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ALGAR DO BOM SANTO: A MIDDLE NEOLITHIC NECROPOLIS IN PORTUGUESE ESTREMADURA

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Abstract: A research project on the Algar do Bom Santo necropolis started in 2010. This paper presents a preliminary synthesis on the exhumed human population and a first insight into the funerary practices recorded during the site excavations in the 1990s, as well as palaeodiet reconstitutions.

Keywords: Neolithic, Bom Santo cave, mortuary practices, palaeodiets.

1. Introduction: the site and the research project

Algar do Bom Santo is a cave site located in the eastern slope of the Montejunto Mountain, facing the Tagus valley at 350m asl, *c.* 50km north of Lisbon (Figure 1). Discovered intact in 1993 by a team of spelunkers, this is a karstic complex with several galleries connected by irregular corridors, which form three distinct main levels. The two upper levels revealed a vast necropolis, subdivided into 11 distinct sectors totalling 285 m^2 (Figure 1).

Systematic survey and excavations took place in 1994, 1995, and 1997, in rooms A and B (Figure 1), under the direction of Cidália Duarte. A fourth field campaign had to be done in 2001 after the violation of the cave by treasure hunters. Its topographic survey was conducted in 1995 and 2001, and the whole area was subjected to a detailed photo and video recording of the surface. From this, a provisional minimum number of 121 individuals were estimated to be lying on the surface (Duarte 1997).

The good state of preservation at the time of discovery is due in part to the collapse of the entrance (or its deliberate closure). A few footprints of barefoot Neolithic individuals, found preserved in 2m^2 of sediments, is an eloquent testimony of this (Figure 1). Generally speaking, more or less complete skeletons were found throughout the cave—as well as numerous secondary depositions—allowing the reconstruction of funerary practices. This observation was immediately made by the archaeologists who first visited the cave (Zilhão and Araújo 1993). A very homogeneous material culture and the absence of thick, multi-stratified archaeological deposits points to a relatively short period of occupation: according to available radiocarbon dates it can presently be estimated at approximately 400 years (*c.* 3800–3400 calBC). In sum, the Bom Santo cave site constitutes one of the best preserved Middle Neolithic necropolises in Portugal.

Given the cave's scientific potential, a research project was submitted to the Portuguese Fundação para a Ciência e a Tecnologia entitled 'Bom Santo cave and the Neolithic societies of Portuguese Estremadura, 6th–4th millennia BC.' Its main effort focuses on the abundant material already excavated and stored at the Museu Nacional de Arqueologia (Lisbon). The research thus relies mostly on laboratorial analyses, ranging from bioanthropology and archaeology, to chemistry and genetics. Human osteological material from other Neolithic sites is also being sampled and analyzed in order to obtain a sound framework for comparisons. Considering the current state of preservation of the site, the philosophy underlying the project has a conservationist perspective and aims for the site's classification as an archaeological reserve for future research.

Observations made during the field work carried out at the site under the direction of C. Duarte remain almost unpublished. Duarte and Arnaud (1996) provided a first presentation of the site, describing its main funerary features and artefacts; Duarte (1998a) focused specifically on the radiocarbon dating of some human remains; and Carvalho (2007, 2009) wrote a preliminary presentation of the research project, followed by a technological and typological analysis of flint blades. The main topics of the project (outlined below) serve not only the study of the cave itself, but also to test current hypothesis and interpretative models concerning the Neolithic of Estremadura and neighbouring regions.

- Reconstruction of funerary practices. Survey and excavation of Bom Santo permitted to observe the diversified practices of formal disposal of the dead. Given the fact that the depositions are spatially distinct from each other, these compartmented places may be understood as mortuary spaces for individuals tied by kinship (households?) or, alternatively, for distinct Neolithic agro-pastoral communities settled in the surrounding territories (lineages?), if one considers the extension of the cave and the great number of individuals it contains. Clearly, both hypotheses need further research—for example, through aDNA tests—and have important consequences concerning our understanding of the social organization at the time. Some preliminary insights on the question will be presented below (see section 2.2).

- Absolute chronology. The phasing of the Neolithic in Estremadura is still blurred and the chronologies of some items of material culture or of specific mortuary practices are open questions. Systematic AMS dating of human bones from well-defined contexts in Bom Santo and from comparison sites is being carried out in order to overcome these difficulties.
- Subsistence economy. Neolithic subsistence strategies are not well known in Portugal, and give rise to disparate interpretations. This is due to the lack of contexts with organic preservation and/or adequate recovery methods. At Bom Santo, stable isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) of human remains provide some insights on the question.
- Detection of migration events. This is an important question presently under discussion, either during the neolithization process or at the transition to the Chalcolithic. For example, Gonçalves (1995) defends a model of coexistence of highly mobile Neolithic groups exploiting vast territories of Estremadura and Alentejo, a pattern

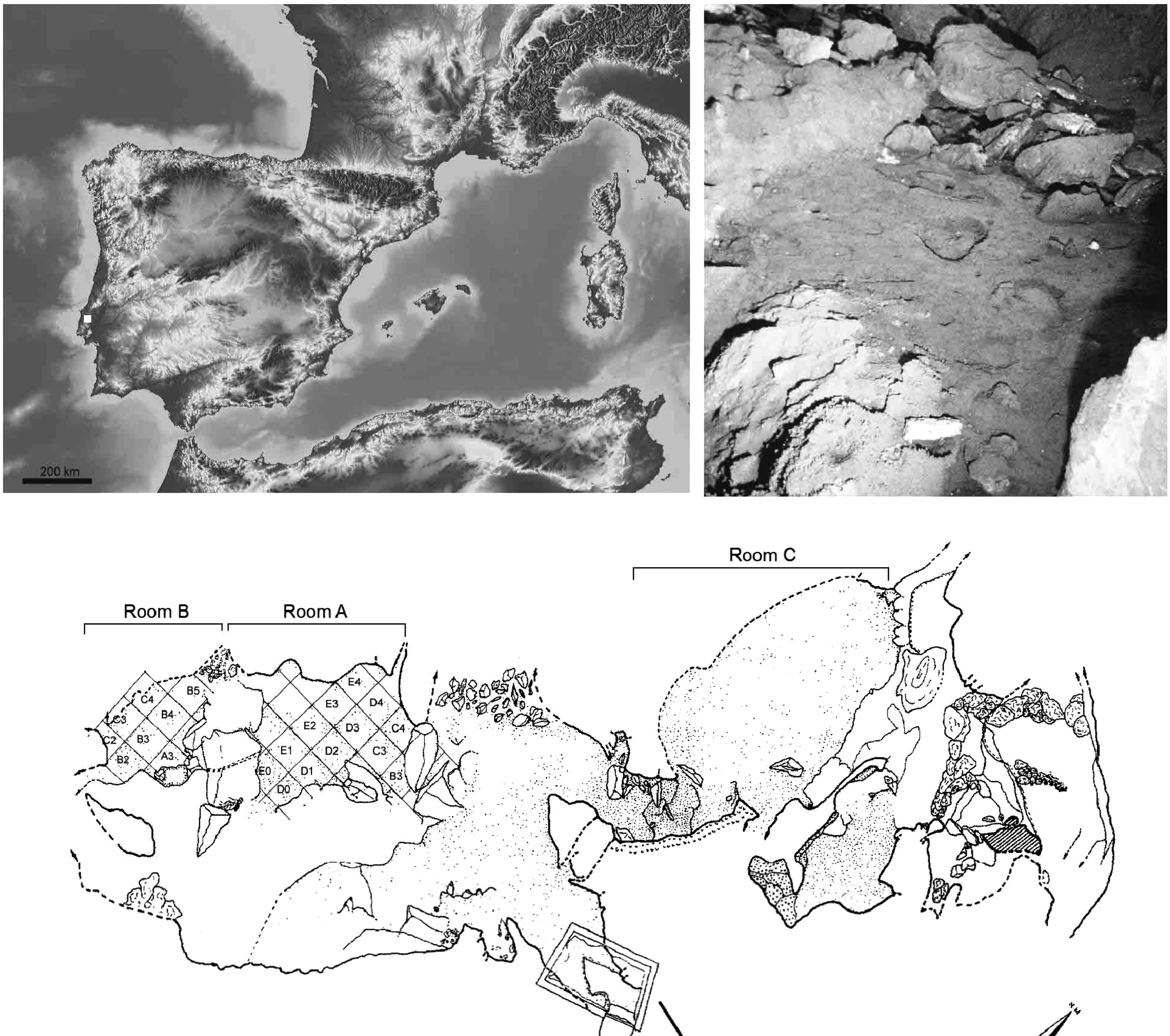

Figure 1. Location and general plan of the Bom Santo cave (map on upper left corner and topography on bottom), and photo of the area with Neolithic barefoot imprints (on the upper right corner; photo C. Duarte).

Room B	Skull	Trunk	Upper Limbs	Lower Limbs	Undetermined	Total
A4	4.00 (n = 2)	3.20 (n = 5)	1.60 (n = 10)	1.80 (n = 10)	4.00 (n = 3)	2.33 (n = 30)
B2	1.83 (n = 18)	3.65 (n = 26)	1.56 (n = 23)	1.58 (n = 26)	3.40 (n = 15)	2.36 (n = 108)
B3	2.02 (n = 160)	3.39 (n = 97)	1.69 (n = 117)	2.18 (n = 57)	3.90 (n = 60)	2.45 (n = 491)
B4	1.87 (n = 193)	2.68 (n = 123)	1.54 (n = 170)	1.78 (n = 146)	3.95 (n = 63)	2.10 (n = 695)
B5	2.67 (n = 193)	2.71 (n = 126)	1.68 (n = 132)	1.83 (n = 116)	3.94 (n = 66)	2.45 (n = 633)
C2	2.54 (n = 28)	3.92 (n = 74)	1.83 (n = 30)	1.53 (n = 55)	3.62 (n = 42)	2.81 (n = 229)
C3	1.88 (n = 197)	3.38 (n = 181)	1.73 (n = 281)	1.80 (n = 315)	3.80 (n = 116)	2.27 (n = 1090)
C4	2.35 (n = 52)	3.05 (n = 62)	2.00 (n = 53)	2.29 (n = 76)	4.00 (n = 22)	2.56 (n = 265)
D3	3.25 (n = 4)	1.00 (n = 1)	1.00 (n = 3)	2.00 (n = 3)	4.00 (n = 3)	2.50 (n = 14)
Total	2.15 (n = 847)	3.17 (n = 695)	2.00 (n = 820)	1.85 (n = 804)	3.84 (n = 390)	2.36 (n = 3557)

Figure 2. Mean preservation of each anatomical region according to the grid of Room B.

Bone	Room A	Room B	Total	Bone	Room A	Room B	Total
Skull	3.34 (n = 184)	3.49 (n = 282)	3.43 (n = 466)	Radius	2.46 (n = 13)	2.16 (n = 57)	2.21 (n = 70)
Mandible	3.42 (n = 38)	3.38 (n = 53)	3.40 (n = 91)	Ulna	2.50 (n = 10)	2.75 (n = 40)	2.70 (n = 50)
Teeth	1.51 (n = 636)	1.26 (n = 607)	1.39* (n = 1243)	Hand	1.59 (n = 150)	1.31 (n = 673)	1.36* (n = 823)
Vertebral Column	3.15 (n = 156)	2.98 (n = 488)	3.02 (n = 644)	Hipbone	3.73 (n = 26)	3.64 (n = 74)	3.66 (n = 100)
Ribs	3.42 (n = 192)	3.39 (n = 318)	3.40 (n = 510)	Femur	2.47 (n = 34)	2.59 (n = 90)	2.56 (n = 124)
Sternum	3.40 (n = 10)	3.44 (n = 25)	3.43 (n = 35)	Patella	1.31 (n = 26)	1.17 (n = 30)	1.23 (n = 56)
Scapula	3.83 (n = 18)	3.38 (n = 58)	3.49 (n = 76)	Tibia	3.09 (n = 35)	2.16 (n = 83)	2.43* (n = 118)
Clavicle	1.86 (n = 14)	2.82 N = 39)	2.57** (n = 53)	Fibula	2.71 (n = 17)	2.58 (n = 50)	2.61 (n = 67)
Humerus	3.08 (n = 25)	2.45 (n = 63)	2.70** (n = 63)	Foot	1.52 (n = 136)	1.38 (n = 604)	1.40 (n = 700)

Figure 3. Preservation of each bone category according to room (*p < .01; **p < .05)

Bone Preservation	A4	B2	B3	B4	B5	C1	C2	C3	C4	C5	D3	Total
Skull > 50%	0	1	4	7	16	0	6	8	0	0	0	42
Skull < 50%	2	3	38	35	97	0	9	31	14	0	3	232
Mandible > 50%	0	1	1	3	3	0	0	1	1	0	0	10
Mandible < 50%	0	1	6	13	5	0	4	9	5	0	0	43
Teeth > 50%	0	11	106	134	72	0	9	145	32	0	1	510
Teeth < 50%	0	1	5	2	0	0	0	3	0	0	0	11
Vert. Column > 50%	1	3	12	46	42	0	1	31	11	0	1	148
Vert. Column < 50%	0	10	34	39	33	0	40	98	27	0	0	281
Ribs > 50%	0	0	7	11	13	0	1	8	9	0	0	49
Ribs < 50%	3	13	40	24	34	0	29	42	12	0	0	197
Sternum > 50%	0	0	2	1	2	0	0	0	0	0	0	5
Sternum < 50%	1	0	2	1	2	0	3	2	3	0	0	14
Scapula > 50%	0	0	2	1	1	0	1	1	0	0	0	6
Scapula < 50%	0	0	7	7	12	0	3	14	2	0	0	45
Clavicle > 50%	0	0	2	4	2	0	0	1	1	0	0	10
Clavicle < 50%	0	0	2	5	3	0	1	8	2	0	0	21
Humerus > 50%	0	2	3	2	0	0	1	3	2	0	0	13
Humerus < 50%	0	0	2	4	5	0	0	4	4	0	0	19
Radius > 50%	0	1	8	9	6	0	3	8	4	0	0	39
Radius < 50%	1	2	0	2	2	0	2	7	1	0	0	17
Ulna > 50%	2	0	3	3	3	0	0	4	2	0	0	17
Ulna < 50%	0	0	1	3	3	0	0	9	7	0	0	23
Hand > 50%	7	16	81	126	90	1	15	204	26	1	3	570
Hand < 50%	0	2	7	4	5	0	3	18	2	0	0	41
Hip Bone > 50%	0	1	0	2	0	0	0	1	0	0	0	4
Hip Bone < 50%	0	5	3	12	12	0	1	14	10	0	0	57
Femur > 50%	0	0	2	6	5	0	1	6	3	0	0	23
Femur < 50%	0	0	2	10	6	0	1	12	9	0	0	40
Patella > 50%	0	0	4	3	4	0	0	7	2	0	0	20
Patella < 50%	1	0	0	0	0	0	0	0	0	0	0	1
Tibia > 50%	0	0	0	7	8	0	0	4	5	0	0	24
Tibia < 50%	0	0	5	3	7	0	0	8	8	0	0	31
Fibula > 50%	0	0	0	7	2	0	0	2	1	0	0	12
Fibula < 50%	2	0	4	7	3	0	2	8	2	0	0	28
Foot > 50%	7	20	30	85	68	0	45	220	33	0	2	510
Foot < 50%	0	0	7	4	1	0	6	33	3	0	1	55
Total > 50%	17	56	267	457	337	1	83	654	132	1	7	2012
Total < 50%	10	37	165	175	230	0	104	320	111	0	4	1156

Figure 4. Bone preservation according to the grid of Room B.

of mobility that would later coexist with the emergence of communities settled in fortified sites and dealing with copper metallurgy and the ‘secondary products revolution’. However, the question of the scale of mobility—or even its very existence—is still an open debate and needs further research. The distinction between ‘locals’ and ‘immigrants’ will be carried out through the detection of strontium and oxygen isotope signatures from archaeological human skeletons, and their comparison with regional geochemical features.

- Ancient DNA analysis. This approach is being applied to the Neolithic human population of Bom Santo,[1] and is expected to reveal its particular genetic composition. Therefore, clues about possible population affinities between the Bom Santo people and other Neolithic and pre-Neolithic populations of Iberia (Fernández *et al.* in print) can be expected. Sex determination and possibly the establishment of kinship relationships are foreseen, both being particularly important for the reconstitution of past social organization.

2. Neolithic population and funerary practices

2.1. Taphonomic analysis

The human remains from the Bom Santo are reasonably preserved apart for some post-mortem fractures.[2] Although some of these are recent and related to the archaeological intervention itself, many others are clearly ancient and were certainly the result of other events such as handling, trampling and crushing of the bones during the numerous visits to the cave for the deposition of new bodies. However, these were not the only post-depositional events leading to the alteration of the osteological remains. Some materials display calcified concretion strongly adhering to the bone itself which in a few cases prevented the analysis of their full surface. In addition, manganese oxide is present in the bones and some similar other stains were probably the result of fungi activity. Bone erosion was also found. Another bone change very common on the Bom Santo material was the result of the action of rodents and carnivores. This kind of feature was mostly observed on long bones. Beside fragmentation, this also caused probable displacement of the bones.

Room B was completely excavated and thus allowed for the assessment of differential bone preservation according to each unit (Figure 2). The results indicated that square B4 included the better preserved remains while the reverse scenario was found for squares C2 and C4. Interestingly, these two squares are adjacent to the C3 square which, as demonstrated further ahead, received the largest amount of body depositions. Therefore, it makes some sense that the laying down of the bodies promoted the fragmentation of the bones located in the contiguous areas due to stepping of the remains that were already in place. In contrast, the C3 square presented some of the better preserved skeletal elements, possibly because this area was somewhat spared from considerable stepping.

As for specific bones, some were clearly more prone to destruction than others (Figure 3). That was the case for the hip bone and for most bones of the cranium and the trunk (including the vertebral column). At the other end of the scope, bones from the hands and from the feet along with teeth presented very good preservation. This was probably related to the size of the bones given that the smallest of them were found more frequently intact than the larger ones. In addition, long bones were better preserved than flat bones possibly due to the better resilience of compact bone.

Noticeably, the preservation of some of the bone categories presented statistically significant differences according to the room of provenance. From these, only the clavicles were significantly better preserved in Room A than in Room B. In contrast, the reverse result was found for the teeth, the humeri, the hands and the tibias.

2.2. Bone dispersion and funerary practices: first insights

One main question that comes to mind whenever necropolises are under scope regards the organization of the funerary space according to specific depositional strategies. The original location of the primary depositions is difficult to assess in Bom Santo due to the intense re-use of the cave and the post-depositional disturbance—intentional or not—of the remains since Neolithic times.

It is particularly so because this necropolis primarily contains surface depositions which, although a few anatomical connections are still present (Figure 4), are mainly composed of isolated bones. In the case of collective assemblages like this one, intentional assemblages of specific bones may have taken place after skeletal disarticulation (Duday 2006) so a dispersion analysis may help to detect such practices.

Figure 5 gives the dispersion of each bone category according to the grid of Room B. Bones, bone fragments, teeth and teeth fragments with more than 50% of preservation were included in this figure. Those with less than 50% of preservation are also given in Figure 5. Clearly, most of the better preserved elements were found in squares B3, B4, B5, C3 and C4 while the southern and eastern parts of the room presented less human remains. In those westerner squares, the sedimentation was much more substantial and funerary structures composed of

[1] Chandler *et al.* (2005, table 1) analysed human ancient mtDNA from 10 Portuguese Mesolithic and Neolithic sites, including 49 samples from Bom Santo with a success recovery of 8%, but no other important data is provided (such as provenance and type of bone, detected haplogroups, etc.).

[2] Preservation was coded for each bone or bone fragment according to four distinct categories (1 = 76 to 100%; 2 = 51 to 75%; 3 = 26 to 50%; 4 = 0-25%) and thus investigated according to the provenance of the remains. The total collection of human remains from rooms A and B presented a mean preservation of 2.38 (sd = 1.34; n = 6030).

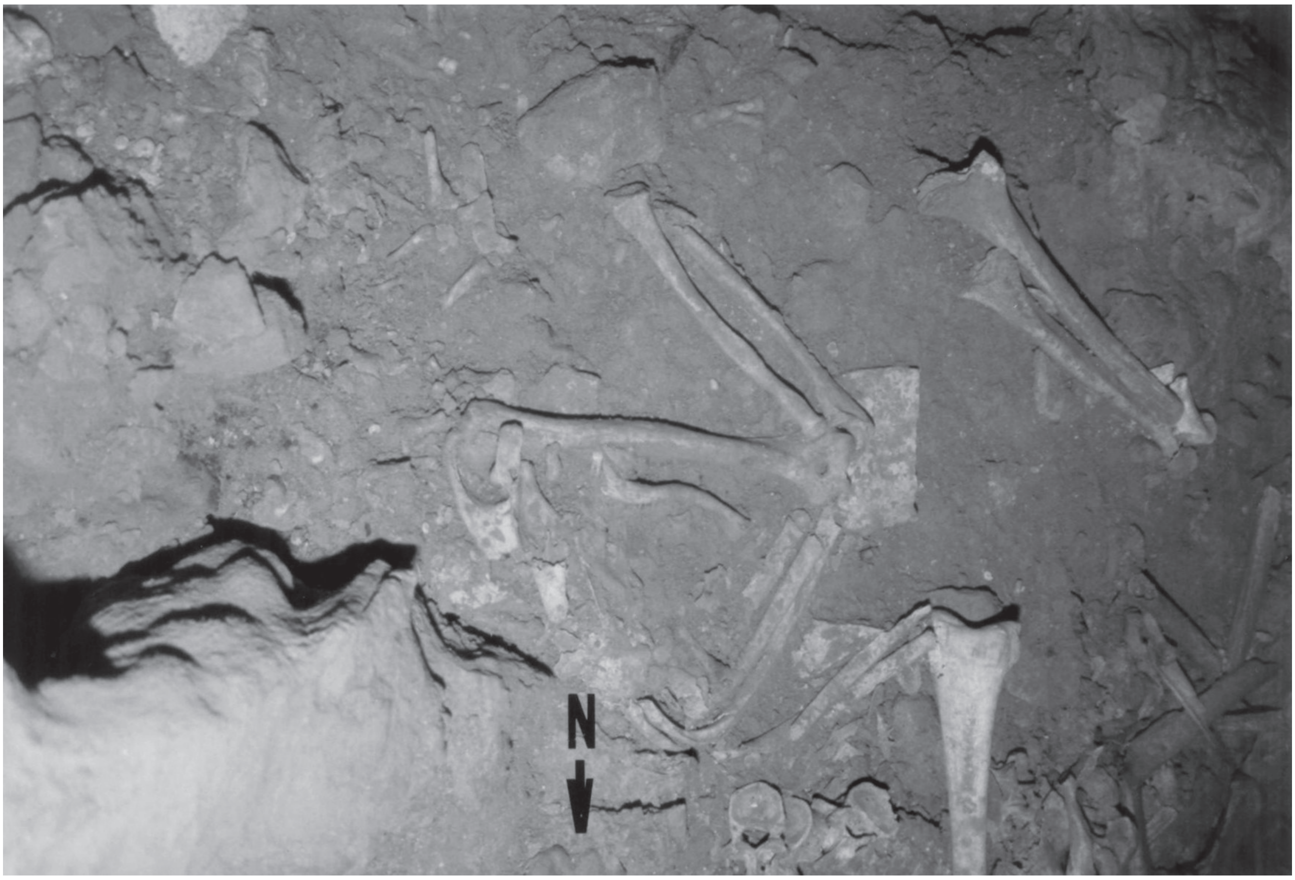

Figure 5. Upper limb in anatomical connection (Room B, unit B4) (photo C. Duarte).

stone-made platforms have been previously described (Duarte 1998b). Therefore, the north-western part of the room was mainly used for the deposition of the remains while the eastern part— including squares A3 and A4—may have been primarily used as a pathway allowing for movements within the room as previously suggested by Duarte (1994).

Most bone categories were present in all squares that displayed significant amount of human remains. The minor exceptions were the B2 square—in which several bones from the limbs were missing along with the sternum—and the C2 square—in which the ulna, the patella and the tibia were absent. Nonetheless, the deposition of the bodies within Room B was apparently carried out throughout its full surface apart from the already mentioned A3 and A4 squares. In fact, an examination of the dispersion of the distal phalanges of the hands and the feet demonstrates that these were found in all squares that presented considerable amount of human remains (Figure 6). Because these are labile articulations and are of small size, these elements tend to be excluded from secondary handling of mortuary remains (Duday 2006). Therefore, distal phalanges are quite reliable markers of primary depositions. We do not know how thorough was the post-depositional re-arrangement of the disarticulated remains—regardless of being intentional or not—but the distal phalanges would probably not be so widely dispersed throughout the room if the bodies had been deposited in a few selected locations. Of course, this inference disregards the potential dispersion caused by animal activity that we are presently unable to assess. Nonetheless, although body deposition occurred throughout the room, a large density of distal phalanges was present in B4 and C3 squares demonstrating that these locations—which also had some of the largest amounts of skeletal remains—were intensively used.

The deposition of the remains may not have been carried out randomly. Body deposition according to kinship or other social organization may hypothetically have taken place both during the primary surface deposition and the secondary practice involving the re- arrangement of bones after skeletal disarticulation (Duday 2006). In fact, assemblages of skulls have been found in rooms A and B. In the first case, six skulls were stacked together next to the southern wall, in squares E0, E1, D0 and D1. As for Room B, four skulls were also stacked together near the southern wall where two individualized skeletons—designated as individuals #01 and #02—were also found. The eventual assemblage of other skeletal elements was not detected.

Some handmade structures were detected within the cave thus supporting the idea that the remains were not deposited in a random fashion. For instance, two different bone assemblages were somewhat separated from each other by stones in Room C (Figure 7). Beside the already

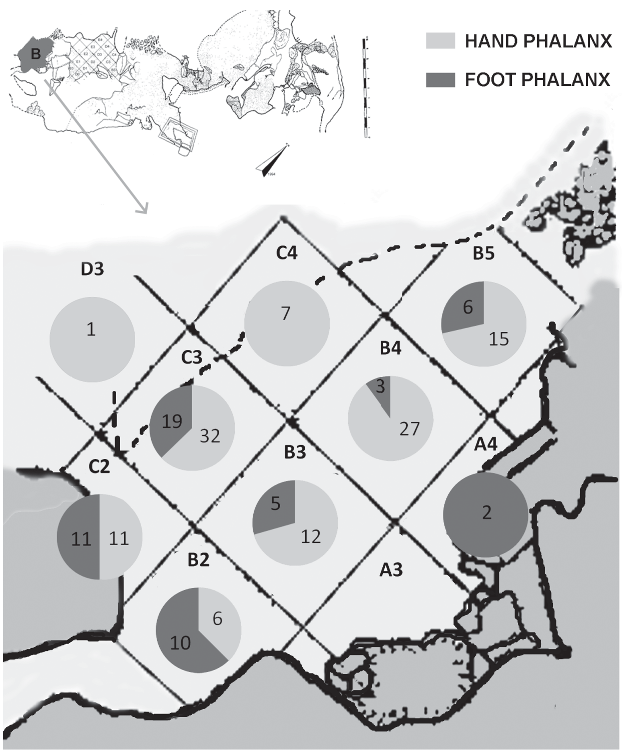

Figure 6. Frequency of distal hand and feet phalanges according to the grid of Room B.

mentioned stone-made platforms, semi-circular structures composed of stones were reported also for Room B which was used to delimitate some of the mortuary assemblages (Duarte 1998b). Apparently, some level of differentiation between skeletal remains was thus present in Room B. However, the explanation for such intentional behaviour is unknown for the time being.

2.3. The population profile

As mentioned above, the analysis of the human remains is currently in progress and therefore not all bones have been examined yet. As a result, the minimum number of individuals was not calculated from all bone categories and our present estimation is just a preliminary one. Nonetheless, most bones that usually allow for the highest estimations are here presented, with the noticeable exception of the dentition. Figure 8- A gives the minimum number of individuals for each bone. A minimum of 42 individuals were detected with certainty, but the method that was used[3] leads to an under-estimation of the actual amount because its accuracy depends heavily on the fragmentation of the bones and therefore on the number of available diagnostic features. A more accurate estimation is possible if the level of maturation of each bone, the adult-like appearance and the antimere analysis[4] are also taken into account because it may find age and size incompatibilities. These criteria contributed for the detection of 52 individuals, although it is possible that an over-estimation may have happened because the developmental maturation of each bone occurs at somewhat different ages (Figure 8-B). As a result, an adult-sized diaphysis with fragmented ends and its un-fused epiphyses may be wrongly counted as two different individuals using such a method. However, we used a conservative approach and tried to discard any dubious cases from the estimation.

Most of the skeletal categories allowed for similar estimations regarding the mature bones (min.: 26; max.: 34). The homogeneity of the remaining results suggests that none of the bones analysed in this study was the subject of systematic removal in this room with the aim of placing it elsewhere as a secondary practice**.** It is important to notice that, although only the better result from the left and right sides are presented in Figure 8-B, the estimation of the minimum number of individuals was quite similar regardless of the side of the bones that were being considered. However, one must bear in mind that the room was not completely excavated and that the unaccounted bones still present today in the cave may well change this current view. Assemblages for specific bones have been reported previously (Araújo and Lejeune 1995) and Jorge (2000) as well as Duday (2006) propose that some bones may have been recovered from the tombs and used as relics. Only the full recovery of the remains from the Algar do Bom Santo and especially the analysis of the representativeness of all bones and teeth may eventually bring more light into that issue.

As for the immature bones, more heterogeneous results were obtained from each bone category. The tibia (n = 14) was the only bone to provide for a somewhat similar estimation to the one obtained by using the femur (n = 18). As for the remaining bones, an unusually low number of individuals was pinpointed while using the skull, namely through the petrous pyramid which is a very sturdy bone and usually is well preserved. Again, the interpretation of this result stumbles on the incomplete recovery of the remains from the cave but at the light of the current data—and assuming that no differential preservation occurred between the skull and the post-cranial bones—one possible explanation may be that the immature skulls could have been deliberately removed from their original depositional location following skeletal disarticulation. Evidently, this is mere speculation for now.

The proportion of immature individuals on Bom Santo would be of about 35% of the 52 individuals. This is well inside the variation found for this kind of necropolises in Portuguese territory which ranges between 18% and 50% (Silva 2003).

The results obtained for the age profile of the individuals present in Bom Santo are still preliminary and only refer to two age groups: 11 adults and 16 juveniles, following

[3] Minimum number of individuals was estimated by looking for the repetition of bones or bone regions.
[4] E.g.: when a left humerus had no possible right counterpart, it was added as an additional individual to the minimum number of individuals obtained through the bones from the right side.

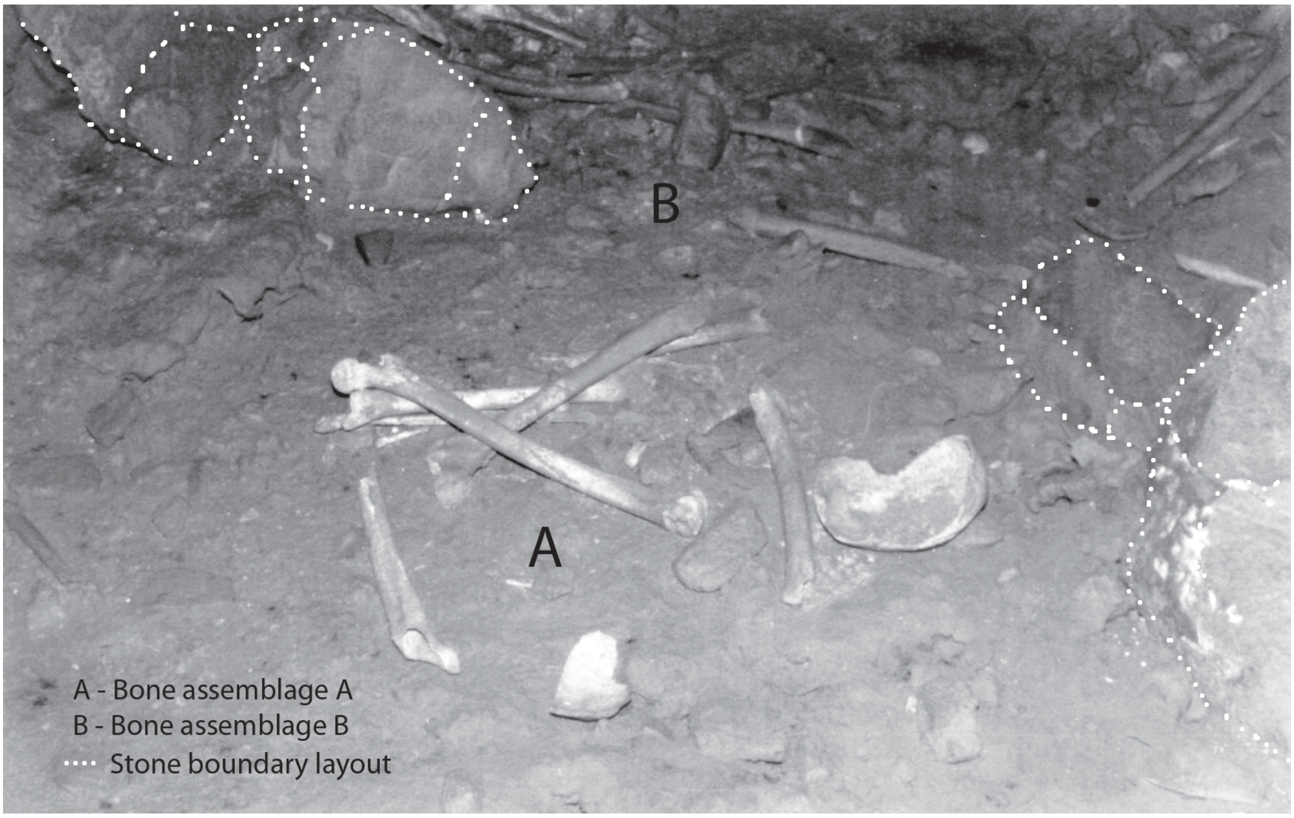

Figure 7. Two distinct assemblages of bone separated by a stone boundary in Room C (photo C. Duarte).

the definition by Scheuer and Black (2004). This profile is somewhat different from the one presented in figure 4 for the investigation regarding the minimum number of individuals because, rather than using the relative bone size as a criterion, only the developmental stage of epiphyseal union and the age-related changes of the pelvis were taken into consideration. This was done in order to reliably detect adults, although these methods are not straightforward because osteological age is not always consistent with chronological age and this is especially troublesome when dealing with anatomically disarticulated bones because we are not able to look at the skeleton as a whole. In addition, all epiphyses of the human skeleton are usually fused by the end of the third decade of life and the other indicators used beyond that age—such as those from the pelvis—are more difficult to use because increasing age potentially leads to greater differences within the diverse age indicators from a same skeleton. As mentioned above, the dentition has not yet been examined so the age profile will become more thorough by the end of the bioanthropological analysis.

The analysis of the distal end of the femur allowed for the broader detection of mature versus immature bones or bone fragments displaying that specific age diagnostic region (Figure 9). In this case, 15 elements were fully matured while this stage had not been attained on 16 elements. Of course, this is not the same to say that 15 adults were detected because the age of fusion for this epiphysis has been documented to start at the age of 16 years-old (Schaefer *et al.* 2009). The examination of the epiphysis of the calcaneus provided for the greater amount of matured bones (n = 21). Here again, the documented age of fusion is as low as 15 years-old (Schaefer *et al.* 2009) and therefore does not provide for an estimation of the minimum number of adult individuals because some of these may still be less than 18 or 21 years-old—depending on the definition of adult. For this assessment, the clavicle allowed for the confident detection of 11 fully adult individuals because its sternal end is completely fused at ages higher than 21 years-old (Schaefer *et al.* 2009). One of them was the previously mentioned individual #01 from Room B. The pelvic indicators were even less informative (6 adults older than 25 years).

One assumption that can be made from the age profile is that the cave was apparently the funeral chamber of all members of the population regardless of age cohort. The bones of juveniles and adults were found in rooms A and B. However, immature bones presented lower frequencies than mature ones. Although this may well be related with differential resilience to the preservation environment, it may also be indicative of the burial of juveniles in dwellings as seen in Costa do Pereiro (unpublished).

The re-construction of the sex profile of the Bom Santo population is a tricky matter due to the almost complete absence of undisturbed skeletons. One adult — individual #01— was a probable male and another adult —individual #02— was also classified as a male. The remaining skeletons could not be individualized so sexual determination had

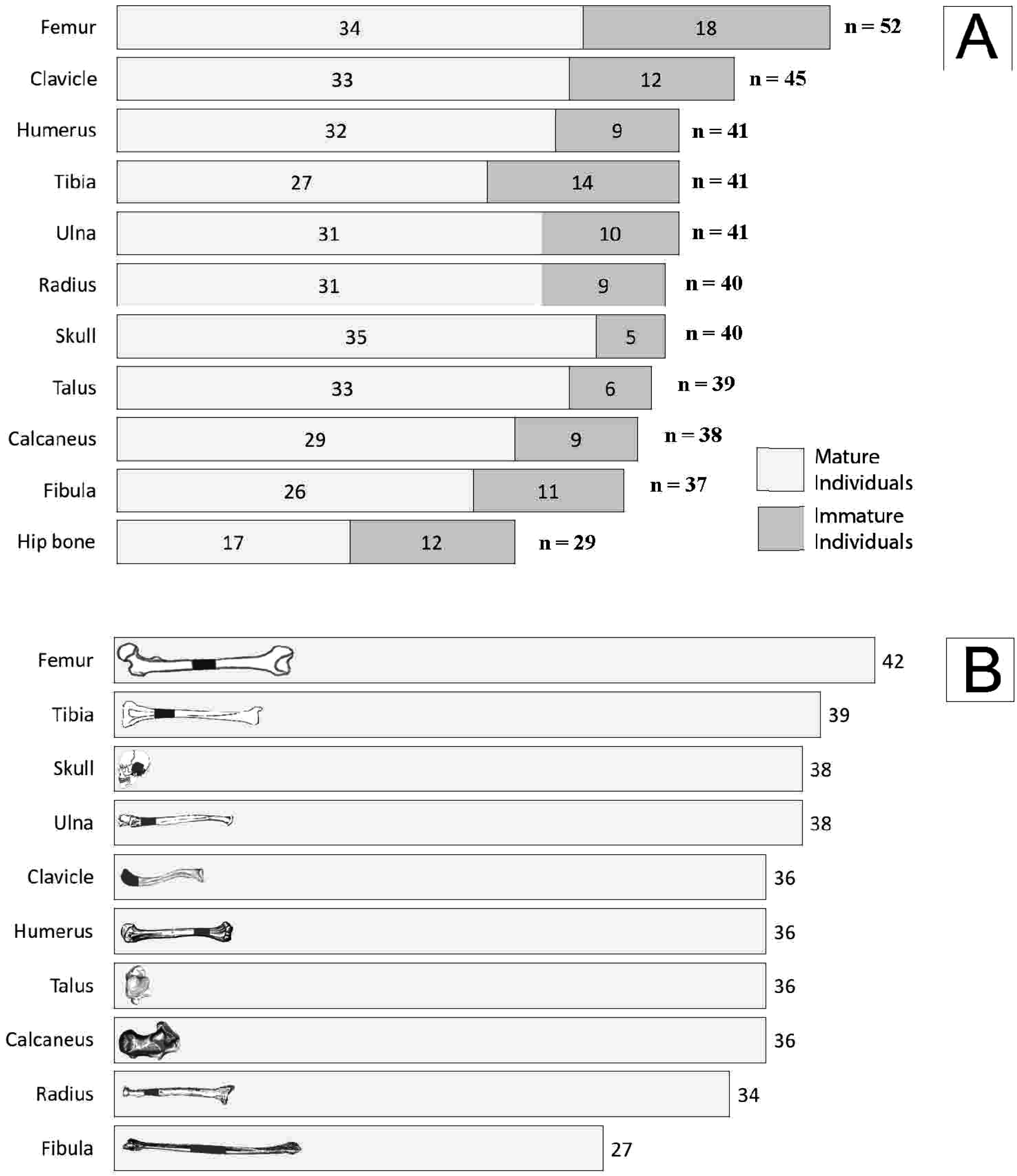

Figure 8. A: estimation of the minimum number of individuals using bone repetition; B: estimation of the minimum number of individuals according to each bone category using bone repetition, antimere analysis, developmental stage and bone size

to be carried out based on isolated bones rather than on systemic skeletal analyses. The mandible was the only cranial bone analysed until now and it allowed for the detection of 6 males and 3 females while the pelvis allowed for the detection of 5 females and 2 males. Very few sex determinations were carried out because both bones were often too fragmented and thus did not allow for the multivariate scoring of their sexually dimorphic traits. This led to a small number of sex determinations. We therefore resorted to univariate analysis based on standard measurements which allowed for a substantial larger amount of sex determinations although this procedure is not as reliable as the morpho-gnostic approach. Figure 10 gives the results regarding the sex determination based on several standard measurements. For all of these, a correct sex classification above 80% has been previously documented on collections of identified skeletons from which sex discriminating cut- off points have been calculated (Silva 1995, Wasterlain 2000). Because these are most probably unadjusted to the Neolithic population present in Bom Santo, all bone measurements within 1 mm of each standard cut-off point were classified

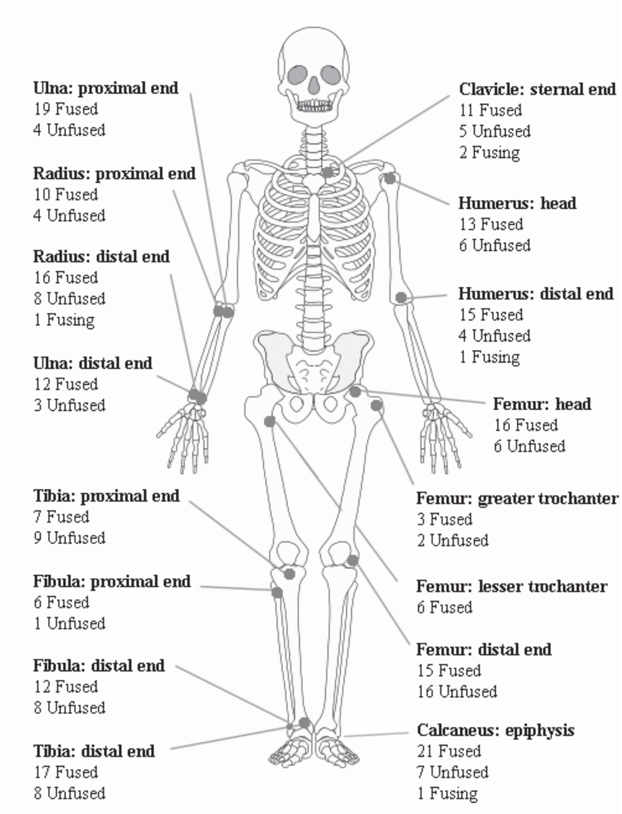

Figure 9. Summary of the frequency of observed bones according to each age marker.

as undetermined although its tendency was nevertheless recorded (M?; F?) . In general, this approach detected more females than males. This difference was especially obvious for the talus thus suggesting that its standard cut-off point may in fact be particularly unsuitable for the sex determination of the Bom Santo population.

This could either be the result of actual over- representation of females on the collection—assuming that the osteometric standards are indeed adequate—or be the result of the flawed application of the standardized cut-off points on a somewhat smaller population.

The largest amounts of males and females estimated through the osteometric data were of 11 and 18 respectively. For the reason above mentioned, the amount of males may have been under-estimated— assuming that the Bom Santo population is indeed physically smaller than the one from which our osteometric standards were developed from—and the female estimation is probably inflated. A more reliable sex profile will certainly be attained after the collection of supplementary data during this ongoing research.

3. Radiocarbon dating and stable isotopic analysis

3.1 Sample preparation

All samples were prepared at the Waikato AMS radiocarbon facility following bone ultrafiltration methodologies outlined in Bronk-Ramsey *et al.* (2004) and Petchey *et al.* (2011). All ultrafiltered gelatin was assessed for purity prior to analysis using standard % gelatin yield, %N, %C and C:N quality assurance parameters.

Most well preserved archaeological bone protein ranges between 11 and 16% N, with an average 35% C and a C:N ratio range of 3.1-3.5 (Ambrose and Norr 1993, Van Klinken 1999). Values that fall outside this C:N range should be evaluated further. The amount of extractable

		Left				Right			
Standard Measurement	C.C.%	M	F	M?	F?	M	F	M?	F?
1. Humerus head vertical diameter	90.00	1	3	0	0	2	3	1	1
2. Humerus head transverse diameter	90.20	0	1	0	0	2	2	0	0
3. Humerus min. circumference	84.45	3	2	0	1	1	2	0	0
4. Humerus epicondylar breadth	90.50	5	9	0	0	3	6	1	1
5. Radius maximum length	84.95	2	3	0	0	2	1	0	0
6. Radius physiological length	83.40	3	3	0	0	4	1	0	0
7. Radius min. Circumference	83.90	4	13	3	0	8	7	2	3
8. Radius discriminant function 1 (5+6+7)	90.50	2	3	-	-	0	2	-	-
9. Femur head vertical diameter	86.00	0	6	0	0	0	3	0	0
10. Femur head transverse diameter	85.00	1	3	2	0	0	3	0	0
11. Tibia natural length	80.00	2	1	0	0	2	3	0	0
12. Tibia sagital diameter (nutr. foramen)	85.00	11	8	5	1	7	2	3	2
13. Tibia min. Circumference	81.00	11	5	0	4	3	7	1	1
17. Tibia discriminant function 4 (12+13)	87.50	8	6	-	-	4	4	-	-
18. Calcaneus maximum length	81.00	5	9	1	1	5	7	0	0
19. Talus maximum length	84.00	2	18	2	3	2	17	2	2

Figure 10. Sex profile based on the osteometric dimensions of the Bom Santo population. C.C.% refers to the published correct sex classification (Silva 1995; Wasterlain 2000)

protein (% gelatin yield) was also used as a guide to the reliability of the results. The radiocarbon dates have been calibrated with the terrestrial calibration curve Intcal09 (Reimer *et al.* 2009) by the programme OxCal v4.1.7 with curve resolution set at 5 (Bronk-Ramsey 2010).

3.2. Results

Radiocarbon, $\delta^{13}C$ and $\delta^{15}N$ values are given in Figure 11. The $\delta^{13}C$ and $\delta^{15}N$ values for the Bom Santo burials are typical of humans that consume terrestrial (C_3) protein, that is, $\delta^{13}C$ = -20±2‰; $\delta^{15}N$ = 5 to 12‰ (Richards and Hedges 1999; Richards and Trinkaus 2009). Variation within the Bom Santo population is small (Waikato data range: $\delta^{13}C$ = 19.2±1‰ /$\delta^{15}N$ = 10.2±1.7‰). This is in keeping with the presumed agro-pastoral economy that may characterize the Middle Neolithic in Portuguese Estremadura, but the sampled population is not large enough for any statistically meaningful assessment of variation based on sex, age or status.

The results for the six previously analyzed samples are also given in Figure 11 (Duarte 1998). These were pre- treated and measured by Oxford Radiocarbon Accelerator Unit (UK), Beta-Analytic (US) and the *Instituto Tecnológico e Nuclear* (Portugal). The OxA samples were gelatinised and then underwent ion exchange purification (pers. comm. F. Brock, Sept. 2011). The samples from Beta were dated on the gelatinous fraction following multiple alkali extractions to remove humic acids (pers. comm. R. Hatfield, Sept. 2011). Similarly, ICEN-1181 was pre-treated to crude gelatin (Soares and Dias 2006).

The success of any bone isotope value is largely dependent on the preservation state (degree of contamination and degradation) and the pre-treatment used to purify and isolate the bone protein. Although gelatinisation can be adequate, ultrafiltration, and ion exchange purification techniques are considered to be more reliable (Van Klinken *et al.* 1994). In all cases, however, the reliability of the bone date must be assessed on the basis of the quality of the fraction dated. The Waikato ultrafiltered gelatin procedure was successful at obtaining isotope data within quality assurance ranges specified above (Figure 11), though three samples (Wk-27983 [#02], Wk-27989 [#08] and Wk-27990 [#09]) fell below the 1% gelatin yield considered to be indicative of well-preserved bones (Brock *et al.* 2007). Unfortunately, similar information is lacking for the Beta, OxA and ICEN results. Observations made when ICEN-1181 was pretreated suggested that the bone protein was highly degraded (pers comm. A.M. Soares, Sept. 2011), and the results should therefore be evaluated with this in mind (similarly, Beta-120047 and Beta-120048) given the likelihood of high level of contamination relative to in situ bone protein.

Small differences in $\delta^{13}C$ for burial #02 between duplicates run at Oxford and Waikato (Figure 11) are possibly symptomatic of the poor preservation state of these bones. The ion exchange and ultrafiltration techniques are generally considered to be the most reliable for ^{14}C work (though see Van Klinken and Hedges 1995). Differences in well-preserved bone $\delta^{13}C$ values between pre-treatment methodologies are often small (Jørkov *et al.* 2007, recorded differences of less than 0.3‰). For poorly preserved bones these differences may be exaggerated and are typically thought to be indicative of remaining contamination in the sample or loss of collagen amino acids (Toross *et al.* 1988). Attempts to reassess the ion exchange gelatin results by Oxford were unsuccessful (pers. comm. F. Brock, Oct. 2011) and confirm the degraded nature of the mentioned sample.

4. Conclusions

Although the current data provided some insights regarding the Algar do Bom Santo necropolis, the research is still ongoing and the information presented here is still preliminary. This is particularly the case of the reconstruction of funerary practices (see section 2.2). Observations such as the finding of partially connected skeletons, arrangement of skulls, or the presence of human made stone structures, all points to a non randomly deposition of the human remains. However, these and other possible manifestations of ritual or funerary practices—use of red ochre, burnt bones (cremations?), associated grave goods—have not been comprehensively analysed yet.

The artefactual assemblage has not yet been fully analysed, and its possible association to specific individuals will be tentatively approached in the near future. Grave goods include polished stone axes and adzes, bone perforators, bracelets made of shell of *Glycymeris glycymeris*, beads made of schist and shell, and flint blades and trapezes. Interestingly, pottery is very scarce; only a few fragments and two intact pots were exhumed. Considering the general homogeneity and simplicity of the material culture, significant differences of status among individuals are not explicit, a fact that seems a priori to reflect an essentially egalitarian community. However, the hypothesis—to be tested in the future—of Bom Santo being a common burial ground of distinct communities seems interesting given this absence of differences in the material culture, which in turn may reflect some higher level of general political integration.

Available radiocarbon dates point to *c.* 3800-3400 calBC as the time period during which the cave was in use; that is, the Middle Neolithic. Evidence on subsistence strategies during this period in southern Portugal is almost nonexistent, and doubts have therefore been raised on the importance of domestic resources in the overall economic structure of these Neolithic communities. Following a traditional view inherited from the Leisners' work on the megalithism of the Alentejo region (Leisner and Leisner 1951), many Portuguese scholars still claim that their economic basis would have been the husbandry of sheep and goat, along with the harvesting of wild resources (both vegetal and aquatic). Isotopic analysis on the Bom Santo population points to a terrestrial- based subsistence,

Individuals	Sex	Age	Provenance	^{14}C Lab number ([1])	Sample	Gelatin yield (%)	Bone isotopes					CRA (BP)	Cal range (BC)
							δ15N (‰)	%N	δ13C ([2]) (‰)	%C	C:N		
unknown	?	?	A / surface	ICEN-1181	femur	—	—	—	-21.80 ([3])	—	—	4030 ± 280	minimum age
unknown	?	?	B / B3	Beta-120047	sternum	—	—	—	-20.70	—	—	4430 ± 50	minimum age
unknown	?	?	C / surface	Beta-120048	temporal	—	—	—	-19.60	—	—	4780 ± 50	minimum age
#01	?	adult	B / B2,B3,C2	Wk-27991	premolar	4.05	8.6	15.66	-19.7	44.20	3.3	4671 ± 30	3520–3370 (1 σ) 3625–3365 (2 σ)
				OxA-5511	femur	—	—	—	-19.60	—	—	4705 ± 65	3630–3375 (1 σ) 3635–3365 (2 σ)
#02	M	adult	B / [6]	Wk-27983	metatarsus	0.57	9.12	15.75	-18.28	44.55	3.3	—	—
				OxA-5512	femur	—	—	—	-19.60	—	—	4630 ± 60	3520–3350 (1 σ) 3635–3110 (2 σ)
#03	F?	adult	B / C3	Wk-27984	premolar	1.06	11.0	16.58	-19.1	45.84	3.2	4949 ± 32	3770–3665 (1 σ) 3790–3655 (2 σ)
#04	M	adult	B / B4	Wk-27985	molar	1.33	11.5	15.68	-18.9	43.76	3.3	4887 ± 30	3695–3645 (1 σ) 3715–3635 (2 σ)
#05	M	adult	B / B5	Wk-27986	molar	1.43	10.1	15.64	-19.0	42.51	3.2	4929 ± 30	3715–3655 (1 σ) 3775–3650 (2 σ)
#06	I	adult	B / B5	Wk-27987	incisive	2.41	9.7	16.03	-19.5	42.63	3.1	4744 ± 30	3635–3515 (1 σ) 3640–3380 (2 σ)
#07	M	adult	B / C3	Wk-27988	premolar	1.14	10.8	15.28	-19.6	44.05	3.4	4960 ± 31	3775–3700 (1 σ) 3800–3655 (2 σ)
#08	I	juvenile	B / B4	Wk-27989	molar	0.32	10.3	15.41	-19.5	43.59	3.3	4732 ± 31	3635–3380 (1 σ) 3635–3375 (2 σ)
#09	I	juvenile	B / C2	Wk-27990	premolar	0.77	9.6	15.63	-19.2	42.25	3.2	4769 ± 30	3635–3525 (1 σ) 3645–3380 (2 σ)
#10	M	adult	B / B2	Wk-27992	incisive	2.83	8.5	15.71	-19.0	44.42	3.3	4810 ± 35	3645–3530 (1 σ) 3660–3520 (2 σ)
#11	I	adult	A / D4	Wk-27993	mandible	1.19	10.47	15.82	-20.16	44.58	3.3	4745 ± 30	3635–3515 (1 σ) 3640–3380 (2 σ)
#12	F?	adult	B / B5	Wk-27994	premolar	1.96	10.12	15.83	-18.69	44.19	3.3	4756 ± 30	3635–3520 (1 σ) 3640–3380 (2 σ)
#13	F	adult	A / B4	Wk-27995	incisive	1.77	10.6	15.71	-19.6	42.90	3.2	4739 ± 35	3635–3385 (1 σ) 3640–3375 (2 σ)
#14	I	adult	B / B3	Wk-27996	molar	1.55	11.81	15.91	-18.18	45.10	3.3	4993 ± 30	3795–3710 (1 σ) 3940–3695 (2 σ)
"hunter"	M?	adult	surface	Wk-25161	rib	1.21	10.22	15.8	-19.19	42.9	3.17	4960 ± 30	3775–3700 (1 σ) 3795–3655 (2 σ)

[1] All determinations by AMS, except ICEN-1181.
[2] Isotopes measured on protein fraction (crude gelatin, ion exchange gelatin or ultrafiltered gelatin). $\delta^{13}C$ values were measured relative to the VPDB standard and have errors of ± 0.2‰ (Beta and Wk) and ~ ± 0.5-1.0‰ (OxA). $\delta^{15}N$ values were measured relative to the AIR standard and have errors of ± 0.2‰ (Wk).
[3] $\delta^{13}C$ values for ICEN were measured on CO_2 generated during preparation of benzene (pers. comm. A.M. Soares, Sept. 2011). This value is used to correct for vacuum line fractionation and should not be used for dietary reconstruction.

Figure 11. Bom Santo: radiocarbon and palaeodietary values.

confirming previous results on the subject (Lubell *et al.* 1994). However, more work is needed in order to define whether these terrestrial resources were mostly wild or domestic, a crucial aspect with consequences at higher levels of inference.

Concerning bioanthropology, future work will focus on the osteological and odontological materials that have not yet been analysed. This will provide for new and more complete data regarding the topics discussed here, also allowing us to tackle other issues such as the morphology and paleopathology of the Bom Santo population. This is especially important because there are few Middle Neolithic sites with sound stratigraphic and contextual records enclosing such a large amount of relatively well preserved individuals. In addition, the complete analysis of the materials from Bom Santo will allow for the better understanding of the funerary behaviour and practices of this community. However, one must bear in mind that these human remains are only a fraction of the complete assemblage present in the cave. Therefore, its representativeness is not guaranteed.

Final remark and acknowledgements

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