéniques des humains et animaux découverts dans ces monuments. Les résultats indiquent une alimentation basée principalement sur des plantes C_3 et sur des animaux terrestres, avec quelques variations possibles dans l'apport des protéines selon l'âge ou le statut des individus. L'analyse du rapport isotopique du strontium ($^{87}Sr/^{86}Sr$) a identifié deux individus sur dix à Rego da Murta I et quatre personnes sur quinze à Rego da Murta II comme exogènes. La comparaison de ces données avec celles obtenues pour d'autres sépultures chalcolithiques du sud-ouest du Portugal a révélé une alimentation semblable dans la région, à l'exception des deux individus exhibant des valeurs $^{87}Sr/^{86}Sr$ très élevées ; ces dernières ne correspondent à aucune autre valeur mesurée dans les habitats dans l'ensemble de la région. Une étude cartographique récente des valeurs $^{87}Sr/^{86}Sr$ au Portugal suggère que les origines des migrants de Rego da Murta pourraient se trouver au nord ou au nord-est du site des dolmens. Translation by Madeleine Hummler

Mots-clés: Portugal, Chalcolithique, alimentation, isotopes du strontium, migration

Isotopische Daten über Ernährung und Mobilität aus den Bestattungen in den Dolmen von Rego da Murta (Portugal)

Diese Untersuchung betrifft die stabilen und radiogenen Isotopen der in den kupferzeitlichen (ca. 3000–1900 v. Chr.) Dolmen von Rego da Murta (Alvaiázere, Portugal) deponierten Menschen und

https://doi.org/10.1017/eaa.2025.1 Published online by Cambridge University Press

Tieren, um die über Ernährung und Mobilität der Bevölkerung, welche diese Denkmäler benutzte, besser zu verstehen. Die Ergebnisse weisen auf eine hauptsächlich auf C_3 Pflanzen und Landtieren beruhende Ernährung mit einigen möglichen Variationen in der Proteinaufnahme, je nach Alter oder Status. Die Analyse der $^{87}Sr/^{86}Sr$ Werte ergibt, dass zwei von zehn Individuen in Rego da Murta I und vier von fünfzehn Menschen in Rego da Murta II nicht einheimisch waren. Der Vergleich von diesen Daten mit anderen kupferzeitlichen Bestattungen in Südwestportugal zeigt, dass die Ernährung in der gesamten Region ungefähr gleich war, aber dass die sehr hohen $^{87}Sr/^{86}Sr$ Werte der zwei Zuwanderer in den Siedlungen der weiteren Gegend nicht belegt sind. Eine vor kurzem durchgeführte kartografische Studie der $^{87}Sr/^{86}Sr$ Werte in Portugal weist auf eine Herkunft in einem Gebiet, das nördlich oder nordöstlich der Dolmen lag. Translation by Madeleine Hummler

Stichworte: Portugal, Kupferzeit, Ernährung, Strontium-Isotopen, Migration

https://doi.org/10.1017/eaa.2025.1 Published online by Cambridge University Press