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A Tale of Two Necropolises: Contrasting Patterns of Diet and Mobility in Late Medieval/Early Modern Lisbon Through Multi- Isotope Analysis

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TITLE: **A TALE OF TWO NECROPOLISES: CONTRASTING PATTERNS OF DIET AND MOBILITY IN LATE MEDIEVAL/EARLY MODERN LISBON THROUGH MULTI-ISOTOPE ANALYSIS**

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ABSTRACT:

The archaeological site of Rua dos Lagares #74, Lisbon, has two distinct phases of use as a burial space. Necropolis I appeared to be a Jewish cemetery that was abandoned by the end of the 15th century, coinciding with the formal expulsion of Jewish communities from Portugal in 1496 CE. Necropolis II was later established and apparently used for multifaith burials in the early 16th century, and at least some of the interred appeared to have African origins and may have been enslaved, freedmen, or labourers living in Lisbon following Portuguese imperial expansion along the West African coast. Multi-isotope analysis of bone collagen ($\delta^{13}C_{col}$, $\delta^{15}N$) and tooth enamel ($\delta^{13}C_{en}$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$) from 53 adult individuals (Necropolis I: 29, Necropolis II: 24) revealed starkly contrasting life histories amongst and between the individuals buried in both necropolises. In Necropolis I, childhood and adulthood diets

were very homogeneous and similar to published isotope values from other late medieval communities in Lisbon. Most individuals in Necropolis I were apparently local, apart from five males. In Necropolis II, extraordinary diversity could be observed in both childhood and adulthood diets of the population as well as in their places of origin. It could be observed, through the isotope data, that not only were most of the Necropolis II individuals non-local to Lisbon, but they also hailed from vastly diverse geographic regions with different food sources. These results represent a rare opportunity to consider the origins and dietary histories of (potentially) enslaved Africans in the Old World, predating the transatlantic slave trade, in the case of Necropolis II, and unique insight into Jewish communities in Lisbon prior to D. Manuel I's Edict of Expulsion in the case of Necropolis I.

1.INTRODUCTION:

It was the best of times for Portuguese imperial expansion, it was the worst of times for many communities who faced religious persecution, expulsion or enslavement in the Portuguese Kingdom's pursuit of religious absolutism and colonial territories. As the 15th century ended, Muslim and Jewish communities who had remained in Portugal after the Christian conquest were forcibly converted or expelled from the Kingdom. At the same time, maritime exploration along the Atlantic coast of West Africa resulted in the rapid establishment and expansion of networks used to trade commercial goods and enslaved African people, many of whom were brought back to Lisbon to be sold locally or transported elsewhere. Historical records documenting the origins and life histories of slaves, freedmen and African labourers living in Lisbon during this time are incredibly sparse, and much information was lost in the destruction of the 1755 CE Lisbon earthquake, if the records existed in the first place. For similar reasons, very little is known about Jewish communities living in Lisbon before and after the 1496 CE Edict of Expulsion. The archaeological site of Rua dos Lagares #74 (38^{o} 43' 2.4564" N, 9^{o} 7' 58.584" W) presented a unique opportunity to better understand these communities, as the area was apparently used as a cemetery for Jewish burials (Necropolis I) until its abandonment around the late 15th century, and later used for mixed-rite burials (Necropolis II) of a multifaith community, some of whom had possible African origins. A multi-isotope analytical approach was used on skeletal material from Necropolis I and Necropolis II to assess the origins and dietary histories of selected adult individuals from both contexts. Stable carbon isotopes in tooth enamel ($\delta^{13}C_{en}$) and bone collagen ($\delta^{13}C_{col}$) reveal information about the type of plants consumed in childhood and adulthood diets, respectively (Van der Merwe and Vogel, 1978; Van der Merwe, 1982; Tykot, 2004), while stable nitrogen isotopes ($\delta^{15}N$) in bone collagen reveal adulthood protein inputs, e.g. marine vs. terrestrial (Schoeninger and Deniro, 1984; Schwarcz and Schoeninger, 1991; Beasley and Somerville, 2023). Tooth enamel oxygen ($\delta^{18}O$) and strontium ($^{87}Sr/^{86}Sr$) isotopes, when compared to regional

hydrological and geological isotope data, allow for the identification of individuals who spent their childhoods non-locally. The combination of this biogeochemical data with historical, archaeological and anthropological information, makes it possible to consider aspects of the lives of individuals buried in Necropolis I and Necropolis II that have hitherto been obscured in a historical grey zone – in part because of the poor treatment of the respective communities and in part because the loss of records in later centuries.

2. GEOGRAPHIC AND GEOLOGICAL CONTEXT, AND ISOTOPE BASELINES

The site of Rua dos Lagares #74 is located in Lisbon, Portugal, adjacent to a garden (Jardim da Cerca da Graça) in an area that is nowadays part of the parish of Graça, in the heart of the neighbourhood of "Mouraria" (the "Moorish Quarter") in historic Old Lisbon, on the northern slope of the hill upon which Castelo de São Jorge is located (Fig 1). Lisbon lies on the northern shore of the Tagus River estuary, around 13 km upstream from where the river flows into the Atlantic Ocean.

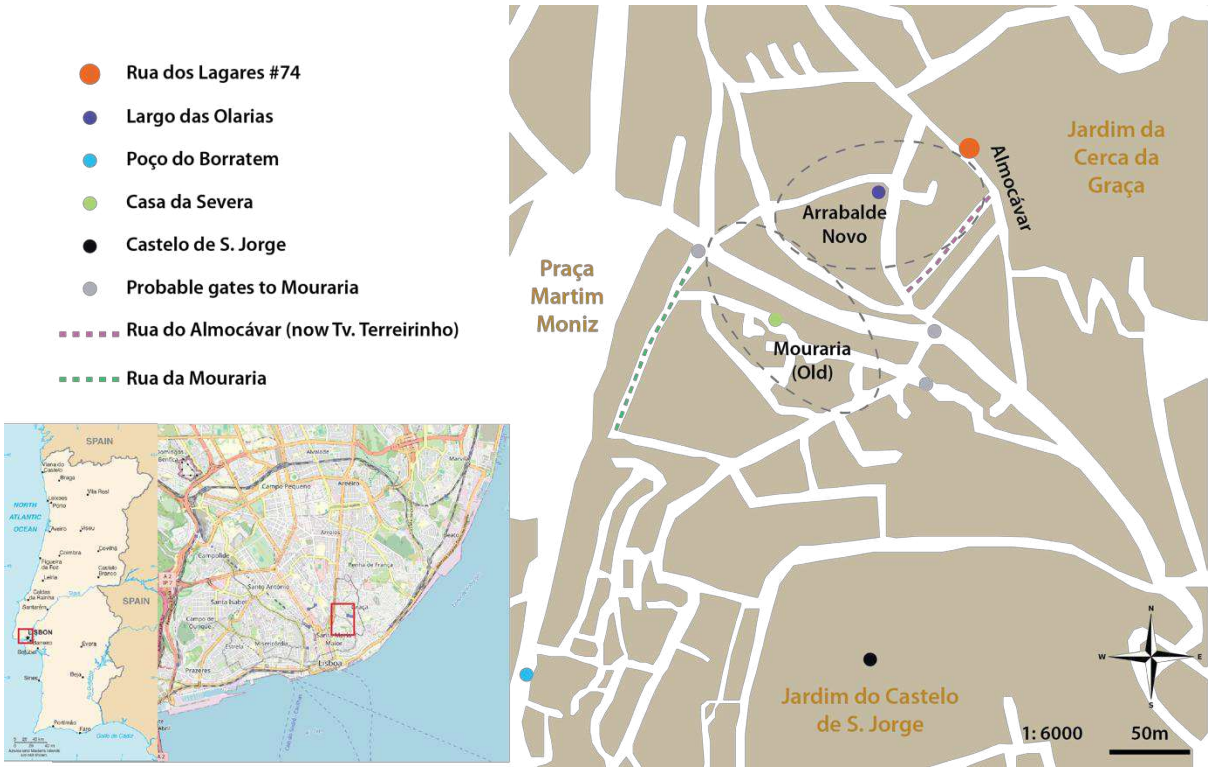


Fig. 1 Map of Mouraria and the sites and locations therein mentioned in Section 6.1. Map inset sources: openstreetmap.org (Lisbon) and commons.wikimedia.org (Portugal)

In terms of geology, Lisbon is part of the Estremadura region and occupies part of the Lusitanian Basin (formed in the northern Atlantic in the Late Triassic during a rifting phase) which is composed of mainly Cretaceous and Jurassic sediments (Schneider, Fürsich and Werner, 2009; Waterman *et al.*, 2014). Geologically younger than other parts of the Iberian Peninsula, the Lusitanian Basin contains

heterogenous lithologies in its landforms (limestones, sandstones, clays, marls, basalts and volcanic rocks). The subsurface geological formations of the city of Lisbon date from the Cretaceous to Miocene and are covered by Pleistocene and Holocene rocks (Matildes *et al.*, 2010). During the Cretaceous (~97 Ma), the area of Lisbon was a marine environment with warm, shallow waters which resulted in the formation of marls intercalated with compact limestone layers (Pinto *et al.*, 2011). Heterogenous fills and slope debris are also present in Lisbon, and the position of the city within an important fluvial network means that alluvial deposits are also to be found (Matildes *et al.*, 2010). Historic Lisbon lies on Miocene deposits (conglomerates, calcareous sandstones and marine deposits of biocalcarenites, siltstones and claystones) while to the north and west lies the Lisbon Volcanic Complex (CVL: 75 – 72 Ma), composed of sheets of basalt, pyroclasts from explosive events, microgabbros and sedimentary intercalations (Pinto *et al.*, 2011; *Mapa Geológico de Espanha e Portugal à escala 1: 1 000 000*, 2015). The lava and ash layers from these volcanic events produced fertile soil perfect for agriculture and human settlement since prehistory, while the Cretaceous limestones and basaltic lavas quarried in Lisbon are still evident in much of the paving throughout the city (Pinto *et al.*, 2011). Although granites and schists are rare in the Lusitanian Basin compared to the Portuguese interior, intrusive massifs of granite are present in Sintra, to the west of Lisbon (Waterman *et al.*, 2014) and Late/Upper Cretaceous syenites are present in Sintra, Sines and Monchique (*Mapa Geológico de Espanha e Portugal à escala 1: 1 000 000*, 2015).

A recent study of $^{87}Sr/^{86}Sr$ values around Portugal (James *et al.*, 2022) yielded the following values for plant samples collected on the various lithologies surrounding Lisbon: on Early/Lower Cretaceous sandstones near Cascais, $^{87}Sr/^{86}Sr$ values ranged from 0.70892 to 0.70942 (samples PT-16-3; PT-16-4-P1; PT-16-5 and PT-16-6); on Mesozoic syenite near Sintra, a $^{87}Sr/^{86}Sr$ value of 0.70866 (PT-16-8) was obtained; on Lower Cretaceous limestone near Carcavelos, a $^{87}Sr/^{86}Sr$ value of 0.70767 (PT-16-1-P2) was obtained; on Late/Upper Cretaceous basalt near Cruz Quebrada, a $^{87}Sr/^{86}Sr$ value of 0.70758 (PT-16-1-P1) was obtained and finally the plant samples on Late/Upper Cretaceous diorites around Sintra yielded $^{87}Sr/^{86}Sr$ values of 0.70680 and 0.70630 (PT-16-7 and PT-16-9, respectively) (James *et al.*, 2022). Based on these bioavailable $^{87}Sr/^{86}Sr$ values, a local range of around 0.707 – 0.7095 could be expected for the area (Fig 2). While this study did not provide $^{87}Sr/^{86}Sr$ values for the Miocene deposits upon which central Lisbon is located, this is probably due to the complications of collecting plant samples in modern, highly urbanised, locations where it would be nearly impossible to find plants free of any modern anthropogenic contamination, which is a requirement for establishing bioavailable $^{87}Sr/^{86}Sr$ baselines (Maurer *et al.*, 2012). Miocene deposits around Portugal were found to have an average $^{87}Sr/^{86}Sr$ value of 0.71178 ± 0.0015 ranging from 0.709 to 0.714 (James *et al.*, 2022).The mean long-term precipitation $\delta^{18}O$ value for Lisbon is -4.5‰ and ranges from -3.5‰ to -5.5‰, according to

the waterisotopes.org database (Bowen and Wilkinson, 2002; Bowen and Revenaugh, 2003; Bowen, 2022). Considering the aforementioned variations, a more 'conservative' ±2‰ can be added to this range in order to identify potential non-local individuals.

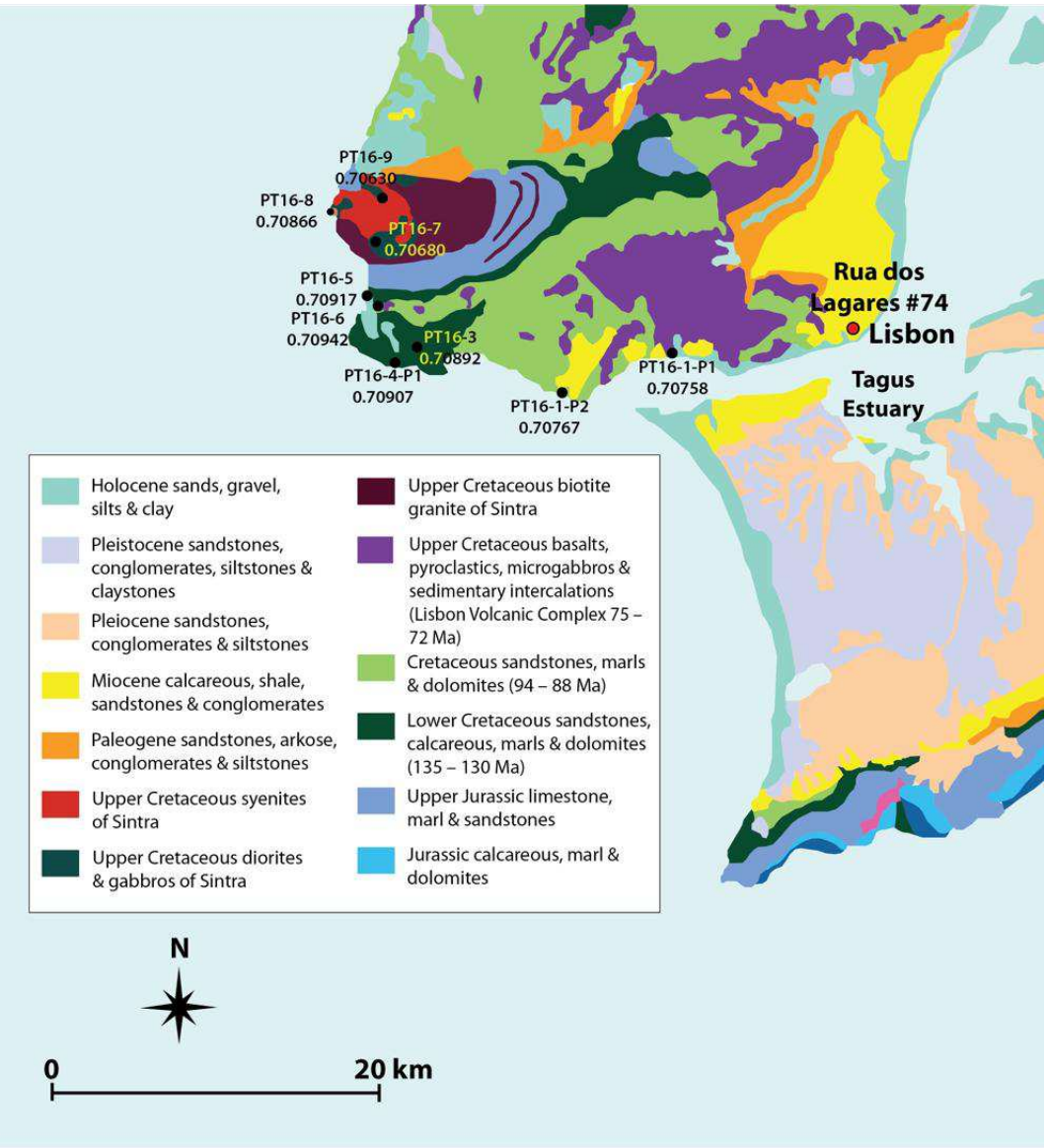


Fig. 2 Geological map of Lisbon with locations of plants sampled by James et al. (2022) and their respective $^{87}Sr/^{86}Sr$ values. Map adapted from LNEG (Mapa Geológico de Espanha e Portugal à escala 1: 1 000 000, 2015)

3. HISTORICAL CONTEXT:
3.1. LATE MEDIEVAL AND EARLY MODERN LISBON

In the late 15th century, Lisbon was a rapidly growing city, with a degree of religious, ethnic and cultural diversity that likely exceeded many contemporaneous European capitals. After the conquest of Lisbon in 1147 CE, the remaining Muslim population (the *mudéjars*) of the city mainly lived in this area which

was, at the time, outside of the city walls (Oliveira and Viana, 1993; Teixeira, Fragoso and Medeiros, 2020). Through the centuries as the city grew (becoming the capital in 1256 CE) Mouraria remained the largest neighbourhood housing the Muslim population, even expanding to the additional neighbourhood of "Arrabalde Novo" in the 15th century as Christians began to occupy the old *mouraria* (Oliveira and Viana, 1993; Teixeira, Fragoso and Medeiros, 2020) with the Muslim cemetery, or *almocávar*, located on the periphery of this neighbourhood, on the Santa Maria da Graça slope (see Fig 1) (Silva, 2025). Lisbon was also home to Sephardic Jewish communities, who lived in designated *judiarias* or Jewish quarters, of which there were three by the 15th century, all located in dynamic mercantile areas and close to the Tagus River (Andrade, 2003). Iberian Jewish communities buried their dead outside of the city walls, as did the Muslims, and some documentation from as early as 1280 CE, and later during the reign of D. Manuel I (r. 1495-1521 CE) refers to a hillside Jewish cemetery in Rua das Olarias (Silva, 2017, 2019, 2025), very close to the location of the *mouraria* in the 15th century (Trindade, 2007; Marado, 2020; Teixeira, Fragoso and Medeiros, 2020).

In 1492 CE the Jewish population was expelled from Spain and many sought refuge amongst Portuguese Jews. The latter had varying levels of power and influence, many held jobs as administrators, tax collectors, merchants, artisans, shopkeepers and labourers, and thus had been somewhat protected by the Portuguese Crown since the Christian conquest due to their economic importance (Disney, 2009). This changed, however, when in December 1496 CE D. Manuel I issued an Edict of Expulsion for both the Jewish and Muslim populations of Portugal, forcing them to convert to Christianity (New Christians or *cristãos novos*) or leave (Soyer, 2008). The *mudéjars* were already a small minority with lesser economic importance and were soon absorbed into the wider population as *mouriscos* or *cristãos novos mouros* but Jewish communities faced much more brutal forced conversion measures. Public-use buildings (e.g. mosques and synagogues) as well as non-Christian cemetery land reverted to the monarchy and were repurposed, while New Christian communities continued to face anti-semitic violence from the civilian population until the establishment of the Portuguese Inquisition in 1536 CE.

3.2. PORTUGUESE IMPERIAL EXPANSION

The strategic position of Lisbon meant that its port was the ideal point of departure for maritime exploration and the expansion of the Portuguese Empire in the 15th and 16th centuries, making it one of the most important cities in Europe for trade and commerce. In the first half of the 15th century, the Portuguese Crown began to dispatch naval expeditions to explore the Atlantic coast of Africa. On

the one hand this was to determine the reach of Muslim territories and seek out Christian peoples who could be traded and allied with, and on the other hand it was to find a route to reach Asia so that Portugal (being isolated from the Mediterranean) could participate more directly in trade outside of Europe (Livermore, 1966; Disney, 2009). In this way, resources from overland, upriver and along the Atlantic coast of Iberia made their way to Lisbon as did those from much further afield, from northern Europe and northern and, subsequently, western Africa. In addition to the movement of resources in and out of Lisbon, there was a largescale movement of people, either voluntarily, through worsening political pressures elsewhere or through the growing slave trade (Livermore, 1966; Saunders, 1982). In the mid-15th century, the Portuguese caravel, a light, fast, and manoeuvrable vessel that could sail windward, was used to venture further south on the sub-Saharan coast than Europeans had previously reached. Trading posts were established in West Africa, (de Flamingh *et al.*, 2021) and the Portuguese began trading Berber captives for black slaves and gold dust and bringing captives from Arguim (modern Mauritania) and further south back to Portugal. By the 1450s, there are reports of the caravels transporting seven or eight hundred enslaved people a year, who had been bought or captured on the West African coast (Livermore, 1966). This number rapidly increased over the following decades, as the demand for labour was very high in urban and rural contexts following population decline in the 14th century because of the Black Death. This influx of enslaved Africans meant that Portugal became the first European society in the modern age in which black slavery was commonplace (Saunders, 1982). Lagos, in the Algarve, was developed into a commercial port and slave exchange, and Lisbon received most of the enslaved people from Africa, who may have been sold locally, exported inland, or sent on to other ports to be sold elsewhere in Europe (Saunders, 1982). By the late 15th and early decades of the 16th century, the Portuguese were trading enslaved people from Benin and the Kongo and transporting them to sugar plantations in São Tomé, but the distance was too far for the European market and survival rates on the slaving ships were dismal. Thus, the majority of enslaved Africans brought to southern Europe (and later to the Americas) were exported from the region of Senegambia and the Guinea rivers (Saunders, 1982; Oliver and Atmore, 2001). The Wolof Empire, which dominated Senegambia, engaged in the slave trade as a means to dominate neighbouring enemies, and enslaved people were traded for horses and other goods from the Portuguese.

The customs collector for slaves (*almoxarife dos escravos*) in Lisbon recorded the number of slaves arriving, and their values, on each ship but generally did not bother to record their places of origin. Valencian records did note, however, that most black slaves received from Lisbon between 1479 CE and 1516 CE were Wolofs (*jalofos*) from Senegambia (Saunders, 1982). Enslaved Africans, freedmen and labourers, sailors, tradesmen and servants who had originated in West Africa would have been

increasingly present in Early Modern Portuguese society. Records were generally poor on the origins and lives of enslaved individuals in Portugal, as well as Muslim and Jewish communities following their official expulsion from the kingdom. Many commercial and fiscal records detailing the Portuguese import of slaves in the 15th and 16th centuries were destroyed in the 1755 CE Lisbon earthquake and subsequent fires, creating a large gap of knowledge concerning this period and many of the people who found themselves on the lower levels of Lisbon society.

4. ARCHAEOLOGICAL AND ANTHROPOLOGICAL CONTEXT:

Following construction work at Rua dos Lagares #74, a rescue excavation, conducted by ERA Arqueologia, was carried out between June 2015 and January 2017, and uncovered a large number of well-preserved burials dating to the 12th – 15th centuries. The space was used as a necropolis in two separate time periods. The first (hereafter referred to as Necropolis I) was an apparent Jewish burial site that was abandoned before the 15th century, and the second (hereafter referred to as Necropolis II) was in use from the mid-15th century for what appeared to be a combination of Muslim and Christian burials (Pinto *et al.*, 2016). The non-continuous use of the site is evidenced by the apparent vandalism of Necropolis I, after which it was completely sealed by landfill deposit (SU 1989), silos for waste were dug into the necropolis and the residues of pottery manufacturing were deposited irregularly over the whole area. It should be noted that the nearby streets "Rua das Olarias" and "Largo das Olarias" refer to the historic legacy of this neighbourhood for ceramic production and the street "Tv. Terreirinho", perpendicular to Rua dos Lagares, was previously known as "Rua do Almocávar", referring to the historic use of the space as a Muslim cemetery (Oliveira and Viana, 1993; Pinto *et al.*, 2016) (see Fig 1). A female individual (RL 2350) buried in Necropolis I was selected for radiocarbon dating, yielding a date of 883 ± 17 BP (SUERC-131887) and calibrated using Oxcal 4.4.4 (Bronk Ramsey, 2021). Date ranges were calibrated using the IntCal20. Atmospheric calibration curve, giving a date of *cal* CE 1053–1219 (95.4% probability; SUERC-131887) and likely *cal* CE 1163–1210 (68.3% probability; SUERC-131887). This date suggests that this site was used as a necropolis for several centuries, even as early as around the time of the conquest of Lisbon in the mid-12th century. This carbon-14 dating is fully consistent with the historical records referring to the existence of a Jewish cemetery on this very site in 1280 CE (Silva, 2025). Within Necropolis I, two subphases of use were identified (Necropolis IA and Necropolis IB) with some regulation of terrain in between (SU 1990). These subphases are mainly distinguished by those that cut directly into the geological substrate (SU 2005) – Necropolis IA, and those that cut into SU 1990 – Necropolis IB. Necropolis II was constructed in the terrain of the deposit that covered Necropolis I and was subsequently covered with similar sediments (ceramic waste) after its own abandonment after the mid-16th century or later, but the interval of time in between the use of these two necropolises is also not currently known. The simplified stratigraphic relationships of

these burial phases are represented in Fig 3. The anthropological assessment of the skeletal material was conducted in the field initially and then in lab conditions on the excavated material in the Centro de Arqueologia de Lisboa (CAL) by Era Arqueologia (Lourenço *et al.*, 2016). This included age at death estimation (Fazecas and Kósa, 1978; Ferembach, Schwidetzky and Stloukal, 1980; Ubelaker, 1989; MacLaughlin, 1990; Scheuer and Black, 2000), diagnosis of biological sex (Ferembach, Schwidetzky and Stloukal, 1980; Silva, 1996; Wasterlain, 2000; Bruzek, 2002), estimation of stature (Olivier *et al.*, 1978), discrete characteristics (Finnegan, 1978; Hauser *et al.*, 1989), degenerative pathologies (articular and non-articular) (Crubézy, 1988) and adult age subgroups were assigned as "young adult" (20 – 40 years), "mature adult" (41 – 66 years) and "senior adult" (>65 years) (Baccino and Schmitt, 2006).

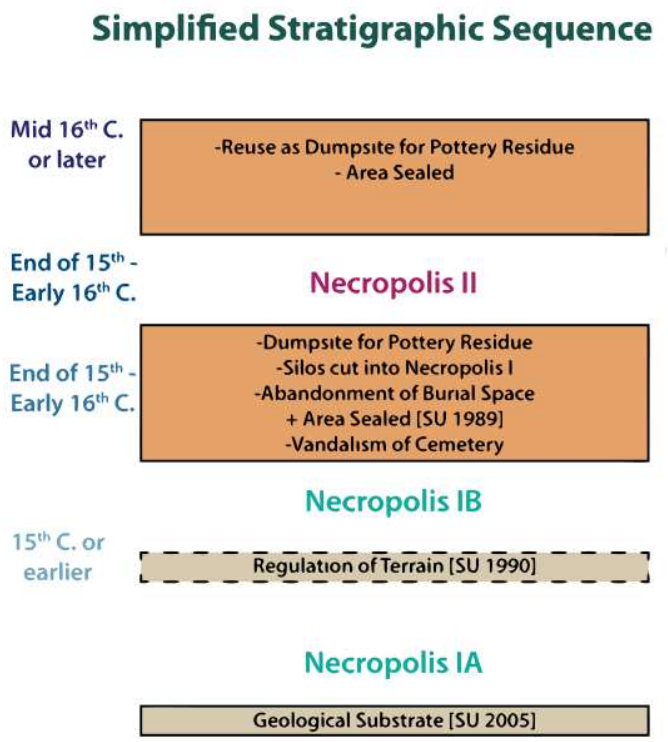


Fig. 3 Simplified stratigraphy of the Rua dos Lagares necropolises. Adapted from Pinto et al. (2016)

4.1. NECROPOLIS I

Necropolis I appeared to be much more extensive than Necropolis II and during this excavation campaign 259 burials were excavated, although the necropolis evidently extended beyond the limits of the excavation and is likely much larger. Most of the graves of IB were simple oval pits while those of IA were either simple anthropomorphic structures (Type 1) or large, rectangular pits (~1.9 x 1.2m)

containing an interior anthropomorphic recession in which the skeletons were placed (Type 2), which may have originally been covered by wood or stone slabs, however these may have been removed when the cemetery was abandoned (Pinto *et al.*, 2016). These grave types are summarised in Table 1 and illustrated in Fig 4. The majority of skeletons were positioned in dorsal decubitus (Table 1), while the small proportion positioned in right or left lateral decubitus, or in foetal position, were mainly new-born babies. The cemetery was therefore likely associated with a Christian or Jewish cult, and with lower limbs extended and upper limbs mostly extended alongside the torso and occasionally slightly bent over the thorax or abdomen, the burial positions are more characteristic of Jewish burial practices as, in medieval Christian burials, the arms are commonly flexed or crossed over the abdomen, or chest (Lilley *et al.*, 1994; Blanchard, 2022; Blanchard, Livet and Di Stefano, 2023; Silva, 2025). Height could be estimated for 87 adult individuals from Necropolis I, giving an average height of 162.23 cm, 156.0 cm (ranging from 141.9 to 172.94 cm) for females and 168.4 cm (ranging from 158.66 to 175.51 cm) for males (Lourenço *et al.*, 2016). Grave goods, although not ubiquitous were rather remarkable in nature, as a collection of jewellery was recovered during the excavation of Necropolis I that contained bronze rings, ornate silver bead necklaces and earrings. In two exceptional cases, females (RL 2350, for whom a radiocarbon date was obtained, and RL 2626) were buried with full sets of silver bead necklaces, decorated silver earrings and silver rings – the unique styles of the latter are reminiscent of "house rings", engagement rings that are symbolic of the marital residence of an engaged Jewish couple (Pinto *et al.*, 2016). A small silver pendant was also recovered in a sub-adult burial, in the shape of a hand with fingers pointed downwards – the "*Hamsa*" or "Hand of Miriam", which is often associated with followers of Islam as well as Sephardic Jewish communities who wore it as a protective talisman (Frankel and Teutsch, 1995; Sabar, 2010).

Table 1.) Summary of Rua dos Lagares #74 burials. Full descriptions in Lourenço *et al*. (2016) and Ponce *et al*. (2017)

Necropolis I	**259**	**Necropolis II**	**60**
Adults	142	Adults	49
Female	49	Female	29
Male	57	Male	17
Unidentified	13	Unidentified	4
Non-adults	117	Non-adults	11
Grave Type		**Grave Type**	
Simple Pit	196	Simple Pit	54
Type 1	26	Individual	51
Type 2	13	Collective	8
Grave Orientation		**Grave Orientation**	
NW-SE	142	W-E	19
W-E	87	SW-NE	19
N-S	15	E-W	7
		NW-SE	7
		S-N	3
		NE-SW	3

		SE-NW	1
		Undetermined	1
Burial Position		**Burial Position**	
Dorsal decubitus	237	Dorsal decubitus	18
		Ventral decubitus	4
		Right lateral decubitus	27
		Left lateral decubitus	3
		Left foetal position	6
		Undetermined	2

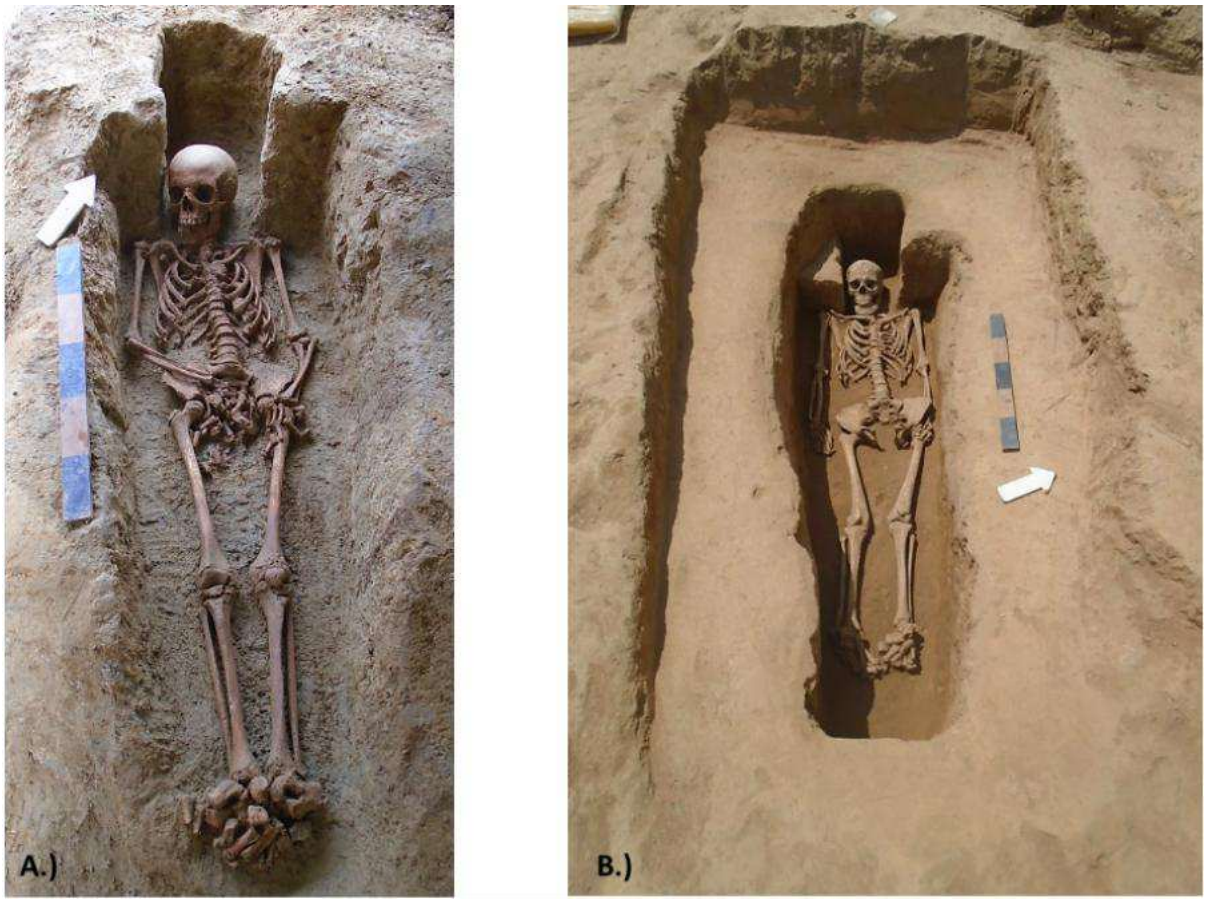


Fig. 4 Necropolis I examples of burials a.) Type 1: simple anthropomorphic structures and b.) Type 2: Rectangular pits with interior anthropomorphic recession. Source: Pinto *et al*. (2016)

4.2. NECROPOLIS II

A female individual (RL 607) buried in Necropolis II was selected for radiocarbon dating, yielding a date of 435 ± 17 BP (SUERC-131888) and calibrated using Oxcal 4.4.4 (Bronk Ramsey, 2021). Date ranges were calibrated using the IntCal20. Atmospheric calibration curve, giving a date of *cal* CE 1435–1470 (95.4% probability; SUERC-131888) and likely *cal* CE 1441–1456 (68.3% probability; SUERC-131888). In Necropolis II, although the positioning and orientation of the skeletons was quite variable (see Table

1), the majority were positioned in such a way as to face in the direction if the *qibla*, towards Mecca, and the cemetery appeared to have a degree of multi-faith usage, by Muslims and Christians. Height could be determined for 37 adults from Necropolis II, giving an average of 170.25 cm with females averaging 164.17 cm (ranging from 147.41 cm to 180.34 cm) and males 176.33 cm (ranging from 164.98 to 190.28 cm), making these individuals 8 cm taller, on average, than those in Necropolis I (Lourenço *et al.*, 2016). Some individuals displayed dental modification, whereby the upper incisors were polished into narrower points, and the lower incisors were polished to create diamond-shapes, an example of which is shown in Fig 5. At least 10 individuals had cranial and non-cranial morphological features that, combined with the dental modification and exceptional heights of some individuals, presented the possibility of a genetic and geographical origin outside of Europe, most likely in Africa (Finucane, Manning and Touré, 2008; Lourenço *et al.*, 2016; Pinto *et al.*, 2016; Ponce *et al.*, 2017). The presence of grave goods was lower than Necropolis I, but six female adults were buried with jewellery: one with a pair of earrings, four with rings and one (RL 607, for whom a radiocarbon date was obtained) with a necklace of blue glass beads, which may be examples of "Aggrey" or "Cori" beads, also known as "trade beads" or "slave beads". Aggrey beads are known to have played an important role in trans-Saharan trade for centuries before the arrival of Europeans in West Africa, and were traded for gold, slaves and other goods by Muslim merchants (Francis, 1990; Babalola, 2022; Babalola and Ajayi, 2022). When the Portuguese began trading for goods and slaves in West Africa in the 15th century, they too engaged in the bead trade and began importing European-made imitation Aggrey beads to use as currency in the early 16th century (Cardinall, 1925; Francis, 1990; Babalola *et al.*, 2018).

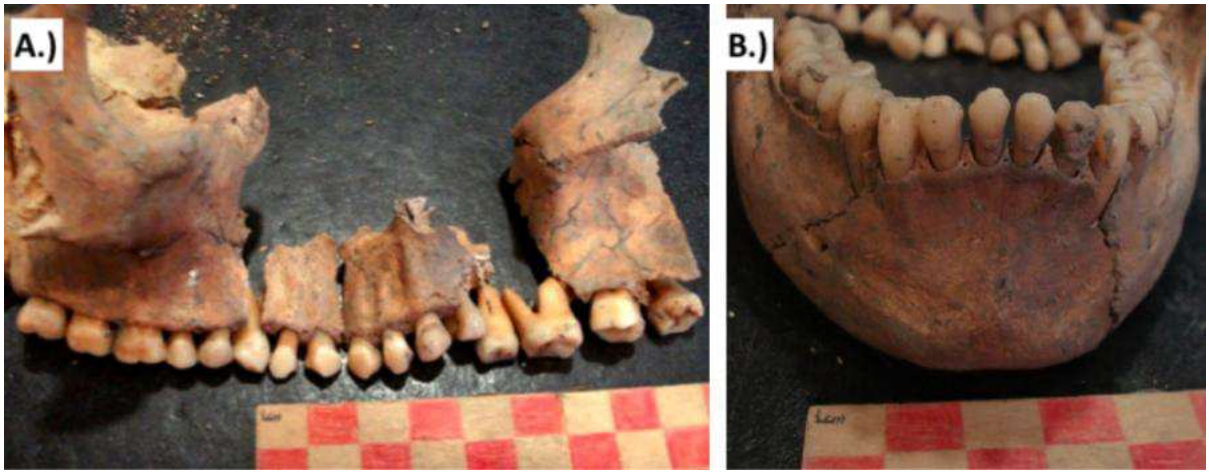


Fig. 5 Dental modification in the a.) upper and b.) lower incisors of the individual RL 1809 in Necropolis II. Source for images: Lourenço et al. (2016)

4.3. SITE INTERPRETATION AND HYPOTHESIS

The hypotheses developed through the archaeological (Pinto *et al.*, 2016) and anthropological (Lourenço *et al.*, 2016) findings of Rua dos Lagares #74 can be summarised as follows:

i.) Necropolis I was a Jewish cemetery, the location of which was previously suggested from sparse surviving documentation but unconfirmed archaeologically. It was in use at least from the 12th/13th century until the 15th century before being abandoned and desecrated, likely because of hostilities towards Jewish communities following the 1496 CE Edict of Expulsion.

ii.) Necropolis II was a multifaith burial site, possibly reflecting a mixed community of Muslims and other unidentified rites, in intensive use for a relatively short period of time between the 15th century and the mid-16th century.

iii.) The presence of Muslim burials in Necropolis II may reflect an effort to preserve the memory of the old *almocávar* that had become urbanised and inaccessible.

iv.) Several individuals buried in Necropolis II probably had non-European origins and may have belonged to a community of slaves or freedmen from West Africa (Wolofs or otherwise).

5. MATERIALS:

Human skeletal material from Rua dos Lagares #74 was selected for sampling and analysis, with authorisation from the Centro de Arqueologia de Lisboa (CAL) where the excavated material is curated. No faunal material was selected from this site because there was already published data available from faunal remains of the nearby sites of Poço do Borratem (14th – 15th cent.) and Casa de Severa (12th – 15th cent.), both located in the area now called "Mouraria" and indicated in Fig.1 (Toso *et al.*, 2021). Concerning the human skeletal material, 53 adult individuals (29 from Necropolis I and 24 from Necropolis II) were selected for the analysis of bone collagen $\delta^{13}C$ and $\delta^{15}N$ in order to reconstruct adulthood dietary patterns, and tooth enamel $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ for the reconstruction of mobility patterns, as well as $\delta^{13}C$ in tooth enamel order to assess whole diet inputs during childhood. Rib bones were selected for all individuals, and loose molar teeth were chosen insofar as possible to avoid excessive damage to well-preserved maxillae and mandibles. First molars (M1s) were preferentially chosen for their potential to record birthplace $^{87}Sr/^{86}Sr$ values, followed by second (M2) and third (M3) molars. The initial criteria for selection of adult individuals were the availability of a well-preserved rib bone and molar tooth for each, and proportional representation of individuals from

Necropolis I (including IA and IB) and Necropolis II in comparable numbers. Effort was made to select equal numbers of males and females, although fewer males were available for Necropolis II (Necropolis I: 15M, 14F; Necropolis II: 8M, 16F) and in order to avoid selection bias, individuals were chosen with various burial positions (right lateral *decubitus*, left lateral *decubitus*, supine) from Necropolis II and various grave types (simple pits and anthropomorphic Type 1 and 2) from Necropolis I. A mix of individuals with grave goods (e.g. jewellery), dental modification, extraordinary height and those with no grave goods or observable distinguishing features were selected, insofar as possible. All human skeletal material is listed in Tables 2 and 3.

1 **Table 2.) Necropolis I: Human Skeletal Material**

Sample	Bone	Tooth	Age	Sex	Est. Height (cm)	Necropolis-Grave Type (T1- Type 1 ; T2- Type 2)	Burial Position	Orientation	Grave Goods
RL 2002	Rib	M3 UR	Young adult	M	-	1B- Simple	Dorsal	NW-SE	-
RL 2009	Rib	M1 UR	Mature adult	F	-	1- Simple	Dorsal	NW-SE	-
RL 2015	Rib	M2? UL	Mature adult	M	170.0	1- Simple	Dorsal	NW-SE	Bronze ring w/ stone
RL 2041	Rib	M2 LL	Mature adult	F	-	1- Simple	Dorsal	NW-SE	-
RL 2053	Rib	M3 UR	Mature adult	M	158.0	1B- Simple	Dorsal	W-E	-
RL 2062	Rib	M1 LR	Mature adult	M	171.0	1A- Anthropomorphic T1	Dorsal	W-E	-
RL 2080	Rib	M1 UR	Mature adult	F	155.0	1B- Anthropomorphic T1	Dorsal	N-S	-
RL 2131	Rib	M3 LL	Mature adult	M	155.0	1B-Anthropomorphic T1	Dorsal	NW-SE	-
RL 2134	Rib	M1 LR	Mature adult	F	140.0	1B- Anthropomorphic T1	Dorsal	NW-SE	-
RL 2137	Rib	M3 U	Mature adult	M	155.0	1B Anthropomorphic T1	Dorsal	NW-SE	-
RL 2167	Rib	M2 UL	Young adult	F	143.0	1A- Anthropomorphic T1	Dorsal	NW-SE	-
RL 2170	Rib	M2 UR	Mature adult	M	-	1B- Anthropomorphic T1	Dorsal	W-E	-
RL 2173	Rib	M1 UR	Mature adult	F	148.0	1B- Anthropomorphic T1	Dorsal	NW-SE	Earrings
RL 2176	Rib	M3 LL	Mature adult	F	143.0	1- Simple	Dorsal	W-E	Button
RL 2182	Rib	M2 UL	Mature adult	F	153.0	1A- Simple	Dorsal	NW-SE	-
RL 2191	Rib	M1 LR	Mature adult	F	-	1B- Anthropomorphic T1	Dorsal	W-E	-
RL 2230	Rib	M1 UR	Young adult	M	-	1A- Simple	Dorsal	W-E	-
RL 2242	Rib	M1 LL	Mature adult	F	142.0	1- Simple	Dorsal	NW-SE	-
RL 2276	Rib	M2 LL	Mature adult	M	-	1- Simple	Dorsal	W-E	-
RL 2298	Rib	M3 LL	Young adult	M	-	1B- Simple	Dorsal	NW-SE	-
RL 2308	Rib	M1 UR	Mature adult	M	-	1A- Anthropomorphic T1	Dorsal	W-E	-
RL 2336	Rib	M3 LR	Mature adult	M	-	1A- Simple	Dorsal	W-E	-
RL 2350^{+}	Rib	M2 LL	Mature adult	F	136.0	1A- Anthropomorphic T1	Dorsal	W-E	Silver necklace, earrings and rings
RL 2375	Rib	M3 UL	Mature adult	M	156.0	1A- Anthropomorphic T2	Dorsal	NW-SE	-
RL 2557	Rib	M3 LL	Young adult	F	146.0	1A- Anthropomorphic T2	Dorsal	NW-SE	Earrings
RL 2563	Rib	M1 UR	Mature adult	M	176.0	1A- Anthropomorphic T2	Dorsal	NW-SE	-
RL 2626	Rib	M2 UR	Mature adult	F	156.0	1B- Simple	Dorsal	W-E	Necklace (bronze and silver), earrings and ring
RL 2706	Rib	M2 UR	Mature adult	M	156.0	1A- Anthropomorphic T2	Dorsal	NW-SE	-

RL 2721	Rib	M1 LR	Mature adult	F	140.0	1B-Simple	Dorsal	NW-SE	

[+]Individuals selected for radiocarbon dating

Table 3.) Necropolis II: Human Skeletal Material

Sample	Bone	Tooth	Age	Sex	Est. Height	Necropolis-Grave Type	Burial Position	Orientation	Dental Mod.	Possible Ancestry	Grave Goods
RL 101	Rib	M3 LR	Mature adult	M	170.0	2- Simple; coll.	Dorsal	NW-SE		?	-
RL 151	Rib	M1 UR	Mature adult	M	180.0	2- Simple; indiv.	Right lateral	S-N		African	-
RL 171	Rib	M2 UR	Adult	F	142.0	2- Simple; reused	Right lateral	SW-NE		?	-
RL 251	Rib	M1 UR	Mature adult	F	157.0	2- Simple; indiv.	Dorsal	SW-NE		?	-
RL 261	Rib	M3 LL	Mature adult	F	-	2- Simple; indiv.	Right lateral	SW-NE		?	-
RL 607[+]	Rib	M1 LL	Young adult	F	150.0	2- Simple; indiv.	Left lateral	SW-NE		?	Blue bead necklace
RL 1809	Rib	M1 UR	Young adult	F	-	2- Simple; indiv.	Left lateral	SW-NE	Y	African	-
RL 1821	Rib	M2 LL	Mature adult	F	152.0	2- Simple; indiv.	Right lateral	W-E		?	-
RL 1833*	Rib	M2 LR	Young adult	M	-	2- Simple; coll.	Right lateral	NW-SE		African	-
RL 1840*	Rib	M3 UR	Young adult	F	-	2- Simple; coll.	Right lateral	E-W		African	-
RL 1856	Rib	M3 LL	Mature adult	F	144.0	2- Simple; indiv.	Left lateral	SW-NE	Y	African	-
RL 1862	Rib	M2 LR	Young adult	M	-	2- Simple; indiv.	Ventral	SE-NW		?	-
RL 1874	Rib	M2 LL	Mature adult	F	-	2- Simple; indiv.	Right lateral	W-E		African	-
RL 1876	Rib	M2 UL	Young adult	M	170.0	2- Simple; indiv.	Right lateral	W-E		African	-
RL 1897	Rib	M3 LR	Mature adult	F	-	2- Simple; indiv.	Left lateral	E-W		?	Ring
RL 1900	Rib	M2 UR	Young adult	F	-	2- Simple; indiv.	Ventral	E-W	Y	African	Ring
RL 1930	Rib	M2 LL	Mature adult	M	180.0	2- Simple; indiv.	Right lateral	W-E		?	-
RL 1939	Rib	M1 UL	Young adult	M	-	2- Simple; indiv.	Right lateral	W-E		?	-
RL 1945	Rib	M3 LR	Young adult	M	180.0	2- Simple; indiv.	Right lateral	SW-NE		African	-
RL 1957	Rib	M3 LR	Mature adult	F	155.0	2- Simple; indiv.	Right lateral	W-E	Y	African	-
RL 1960	Rib	M3 LL	Mature adult	F	-	2- Simple; indiv.	Right lateral	SW-NE		?	-
RL 1963	Rib	M2 LR	Mature adult	F	-	2- Simple; indiv.	Dorsal	SW-NE		?	-
RL 2179	Rib	M1 UL	Young Adult	F	-	2- Simple; indiv.	Ventral	NE-SW		?	-
RL 2745	Rib	M1 UL	Mature adult	F	-	2- Simple; indiv.	Dorsal	SW-NE		?	-

*The individuals RL 1833 and RL 1840 shared a collective grave and were positioned back-to-back and head to toe

[+]Individuals selected for radiocarbon dating

6. METHODOLOGY:

6.1. COLLAGEN EXTRACTION AND CARBON AND NITROGEN ISOTOPE ANALYSIS

Bone collagen extraction as well as carbon and nitrogen isotope analysis was performed at Laboratório HERCULES, University of Évora, and followed the methods described in MacRoberts *et al*. (2024) including the calibration methods. 1577C (δ^{13}C: -17.5‰; δ^{15}N: +8.2‰) was used as an in-house check standard interspersed during each run. Measurement uncertainty was calculated according to the method presented by Szpak *et al*. (2017), using the Microsoft Excel spreadsheet templates provided in that paper (see Appendix I). Standard uncertainty (u_c) is estimated as a pooled standard deviation of precision (u(R_w) ±1σ) while accuracy (u(*bias*) ±1σ) is calculated using the variability in calibration standards and check standards (Szpak, Metcalfe and Macdonald, 2017). Precision (u(R_w)) was determined to be ±0.07‰ for δ^{13}C and ±0.22‰ for δ^{15}N, accuracy (u(*bias*)) was determined to be ±0.11‰ for δ^{13}C and ±0.16‰ for δ^{15}N and the total uncertainty over 3 analytical sessions was estimated to be ±0.13‰ for δ^{13}C and ±0.27‰ for δ^{15}N.

6.2. ENAMEL PREPARATION AND CARBON, OXYGEN AND STRONTIUM ISOTOPE ANALYSIS

Stable carbon and oxygen isotope analysis of tooth enamel was carried out at the Institute of Geosciences, University of Mainz, following methods described in MacRoberts *et al*. (2024). The average precision error (1σ) was found to be better than 0.04‰ for δ^{13}C and 0.07‰ for δ^{18}O, while the accuracy was within 0.02‰ for both isotope systems. For the purpose of comparing tooth enamel δ^{18}O values to regional precipitation δ^{18}O values, a number of conversion equations were applied. The δ^{18}O values (relative to VPDB) were first converted to the VSMOW-scale using the equation (see MacRoberts *et al*. 2024) established by Coplen *et al*. (1983) and the conversion of carbonate to phosphate oxygen isotope values ($\delta^{18}O_c$ to $\delta^{18}O_p$) was done using the equation (see MacRoberts *et al*. 2024) proposed by Chenery *et al*. (2012). The estimated drinking water oxygen isotope values ($\delta^{18}O_{DW}$) were calculated using the equation (see MacRoberts *et al*. 2024) established by Chenery *et al*. (2012) which in turn is based on the drinking water equation of Daux *et al*. (2008). It should be noted that the employment of such conversions can introduce a degree of uncertainty, ±1‰ (2σ) (Chenery *et al.*, 2012). Furthermore, intrapopulation variation can be quite large within the same location, as factors such as culinary practices (boiling water for soups and stews etc.) can result in relatively large deviations in the δ^{18}O values of water consumed, compared to the δ^{18}O values in local precipitation (Pederzani and Britton, 2019). Modern precipitation δ^{18}O values can still be useful in identifying mobility patterns in archaeological populations if these uncertainties are kept in mind.

For strontium isotope analysis, tooth enamel sampling and pre-treatment followed the method described in MacRoberts *et al*. (2024). Samples were further processed at the Laboratori d'Isòtops Radiogènics i Ambientals (LIRA) at Universitat de Barcelona. Strontium purification is then carried out using standard procedures with Triskem® Sr-Spec resin, with high specificity for Sr^{2+} that achieves an excellent separation from interfering element Rb. Following sample purification, Sr isotope ratios were determined by multicollector inductively coupled mass spectrometry on a Nu Instruments (Wrexham, UK) Plasma 3 MC-ICPMS at the University of Barcelona (CCiT-UB). For strontium isotope analysis a mathematical correction of the ^{87}Rb isobaric interference on ^{87}Sr was performed from the signal measured for ^{85}Rb assuming an $^{87}Rb/^{85}Rb$ value of 0.3857 (de Laeter *et al.*, 2003). An iterative mathematical correction of the ^{86}Kr isobaric interference on ^{86}Sr signal (Weber *et al.*, 2020) was carried out using the measured ^{83}Kr signal and assuming a $^{86}Kr/^{83}Kr$ ratio of 1.503 (de Laeter *et al.*, 2003). A total of 5 iterations was enough to obtain a constant value for the mass bias factor and the $^{87}Sr/^{86}Sr$ ratio. An internal correction of mass bias was carried out by measuring the $^{88}Sr/^{86}Sr$ ratio and using the exponential model (Womberbacherab and Rehkämper, 2003) to correct $^{86}Sr/^{88}Sr = 0.1194$ for mass bias correction. The reference material SRM 987 (NIST) was also analysed bracketing the samples using a value of 0.710249 for the $^{87}Sr/^{86}Sr$ in the SRM 987 (Azmy *et al.*, 1999; Ando *et al.*, 2011; Cramer *et al.*, 2011). Samples and standards were matched in matrix and concentration. The yield of the chromatographic separation of Sr and Rb was verified by measuring [Sr]/[Rb] ratio >1000, thus leading to a negligible effect of the Rb interference correction on the accuracy of results. External analytical reproducibility during the session was ± 0.000018 (2σ, n=19).

6.3. EXPLORATION OF PROVENANCE AREAS OF THE INDIVIDUALS

In order to investigate the potential origins of some of the non-local individuals, their enamel O and Sr isotope values were first discussed regarding available large scale isoscapes. For O isotopes, an isoscape displaying the mean annual precipitation $\delta^{18}O$ values across southern Europe, North Africa and West Africa (Fig 6b) recorded in the waterisotopes.org database was used (Bowen and Wilkinson, 2002; Bowen and Revenaugh, 2003; Bowen, 2022). For Sr isotopes, an isoscape map published by (Bataille *et al.*, 2020; Bowen, 2022), available in the waterisotopes.org database, and illustrating the range of $^{87}Sr/^{86}Sr$ values across southern Europe, North Africa and West Africa was combined with a recent isoscape published by (Wang *et al.*, 2024), which does not extend to regions north of the Gambia River valley (Fig 6a). The latter isoscape has provided much more data on bioavailable $^{87}Sr/^{86}Sr$ values in sub-Saharan Africa, a region where data collection has long been hindered by insufficient scientific resources, logistical difficulties and political instabilities. The isoscape developed by Wang *et al*. (2024) has the potential to strengthen archaeological studies focused on tracing the origins of

victims of the transatlantic slave trade and can be equally useful in tracing the origins of non-locals buried in Necropolis II, some of whom have possible African genetic ancestry.

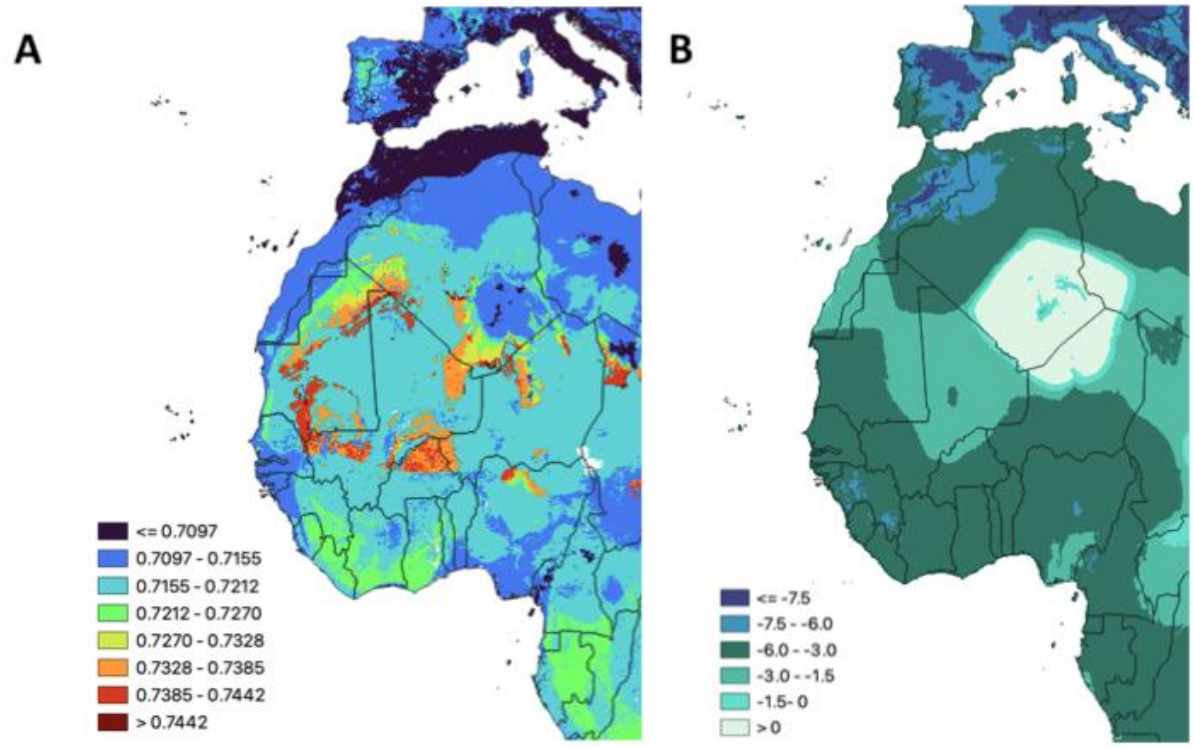


Fig. 6 a.) Global 87Sr/86Sr values over the region of interest. Interpolated map obtained from waterisotopes.org (Bataille et al., 2020; Bowen, 2022) and adapted and combined with isoscape for the West Africa region from Wang et al. (2024) in QGIS v.3.34.7. and b.) Mean annual precipitation d18O values over the region of interest. Interpolated map obtained from waterisotopes.org (Bowen, 2022) and adapted in QGIS v.3.34.7

Provenance probability models were also used to narrow down the potential areas of provenance of some of the individuals buried in Necropolis II. The models were based on the two functions calcCellProb and calcNormProb (see Bataille *et al*., 2021). Using a provided isoscape and its associated uncertainty, calcCellProb calculates the normal probability density for an isotope value (i.e., of an individual) at each cell of the raster and returns a raster of probabilities for this value. CalcNormProb normalises the probability density of each of the raster cell to the maximum raster value so that the probabilities range from 0 (lowest probability) to 1 (highest probability).

For $^{87}Sr/^{86}Sr$, the probability density was first computed from three isoscapes and their associated uncertainties, and the resulting probability rasters were further combined. For Portugal, the isoscape generated in Maurer *et al*. (2025) was used (see Supporting Information, S1), while that of Wang *et al*. (2024) was used for southern West Africa, and that of Bataille *et al*., (2020) for the broader region. For $\delta^{18}O$, the global isoscape of Terzer *et al.* (2013) was used. Probability rasters were generated from the sample $^{87}Sr/^{86}Sr$ and the estimated drinking water $\delta^{18}O_{DW}$ values (see 6.2). The dual assignment

($^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values) probability rasters obtained for selected individuals resulted from the product of each single one.

7. RESULTS:

7.1. BONE COLLAGEN PRESERVATION

The bone collagen samples presented here (Table 4) had C:N ratios within the acceptable range (DeNiro, 1985; Ambrose, 1990; Guiry and Szpak, 2021) for good preservation (3.17 ± 0.06) and overall had good collagen yields (9.8 ± 4.2%), with all samples yielding sufficient collagen for further analysis. The carbon (35.4 ± 8.6%) and nitrogen (13.0 ± 3.1%) amounts indicated good collagen preservation overall (Ambrose, 1990; Van Klinken, 1999), although there were ten individuals with low carbon (<30%) and nitrogen (<11%) amounts: RL 101; RL 151; RL 1874; RL 1900; RL 1930; RL 1945; RL 1963; RL 2134; RL 2276 and RL 2557. However, the decision was made not to exclude these individuals for a number of reasons: firstly, they had good collagen yields and acceptable C:N ratios, but more importantly the $\delta^{13}C$ and $\delta^{15}N$ values (to be presented in the following section) yielded by these individuals fit within the overall data pattern, were not outliers, and did not appear to skew the data; when these individuals were excluded, the total population mean only differed by +0.3‰ for $\delta^{13}C$ and by -0.01‰ in the $\delta^{15}N$, while for Necropolis I the difference was as follows: $\delta^{13}C$ -0.02‰; $\delta^{15}N$ +0.01‰ and for Necropolis II a mean difference of +0.2‰ and -0.2‰ were observed in $\delta^{13}C$ and $\delta^{15}N$ values, respectively, when these individuals were excluded. With such negligible differences in the data, and considering the fact that Necropolis II males, already the least represented group, was disproportionately affected by low carbon and nitrogen amounts, their exclusion may have presented issues for later data comparison.

Table 4.) Results- Bone Collagen

Sample	Collagen Yield (wt %)	%C	%N	C/N	$\delta^{13}C_{col}$ (‰) VPDB	$\delta^{15}N$ (‰) AIR
Necropolis I						
RL 2002	12.5	39.4	14.4	3.18	-18.5	11.0
RL 2009	15.7	30.3	11.2	3.15	-18.0	12.1
RL 2015	8.2	41.6	15.2	3.19	-17.9	12.6
RL 2041	11.3	31.2	11.0	3.31	-18.9	11.7
RL 2053	16.9	41.3	15.2	3.17	-17.6	11.2
RL 2062	8.1	41.6	15.2	3.20	-17.4	11.6
RL 2080	4.9	41.0	15.0	3.18	-18.5	11.7
RL 2131	13.3	40.5	14.9	3.16	-18.3	12.1
RL 2134	22.1	26.2	9.8	3.15	-18.3	11.4
RL 2137	6.4	40.9	15.0	3.17	-18.9	11.6
RL 2167	8.8	42.1	15.4	3.20	-18.0	12.2
RL 2170	4.5	39.4	14.3	3.22	-17.6	11.8

RL 2173	9.7	41.5	15.3	3.17	-17.7	12.4
RL 2176	5.7	39.6	14.5	3.19	-17.7	11.0
RL 2182	10.3	40.5	14.8	3.19	-17.8	11.9
RL 2191	8.0	41.9	15.2	3.21	-18.0	10.5
RL 2230	7.9	40.5	14.9	3.18	-18.5	10.4
RL 2242	7.1	40.1	14.5	3.23	-18.2	10.8
RL 2276	7.7	18.2	6.7	3.15	-18.0	11.6
RL 2298	8.3	44.6	16.2	3.20	-17.5	12.7
RL 2308	4.8	39.3	14.4	3.19	-17.9	12.2
RL 2336	5.4	39.3	14.3	3.20	-17.7	11.9
RL 2350	9.6	40.9	15.0	3.19	-18.1	11.5
RL 2375	17.7	34.0	12.6	3.14	-18.1	12.6
RL 2557	6.2	24.9	9.3	3.12	-17.9	11.6
RL 2563	5.7	36.8	13.5	3.17	-17.0	11.7
RL 2626	6.1	33.8	12.4	3.20	-17.8	10.6
RL 2706	12.4	40.9	15.0	3.18	-16.9	12.3
RL 2721	10.4	40.6	14.9	3.19	-17.8	10.5
Necropolis II						
RL 101	7.7	18.0	6.7	3.14	-13.6	8.5
RL 151	8.3	12.4	4.8	3.00	-18.5	10.8
RL 171	9.7	36.3	13.2	3.18	-18.2	10.8
RL 251	5.1	39.8	14.7	3.15	-9.5	12.4
RL 261	6.2	40.5	14.8	3.18	-18.7	9.8
RL 607	3.9	37.7	13.8	3.19	-20.5	11.0
RL 1809	17.7	41.8	15.5	3.15	-13.2	7.1
RL 1821	13.3	42.6	15.7	3.17	-7.0	9.4
RL 1833	14.2	42.1	15.5	3.17	-7.3	11.6
RL 1840	11.8	32.4	12.0	3.15	-10.4	7.2
RL 1856	12.3	41.4	15.2	3.18	-14.0	6.4
RL 1862	5.4	39.9	14.6	3.19	-20.7	11.2
RL 1874	12.1	25.3	8.7	3.39	-11.1	9.3
RL 1876	17.5	35.5	13.1	3.17	-7.3	10.6
RL 1897	4.4	38.1	14.0	3.18	-12.4	12.1
RL 1900	6.8	11.7	4.5	3.05	-21.1	9.0
RL 1930	7.6	17.9	6.8	3.08	-11.2	12.1
RL 1939	11.1	42.0	15.4	3.17	-12.8	6.6
RL 1945	7.8	17.9	6.9	3.04	-8.2	13.2
RL 1957	15.9	43.3	16.0	3.16	-20.6	9.4
RL 1960	12.6	30.2	11.3	3.11	-14.9	10.8
RL 1963	12.8	24.7	9.3	3.11	-8.6	12.1
RL 2179	5.1	38.7	14.2	3.20	-9.9	12.0
RL 2745	13.9	30.9	11.4	3.16	-16.6	9.6
Mean	**9.8 ± 4.2**	**35.4 ± 8.6**	**13.0 ± 3.1**	**3.17 ± 0.06**	**-16.0 ± 3.9**	**10.9 ± 1.6**

7.2. STABLE CARBON AND NITROGEN ISOTOPE ANALYSIS

The bone collagen of the Rua dos Lagares #74 skeletons yielded a total mean $\delta^{13}C_{col}$ value of -16.0 ± 3.9‰, ranging from -21.1‰ to -7‰ and a mean $\delta^{15}N$ value of 10.9 ± 1.6‰, ranging from 6.4‰ to 13.2‰. When considered separately, Necropolis I yielded respective mean $\delta^{13}C_{col}$ and $\delta^{15}N$ values of -

126 17.9 ± 0.5‰ (ranging from -18.9‰ to -16.9‰) and 11.7 ± 0.7‰ (ranging from 10.5‰ to 12.7‰), while
127 Necropolis II yielded mean values of -13.6 ± 4.7‰ (ranging from -21.1‰ to -7‰) in $\delta^{13}C_{col}$ and 10.1 ±
128 1.9‰ (ranging from 6.4‰ to 13.2‰) in $\delta^{15}N$.

129 ## 7.3. TOOTH ENAMEL STABLE CARBON AND OXYGEN ISOTOPES
130
131 Stable carbon isotopes were also analysed in the tooth enamel ($\delta^{13}C_{en}$) of teeth of all 53 individuals to
132 assess whole diet inputs during childhood. These values are all given in Table 5. These results yielded
133 a mean $\delta^{13}C_{en}$ value of -9.6 ± 4.1‰, ranging from -15.8‰ to -0.6‰. Stable oxygen isotopes were
134 analysed to assess the mobility of the individuals. Following the conversion calculations described in
135 Section 4, a mean $\delta^{18}O_{DW}$ value of -5.0 ± 2.4‰ was calculated from the tooth enamel of these
136 individuals, ranging from -9.3‰ to +2.2‰. Necropolis I yielded respective mean $\delta^{13}C_{en}$ and $\delta^{18}O_{DW}$
137 values of -11.8 ± 0.3‰ (ranging from -12.5‰ to -11.2‰) and -5.0 ± 1.6‰ (ranging from -9.3‰ to -
138 2.9‰), while Necropolis II yielded mean values of -6.9 ± 5.0‰ (ranging from -15.8‰ to -0.6‰) in
139 $\delta^{13}C_{en}$ and -5.0 ± 3.2‰ (ranging from -8.5‰ to +2.2‰) in $\delta^{18}O_{DW}$.

140 **Table 5.) Results- Tooth Enamel**

Sample	Tooth	$\delta^{13}C_{en}$ (‰) VPDB	$\delta^{18}O_c$ (‰) VPDB	$\delta^{18}O_c$ (‰) VSMOW	$\delta^{18}O_p$ (‰) VSMOW	$\delta^{18}O_{DW}$ (‰) VSMOW	$^{87}Sr/^{86}Sr$
Necropolis I							
RL 2002	M3	-12.0	-2.7	28.1	19.3	-3.9	0.709949
RL 2009	M1	-11.6	-4.4	26.3	17.5	-6.8	0.709086
RL 2015	M2?	-12.2	-4.8	26.0	17.1	-7.4	0.715260
RL 2041	M2	-11.8	-3.0	27.8	19.0	-4.5	0.708819
RL 2053	M3	-11.4	-3.0	27.8	19.0	-4.4	0.708821
RL 2062	M1	-11.8	-2.9	27.9	19.2	-4.2	0.708959
RL 2080	M1	-11.8	-3.5	27.4	18.5	-5.1	0.709463
RL 2131	M3	-11.6	-4.3	26.5	17.7	-6.5	0.714011
RL 2134	M1	-12.2	-4.0	26.8	18.0	-6.0	0.709054
RL 2137	M3	-12.1	-6.0	24.7	15.8	-9.3	0.710550
RL 2167	M2	-12.1	-3.9	26.9	18.1	-5.9	0.709161
RL 2170	M2	-11.2	-2.9	27.9	19.1	-4.3	0.708803
RL 2173	M1	-11.8	-3.7	27.1	18.3	-5.5	0.709177
RL 2176	M3	-11.3	-2.6	28.2	19.4	-3.8	0.708506
RL 2182	M2	-11.7	-3.3	27.5	18.7	-4.9	0.709335
RL 2191	M1	-12.3	-2.1	28.8	20.0	-2.9	0.709104
RL 2230	M1	-11.4	-4.0	26.8	18.0	-6.0	0.709085
RL 2242	M1	-11.4	-2.3	28.5	19.8	-3.3	0.709538
RL 2276	M2	-12.1	-3.1	27.7	18.9	-4.6	0.714510
RL 2298	M3	-11.9	-2.2	28.6	19.9	-3.1	0.708733
RL 2308	M1	-11.3	-4.0	26.8	18.0	-6.0	0.709412
RL 2336	M3	-11.7	-2.8	28.0	19.2	-4.1	0.709134
RL 2350	M2	-12.3	-2.3	28.5	19.7	-3.3	0.708883
RL 2375	M3	-12.1	-5.1	25.6	16.8	-7.9	0.713903
RL 2557	M3	-12.5	-2.1	28.7	19.9	-3.0	0.708862
RL 2563	M1	-12.0	-3.4	27.4	18.6	-5.0	0.708948
RL 2626	M2	-11.9	-3.3	27.5	18.7	-4.9	0.708844

RL 2706	M2	-11.6	-3.0	27.8	19.0	-4.4	0.708860
RL 2721	M1	-11.7	-2.7	28.1	19.3	-4.0	0.709060
Necropolis II							
RL 101	M3	-4.2	0.5	31.4	22.7	1.3	0.713330
RL 151	M1	-1.3	-2.6	28.3	19.5	-3.7	0.710897
RL 171	M2	-11.8	-5.2	25.5	16.6	-8.1	0.708182
RL 251	M1	-5.1	-3.8	27.0	18.2	-5.6	0.711988
RL 261	M3	-12.0	-0.7	30.2	21.5	-0.6	0.709563
RL 607	M1	-14.2	-3.7	27.1	18.3	-5.6	0.709920
RL 1809	M1	-7.9	-5.4	25.3	16.4	-8.4	0.713921
RL 1821	M2	-4.2	-5.3	25.5	16.6	-8.1	0.712816
RL 1833	M2	-0.6	-1.0	29.9	21.2	-1.1	0.711815
RL 1840	M3	-5.8	-4.0	26.8	18.0	-6.0	0.720608
RL 1856	M3	-10.8	-5.1	25.7	16.8	-7.8	0.713741
RL 1862	M2	-15.8	-3.5	27.3	18.5	-5.2	0.718161
RL 1874	M2	-0.6	-5.0	25.8	16.9	-7.7	0.711556
RL 1876	M2	-1.3	-5.5	25.3	16.4	-8.5	0.711949
RL 1897	M3	-3.9	-3.7	27.1	18.3	-5.5	0.710822
RL 1900	M2	-14.4	-4.4	26.4	17.5	-6.7	0.713060
RL 1930	M2	-1.5	0.2	31.1	22.4	0.8	0.711620
RL 1939	M1	-7.7	-4.3	26.5	17.6	-6.6	0.715222
RL 1945	M3	-1.6	-4.5	26.3	17.5	-6.8	0.712890
RL 1957	M3	-14.4	-4.2	26.6	17.8	-6.4	0.712526
RL 1960	M3	-5.8	-4.9	25.9	17.0	-7.5	0.714074
RL 1963	M2	-4.3	1.0	31.9	23.3	2.2	0.711835
RL 2179	M1	-6.2	-2.1	28.7	20.0	-3.0	0.711670
RL 2745	M1	-10.9	-3.4	27.5	18.7	-5.0	0.708742
Mean		**-9.6 ± 4.1**	**-3.4 ± 1.5**	**27.4 ± 1.5**	**18.6 ± 1.6**	**-5.0 ± 2.4**	**0.711070 ± 0.002654**

7.4. TOOTH ENAMEL RADIOGENIC STRONTIUM ISOTOPES

The $^{87}Sr/^{86}Sr$ values obtained from the human tooth enamel of 40 individuals, given in Table 5 gave a mean value of 0.71107 ±0.00265, ranging from 0.70818 to 0.72061. Necropolis I yielded a mean $^{87}Sr/^{86}Sr$ value of 0.70986 ± 0.00191 (ranging from 0.70851 to 0.71526) while Necropolis II yielded a mean value of 0.71258 ± 0.00272 (ranging from 0.70818 to 0.72061).

7.5. STATISTICAL ANALYSIS

Statistical analysis, using Mann-Whitney *u* tests (*Statistics Kingdom*, 2017), verified that these two populations (Necropolis I and Necropolis II) were significantly different in their $\delta^{13}C_{col}$, $\delta^{13}C_{en}$, $\delta^{15}N$ and $^{87}Sr/^{86}Sr$ values. Results of statistical analysis are provided in Table 6.

Table 6. Result- Statistical analysis. Mann-Whitney *u* tests performed using the online calculator "Statistics Kingdom" (2017)

Isotope Values	Statistically Significant Difference: Necropolis I vs. Necropolis II	p-value	Z-test
$\delta^{15}N$	Yes	0.0006	3.4532
$\delta^{13}C_{col}$	Yes	0.0049	-2.8165
$\delta^{13}C_{en}$	Yes	0.0004	-3.5203
$\delta^{18}O_{DW}$	No	0.2174	1.2334
$^{87}Sr/^{86}Sr$	Yes	0.00014	-3.8149

158

159

160 8. DISCUSSION:

161 8.1. DIETARY PATTERNS IN LATE MEDIEVAL LISBON

162

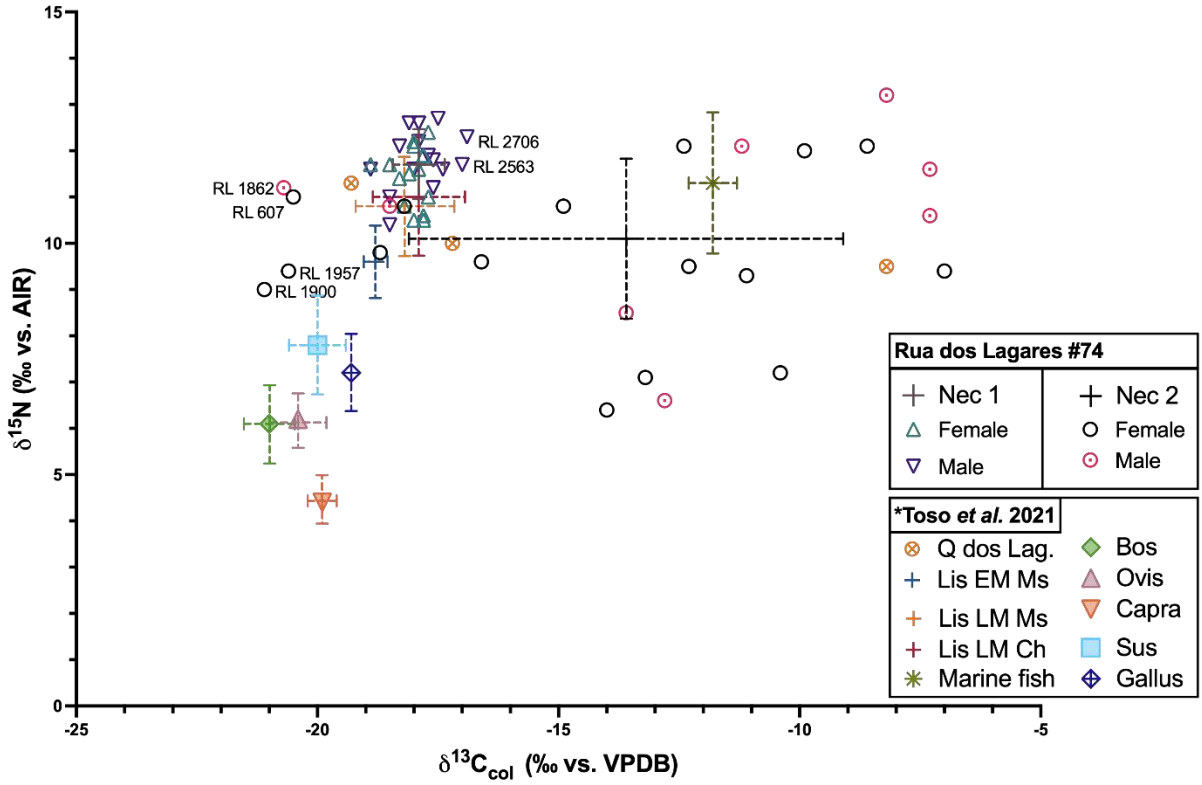
163 In this study, faunal material was not analysed due to readily available published datasets (Toso *et al.*,
164 2021) of fauna from the nearby sites of Casa de Severa (12th – 15th cent.) in Mouraria and Poço do
165 Borratem (14th – 15th cent.), the locations of which are indicated in the map in Fig 1. The faunal $\delta^{13}C_{col}$
166 and $\delta^{15}N$ values published by Toso *et al.* (2021) were thus used to establish the local dietary baseline
167 for Rua dos Lagares #74 and are shown in Fig 7. The diets of these animals likely consisted of C_3 plant
168 input and livestock was likely raised in a somewhat urbanised environment in which small agricultural
169 plots would have been intensively used (Toso *et al.*, 2021). Concerning the Rua dos Lagares #74
170 humans, the Necropolis I population displays $\delta^{13}C_{col}$ and $\delta^{15}N$ values consistent with a diet based on
171 C_3 plants and local animal products, whereas the Necropolis II population yielded highly variable $\delta^{13}C_{col}$
172 and $\delta^{15}N$ values, and all but three individuals (RL 151, RL 171 and RL 261) are unlikely to have
173 consumed local fauna. While four individuals (RL 607, RL 1862, RL 1900 and RL 1957) from Necropolis
174 II had C_3 plant-based diets that are nevertheless distinct from those in Necropolis I, most of the
175 Necropolis II population appeared to have C_4 plant input in their diets to varying degrees. In addition
176 to the faunal data obtained from Toso *et al*. (2021), human $\delta^{13}C_{col}$ and $\delta^{15}N$ data from medieval sites
177 in Lisbon was also available for comparison (Table 7, Fig 9). This included Early Medieval Muslims
178 (Largo de Santa Marinha 8th – 12th cent.), Late Medieval Muslims in Mouraria (Largo das
179 Olarias/Quarteirão dos Lagares 13th – 15th cent.) and Late Medieval Christians (Poço do Borratem 14th
180 – 15th cent.) (Toso *et al.*, 2021). The skeletons from Largo das Olarias and Quarteirão dos Lagares were
181 excavated in separate campaigns but were believed to have belonged to the same Muslim necropolis
182 due to their proximity and were thus combined for comparative purposes as only three skeletons were
183 sampled from the latter (Toso *et al.*, 2021). In fact, Quarteirão dos Lagares refers to the same site as
184 Rua dos Lagares #74 and Largo das Olarias may reflect an earlier use of the necropolis which became
185 urbanised with the expansion of Mouraria in the 15th century (as explained in section 1) (Teixeira,
186 Fragoso and Medeiros, 2020). The $\delta^{13}C_{col}$ and $\delta^{15}N$ values from Necropolis I are notably similar to those
187 of the other late medieval populations, with an identical mean $\delta^{13}C_{col}$ value to the Late Medieval

Christians and slightly elevated $\delta^{15}N$ (+0.6‰), which could result from a higher consumption of poultry or eggs, for example, in Necropolis I or perhaps fish, particularly in the case of the males (RL 2563 and RL 2706) who also have higher $\delta^{13}C_{col}$ values. Taking into account the anthropological and archaeological information that was previously mentioned concerning Necropolis I, this data pattern reflects a level of consistency in the diets of Late Medieval Christians and Jews in Lisbon, that was probably dictated by food availability in this urban environment with minor influences of individual choice and/or cultural or religious factors.

Table 7. Published data for medieval Lisbon from neighbouring sites

Category	Sites	Species	$\delta^{13}C_{col}$ (‰) VPDB	$\delta^{15}N$ (‰) AIR	Reference
Fauna for Baseline	Casa de Severa (12^{th} – 15^{th} C.) Poço do Borratem (14^{th} – 15^{th} C.)	*Bos taurus* (15)	-21.0 ± 0.5	6.1 ± 0.8	Toso *et al*. (2021)
		Ovis (9)	-20.4 ± 0.6	6.2 ± 0.6	
		Capra (3)	-19.9 ± 0.3	4.4 ± 0.5	
		Sus (4)	-20.0 ± 0.6	7.8 ± 2.1	
		Gallus (2)	-19.3 ± 0	7.2 ± 0.8	
Early Medieval Muslim	Largo de Santa Marinha (8^{th} – 12th C.)	Humans (18)	-18.8 ± 0.2	9.6 ± 0.7	Toso *et al*. (2021)
Late Medieval Muslim	Largo das Olarias & Quarteirao dos Lagares (13^{th} – 15^{th} C.)	Humans (22) Mean QDL 104 QDL 124 QDL 131	 -18.2 ± 1.0 -8.2 -19.3 -17.2	 10.8 ± 1.1 9.5 11.3 10.0	Toso *et al*. (2021)
Late Medieval Christian	Poço do Borratem (14^{th} – 15^{th} C.)	Humans (46)	-17.9 ± 0.9	11.0 ± 1.2	Toso *et al*. (2021)

In Necropolis II, however, the picture is quite different. The extremely heterogenous $\delta^{13}C_{col}$ and $\delta^{15}N$ values differ greatly from the other late medieval populations at first glance. In fact, the mean "Late Medieval Muslim" group from Toso *et al*. (2021) is largely influenced by the Largo das Olarias population, but when the Quarteirão dos Lagares values are considered individually, there is an evident similarity to those in Necropolis II. These patterns reflect a population with extraordinarily diverse diets in the final years of life, compared to one another and compared to other populations living in Lisbon in the Late Middle Ages.

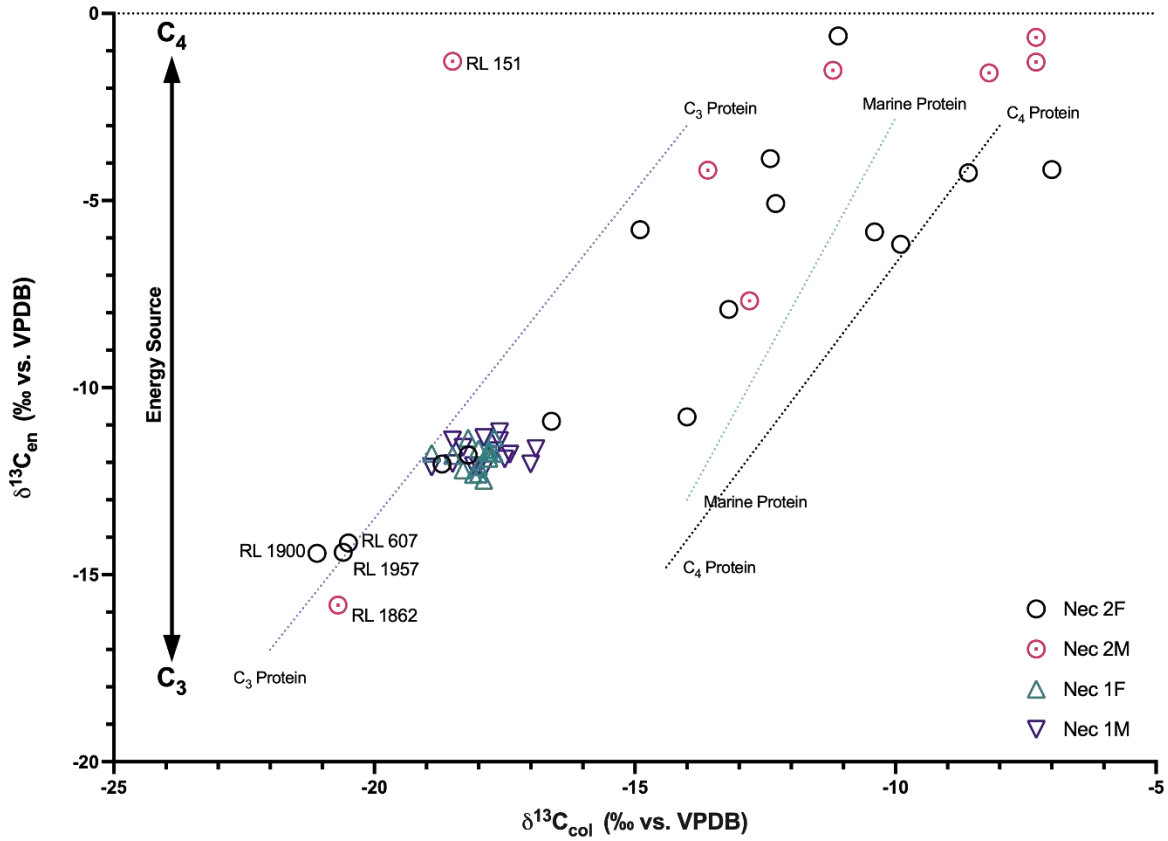


205

206 **Fig. 7 Human $\delta^{15}N$ and $\delta^{13}C_{col}$ values compared to those of humans (Early Medieval Muslim, Late Medieval**
207 **Muslim, Late Medieval Christian and Quarteirão dos Lagares) and fauna from medieval Lisbon published in**
208 **Toso *et al*. (2021)**

209

210 When the $\delta^{13}C$ from both the bone collagen and the tooth enamel are compared, i.e. comparing
211 protein dietary inputs in adulthood to whole dietary inputs in childhood, a very similar pattern is
212 present, as illustrated in Fig 8. The Necropolis I population displays homogenous $\delta^{13}C_{en}$ values that
213 reflect a mixture of mainly C_3 and some C_4 plant inputs in childhood that, once again, were probably
214 dictated by access to similar resources (grain, bread, porridge etc.) that were somewhat constrained
215 by the urban environment in which these individuals lived. The regression lines (Kellner and
216 Schoeninger, 2007) also further indicate that C_3 protein was the dominant source during adulthood
217 for those buried in Necropolis I.



218

219 **Fig. 8 Human $\delta^{13}C_{col}$ and $\delta^{13}C_{en}$ values plotted against regression lines (Kellner and Schoeninger, 2007)**
220 **indicating main protein and energy sources in diet in adulthood and childhood, respectively**

221 For Necropolis II, however, the $\delta^{13}C_{en}$ values are very heterogenous and reflect varying inputs of C_3
222 and some C_4 plants during childhood. Only two individuals (RL 171 and RL 261) have $\delta^{13}C_{en}$ values that
223 fall within the range of the Necropolis I population $\delta^{13}C_{en}$ values. Four individuals (RL 607, RL 1862, RL
224 1900 and RL 1957) have lower $\delta^{13}C_{en}$ values, indicating greater C_3 input in childhood (or different C_3
225 sources), and their reliance on C_3 protein in adulthood has already been mentioned above. The rest of
226 the Necropolis II individuals had $\delta^{13}C_{en}$ values reflecting increased C_4 energy inputs compared to those
227 in Necropolis I. In one interesting case, an individual, RL 151, the adulthood diet of whom appeared
228 similar to those in Necropolis I, evidently consumed almost entirely C_4 inputs during the period of
229 tooth formation but mainly C_3 protein during the last years of life. Some individuals in Necropolis II
230 appear to have consumed exclusively C_4 inputs in childhood and C_4 protein in adulthood, while others
231 have varying degrees of C_4 and C_3 source mixing during childhood and adulthood.

232 The clear influence of C_4 plants on the diets of those in Necropolis II, not present in Necropolis I or in
233 other late medieval populations in Lisbon, is an interesting feature. The introduction of maize from
234 the New World began in 1520 CE in Portugal (Disney, 2009), which is most likely too late to have
235 become widespread enough and influential on the diets (childhood and adulthood) of those buried in

Necropolis II. The archaeological evidence, supported by the radiocarbon date of RL 607, points to the use of the burial space during the late 15th to early 16th century, while the establishment of the Portuguese Inquisition in 1536 CE likely meant that burials following Islamic rites would no longer be carried out after the first decades of the 16th century, due to the inherent risk of persecution (Disney, 2009). Therefore, it seems probable that other C_4 crops, such as sorghum or millet, played an influential role in the diets of many individuals buried in Necropolis II. While these crops were certainly cultivated in Portugal at this point in time and indeed were probably incorporated into the childhood diets of the Necropolis I population, the strong dependence on C_4 sources for many Necropolis II individuals may reflect dietary practices of different places altogether, such as parts of North and/or West Africa where sorghum and millet were much more prevalent in diets.

8.2. DIETARY PATTERNS IN A (POTENTIALLY) AFRICAN POPULATION

West Africa has two distinct crop zones: African rice (*Oryza glaberrima*), a C_3 plant, was domesticated around 3000 years ago, possibly in the Niger River delta in Mali (or in several places) and diffused westward along the coast of the regions that are now Senegal and Gambia and south to Côte d'Ivoire as well as into the Guinea Highlands and eastwards to Lake Chad, becoming the main staple in these regions (de Wet, 1977; Carney, 2005; Nayar, 2010; Kay *et al.*, 2019; Veltman *et al.*, 2019). The extent of rice cultivation in Guinea was even noted by the Portuguese caravel captain Estevão Afonso in 1446 CE (de Wet, 1977). Some upriver regions practiced mixed agriculture, growing rice in wet seasons and sorghum and millet in drier ones (Kay *et al.*, 2019). The remaining regions of West Africa, including Mauritania, large parts of Mali, Niger, Chad and northern Nigeria belong to the pearl millet/sorghum (C_4 plant) crop zone (Obertová *et al.*, 2023). Other important West African staple foods were starchy tubers including yams (*Dioscorea rotundata*) and plantains (*Musaceae*) which are also C_3 plants, cultivated in Côte d'Ivoire and further eastwards (Blench, 2009; Scarcelli *et al.*, 2019; Obertová *et al.*, 2023).

During the anthropological study of the Rua dos Lagares #74 skeletons, a number of individuals were identified as having possible African genetic ancestry (Lourenço et al., 2016). These individuals are illustrated and labelled in Fig 9. While some of these individuals were among those with the most elevated $\delta^{13}C_{col}$ values, reflecting a large influence of C_4 in their diets, others displayed some of the lowest $\delta^{13}C_{col}$ values in Necropolis II, indicating a strong reliance on C_3 food sources. The initial archaeological hypothesis suggested that some individuals buried in Necropolis II may have been enslaved and imported to Portugal from West Africa, more specifically Wolofs (Pinto et al., 2016; Ponce et al., 2017) who, along with Africans from the Guinea Coast and the region of modern-day

Sierra Leone, are known to have been included in the Portuguese slave trade in the 15th and 16th centuries (Saunders, 1982; Tymowski, 2013). One could expect $\delta^{13}C_{col}$ values reflecting C_3 plant consumption in Africans who had lived in the Guinea Coast region and subsisted mainly on rice, and indeed this could be the case for some Necropolis II individuals with probable African origins (i.e. RL 1900 and RL 1957, both of whom also had dental modification). Others with probable African origins had diets clearly based on mainly C_4 (RL 1833, RL 1876 and RL 1945) and varying proportions of C_4 (RL 1809, RL 1840, RL 1856 and RL 1874). Finally, RL 151, as already mentioned in the previous section, had a distinct transition from a childhood C_4 diet to an adulthood C_3 diet that may be indicative of a change in location and hence in the available resources. The extraordinary dietary diversity among the Necropolis II population raised the possibility of the origins of these individuals being in diverse regions where the dietary bases are different, i.e. beyond what could be expected if they had all (or mostly) originated in the rice-growing regions of Senegambia.

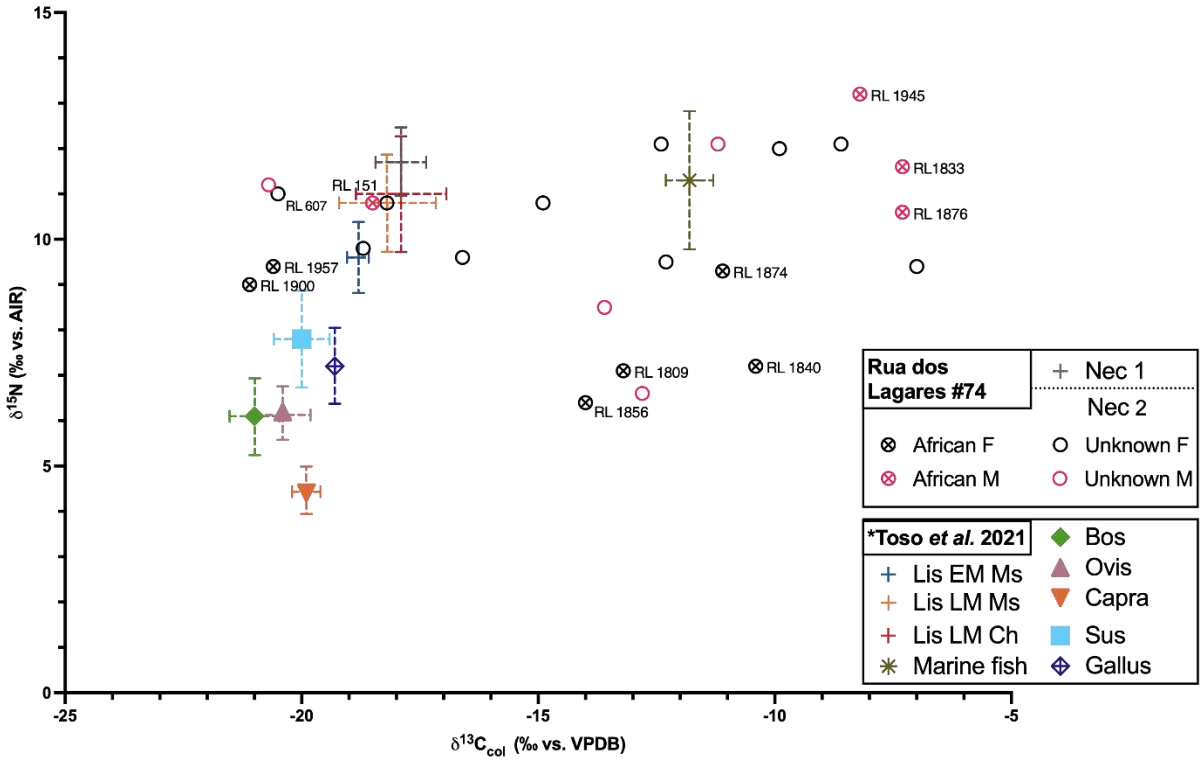


Fig. 9 Necropolis II $\delta^{13}C_{col}$ and $\delta^{15}N$ values according to possible genetic origins. Mean values are provided for Necropolis I and medieval Lisbon (human and fauna) from the sites published in Toso *et al*. (2021)

Concerning the $\delta^{15}N$ values, there is a pattern of higher values in those with more C_4 dietary inputs which could be indicative of marine fish consumption, which is relatively common in the coastal areas of West Africa. Additionally, some other important factors bear consideration. Firstly, it had been observed, during the anthropological assessment of the skeletons, that incidences of metabolic pathologies, including physiological stress, were very high in the Necropolis II population, being

present in 40% of individuals compared to 11.6% of individuals in Necropolis I (Lourenço *et al.*, 2016). The degree of physiological and metabolic stress is consistent with what may be expected for individuals who had been enslaved and forced to carry out hard physical labour until their deaths and may even have been malnourished at certain points. Nutritional stress has been known to produce elevated $\delta^{15}N$ values in body tissues as, in the absence of sufficient protein intake, existing protein is catabolised and its products used to form new proteins (Katzenberg, 2008). This may well have influenced the $\delta^{15}N$ values (and their variability) of some individuals in Necropolis II. Secondly, prolonged water stress can also produce elevated $\delta^{15}N$ values (Ambrose, 1991; Schwarcz and Schoeninger, 1991; Katzenberg, 2008), so if some of these individuals had lived in more arid regions, such as those areas where C_4 crops are better suited to cultivation and make a more significant contribution to diets, this could also result in higher $\delta^{15}N$ values in their bone collagen it still reflects the dietary input of their places of origin.

8.3. MOBILITY PATTERNS IN RUA DOS LAGARES #74

The $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values measured in the skeletons were compared to the local oxygen and strontium baselines established in section 2. In Fig 10, the measured (vertical dark grey box) and conservative (vertical light grey box) $\delta^{18}O$ ranges have been illustrated, and the measured $^{87}Sr/^{86}Sr$ values of plant samples from around Lisbon (James *et al.*, 2022) are provided to estimate the local $^{87}Sr/^{86}Sr$ range (horizontal light grey box). Although the individuals in Necropolis I were very homogenous in all their dietary indicators, the $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values suggest that at least some individuals in this population spent their childhoods non-locally (Fig 10). In Necropolis II, most individuals were apparently non-local to the Lisbon area with the exceptions of the females RL 2745, whose $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values fell within the local ranges, and RL 607 who had values close to the local ranges.

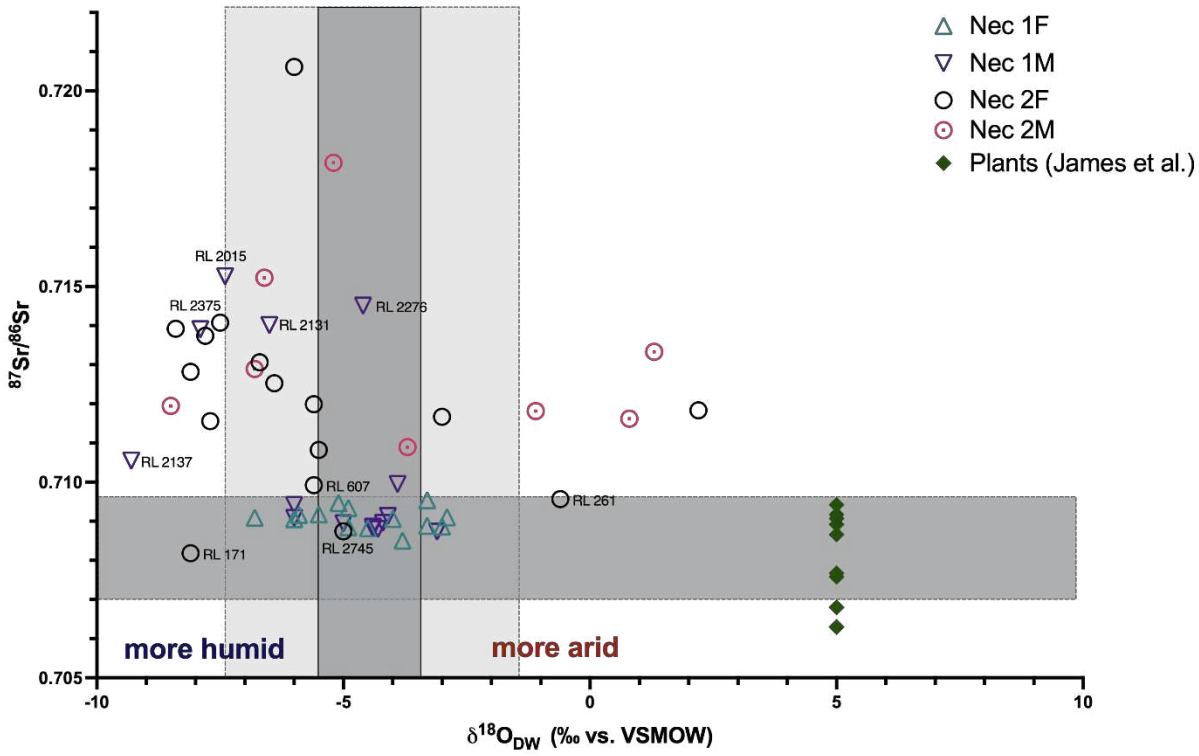


Fig. 10 Human δ^{18}ODW and $^{87}Sr/^{86}Sr$ values with estimated local ranges. Measured precipitation (vertical dark grey box) from waterisotopes.org (Bowen, 2022) and conservative (±2‰) range accounting for intrapopulation variability (vertical light grey box). Plant $^{87}Sr/^{86}Sr$ values from James et al. (2022) used to estimate local $^{87}Sr/^{86}Sr$ range (horizontal grey box). Necropolis I non-locals and Necropolis II possible locals are labelled

While the majority of Necropolis I individuals had $\delta^{18}O_{DW}$ values consistent with the measured local precipitation range and $^{87}Sr/^{86}Sr$ values similar to plants sampled on the Cretaceous and Paleogene deposits near Lisbon (James *et al.*, 2022), some fell within the more 'conservative' $\delta^{18}O_{DW}$ range but could be identified as non-local by their higher $^{87}Sr/^{86}Sr$ values (RL 2015: 0.715260, RL 2131: 0.714011 and RL 2276: 0.714510). In fact, the $\delta^{18}O_{DW}$ range of locals (as determined by their clustered $^{87}Sr/^{86}Sr$ values) could also be used as a method to constrain the local $\delta^{18}O_{DW}$ range (Pederzani and Britton, 2019), which would be -6.8 to -2.9‰. RL 2137 and RL 2375 had $\delta^{18}O_{DW}$ values below -7.5‰: -9.3‰ and -7.9‰, respectively, and higher $^{87}Sr/^{86}Sr$ values than the local range (0.710550 and 0.713903, respectively). These values would be consistent with time spent in more radiogenic geological regions with higher rainfall over the period of tooth enamel formation (late childhood in both cases as the teeth sampled for both were third molars). Such low long-term precipitation $\delta^{18}O$ values are not found in Portugal due to the general regional aridity, but $\delta^{18}O$ values <-7.5‰ have been recorded in the more mountainous regions of neighbouring Spain and North Africa (Hatvani *et al.*, 2020; Bowen, 2022). The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values for RL 2015, RL 2131, RL 2276, RL 2137 and RL 2375 suggest (childhood) origins in different regions: coastal with high humidity for RL 2137 and inland with low (RL 2276) to moderate (RL 2131) to higher humidity (RL 2015 and RL 2375) – various regions of central Iberia, for

example. It is interesting to note that all non-locals in Necropolis I were males and considering the association of the burial space with a Jewish population, and its abandonment that seemed to coincide with the 1496 CE Edict of Expulsion, a few possibilities may be considered. Portugal received many refugees of the Sephardic communities expelled from Castille and Aragon in 1492 CE and allowed them to resettle amongst the Portuguese Jewish communities before they were, in turn, expelled (Livermore, 1966; Soyer, 2008). Prior to these events, there was also frequent movement between Jewish communities in Iberia as well as North Africa because of trade and commercial activities, particularly amongst males (Ray, 2006; Barros and Tavim, 2021). Thus, the individuals with lower $\delta^{18}O$ and higher $^{87}Sr/^{86}Sr$ values may plausibly have been among the Sephardim who spent their childhoods in more humid and/or mountainous regions of Spain and moved to Lisbon later in life. No discernible patterns could be identified amongst individuals with different grave types in Necropolis I.

The proportion of probable non-locals is much higher in Necropolis II and they display great heterogeneity in their $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values. Seven individuals have low $\delta^{18}O_{DW}$ values that reflect childhood origins in regions with higher rainfall than the estimated 'conservative' local range (see Fig 10) and five individuals appear to have spent their childhoods in regions that are more arid than the 'conservative' local range. In fact, only two individuals have $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values similar to the estimated local ranges (and to the Necropolis I locals) – RL 2745 and RL 607, both females and the latter was buried with the blue glass bead necklace of Aggrey beads or 'Trade' beads. All other Necropolis II individuals had higher $^{87}Sr/^{86}Sr$ values, consistent with origins in older (but diverse) geological zones, $\delta^{18}O_{DW}$ values outside the 'conservative' local range (RL 171 and RL 261), or both.

According to the O isoscape (Fig 6b, section 6.3), long-term precipitation $\delta^{18}O$ values >-1.5‰ are not found in Europe but have been recorded in and around the Sahara, while large regions of North and West Africa also have $\delta^{18}O$ values that overlap with southern and central Portugal, including Lisbon. Lower $\delta^{18}O$ values (<-7.5‰) have also been recorded in the Atlas Mountain region of North Africa as well as in the Guinea Highlands and parts of the Guinea coast. While O isotopes depend on geo-environmental factors, Sr isotopes recorded in tooth enamel relate to the underlying geology. Large parts of West Africa are underlain by Precambrian structures of the West African Craton which are ancient (>2000 Ma) and high in rubidium, thus yielding high $^{87}Sr/^{86}Sr$ values (>0.730), particularly in parts of Ghana, Burkina Faso, Côte d'Ivoire, Mali, eastern Guinea and Mauritania (Schlüter, 2008; Wang *et al.*, 2024). Some more recent deposits, such as Cenozoic rock of alluvial, fluvial and marine sedimentation underlie the Guinea Coast, Senegal and the Gambia River valley, where $^{87}Sr/^{86}Sr$ values as low as 0.704 are found (Schlüter, 2008; Wang *et al.*, 2024), and modern fish otoliths and water samples in the Gambia River (considered to be free of anthropogenic contamination) have also yielded

$^{87}Sr/^{86}Sr$ values around 0.712 (Höpker *et al.*, 2022). Overall, the geology of West Africa is highly variable in age and composition, and a broad range of $^{87}Sr/^{86}Sr$ values could be expected in tooth enamel of individuals of African origin unless they had spent their childhoods in the same place. Many of the Necropolis II population had $^{87}Sr/^{86}Sr$ values between 0.711 and 0.714 but were from (different) regions with varying humidity and aridity according to their $\delta^{18}O$ values (Fig. 10). Two individuals had very high $^{87}Sr/^{86}Sr$ values (RL 1840: 0.720608 and RL 1862: 0.718161) but came from regions with similar $\delta^{18}O$ ranges to Lisbon. The areas of West and North Africa with $^{87}Sr/^{86}Sr$ values and precipitation $\delta^{18}O$ values that are consistent with the diverse Necropolis II $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values are, however, incredibly vast and sometimes overlap with values in Iberia, but may potentially be narrowed down by combining anthropological and historical information with the isotope data.

For individuals of African origin, more specifically Wolof (following the archaeological hypothesis), one could expect a pattern of moderate to relatively low $\delta^{18}O_{DW}$ values (broadly around -7‰ to -4‰), reflecting the humidity of parts Senegambia and Guinea, and $^{87}Sr/^{86}Sr$ values broadly around 0.704-0.712 (or lower) in the coastal areas and higher $^{87}Sr/^{86}Sr$ values (0.712-0.716) further inland (Wang *et al.*, 2024). The $\delta^{13}C_{en}$ values could also be expected to be low, reflecting a diet dominated by C_3 plant input (in accordance with the reliance on African rice in this region during the 15th and 16th centuries) or perhaps reflecting mixed C_3 and C_4 inputs (for those living in upland regions where agriculture was mixed) (Kay *et al.*, 2019). Indeed, some individuals in Necropolis II match this pattern, including two who had been identified as having possible African genetic origins (RL 1900 and RL 1957), but the apparent diversity of origins for most individuals, based on $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values and also suggested by the diversity of childhood diets ($\delta^{13}C_{en}$ values), allows for the consideration of different geological, climatic and crop zones in West Africa as places of origin for this population. Probability models (Fig 11a, see section 6.3) that compared individual $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values to expected regional ones across Iberia, northern and western Africa have allowed for several different potential regions of origin to be proposed for those buried in Necropolis II.

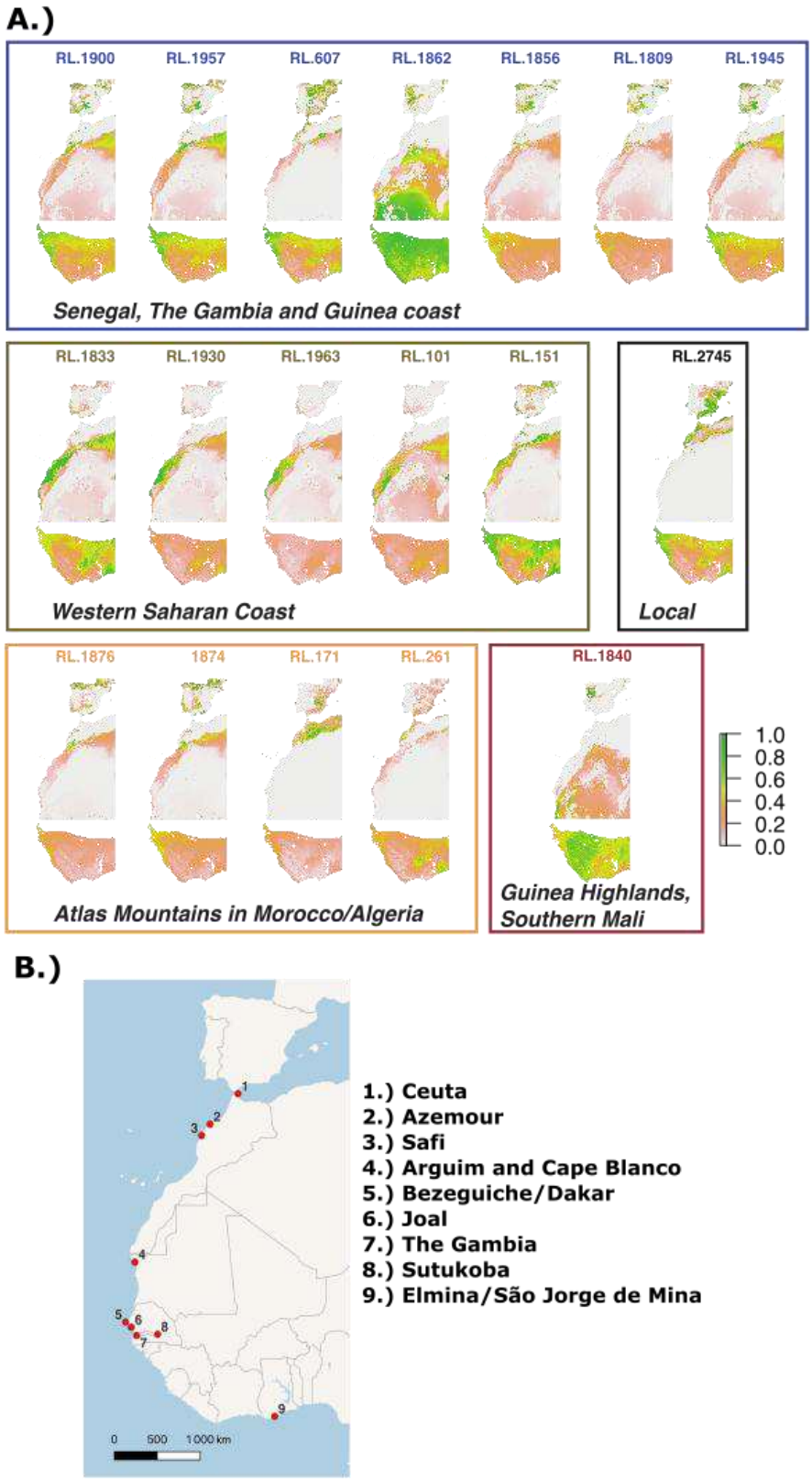


Fig. 11 a.) Probability models for origins of selected individuals in Necropolis II and b.) Known Portuguese trading ports in the 15th and 16th centuries

- Likely origins in Senegal, The Gambia and Guinea Coast:

  RL 1900, RL 1957 and RL 607 correlated well to this region as well as to some parts of Portugal and central/northern Iberia, but not Lisbon (Fig 11a). All three had distinctly C_3-based diets and the dental modification of RL 1900 and RL 1957, as well as the blue glass bead necklace on RL 607, suggest cultural ties to West Africa. RL 1862 correlated well to the abovementioned regions as well as a much vaster area of inland West Africa (Fig 11a) because of their high $^{87}Sr/^{86}Sr$ value (0.71816). RL 1856 and RL 1809 had a weaker correlation to this region and correlated well to central and northwestern Iberia (Fig 11a), but both had dental modification that would make an African origin more likely in a cultural context, adding ambiguity to the results. It should not be overlooked that there is an absence of isoscape data in parts of West Africa, which may account for the low correlation in this region. RL 1945 correlated to Senegambia and the Guinea coast, as well as parts of southern Portugal, northwestern Iberia and the western Atlas Mountains in Morocco (Fig 11a). This individual had a very C_4 diet and probable African ancestry, so a diet of millet/sorghum and fish on the Senegalese coast is plausible.

- Local origins:

  While RL2745 does correlate well with the Senegambia/Guinea Coast region (Fig 11a), it is the only individual to display a strong likelihood of a local (Lisbon) origin.

- Guinea Highlands and Southern Mali:

  RL 1840 had the highest $^{87}Sr/^{86}Sr$ value (0.72061) and correlates with the inland regions of West Africa as well as the Mauritanian coast (Fig 11a). The strong influence of C_4 in this individual's diet makes either of these scenarios possible.

- Western Saharan Coast:

  RL 1833, RL 1930 and RL 1963, all of whom had C_4 diets and were from arid regions, correlated well with this area while RL 101 had a likely origin further inland of Western Sahara or on the northern Mauritanian coast (Fig 11a). RL 151 (also with probable African ancestry) correlated with the Saharan coast as well as Senegambia/Guinea, but their very C_4 diet could be reflective of millet, sorghum or fish consumption on either the Saharan or Senegalese coasts. While the model also showed likely origins in Burkina Faso/Benin/Togo for RL 151 (Fig 11a), this is historically improbable and inconsistent with the reflected diet.

- Atlas Mountains in Morocco/Algeria:

  RL 1876, RL 1874 (both with likely African ancestry) and RL 171 all show some correlation to more humid regions in Iberia, mainly the northwest (RL 1876 and RL1874) and the east (RL 171) as well as the Atlas Mountains (Fig 11a) – regions which have overlapping isotopic ranges

that obscure the interpretation of the data. In the case of RL 261, an origin in Iberia, except for Gibraltar, is unlikely according to the model (Fig 11) but there is better correlation with the northern coast of Morocco. This individual also shows correlation with northeastern Burkina Faso and southern Benin/Togo, but these regions are historically improbable and therefore excluded.

The Necropolis II individuals are organised by the above potential regions of origin in Fig 12 ($^{87}Sr/^{86}Sr$ vs. $\delta^{18}O_{DW}$) and Fig 13 ($^{87}Sr/^{86}Sr$ vs. $\delta^{13}C_{en}$). It is particularly interesting to note the correlation between regions of origin (based on $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values) and $\delta^{13}C_{en}$ values in Fig 13, indicating a strong link between crop reliance and regionality, which reflect the estimated cultivation zones of North and West Africa (Kay *et al.*, 2019). Diets from those with (various) African origins are also isotopically distinct from the (local) Necropolis I population, except for two individuals with possible origins in the Atlas Mountains (RL 171 and RL 261).

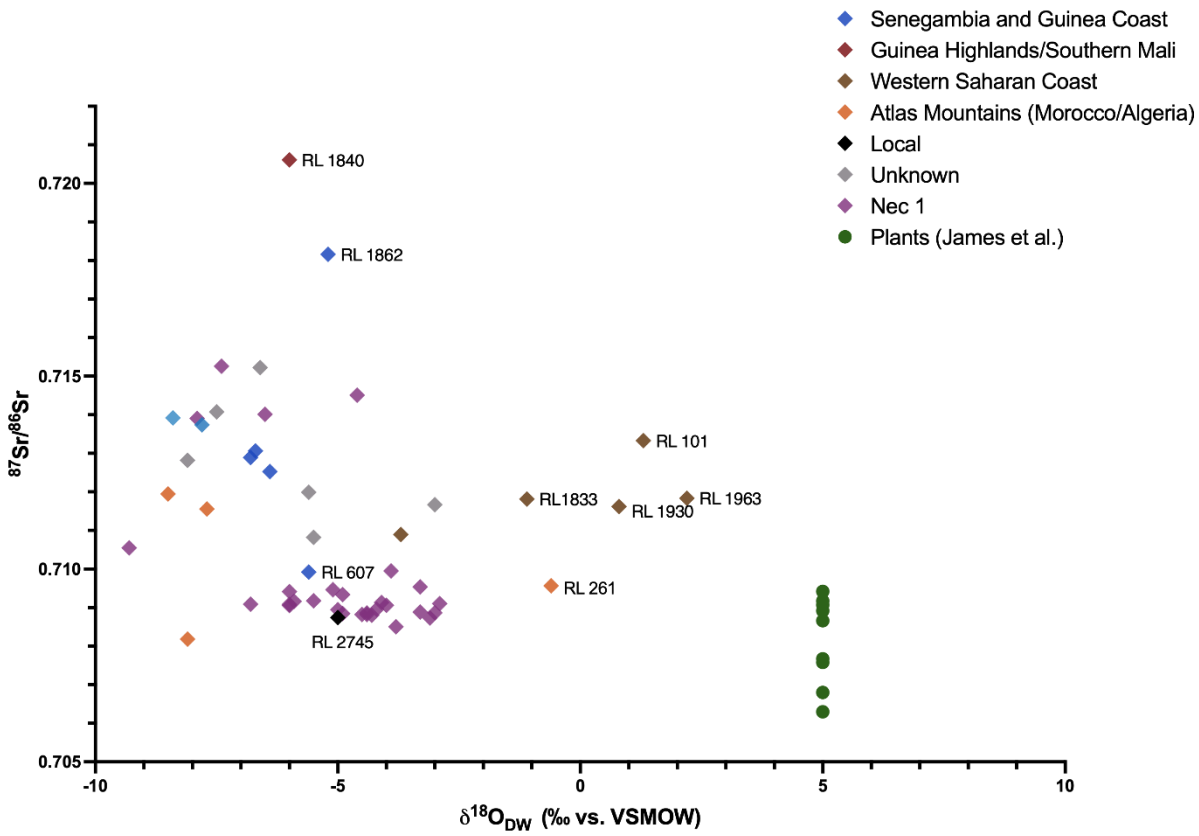


Fig. 12 Necropolis II organised by potential regions of origin ($^{87}Sr/^{86}Sr$ vs. $\delta^{18}O$ values)

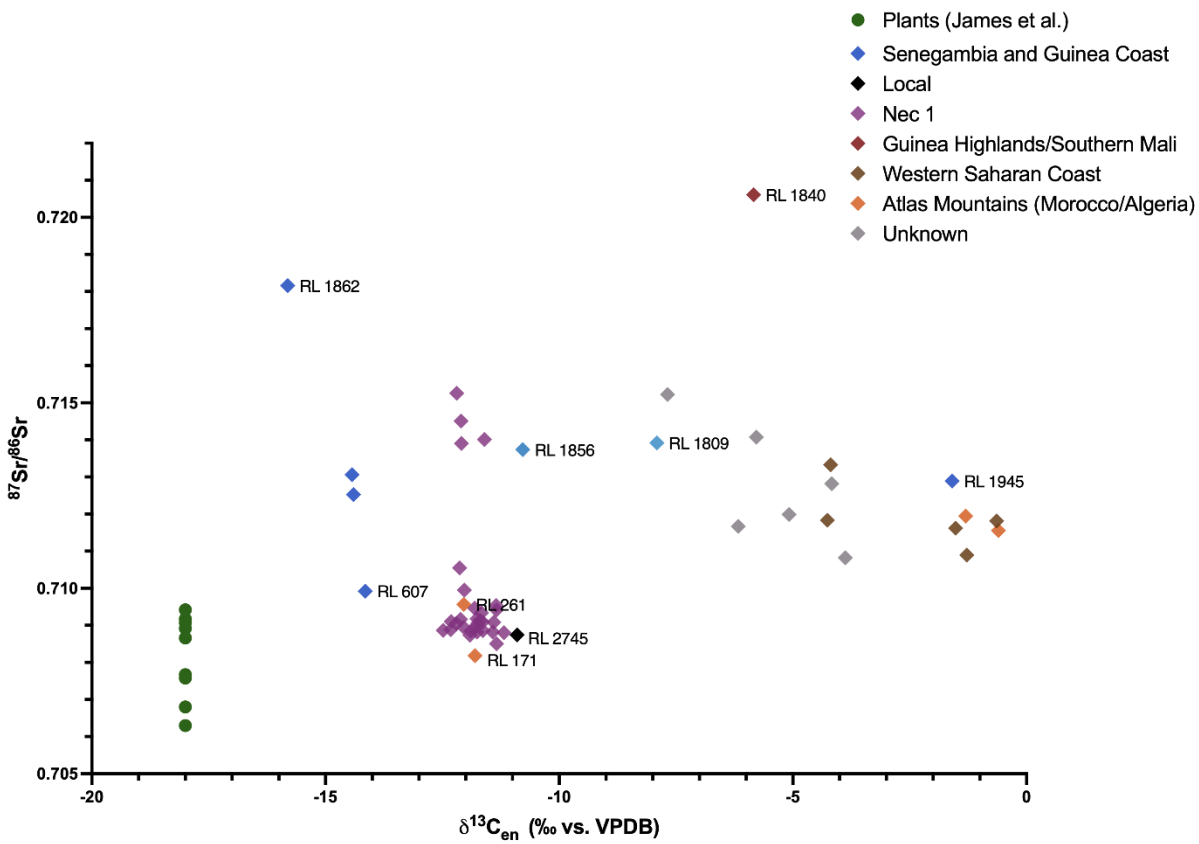


Fig. 13 Necropolis II organised by potential regions of origin ($^{87}Sr/^{86}Sr$ vs. $\delta^{13}C_{en}$ values)

While the suggested regions for the origins of those buried in Necropolis II are incredibly vast, they correlate well with known Portuguese trading posts in the late 15th and early 16th centuries, illustrated in Fig 11b, which were located on the Moroccan coast (Ceuta, Azemour and Safi), Mauritania (Arguim and Cape Blanco), Senegambia (Bezeguiche/Dakar, Joal, Sutukoba and the Gambia River) and (later) Elmina/São Jorge de Mina (Boxer, 1991; Crowley, 2015; de Flamingh *et al.*, 2021). The data patterns make sense if individuals among this population were indeed enslaved people or freedmen who had spent earlier parts of their life in (diverse) regions in West and North Africa, before being brought to Lisbon through the Portuguese slave trade in the 15th and 16th century. It is important to emphasise that the suggested regions of potential origin are by no means confirmative and that there is a good deal of overlap in the ranges of $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ for Iberia and parts of North and West Africa. However, the dietary patterns described above as well as the archaeological and anthropological evidence, and the striking contrasts in the data patterns of Necropolis I and Necropolis II for all isotopes analysed, indicate that the individuals of these two populations had very different life histories. More than accurately predicting places of origin, it should be emphasised that the isotopic

463 evidence reflects a population buried in Necropolis II that was extraordinarily diverse in their dietary
464 habits and places of childhood origin.

465

466 ## 9. CONCLUSION

467

468 While Rua dos Lagares #74 is undoubtedly a very complex site, what is clear is the use of the space for
469 the burials of very different communities at two different points in time. In Necropolis I, there was a
470 community characterised by Jewish burials, with material evidence that suggested a Jewish religious
471 character. This group consumed very homogenous diets throughout life that showed great
472 consistency with other Late Medieval Christian (and to a slightly lesser extent, Muslim) populations
473 that were buried in and around Mouraria, Lisbon. For the most part, the Necropolis I population also
474 had local childhood origins (or at least origins in climatically similar areas) with the exception of five
475 males who originated in places with more radiogenic $^{87}Sr/^{86}Sr$ values and higher elevation and/or
476 increased rainfall. The movement of Jewish individuals (males in particular) within and between
477 communities in Portugal, Spain and North Africa may have occurred through mercantile networks, or
478 because of persecution in their birthplaces, and was a relatively frequent occurrence until the 1496
479 CE Edict of Expulsion.

480 In Necropolis II, the identities and life histories of the population appear to have been vastly different
481 to those of the Necropolis I population. The diets of the Necropolis II population are not only different
482 to Necropolis I, but are highly variable compared to each other, in both childhood and adulthood. The
483 isotope data showed that individuals relied on different plant resources: some entirely on C_3, some
484 entirely on C_4 and others of various combinations of the two. While marine fish consumption may
485 have influenced the diets of some individuals, their elevated $\delta^{15}N$ values could also be a product of
486 nutritional stress or water stress (from an arid environment) in the years prior to their deaths.
487 Concerning the mobility of the Necropolis II population, it would also appear to have been highly
488 variable, based on the heterogeneity of the $\delta^{18}O_{DW}$ and $^{87}Sr/^{86}Sr$ values. Some individuals spent their
489 childhoods in more humid regions and others in very arid regions, beyond what could be expected for
490 Lisbon. The $^{87}Sr/^{86}Sr$ values for Necropolis II overall reflect origins in diverse regions, some with older
491 and more radiogenic geological bases than Lisbon. Taking into consideration the archaeological and
492 anthropological information that suggested at least some individuals had genetic and geographic
493 origins in Africa, the isotope data supports the notion that these individuals came from several
494 different regions of West Africa. These regions span different geological regions, climatic zones and,
495 subsequently, different crop cultivation regions, capable of producing such heterogenous data

patterns in these individuals. While the degree of overlap between precipitation $\delta^{18}O$ values in central and southern Portugal, and in large areas of West and North Africa, adds a degree of ambiguity to these interpretations, the combination of this data with $^{87}Sr/^{86}Sr$ and $\delta^{13}C_{en}$ values increases the possibility of assessing childhood origins in West Africa for many of these individuals.

The populations in both Necropolis I and Necropolis II of Rua dos Lagares #74 were communities who, in all likelihood, lived (perhaps only briefly for some) on the peripheries of Portuguese Catholic society and died in medieval and early modern Lisbon. The Portuguese Inquisition, the harsh realities of a life in a slaving society, and the destruction of records in the disastrous 1755 CE earthquake and fire in Lisbon, meant that surviving information concerning these respective communities was sparse at best. The unique finds at the site of Rua dos Lagares #74, and a detailed consideration of the dietary practices and mobility patterns of the individuals buried there – through multi-isotopic analysis – has added valuable insight that will, hopefully, facilitate more nuanced understanding to future studies of this complicated era of Portuguese history.

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Data availability

All data are included within this manuscript.

Conflicts of interest/Competing interests

The authors declare having no conflict of interest

Authors' Contributions

Rebecca Anne MacRoberts: conceptualisation; methodology; data curation; formal analysis; investigation; writing-original draft; writing-review and editing

Lucy Shaw Evangelista: methodology; resources; writing-original draft; writing-review and editing

Marina Lourenço: methodology; writing-review and editing

Manuel Fialho Silva: resources; writing-review and editing

Bernd R. Schöne: methodology; writing-review and editing

Leopoldo D. Pena: methodology

Cristina Barrocas Dias: resources

Anne-France Maurer: Conceptualisation; methodology; investigation; writing-original draft; writing-review and editing; supervision; project administration; funding acquisition

Captions

Supplementary Files

S1. Mobility Modelling Methodology

Tables

Table 1. Summary of Rua dos Lagares #74 burials. Full descriptions in Lourenço *et al*. (2016) and Ponce *et al*. (2017)

Table 2. Necropolis I: Human Skeletal Material

Table 3. Necropolis II: Human Skeletal Material

Table 4. Results- Bone Collagen

Table 5. Results- Tooth Enamel

Table 6. Result- Statistical analysis. Mann-Whitney *u* tests performed using the online calculator "Statistics Kingdom" (2017)

Table 7. Published data for medieval Lisbon from neighbouring sites

Figures

Fig. 1 Map of Mouraria and the sites and locations therein mentioned in Section 6.1. Map inset sources: openstreetmap.org (Lisbon) and commons.wikimedia.org (Portugal)

Fig. 2 Geological map of Lisbon with locations of plants sampled by James et al. (2022) and their respective $^{87}Sr/^{86}Sr$ values. Map adapted from LNEG (Mapa Geológico de Espanha e Portugal à escala 1: 1 000 000, 2015)

Fig. 3 Simplified stratigraphy of the Rua dos Lagares necropolises. Adapted from Pinto et al. (2016)

Fig. 4 Necropolis I examples of burials a.) Type 1: simple anthropomorphic structures and b.) Type 2: Rectangular pits with interior anthropomorphic recession. Source: Pinto *et al*. (2016)

Fig. 5 Dental modification in the a.) upper and b.) lower incisors of the individual RL 1809 in Necropolis II. Source for images: Lourenço et al. (2016)

Fig. 6 a). Global 87Sr/86Sr values over the region of interest. Interpolated map obtained from waterisotopes.org (Bataille et al., 2020; Bowen, 2022) and adapted and combined with isoscape for the West Africa region from Wang et al. (2024) in QGIS v.3.34.7. and b.) Mean annual precipitation d18O values over the region of interest. Interpolated map obtained from waterisotopes.org (Bowen, 2022) and adapted in QGIS v.3.34.7

Fig. 7 Human $\delta^{15}N$ and $\delta^{13}C_{col}$ values compared to those of humans (Early Medieval Muslim, Late Medieval Muslim, Late Medieval Christian and Quarteirão dos Lagares) and fauna from medieval Lisbon published in Toso *et al*. (2021)

Fig. 8 Human $\delta^{13}C_{col}$ and $\delta^{13}C_{en}$ values plotted against regression lines (Kellner and Schoeninger, 2007) indicating main protein and energy sources in diet in adulthood and childhood, respectively

Fig. 9 Necropolis II $\delta^{13}C_{col}$ and $\delta^{15}N$ values according to possible genetic origins. Mean values are provided for Necropolis I and medieval Lisbon (human and fauna) from the sites published in Toso *et al*. (2021)

Fig. 10 Human $\delta^{18}ODW$ and $^{87}Sr/^{86}Sr$ values with estimated local ranges. Measured precipitation (vertical dark grey box) from waterisotopes.org (Bowen, 2022) and conservative (±2‰) range accounting for intrapopulation variability (vertical light grey box). Plant $^{87}Sr/^{86}Sr$ values from James et al. (2022) used to estimate local $^{87}Sr/^{86}Sr$ range (horizontal grey box). Necropolis I non-locals and Necropolis II possible locals are labelled

Fig. 11 a.) Probability models for origins of selected individuals in Necropolis II and b.) Known Portuguese trading ports in the 15th and 16th centuries

Fig. 12 Necropolis II organised by potential regions of origin ($^{87}Sr/^{86}Sr$ vs. $\delta^{18}O$ values)

Fig. 13 Necropolis II organised by potential regions of origin ($^{87}Sr/^{86}Sr$ vs. $\delta^{13}C_{en}$ values

Bibliography

Ambrose, S. H. (1990) 'Preparation and characterization of bone and tooth collagen for isotopic analysis', *Journal of Archaeological Science*, 17(4), pp. 431–451. doi: https://doi.org/10.1016/0305-4403(90)90007-R.

Ambrose, S. H. (1991) 'Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs', *Journal of Archaeological Science*, 18(3), pp. 293–317. doi: https://doi.org/10.1016/0305-4403(91)90067-Y.

Ando, A. *et al.* (2011) 'Chemostratigraphic documentation of a complete Miocene intermediate-depth section in the Southern Ocean: Ocean Drilling Program Site 1120, Campbell Plateau off New Zealand', *Marine Geology*, 279(1–4), pp. 52–62. doi: 10.1016/j.margeo.2010.10.012.

Andrade, A. A. (2003) 'O desaparecimento espacial das judiarias nos núcleos urbanos portugueses de finais da Idade Média: o caso de Lisboa', *Estudos de Homenagem ao Prof. Doutor José Marques*, 1, pp. 143–163.

Azmy, K. *et al.* (1999) 'Silurian strontium isotope stratigraphy', *Geological Society of America Bulletin*, 111(4), pp. 475–483. doi: 10.1130/0016-7606(1999)111<0475:SSIS>2.3.CO;2.

Babalola, A. B. *et al.* (2018) 'Chemical analysis of glass beads from Igbo Olokun, Ile-Ife (SW Nigeria): New light on raw materials, production, and interregional interactions', *Journal of Archaeological Science*. Elsevier Ltd, 90, pp. 92–105. doi: 10.1016/j.jas.2017.12.005.

Babalola, A. B. (2022) *Glass Beads in West Africa*, *Oxford Research Encyclopedia of Anthropology*. doi: 10.1093/acrefore/9780190854584.013.280.

Babalola, A. B. and Ajayi, B. D. (2022) 'Of glass, stone, shell, and metal: Ecologies of beads in medieval and post-medieval West Africa', *Postmedieval*, 13(1–2), pp. 197–221. doi: 10.1057/s41280-022-00231-5.

Baccino, E. and Schmitt, A. (2006) 'Determination of adult age at death in the forensic context. I', in Schmitt, A., Cunha, E., and Pinheiro, J. (eds) *Forensic anthropology and Medicine: complementary sciences from recovery to cause of death*. New Jersey, USA: Humana Press, pp. 259–280.

Barros, F. and Tavim, J. A. (2021) 'Mobilities and Communities between North Africa and Portugal: Muslims and Jews in the Medieval and Early Modern Ages', *Ler História*, (78), pp. 17–38. doi: 10.4000/lerhistoria.8210.

Bataille, C. P. *et al.* (2020) 'Advances in global bioavailable strontium isoscapes', *Palaeogeography, Palaeoclimatology, Palaeoecology*, 555, p. 109849. doi: https://doi.org/10.1016/j.palaeo.2020.109849.

Beasley, M. M. and Somerville, A. D. (2023) *Exploring Human Behavior Through Isotope Analysis: Applications in Archaeological Research*.

Blanchard, P. (2022) 'Jewish Funerary Practices in Medieval Europe', in Knüsel, C. J. and Schotsmans, E. M. (eds) *The Routledge Handbook of Archaeothanatology: Bioarchaeology of Mortuary Behaviour*. London: Routledge. doi: 10.4324/9781351030625-22.

Blanchard, P., Livet, J. and Di Stefano, V. (2023) 'Archaeological Interventions in Medieval Jewish Cemeteries in Western Europe', *Fasciculi Archaeologiae Historicae*, 36, pp. 7–27. doi: 10.23858/fah36/2023.001.

Blench, R. (2009) 'Bananas and Plantains in Africa', *Ethnobotany Research and Applications*, 7, pp. 363–380.

Bowen, G. J. (2022) *Waterisotopes.org*, *Isoscapes: Understanding Movement, Pattern and Process on Earth Through Isotope Mapping*. Available at: https://wateriso.utah.edu/waterisotopes/pages/data_access/figures.html (Accessed: 25

February 2022).
Bowen, G. J. and Revenaugh, J. (2003) 'Interpolating the isotopic composition of modern meteoric precipitation', *Water Resources Research*. John Wiley & Sons, Ltd, 39(10). doi: https://doi.org/10.1029/2003WR002086.
Bowen, G. J. and Wilkinson, B. (2002) 'Spatial distribution of δ18O in meteoric precipitation', *Geology*, 30(4), pp. 315–318. doi: 10.1130/0091-7613(2002)030<0315:SDOOIM>2.0.CO;2.
Boxer, C. R. (1991). *The Portuguese seaborne empire 1415 – 1825*. Exeter: Carcanet, SRP Ltd.
Bronk Ramsey, C. (2021). OxCal Program (v4.4.4). Radiocarbon Accelerator Unit, University of Oxford.
Bruzek, J. (2002) 'A method for visual determination of sex, using the human hip bone', *American Journal of Biological Anthropology Anthropology*. John Wiley & Sons, Ltd, 117(2), pp. 157–168. doi: https://doi.org/10.1002/ajpa.10012.
Cardinall, A. W. (1925) 'Aggrey Beads of the Gold Coast', *Journal of the Royal African Society*, 24(96), pp. 287–298.
Carney, J. (2005) 'Rice and memory in the age of enslavement: Atlantic passages to suriname', *Slavery and Abolition*, 26(3), pp. 325–348. doi: 10.1080/01440390500319562.
Chenery, C. A. *et al.* (2012) 'The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite', *Rapid Communications in Mass Spectrometry*, 26(3), pp. 309–319. doi: 10.1002/rcm.5331.
Cramer, B. D. *et al.* (2011) 'A Revised 87Sr/86Sr Curve for the Silurian: Implications for Global Ocean Chemistry and the Silurian Timescale', *The Journal of Geology*, 119(4), pp. 335–349. doi: 10.1086/660117.
Crowley, R. (2015) *Conquerors: How Portugal forged the first global empire*. New York: Random House.
Crubézy, E. (1988) *Interactions entre facteurs bio-culturals, pathologieetcaracteresdiscrets. Exempled'une population medievale. Canac (Aveyron).* Universite de Montpellier I.
DeNiro, M. J. (1985) 'Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction', *Nature*. Nature Publishing Group UK London, 317, pp. 806–809. doi: https://doi.org/10.1038/317806a0.
Disney, A. R. (2009) *A history of Portugal and the Portuguese empire: From beginnings to 1807 volume 2, the Portuguese empire*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511813337.
Fazecas, I. G. and Kósa, F. (1978) *Forensic Fetal Osteology*, *Budapeste Akadémiai Kiadó*. Budapest.
Ferembach, D., Schwidetzky, I. and Stloukal, M. (1980) 'Recomendations for age and sex diagnosis of skeletons.', *Journal of Human Evolution*, 9(7), pp. 517–549.
Finnegan, M. (1978) 'Non metric variation of the infracranial skeleton.', *Journal of Anatomy*, 125(1), pp. 23–37.
Finucane, B. ., Manning, K. and Touré, M. (2008) 'Prehistoric Dental Modification in West Africa – Early Evidence from Karkarichinkat Nord, Mali', *International Journal of Osteoarchaeology*, (May 2007). doi: 10.1002/oa.
de Flamingh, A. *et al.* (2021) 'Sourcing elephant ivory from a sixteenth-century Portuguese shipwreck', *Current Biology*, 31(3), pp. 621–628. doi: 10.1016/j.cub.2020.10.086.
Francis, P. (1990) 'Beads in Ghana (West Africa) Part II', *The Margaretologist: The Journal of the Center for Bead Research*, 3(2).
Frankel, E. and Teutsch, B. P. (1995) *The Encyclopedia of Jewish Symbols*. Jason Aronson, Incorporated. Available at: https://books.google.pt/books?id=1ZktAAAAQBAJ.
Guiry, E. J. and Szpak, P. (2021) 'Improved quality control criteria for stable carbon and nitrogen isotope measurements of ancient bone collagen', *Journal of Archaeological Science*. Elsevier Ltd, 132(October 2020), p. 105416. doi: 10.1016/j.jas.2021.105416.
Hatvani, I. G. *et al.* (2020) 'Analysis of the Spatial Distribution of Stable Oxygen and Hydrogen Isotopes in Precipitation across the Iberian Peninsula', *Water*, 12(2). doi:

10.3390/w12020481.
Hauser, G. *et al.* (1989) *Epigenetic variants of the human skull.* Stuttgart: Schweizerbart`sche Verlagsbuchhandlung.
Höpker, S. N. *et al.* (2022) 'Sr Isotope Ratios (87Sr/86Sr) in Water and Fish Otoliths as Estuarine Salinity Tracers: Case Studies from Three NW African Rivers', *Estuaries and Coasts*. Springer US, 45(6), pp. 1780–1802. doi: 10.1007/s12237-021-01041-x.
James, H. F. *et al.* (2022) 'A large-scale environmental strontium isotope baseline map of Portugal for archaeological and paleoecological provenance studies', *Journal of Archaeological Science*. Elsevier Ltd, 142. doi: 10.1016/j.jas.2022.105595.
Katzenberg, M. A. (2008) 'Stable Isotope Analysis: A tool for studying past diet, demography and life history', in Katzenberg, M. A. and Saunders, S. R. (eds) *Biological Anthropology of the Human Skeleton*. New Jersey, USA: John Wiley & Sons, Inc., pp. 491-.
Kay, A. U. *et al.* (2019) *Diversification, Intensification and Specialization: Changing Land Use in Western Africa from 1800 BC to AD 1500*, *Journal of World Prehistory*. doi: 10.1007/s10963-019-09131-2.
Kellner, C. M. and Schoeninger, M. J. (2007) 'A simple carbon isotope model for reconstructing prehistoric human diet', *American Journal of Physical Anthropology*, 133(4), pp. 1112–1127. doi: 10.1002/ajpa.20618.
Van Klinken, G. J. (1999) 'Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements', *Journal of Archaeological Science*, 26(6), pp. 687–695. doi: 10.1006/jasc.1998.0385.
de Laeter, J. *et al.* (2003) 'Atomic weights of the elements. Review 2000 (IUPAC Technical Report)', *Pure Appl Chem*, 75(6), pp. 683–800. doi: 10.1351/pac200375060683.
Lilley, J. *et al.* (1994) 'The Jewish burial ground at Jewbury', *The Archaeology of York: The Medieval Cemeteries*, 12(3).
Livermore, H. V (1966) *A New History of Portugal*. Cambridge University Press. Available at: https://books.google.pt/books?id=voE6AAAAIAAJ.
Lourenço, M. *et al.* (2016) *Relatório dos trabalhos antropológicos, Rua dos Lagares, 74, Projecto no 1447.15*. Lisbon, Portugal.
MacLaughlin, S. M. (1990) 'Epiphyseal Fusion at The Sternal End of The Clavicle In a Modern Portuguese Skeletal Sample.', *Antropologia Portuguesa*, 8, pp. 59–68.
Mapa Geológico de Espanha e Portugal à escala 1: 1 000 000 (2015) *LNEG*. Available at: https://www.lneg.pt/product/mapa-geologico-de-espanha-e-portugal-a-escala-11-000-000/ (Accessed: 21 November 2022).
Marado, C. A. (2020) 'The mendicant equilibrium in medieval Lisbon: Religious houses and urban growth', *Hortus Artium Mediaevalium*, 26(January 2020), pp. 344–357. doi: 10.1484/J.HAM.5.121716.
Matildes, R. *et al.* (2010) '3D geological model of Lisbon', pp. 2201–2208.
Maurer, A.-F. *et al.* (2012) 'Bioavailable 87Sr/86Sr in different environmental samples — Effects of anthropogenic contamination and implications for isoscapes in past migration studies', *Science of The Total Environment*, 433, pp. 216–229. doi: https://doi.org/10.1016/j.scitotenv.2012.06.046.
Maurer, A-F. *et al.* (2025) 'Mobility of populations in the transition from Muslim world to Portuguese Kingdom in the Algarve, South Portugal, 11th – 13th centuries', *Archaeol Anthropol Sci,* 17(225). doi: https://doi.org/10.1007/s12520-025-02322-3
Van der Merwe, N. J. (1982) 'Carbon isotopes, photosynthesis, and archaeology: Different pathways of photosynthesis cause characteristic changes in carbon isotope ratios that make possible the study of prehistoric human diets', *American scientist*. JSTOR, 70(6), pp. 596–606.
Van der Merwe, N. J. and Vogel, J. C. (1978) '13C content of human collagen as a measure of prehistoric diet in woodland North America', *Nature*. Nature Publishing Group UK London, 276(5690), pp. 815–816.

751 Nayar, N. M. (2010) 'The history and genetic transformation of the African rice, Oryza glaberrima
752 Steud. (Gramineae)', *Current Science*. Temporary Publisher, 99(12), pp. 1681–1689. Available
753 at: http://www.jstor.org/stable/24073492.
754 Obertová, Z. *et al.* (2023) 'Stable Isotope Provenance of Unidentified Deceased Migrants—A Pilot
755 Study', *Biology*, 12(11). doi: 10.3390/biology12111371.
756 Oliveira, L. F. and Viana, M. (1993) 'A Mouraria de Lisboa no Século XV', *Arqueologia Medieval*,
757 2(Mértola: Edições Afrontamento), pp. 191–209.
758 Oliver, R. and Atmore, A. (2001) *Medieval Africa, 1250-1800*. Cambridge: Cambridge University
759 Press.
760 Olivier, G. *et al.* (1978) 'New estimation of stature and cranial capacity in modern man. J', *Journal of*
761 *Human Evolution*, 7(6), pp. 513–518.
762 Pederzani, S. and Britton, K. (2019) 'Oxygen isotopes in bioarchaeology: Principles and applications,
763 challenges and opportunities', *Earth-Science Reviews*. Elsevier, 188, pp. 77–107. doi:
764 10.1016/j.earscirev.2018.11.005.
765 Pinto, C. *et al.* (2011) 'Inventory, dissemination and preservation of the geological heritage in urban
766 areas – lisbon city case study', *GeoJournal of Tourism and Geosites*, 8(2), pp. 263–271.
767 Pinto, M. *et al.* (2016) *Relatório Final dos trabalhos arqueológicos- Rua dos Lagares, 74, Lisboa,*
768 *Projecto no 1447.15*. Lisbon, Portugal.
769 Ponce, M. *et al.* (2017) 'O sítio dos Lagares (Lisboa): um espaço pluricultu(r)al', in *Trabalho*
770 *apresentado em Arqueologia em Portugal / 2017 – Estado da Questão, Lisboa, 2017*, pp.
771 1703–1714.
772 Ray, J. (2006) *The Sephardic Frontier: The Reconquista and the Jewish Community in Medieval Iberia*,
773 *Journal GEEJ*. Ithaca and London: Cornell Univerity Press.
774 Sabar, S. (2010) 'From Sacred Symbol to Key Ring : The Hamsa in Jewish and Israeli Societies', in
775 Bronner, S. J. (ed.) *Jews at Home: The Domestication of Identity*. Oxford. Portland, Oregon:
776 The Littman Library of Jewish Civilization, pp. 140–162.
777 Saunders, A. de C. (1982) *A social history of black slaves and freedmen in Portugal 1441-1555*. Edited
778 by P. . Russell. New York: Cambridge University Press.
779 Scarcelli, N. *et al.* (2019) 'Yam genomics supports West Africa as a major cradle of crop
780 domestication', *Science Advances*, 5(5), pp. 1–7. doi: 10.1126/sciadv.aaw1947.
781 Scheuer, L. and Black, S. (2000) 'Development and ageing of the juvenile skeleton', *Human osteology*
782 *in archaeology and forensic science*. Greenwich Medical Media London, pp. 9–22.
783 Schlüter, T. (2008) *Geological Atlas of Africa*, *Economic Geology*. Berlin, Heidelberg: Springer Berlin
784 Heidelberg. doi: 10.2113/gsecongeo.103.6.1379.
785 Schneider, S., Fürsich, F. T. and Werner, W. (2009) 'Sr-isotope stratigraphy of the Upper Jurassic of
786 central Portugal (Lusitanian Basin) based on oyster shells', *International Journal of Earth*
787 *Sciences*, 98(8), pp. 1949–1970. doi: 10.1007/s00531-008-0359-3.
788 Schoeninger, M. J. and Deniro, M. J. (1984) 'Nitrogen and carbon isotopic composition of bone
789 collagen from marine and terrestrial animals', *Geochimica et Cosmochimica Acta*, 48(4), pp.
790 625–539. doi: https://doi.org/10.1016/0016-7037(84)90091-7.
791 Schwarcz, H. P. and Schoeninger, M. J. (1991) 'Stable Isotope Analyses in Human Nutritional
792 Ecology', *American Journal of Physical Anthropology*, 34(13), pp. 283–321. doi:
793 https://doi.org/10.1002/ajpa.1330340613.
794 Silva, A. M. (1996) *O Hipogeu do Monte de Canelas I (IV-III milénios a.C.): Estudo paleobiológico da*
795 *população humana exumada. Trabalho de síntese. Provas de Aptidão e Capacidade*
796 *Científica.* Coimbra.
797 Silva, M. F. (2017) *Mutação urbana na Lisboa medieval: das Taifas a D. Dinis*. Universidade de Lisboa
798 (Portugal).
799 Silva, M. F. (2019) 'Morfologias urbanas na Lisboa Medieval: O caso das Judiarias (1147 - 1325)', in
800 Andrade, A. A. et al. (eds) *Inclusão e exclusão na Europa urbana medieval. Inclusion and*
801 *Exclusion in Medieval Urban Europe*. 19th edn. Lisbon, Portugal: IEM – Instituto de Estudos

Medievais, pp. 289–306.
Silva, M. F. (2025) 'Uma necrópole medieval na Encosta de S. Gens. História e Arqueologia', in *Fragmentos de Arqueologia*, nº 5. Lisbon, Portugal: Centro de Arqueologia de Lisboa, pp. 56-69.
Soyer, F. (2008) 'The Expulsion of the Muslims from Portugal (1496–1497)', *Al-Masaq: Islam and the Medieval Mediterranean*, 20(2), pp. 215–234. doi: 10.1080/09503110802283432.
Statistics Kingdom (2017) *Statistics Calculator*. Available at: http://www.statskingdom.com (Accessed: 18 April 2022).
Szpak, P., Metcalfe, J. Z. and Macdonald, R. A. (2017) 'Best practices for calibrating and reporting stable isotope measurements in archaeology', *Journal of Archaeological Science: Reports*, 13, pp. 609–616. doi: 10.1016/j.jasrep.2017.05.007.
Teixeira, A., Fragoso, Í. and Medeiros, L. (2020) 'Arqueologia, recuperação da memória e afirmação da identidade: o caso do Bairro da Mouraria, Lisboa Archaeology, recovery of memory and affirmation of identity: the case of the Mouraria quarter, Lisbon', *Revista memória em rede*, 12(23), pp. 19–48. Available at: https://doi.org/10.15210/rmr.v12i23.19212.
Terzer. S. *et al*. (2013) 'Global isoscapes for $\delta^{18}O$ and $\delta^{2}H$ in precipitation: improved prediction using regionalized climatic regression models', *Hydrol. Earth Syst. Sci*., 17, 4713–4728, doi: https://doi.org/10.5194/hess-17-4713-2013
Toso, A. *et al.* (2021) 'Beyond faith : Biomolecular evidence for changing urban economies in multi-faith medieval Portugal', *American Journal of Biological Anthropology*, 176(2), pp. 208–222. doi: 10.1002/ajpa.24343.
Trindade, L. (2007) 'From Islam to Christianity: Urban Changes in Medieval Portuguese Cities', *Religion and Power in Europe: Conflict and Convergence*. Edizioni Plus, 2, p. 29.
Tykot, R. H. (2004) 'Stable isotopes and diet : You are what you eat', *Proceedings of the International School of Physics 'Enrico Fermi'*, 154, pp. 433–444. doi: 10.3254/978-1-61499-010-9-433.
Tymowski, M. (2013) 'The cultural-psychological aspects of the presence of African slaves in Portugal in the fifteenth and early sixteenth centuries', *Acta Poloniae Historica*, 107, pp. 45–82. doi: 10.12775/APH.2013.107.02.
Ubelaker, D. H. (1989) *Human Skeletal Remains - excavation, analysis, interpretation.* Second. Washington: Smithsonian Institute.
Veltman, M. A. *et al.* (2019) 'Origins and geographic diversification of African rice (Oryza glaberrima)', *PLoS ONE*, 14(3), pp. 1–28. doi: 10.1371/journal.pone.0203508.
Wang, X. *et al.* (2024) 'Strontium isoscape of sub-Saharan Africa allows tracing origins of victims of the transatlantic slave trade', *Nature communications*, 15(1), p. 10891. doi: 10.1038/s41467-024-55256-0.
Wasterlain, R. . (2000) *Morphé: Análise das proporções entre os membros, dimorfismo sexual e estatura de uma amostra da colecção de esqueletos identificados do Museu Antropológico da Universidade de Coimbra.* Universidade de Coimbra.
Waterman, A. J. *et al.* (2014) 'In search of homelands: Using strontium isotopes to identify biological markers of mobility in late prehistoric Portugal', *Journal of Archaeological Science*. Academic Press, 42(1), pp. 119–127. doi: 10.1016/j.jas.2013.11.004.
Weber, M. *et al.* (2020) 'NanoSr – A New Carbonate Microanalytical Reference Material for In Situ Strontium Isotope Analysis', *Geostandards and Geoanalytical Research*, 44(1), pp. 69–83. doi: 10.1111/ggr.12296.
de Wet, A. J. M. J. (1977) 'Domestication of African Cereals', *African Economic History*, 3(3), pp. 15–32.
Womberbacherab, F. and Rehkämper, M. (2003) 'Investigation of the mass discrimination of multiple collector ICP-MS using neodymium isotopes and the generalised power law', *Journal of Analytical Atomic Spectrometry*, 18(11), pp. 1371–5. doi: 10.1039/B308403E.

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