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NEW EVIDENCE FOR THE PRESENCE OF ENDEMIC ELEPHANTS FROM THE LATE PLEISTOCENE OF ALGHERO (NORTWESTERN SARDINIA, ITALY).

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ABSTRACT: This short note aims to give notice of the vestige (the external imprint and few minute fragments) of the distal portion of an elephant tusk found in a sandstone deposit exposed at a small sheltered bay, Las Tronas bay, located at the north side of the El Tro' Carlos V bay (Alghero, NW Sardinia). The coarse sandstone and the overlain aeolian sediments deposited during the end of MIS 5, confirming the presence of elephant populations in the Alghero area at least since 100 ka BP (MIS 5c). Although the Schreger lines are not detectable in the dentine fragments, the dimensions and the curvature of the external imprint enable us to hypothesize that the tusk could belong to the dwarf mammoth, *Mammuthus lamarmorai,* already recorded in Late Pleistocene deposits of the same area (Tramariglio and the coast south of Alghero).

Keywords: *Mammuthus*, tusk imprint, insularity, MIS 5c.

1. INTRODUCTION

The Quaternary deposits exposed along the rocky cliff bounding the Alghero coast and its bays (NW Sardinia), are well known in the palaeontological literature due to the richness of vertebrate remains preserved in aeolian deposits, bone breccias mainly filling tectonic fissures of the Triassic carbonate cliff, and fossiliferous layers of grottos and caves, such as those opening in the high cliff of Capo Caccia Promontory (e.g. Malatesta, 1954, 1977; Malatesta & Settepassi, 1954; Comaschi Caria, 1956, 1968; Gliozzi, 1985; Palombo & Ibba, 2008; Palombo et al., 2017a, b and references therein). The best-preserved Pleistocene sediments extend quasi -continuously more than 5 km along the coast south of the Alghero town.

The Quaternary deposits of Alghero area have been widely studied and Luminescence (quarz Optically Stimulated Luminescence, OSL, and K-feldspar pIRIR290) chronologically constrained. The sedimentary successions mainly consist of shallow-marine to coastal aeolian and alluvial sediments deposited during major climatic changes and sea-level variations related to alternating latest Middle and Late Pleistocene stadial/glacial and interstadial/interglacial cycles, from MIS 6 to MIS 3 (150 to 40 ka) (Andreucci et al., 2010; Pascucci et al., 2014). The geological and stratigraphical researches developed in the last decade permitted a detailed reconstruction of the palaeoenvironmental evolution of the area during the Late Pleistocene (Andreucci et al., 2010, 2011, 2017; Sechi et al., 2013, 2020; Pascucci et al., 2014; Casini et al., 2020).

This note aims to give notice of a distal large fragment of an elephant tusk recently noticed in a deposit exposed at a small sheltered bay (Las Tronas bay hereinafter), located at the north side of the main El Tro' Carlos V bay, both not far from the centre of the Alghero town, cliff-bounded by Triassic limestones and Late Pleistocene sandstones (Fig. 1).

2. THE TUSK IMPRINT AND ITS STRATIGRAPHICAL CONTEXT

The imprint of a fragment 48 cm-long of an elephant tusk was discovered in the natural section of a sandstone layer, cropping for about 20 cm above the present sea level, close to the shore and the high tide line (Fig. 2 A.2, B). Along the shoreline some scattered outcrops are preserved, locally capped by an aeolian deposit. Two incomplete antlers of deer (likely *Praemegaceros cazioti*) have been detected nearly at the top of such aeolian layers (Fig. 2 A.1).

The presence of the tusk imprint, already noted by some people but regarded as unimportant, was recognized in February 2020 by one of us (MZ), who immediately informed the local Archaeological Superintendence of Sardinia.

The elephant and deer fossil remains (tusk and antlers) are still in place because the emergence status created by the Covid-19 pandemic disease prevents the recovering activity scheduled by a team of the Superintendence. An exhaustive description of the deer antlers

Fig. 1 - The Alghero area (Sardinia, Italy) in the Mediterranean Sea with the location of the localities mentioned in text. 1, Las Tronas bay; 2, El Trò bay. Bar scale 200 m.

in the frame of the fossil record of Sardinian deer and some notes on the palaeogeographical and palaeoenvironmental evolution of the Alghero area will be provided elsewhere (Palombo et al., in prep).

2.1. The stratigraphical context

Quaternary shallow-marine to coastal sediments, aeolian and alluvial deposits are discontinuously present along the coast north of Alghero, locally preserved and well exposed along the coast south of Alghero, and some are exposed in the embayments of the town coast. Along the southern Alghero coast, the oldest Pleistocene deposits, high angle planar cross-bedded coastal dunes, are Luminescence dated at about 275 ka (MIS 8), while a couple of discontinuous conglomerate deposits, marking the transition from MIS 7 to MIS 6, outcrops in the northern Le Bombarde beach (Casini et al., 2020).

The tusk imprint is embedded in one of the Quaternary deposits exposed here and there in the small to wide bays located along the city coast, which mainly date to the Late Pleistocene (MIS 5-MIS 3) and are locally caped by Holocene deposits (e.g. Sechi et al., 2013; Pascucci et al., 2014). The small outcropping to which the fossiliferous sandstone layer belongs is exposed in the northernmost part of Las Tronas bay, nearly to the shore (Figs. 1-2.) The fossiliferous layer consists of about 40 cm of medium to coarse well-sorted planar low angle cross-stratified sandstone (Fig. 3). On the beach, the surface of the sandstone layer is sub-

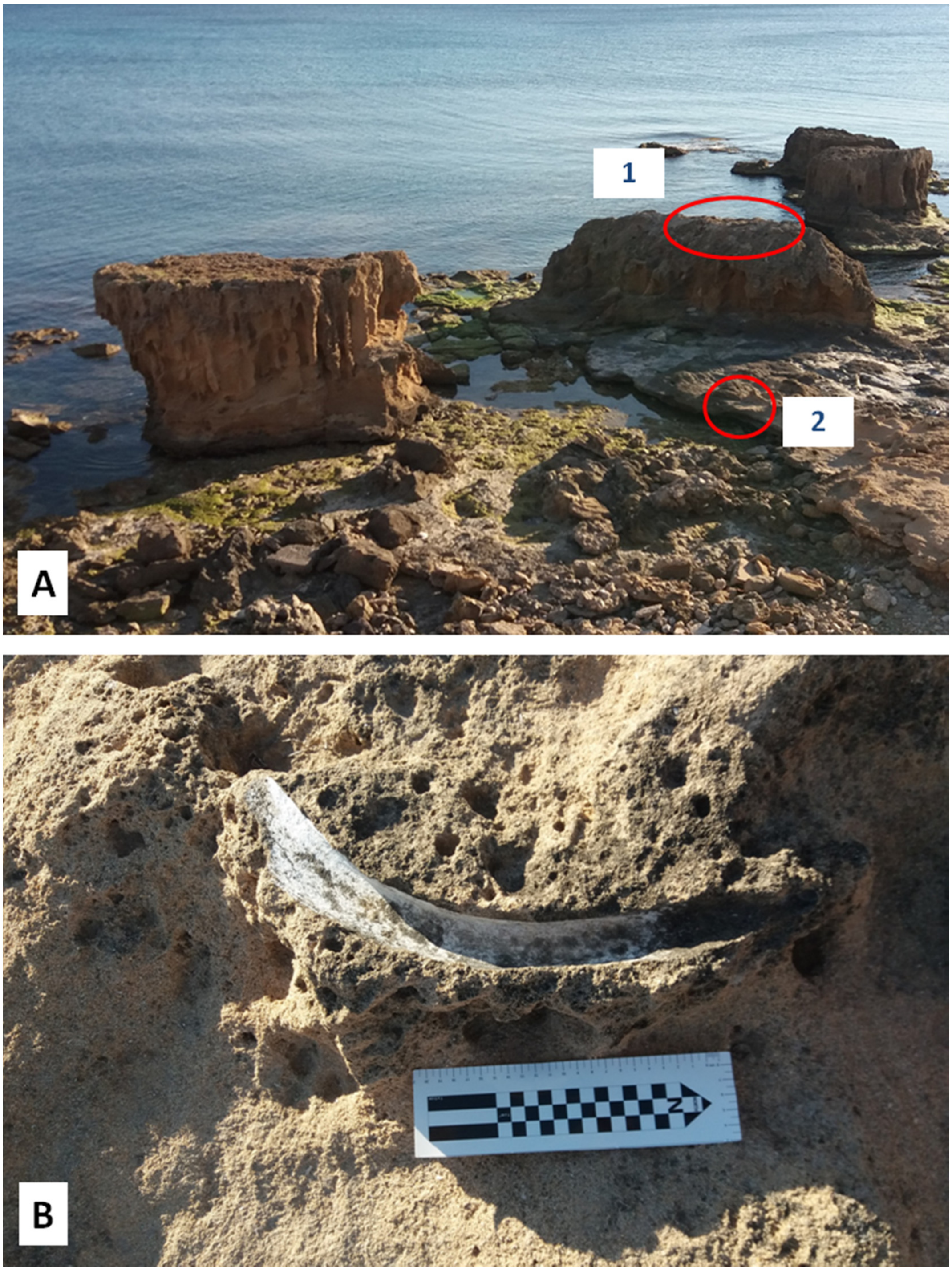

Fig. 2 - A: panoramic view of the fossiliferous layers exposed at Las Tronas bay; the red circles indicate the location of the deer antlers (1) and the tusk imprint (2). B: the imprint of the distal part of the elephant tusk.

planar, highly eroded by the wave action. It constitutes the bottom of some scattered outcrops preserved along the shoreline, mainly represented by medium to coarse sandy sediments, passing to 3.5 m-thick medium to coarse grained, high angle cross stratified and well-cemented sandstone deposits that have been interpreted as beach backshore passing to well developed coastal dunes (Figs. 2, 3).

The environmental context of this small bay sector corresponds to an incipient relict pocket beach characterized by a fairly sandy-gravelly foreshore, passing to a well-developed sandy backshore and coastal dune sys-

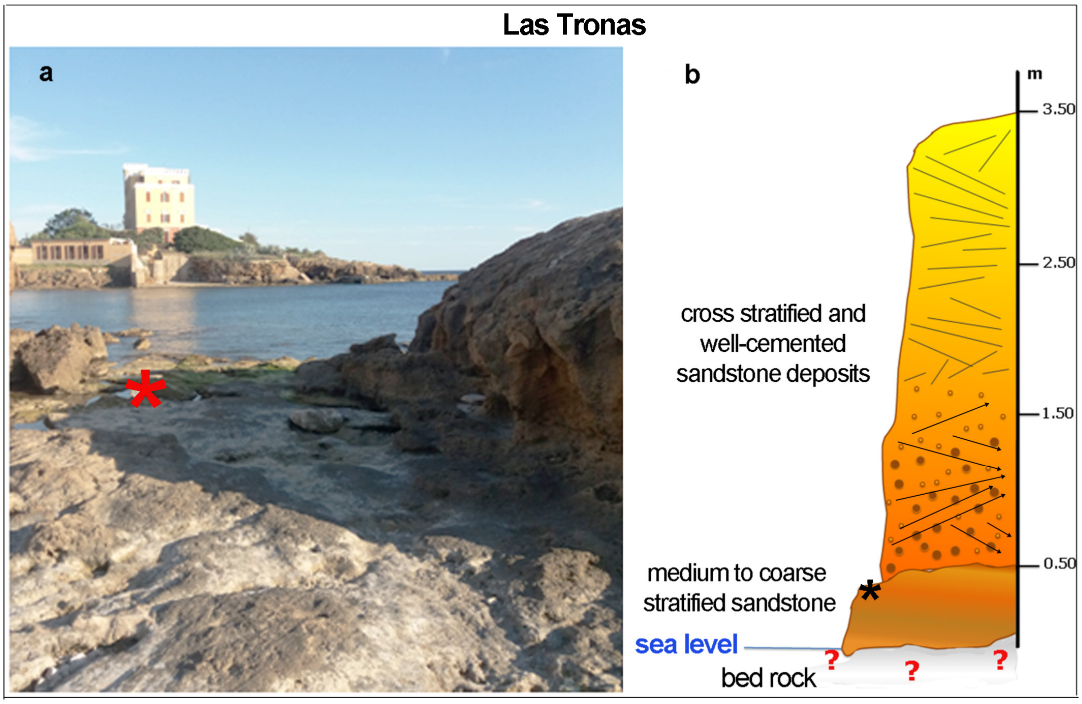

Fig. 3 - The deposits correlated with MIS 5c exposed at Las Tronas, the asterisks indicates the location of the tusk imprint: a) panoramic view of the northern sector of the Las Tronas bay, b) stratigraphic sketch of the deposits.

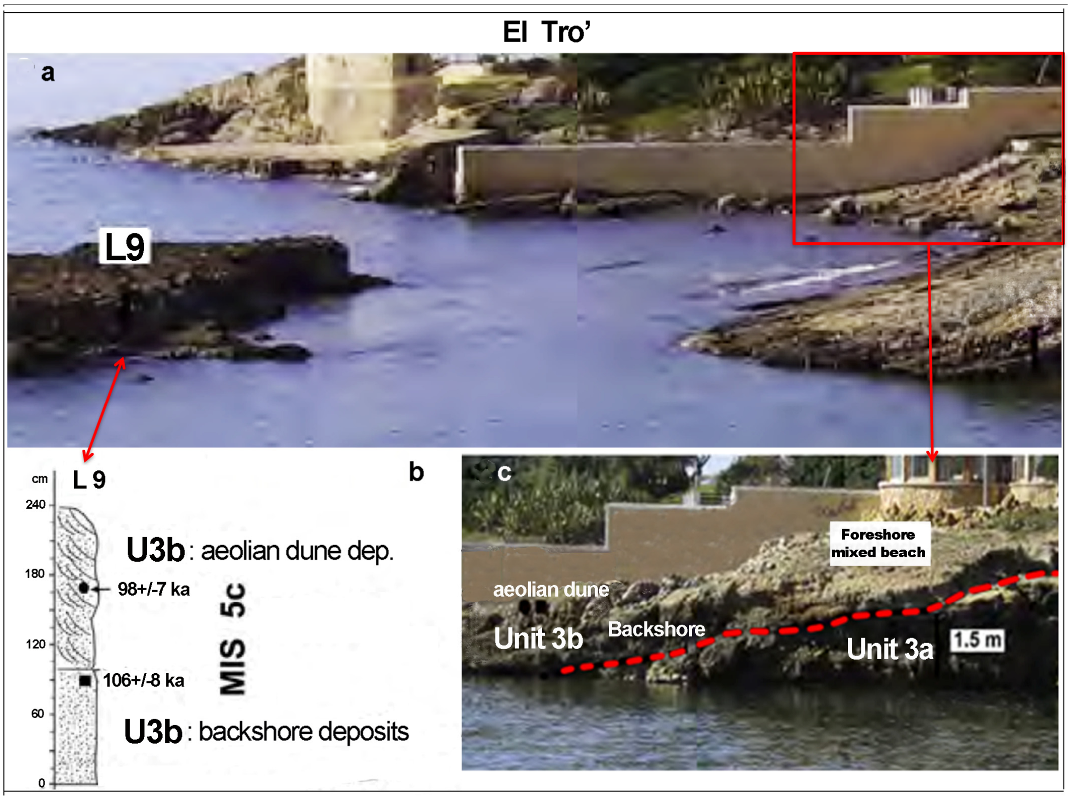

Fig. 4 - The deposits correlated with MIS 5c exposed at El Tro' bay: a) panoramic view. L9 indicates the location of the log b; b) log showing the deposits dated to MIS 5c; c) Outcrop details of Unit 3b exposed in the northern sector of El Tro' bay (modified from Pascucci et al., 2014, fig. 8).

tem. In the southern part of the bay, at the bottom of the exposed sections, clast supported conglomerates prevail. Locally some sandy low angled stratified layers and fragments of shells could be present. A clast-supported conglomerate with a medium to fine-grained sandy siltstone matrix unconformably overlies these layers.

Las Tronas fossiliferous deposit has a small extension so that it is possible inferring its depositional context and fine chronology only by considering it in the wider context of the stratigraphic sections present in the adjacent areas.

Along the town coast, sandstone deposits are generally not well preserved because of the intense extractive activity and the number of quarries opened in the area since the Roman time.

The sections exposed at the El Tro' bay (Figs. 1, 4) are among the best preserved and studied.

The El Tro' Quaternary stratigraphic succession manly consists of sandy and/or conglomeratic layers, unconformably overlying the Triassic carbonate bedrock. The succession has been subdivided in three unconformity bounded units: U3a, U3b and U4 (Sechi et al., 2013, 2018 2020; Pascucci et al., 2014).

According to Sechi et al. (2013, 2020), in the southern part of the bay, U3a consists of scattered deposits of fossil-rich clast-supported conglomerates, regarded as the submerged part of a small shallow gravelly pocket beach, and OSL dated to MIS 5e highstand (125±9 ka). In the central part of the bay, U3a consists of 50 cm thick clast-supported conglomerate, encrusted by an algal rim dated at 114±9 ka), and covered by a second clast-supported conglomerate, gently dipping seaward, and capped by a coarse sandstone (Sechi et al., 2013; 2020 and Pascucci el al., 2014).

An unconformity surface separates these deposits from the overlain U3 b unit, consisting at the bottom of pebbly-cobbly conglomerates, passing sea-ward to a 2 m-thick medium to coarse sandstone capped by laminated high angle cross stratified 1 m-thick sandstone. The succession was considered as a mixed sand-gravel high-energy beach system, passing upward to a well-developed sandy backshore dated at 106±8, and to a dune system dated at 98±7 ka. Therefore, the succession deposited during the MIS 5c highstand (Sechi et al., 2013; 2020 and Pascucci el al., 2014).

New researches and luminescence dating results (quartz OSL and K-feldspar pIRIR290) confirm the chronological framework of the deposits cropping at El Tro' bay (cfr. Pascucci et al., 2014; Sechi et al., 2020). The new data (forereshore sediments Qtz OSL and Kf dated at 94±8 of 100±6 ka respectively, backshore deposits dated at 106±8 ka) confirm that Unit 3b, deposited during MIS 5c. Moreover the uppermost sandstones yield a Qtz-OSL minimum age of 76 ka and a pIRIR290 age of 103±7 ka (cfr. Pascucci et al., 2014, 2019; Sechi et al., 2020 and references therein).

Based on available data, such as the stratigraphic evidence available for El Tro' bay, the similarity shown by the deposits of the southern part of Las Tronas with those of El Tro' sections (particularly with the lenses of well sorted parallel or low angle laminated coarse-grained sandstone, locally showing surface laminas with well-preserved deer footprints), and considering the gently dipping towards the sea of the medium-coarse, low to high angle cross stratified and well-cemented sandstone deposits cropping in the bay, the fossiliferous layers of the small stratigraphic sequence exposed in the northernmost part of Las Tronas bay can be correlated with the backshore and dune system deposits of Unit 3b and thus referred to MIS 5c.

3. THE EXTERNAL IMPRINT OF THE ELEPHANT TUSK, DESCRIPTION AND REMARKS

The external imprint likely corresponds to less than the longitudinal half of the distal portion of the elephant tusk. An extremely thin layer of tusk surface is still preserved in some parts, as well as few small fragments, with a millimetric thickness, of the external dentine cones (Fig. 2-B). Unfortunately, due to the small dimension and the preservation status of the dentine fragments neither the Schreger lines nor their pattern can be detected, so that the most compelling diagnostic datum for identifying the genus the specimen belongs to (*Mammuthus* or *Palaeoloxodon)* is missing (e.g. Palombo & Villa 2007; Ábelová, 2008).

The length of the tusk imprint is about 480 mm and 410 mm along respectively the convex (inferior) and the concave (superior) edges. The height (chord of the arch of the transverse section) of the tusk imprint is 51 mm at the distal end, and about 39.5 mm near the apex of the tip. Hypothesising that the tusk external imprint from Las Tronas bay may account for about a quarter of the tusk, the maximum circumference is supposed to be >160 mm and <175 mm.

The convex and concave edges of the imprints run nearly parallel for most of the tusk section, except for the tip where the outline of the concave edge bents moderately downward. The imprint is gently and regularly curved upwards in the vertical plane (radius of curvature =35.7 mm), and the imprint tip is slightly directed upwards.

The dimensions of the Las Tronas imprint indicate that the tusk was similar in size to the fragment of *Mammuthus lamormorai* tusk found at Guardia Pisano hill (Gonnesa, SW Sardinia) that is the only tusk belonging to the Sardinian endemic mammoth known to date (Palombo et al., 2012, figure 2). In the small fragment from the Guardia Pisano hill (maximum length =118 mm, estimated circumference at the broken proximal surface =223 mm), the diameter of the pulpar cavity, still detectable on the natural transverse section of the broken distal surface, is less than 2 mm, suggesting that the fragment may correspond to a distal intralveolar plus a proximal extralveolar part of the tusk.

The Las Tronas tusk imprint does not show any evidence of twist and its gentle curvature seems to be mostly developed in a single plane, as seen in *Palaeoloxodon*. Therefore, the tusk that left the imprint apparently did not have the curving, twisting form, gradually bending inwards that gives to the *Mammuthus* tusks the characteristic spiral shape. The curvature index (CI =chord length vs external length ratio =0.82) is, however, inferior to the value calculated for the majority of the straight tusked elephants found in the Italian peninsula [e.g. Grotte Santo Stefano, Viterbo (Trevisan, 1949) =0.97; Ceprano, Frosinone (Ambrosetti, 1963) =0.85; Pignataro Interama, Frosinone (adult female, fide Maccagno, 1962) =0.98; Pignataro Interama, Frosinone (juvanile individual, D'Erasmo and Moncharmont Zei, 1955) =0.98; La Polledrara di Cecanibbio, Roma (preliminary personal data, MRP) variation range =0.85-0.97, M =0.94]. Noteworthy, in the majority of the Italian *P. antiquus,* the CI value augments from the proximal to the distal part of the tusk (e.g. Ambrosetti, 1963, pag. 209), suggesting that CI of the part near to the tusk tip is in general higher than that calculated for the Las Tronas imprint. The latter is similar to the maximum value of the variation range of dwarf mammoth, *Mammuthus exilis* from the Channel Islands, California (variation range =0.35-0.87, M =0.74) (Agenbroad, 2003) but it is similar, for instance, to the average CI value calculated for the tusks of juvenile individuals of *Mammuthus primigenius* from Yana RHS, Artic Siberia (variation range =0.63-0.94, M =0.84), while it is higher than that of adult individuals from the same locality (variation range =0.53-0.75, M =0.62) (Pitulko et al., 2015). The CI value of the curvature index of the distal part of the Las Tronas tusk is higher than that estimated for some Italian *Mammuthus* representatives, such as *Mammuthus meridionalis* from Leffe, Bergamo (CI =0.79, Vialli, 1956), Scoppito, L'Aquila [CI =0.68 (total tusk length), CI =0.60 (extralveolar length), Maccagno, 1962], *Mammuthus trogontherii*, via Flaminia km 7.2, Roma [CI =0.79 (incomplete tusk, the distal is missing), Palombo, 1972], *Mammuthus primigenius* from Tarquinia, Viterbo (CI =0.70, Ambrosetti, 1964), Asolo (CI =0.60) and Vidor (CI =0.68), Treviso (Reggiani & Sala, 1992).

All in all, the morphological and dimensional evidences provided by the external imprint of the elephant tusk found at Las Tronas bay are not conclusive enough for a firm taxonomical identification. However, the size and curvature of elephant permanent tusks show a wide range of inter and intra-specific variation because of their indeterminate growth, ontogenetic changes and marked sexual dimorphism (see e.g. Smith & Fisher, 2013 and references therein). Moreover, in *M. exilis*, the tusk length and maximum diameters are approximately 50% those of its continental ancestor *M. columbi*, while the average CI value is definitely higher (=0.84 in *M. exilis*, =0.64 in *M. columbi* from Channel Islands) (Agenbroad, 2003; Muhs et al., 2015). Tusks of adult *M. exilis* individuals do not show the curving, twisting form typical of *Mammuthus* (which is also evident, though not strongly marked, in *M. columbi),* so that they are similar in shape to the tusk of young *M. primigenius.* Consequently, it could be speculated that the tusks of adult dwarfed mammoths exhibit some juvenile features, thought more data are required to validate the soundness of this hypothesis. If, for instance, paedomorphic traits characterise the skull of the extremely dwarfed *Palaeoloxodon* ex gr. *P. falconeri* from Spinagallo cave (Siracusa, Sicily), similar evidence is not clearly detectable in tusks (Palombo, 2003 and references therein). Moreover, in *Palaeoloxodon* ex gr. *P. mnaidriensis* from Puntali cave (Palermo, Sicily) (Ferretti, 2008), moderately reduced in size, with a stature rougly similar to *M. lamarmorai*, the skull does not show any paedomorphic traits, while the tusks are even more twisted than in its continental ancestor *P. antiquus.*

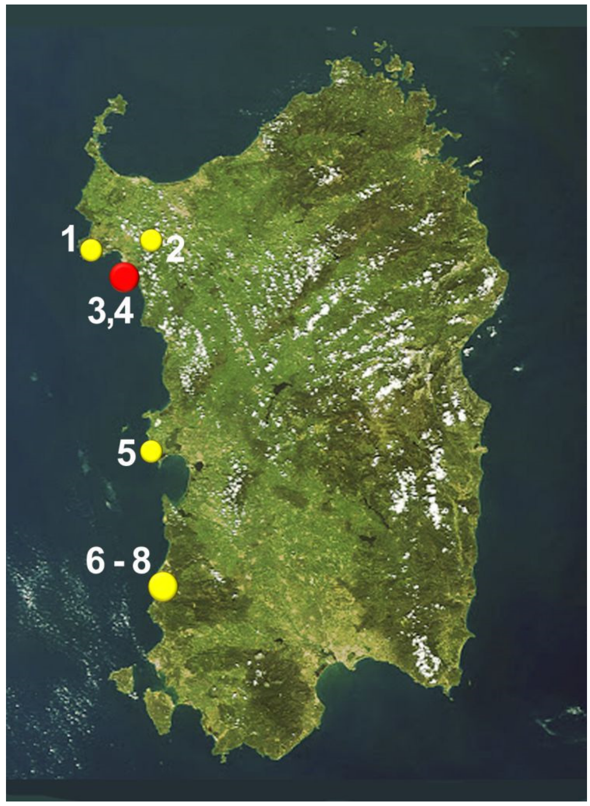

Fig. 5 - A map of Sardinia showing localities where elephant remains were discovered: 1: Tramariglio (molariform tooth); 2: Campo Giavesu (two molariform teeth); 3-4 Las Tronas bay (external imprint of a tusk fragment) and an undefined point along the southern Alghero coast (incomplete tibia); 5: San Giovanni di Sinis (molariform tooth); 6-8: Guardia Pisano (skeleton and tusk fragment) and Funtana Morimenta (footprints).

All things considered, the few available data support the idea that the tusk from Las Tronas bay may belong to the only elephant species known in Sardinia. Thus, to identify the tusk imprint as *M. lamarmorai,* seems to be to most parsimonious, even if provisional, hypothesis.

4. FINAL REMARKS

Although endemic elephants have been reported from a number of eastern and western Mediterranean islands, the majority originated from the mainland straight-tusked elephant *Palaeoloxodon antiquus*, while dwarf mammoth remains are recorded only from Crete and Sardinia.

On Crete, a few remains of adult elephants (a lower third molariform tooth clearly showing *Mammuthus* morphological features, some fragment of other teeth, a humerus and ribs) have been reported from Cape Maleka 1 (Chania). The inferred age of the deposits (late

Early Pleistocene) and the small size of the specimens make the Crete mammoth, *Mammuthus creticus,* the smallest insular dwarf mammoth known to date (Herridge & Lister, 2012), similar in size to the smallest endemic straight-tusked elephants *P. falconeri* from Malta and Sicily high at the shoulder about 1 m or a little more (Larramendi & Palombo, 2015).

On western Sardinia, a few elephant remains have been reported from late Middle to Late Pleistocene deposits, while no elephant remains are known to date in other parts of the island (Fig. 5). These remains have been ascribed to the *Mammuthus* genus, based on the taxonomically informative characters shown by the molariform teeth found at Campo Giavesu (Giave, Sassari) and San Giovanni di Sinis (Oristano), and on the Schreger line patterns shown by the tusk fragment from Guarda Pisano (Gonnesa) hill (Palombo et al., 2005, 2012 and references therein). Based on this evidence, it has been assumed that even the specimens without firm diagnostic features (e.g the tooth from Tramariglio and the incomplete tibia from the southern coast of Alghero) may belong to the same genus, as well as the incomplete postcranial skeleton, found in 1881 on the slope of Guardia Pisano hill (Gonnesa) and afterward described by Major as a new species,*"Elephas lamarmorae",* of an endemic dwarfed elephant, which stood about 1.40 m at the shoulder (Palombo et al., 2012; Zoboli et al., 2018).

As a result, all the elephant remains recorded to date in Sardinia have been attributed to the dwarf mammoth *M. lamarmorai* (cf. Palombo et al., 2017b and references therein; Pillola & Zoboli, 2017).

The paucity of fossils, the uncertainties about the chronology of some remains, which prevents knowing if the differences and the potential dimensional scaling shown by the molariform teeth from different localities (Palombo et al., 2005) result from a progressive dwarfing due to anagenetic evolution, or if mainland mammoths entered the island more than once. Considering in addition the impossibility to define the actual dimensional range of *M. lamarmorai* and the well-known variability characterising elephant size, the question remains unanswered as to whether or not only one species inhabited the island (see discussion in Palombo et al., 2012, 2017b).

Although the finding of the external imprint of the elephant tusk tentatively ascribed to *M.* cfr. *M. lamarmorai* does not provide any useful hint for resolving the question, it is however of some significance because it is the first Sardinian elephant remain with a firm chronological constrain, confirming the presence of elephant populations in NW Sardinia at least since MIS 5c.

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