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Pleistocene mammals from Sa Cona Cave (Teulada, south-western Sardinia, Italy)

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ABSTRACT - Quaternary fossil vertebrates are reported from numerous deposits of Sardinia and can be a suitable tool to correlate localities in different depositional contexts (e.g. fissure fillings, caves, aeolian deposits). Here, a mammal assemblage collected from a deposit within Sa Cona Cave (Teulada, south-western Sardinia, Italy) is described. The sample is primarily represented by small mammal remains and a few, badly preserved remains of large mammals. The following taxa have been identified: *Cynotherium sardous*, *Praemegaceros cazioti*, *Prolagus sardus*, *Microtus* (*Tyrrhenicola*) *henseli*, *Rhagamys orthodon*, and "*Asoriculus*" *similis*. Similar faunal assemblages, known from some localities of Sardinia and Corsica, have been generally regarded as Late Pleistocene in age (Dragonara Faunal Sub-Complex). The sequence of Sa Cona Cave represents to date one of the most rich Quaternary mammal deposits known from the extreme south-western Sardinia.

Keywords: insular fauna; vertebrate palaeontology; biochronology; systematic.

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1. INTRODUCTION

Sardinia is an important source of data for our knowledge of the evolution of insular vertebrates. Several mammalian taxa have been reported from Paleogene deposits (Major, 1891; Bosco, 1902; Dal Piaz, 1929; Mennecart et al., 2017) and different insular mammalian assemblages are known to have existed here during the Neogene (Pecorini et al., 1974; Van der Made, 1999, 2008; Angelone and Kotsakis, 2001; Abbazzi et al., 2008a, 2008b; Zoboli and Pillola, 2017a; Mennecart et al., 2018) and Quaternary (Van der Made, 1999; Sondaar, 2000; Palombo, 2009, 2018).

Quaternary mammals from the Sardinia-Corsica Massif have been studied since the early part of the XIX century by several palaeontologists (e.g. Cuvier, 1812; Wagner, 1829; Studiati, 1857). Fossil deposits localised in several localities testify several turnovers of terrestrial mammalian species characterised by the arrivals of new taxa from the mainland and the contemporaneous disappearance of endemic elements (e.g. Van der Made, 1999; Sondaar, 2000; Palombo, 2006, 2009, 2018). Palombo (2006, 2009, 2018) recognised two main mammalian faunal complexes: the oldest "*Nesogoral*" Faunal Complex (Late Pliocene-Early Pleistocene), including two subcomplexes (Mandriola Faunal Sub-Complex and Capo Figari/Orosei 1 Faunal Sub-Complex) and the more recent "*Microtus* (*Tyrrhenicola*)" Faunal Complex (late Early Pleistocene-Early Holocene), including the Orosei 2 and Dragonara Faunal Sub-Complexes.

Quaternary mammal remains of the island are mainly recovered from bone breccias localised in karstic fissures and caves (e.g. among several others Studiati, 1857; Dehaut, 1911; Comaschi Caria, 1968; Malatesta, 1954, 1970, 1977; Caloi and Malatesta, 1974; Engesser, 1976; Brandy, 1978; Kotsakis, 1981; Willemsen and Malatesta, 1987; Gliozzi, 1985; Palombo et al., 2003; Sondaar, 2000; Abbazzi et al., 2004; Melis et al., 2016; Palombo and Rozzi, 2014; Palombo and Zedda, 2016; Rook et al., 2018) and subordinately from aeolian deposits (e.g. Acconci, 1881; Major, 1883; Comaschi Caria, 1955a, 1955b, 1965; Ambrosetti, 1972; Melis et al., 2001; Chesi at al., 2007; Fanelli et al., 2007; Palombo et al., 2017a; Zoboli et al., 2018). The bone breccias and cave deposits are principally situated from the karst areas of the central and western subregions of Sardinia (e.g. Barbagia, Baronie, Ogliastra, Nurra, Monreale, Sulcis-Iglesiente) (Comaschi Caria, 1970; Malatesta, 1954, 1970, 1977; Ulzega et al., 1980; Gliozzi et al., 1984; Minieri et al., 1995; Palombo et al., 2003; Abbazzi et al., 2004; Madurell-Malapeira et al., 2015; Zoboli et al., 2016). However, bone breccias rich in mammal remains were also recorded at small calcareous outcrops (e.g. eastern Gallura, Marghine, central and southern Campidano) (Studiati, 1857; Dehaut, 1911; Azzaroli, 1946; Engesser, 1976; Zoboli and Pillola, 2016).

The aim of this study is to give notice of a mammalian

assemblage from a sedimentary sequence located in Sa Cona Cave (Teulada, SW Sardinia) and to propose its biochronological assignment.

2. MATERIAL AND METHODS

We collected sediments from different levels of the sedimentary sequence in order to recover fossil remains. The studied material was collected from an uncemented sandy-clay level (thickness about 30 cm) rich in small mammal remains (Fig. 1). The sampled sediments were wet-sifted using sieves with mesh 2.5-0.5 mm after which the dried residues were inspected using a Leica DMS1000 digital microscope. Photographs and measurements of the retrieved fossils were taken with a Nikon D5000 digital camera and a Leica DMS1000 digital microscope respectively. We used an air engraving pen (3400BPM) to prepare the macromammal remains. Afterwards, several bones were consolidated using Paraloid B-72. Subsequently, we used a digital caliper (Rupac 0-150mm/0.01 ABS) to measure the macromammal remains. Comparison was made using data from the literature and material housed at the Museo Sardo di Geologia e Paleontologia D. Lovisato (acronym MDLCA) of the University of Cagliari: *P. sardus* (MDLCA14820-14823 from Bonaria, MDLCA23535-23559 from Surconis, MDLCA23631-23633 from Su Concali), *M.* (*Tyrrhenicola*) *henseli* (MDLCA14043/1-9 from Grotta dei Fiori, MDLCA14844 from Bonaria, MDLCA23560-23567 from Surconis, MDLCA23622-23630 from Su Concali), *R. orthodon* (MDLCA14042/1-9 from Grotta dei Fiori, MDLCA14865 from Bonaria, MDLCA23568-23571 from Surconis, MDCLA23618-23620 from Su Concali), *P. cazioti* (MDLCA23578-23582 from Surconis, MDLCA23608-23613 from Su Concali), "*Asoriculus*" sp. (MDLCA14044/1-13 from Grotta dei Fiori, MDLCA23634-23635 from Su Concali). Sixty-one lower first (m1) of the cricetid rodent *Microtus* (*Tyrrhenicola*) *henseli* (Major, 1905) have been preliminary studied. Comparison was made with samples of *M.* (*Tyrrhenicola*) spp. from different cave deposits and fissure fillings of Sardinia (data from Mezzabotta et al., 1995; Minieri et al., 1995; Marcolini et al., 2005, 2006; Boldrini, 2008; Boldrini et al., 2010; Palombo et al., 2017b; Zoboli and Pillola, 2016, 2017b). Measurements and morphological indices of the m1 of *M.* (*Tyrrhenicola*) *henseli* were taken according to Van der Meulen (1973) and Marcolini et al. (2006) with further modifications as proposed by Boldrini (2008). The nomenclature, the measurements and the comparisons used for the teeth of the other micromammals follow López Martínez (1989) and Angelone (2007) for Ochotonidae, Michaux (1971) for Muridae, and Reumer (1984) for Soricidae. Large mammal bones were measured according to Von den Driesch (1976). All measurements are given in mm. The studied material is stored at the MDLCA.

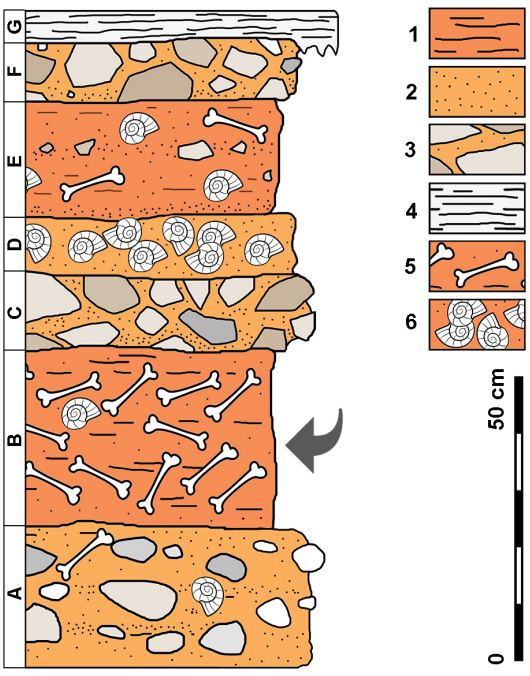

Fig. 1 - Stratigraphic sketch of the studied sedimentary sequence: 1, clayey sediments; 2, sandy-clay sediments; 3, angular and sub-angular clasts of carbonate rocks; 4, flowstone; 5, vertebrate remains; 6, pulmonata remains. A-G: levels. The arrow indicates the vertebrate-rich level B.

3. GEOLOGICAL SETTING

Sa Cona is a karstic cave located in the south-western Sardinia (Italy), about 1 km SW of the village of Teulada (38°57'33"N/8°45'21"E, Fig. 2a). The cave developed in the karstic complex of Mt. Sa Cona in marginally metamorphosised lower Cambrian limestone and dolostone of the Gonnesa Group (Pillola, 1991). The cave is characterised by a complex speleogenetical evolution (Grussu et al., 2001). Morphological features of halls, galleries and deposits suggest different cycles of sedimentation, erosion and collapsing phases. Quaternary deposits are present in different sectors of the cave and are generally represented by coarse as well as fine sediments. The studied sedimentary sequence is located about 30 m from the principal entrance (Fig. 2b).

3.1. STRATIGRAPHY

The sequence (about 1 m thick) includes several levels (A-G, Fig. 1) from which vertebrate and invertebrate remains were collected. The nature of the sediments indicates a transport into the cave by water flows during different phases. Moreover, the alternation of levels characterised by angular and sub-angular clasts (maximum length of about 10 cm) of Cambrian rocks (levels A, C, F) and clayey and sandy-clay sediments (levels B, D, E) indicates different energy of transport from the surrounding area. The presence of a clay level of about 30 cm thick (level B) in the lower part of the sequence indicates a very scarce water energy that allowed an abundant accumulation of small mammal remains. Scarce vertebrate remains are

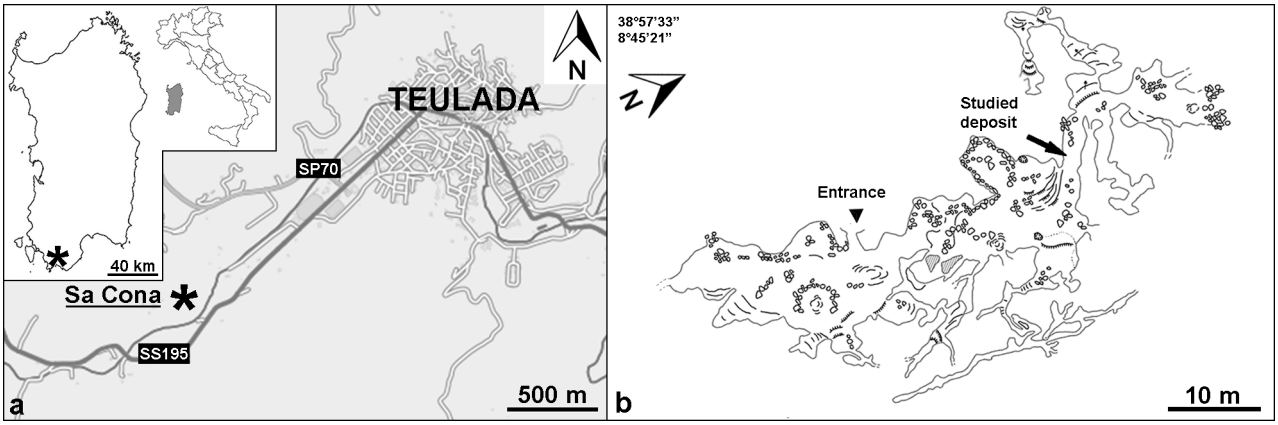

Fig. 1 - a) Location map of Sa Cona Cave; b) planimetry of northern part of the cave and location of the studied deposit. Cave planimetry modified from Grussu et al. (2001).

also present in the levels A and E, while the level D is characterised by the abundance of pulmonate gastropod remains. A flowstone layer 10 cm thick (level G) closes the top of the sequence.

4. SYSTEMATIC PALAEONTOLOGY

Ord. Carnivora Bowdich, 1821
Fam. Canidae Fischer, 1817
Gen. ***Cynotherium*** Studiati, 1857
Cynotherium sardous Studiati, 1857
Pl. 1, Figs. 1-2

Material-MDLCA23707: one fragment of a parietal; MDLCA23708: one incomplete right humerus (Pl. 1, Fig. 1); MDLCA23709: one incomplete left ulna (Pl. 1, Fig. 2).

Remarks-A few isolated and incomplete bones are the only fossils referable to a carnivore. The sample is represented by a small fragment of a cranium and two incomplete limb bones. The shape and the thickness of the cranial fragment allow to refer the sample to a parietal. The collected right humerus (Pl. 1, Fig. 1) is slender and lacks the distal part of the diaphysis and the distal epiphysis. The absence of the proximal epiphysis due to incomplete ossification indicates an immature specimen. The deltoid ridge is not large as observed in fully mature specimens (e.g. Dragonara-Medusa Cave, Malatesta, 1970; Corbeddu Cave, Lyras et al., 2006). The distal epiphysis of the humerus is short and broad. The left ulna (Pl. 1, Fig. 2), referable to an adult specimen, lacks a part of the diaphysis and the distal epiphysis. The ulna shows a robust olecranon and a shallow trochlear notch as observed in the samples from Dragonara-Medusa Cave and Corbeddu Cave (Malatesta, 1970; Lyras et al., 2006). The available measurements of the ulna are paragonable or slightly higher than the mean values of the Dragonara-Medusa Cave sample provided by Malatesta, 1970 (table 7, p. 41 in Malatesta, 1970): linear measure "b" of the olecranon of MDLCA23709: 32.5 mm (mean of "b" for the Dragonara-Medusa sample: 31.5 mm), linear measure "c" of MDLCA23709: 22.8 mm (mean of "c" for the Dragonara-Medusa sample: 21.2 mm). Regarding the dimensions (for the humeri see Tab. 1) and shape, different than the other Pleistocene carnivorous known in the Sardinian fossil record (e.g. the endemic mustelids, Malatesta, 1977; Gliozzi, 1985; Willemsen and Malatesta, 1987; Rook et al., 2018), the three fossils can be attributed to the only middle size carnivorous known in the

Tab. 1 - Measurements (in mm) of the humeri of *Cynotherium* from different localities of Sardinia and Corsica. DTd, distal transverse diameter; DTD, transverse diameter of the diaphysis. *C. sardous* from Sa Cona, Medusa-Dragonara Cave (data from Malatesta, 1970), Castiglione 3 (data from Salotti et al., 2000), and fissure VII-2 of Mt. Tuttavista (data from Abbazzi et al., 2005); *Cynotherium* cf. *C. sardous* from fissure VI-Banco6 of Mt. Tuttavista (data from Abbazzi et al., 2005); *Cynotherium* sp. from fissure IX-*Prolagus* of Mt. Tuttavista (data from Abbazzi et al., 2005).*inferred measurement.

Locality	n	DTd			n	DTD		
		Min	Mean	Max		Min	Mean	Max
Sa Cona	1		29.0		1		9.7	
Medusa-Dragonara	20	28.0	30.3	36.0				
Castiglione 3	13	28.9	30.9	33.6				
Mt. Tuttavista (VII-2)						8.87	9.29	9.72
Mt. Tuttavista (VI-B6)	1		30.6		2	10.50	10.90	11.30
Mt. Tuttavista (IX-Prolagus)	1		30.0*		1		12.29	

Quaternary of the Corsica-Sardinia Massif, the endemic canid *Cynotherium* Studiati, 1857. This genus is one of the most typical elements in the mammalian assemblages of Sardinia during the ?late Early-Late Pleistocene (Malatesta, 1970; Abbazzi et al., 2005; Madurell-Malapeira et al., 2015). Two species of *Cynotherium* were reported from the island: the type species *C. sardous* Studiati, 1857 (Middle-Late Pleistocene) and its putative ancestor *Cynotherium malatestai* Madurell-Malapeira et al., 2015 (?late Early Pleistocene or early Middle Pleistocene, radiometric age >500 ka, Melis et al., 2013). In addition, Abbazzi et al. (2005) reported the following taxa from the fissure fillings of Mt. Tuttavista (Orosei): Canidae indet. (fissure X-3 uccelli), *Cynotherium* sp. (fissures XI-canide, XI-Dic2001, IV-20, IX-*Prolagus*, IX-cervo and V), *Cynotherium* cf. *C. sardous* (fissure VI-Banco6) and *C. sardous* (fissure VII-2). *C. malatestai* differs from *C. sardous* in its larger dimensions as well as its more robust and deeper mandibular corpus. Moreover, in *C. malatestai*, the mandibular condyle does not surpass the occlusal level, whereas it is situated in a higher position in most of the specimens from Dragonara-Medusa Cave assigned to *C. sardous* (Madurell-Malapeira et al., 2015).

The scarce fossil material of Sa Cona Cave allows to take only few useful measurements, however, the breadth of the distal epiphysis (29.0 mm) and the breadth of the diaphysis (9.7 mm) of the humerus are in agreement with the samples of *Cynotherium* spp. from different localities of Sardinia and Corsica (Tab. 1).

On the basis of the dimensions and morphology, the remains of the canid from the studied deposit are here assigned to *C. sardous*.

Ord. Artiodactyla Owen, 1848
Fam. Cervidae Goldfuss, 1820
Gen. ***Praemegaceros*** Portis, 1920
Praemegaceros cazioti (Depéret, 1897)
Pl. 1, Figs. 3-7

Material-MDLCA23710: one incomplete left jugal; MDLCA23711: one incomplete left hemimandible (fragment of a body without teeth); MDLCA23712: one incomplete right hemimandible (coronoid process); MDLCA23713/1-9: nine rib fragments; MDLCA23714: one incomplete right humerus (Pl. 1, Fig. 3); MDLCA23715: one left cuneiform (Pl. 1, Fig. 4); MDLCA23716/1-2: two incomplete metapodials; MDLCA23717: one incomplete anterior first phalanx (Pl. 1, Fig. 5); MDLCA23718: one complete anterior second phalanx (Pl. 1, Fig. 6); MDLCA23719/1-3: three anterior third phalanges (Pl. 1, Fig. 7).

Remarks-Very few deer remains were collected in the deposit. The fossils are represented by fragments of cranium, mandibles, ribs and limb bones. The fragmentary nature of the available material from Sa Cona allows us to take only few linear measurements from the most complete bones of the acropodium (Tab. 2).

Fossil remains ascribed to the genus *Praemegaceros* are relatively frequent in Pleistocene deposits of Sardinia and Corsica (Depéret, 1897; Comaschi Caria, 1955a, 1955b, 1968; Caloi and Malatesta, 1974; Salotti et al., 2000; Palombo et al., 2003; Croitor, 2006; Croitor et al., 2006; Van der Made and Palombo, 2006; Melis et al., 2016 and references therein; Zoboli and Pillola, 2017b). In addition to the fossils, several footprints contributed to *Praemegaceros* were reported from different localities along the west coast of Sardinia (Fanelli et al., 2007; Pillola and Zoboli, 2017; Zoboli and Pillola, 2018). Currently, two species are known from Sardinia: *Praemegaceros cazioti* (Depéret, 1897) and *Praemegaceros sardus* Van der Made and Palombo, 2006. This latter taxon is considered the ancestor of *P. cazioti* and its size is about 25-40% larger than *P. cazioti* (Van der Made and Palombo, 2006). Moreover, the fossil remains of a large deer from Su Fossu de Cannas Cave (Sadali) indicate the most primitive Megacerine found in Sardinia and the first representative of the Sardinian endemic lineage (Melis et al., 2016).

The fossils from Sa Cona Cave are comparable in size with the samples of the Late Pleistocene collected in different localities of Sardinia (e.g. Dragonara-Medusa Cave, Caloi and Malatesta, 1974; Surconis, Zoboli and Pillola, 2016; Su Concali, Zoboli and Pillola, 2017b) and Corsica (e.g. Castiglione 3, Salotti et al., 2000; Coscia, Croitor et al., 2006) (Fig. 3) and are here assigned to the smallest and most recent species *P. cazioti*.

Ord. Lagomorpha Brandt, 1855
Fam. Ochotonidae Thomas, 1897
Gen. ***Prolagus*** Pomel, 1853
Prolagus sardus (Wagner, 1829)
Pl. 1, Figs. 13-15

Material-MDLCA23720/1-4: four incomplete crania (Pl. 1, Fig. 13); MDLCA23721/1-4: four right maxillae; MDLCA23722/1-3: three left maxillae; MDLCA23723/1-10: 10 right hemimandibles (Pl. 1,

Tab. 2 - Measurements (in mm) of the anterior phalanges of *Praemegaceros cazioti* from Sa Cona Cave. DAPp, proximal antero-posterior diameter; DAPd, distal antero-posterior diameter; DTp, proximal transverse diameter; DTd, distal transverse diameter; L, total length.

Bone element	DAPp	DAPd	DTp	DTd	L
1st phalanx MDLCA23717		12.1		14.0	
2nd phalanx MDLCA23718	18.8	17.9	16.6	15.2	30.6
3rd phalanx MDLCA23719/1	22.0		14.1		35.3
3rd phalanx MDLCA23719/2	21.9		12.4		35.9
3rd phalanx MDLCA23719/3	22.8		14.0		

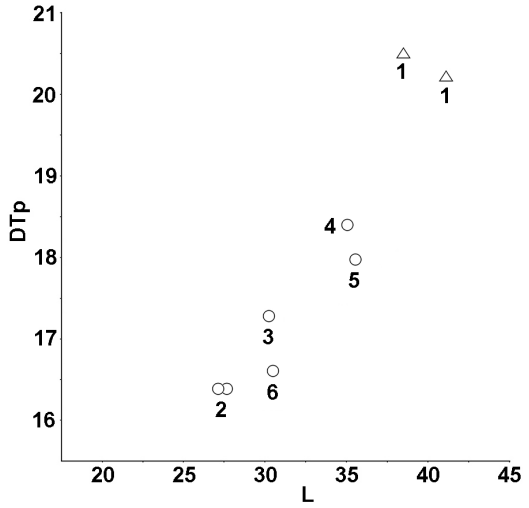

Fig. 3 - Scatter diagram of the second phalanx (L: length, DTp: proximal transverse diameter) of *Praemegaceros sardus* (triangles) and *Praemegaceros cazioti* (circles) from Sardinia and Corsica: 1, S. Lucia; 2, Castiglione 3; 3, Coscia; 4, Surconis; 5, Su Concali; 6, Sa Cona. Data are from Salotti et al. (2000), Croitor et al. (2006), Van der Made and Palombo (2006), Zoboli and Pillola (2016, 2017b). Measurements in mm.

Fig. 15); MDCLA23724/1-11: 11 left hemimandibles; MDLCA23725: one third cervical vertebra; MDLCA23726: one first thoracic vertebra; MDLCA23727/1-2: two lombar vertebrae; MDLCA23728/1-4: four sacra; MDLCA23729/1-7: seven right humeri; MDLCA23730/1-7: seven left humeri; MDLCA23731/1-6: six right ulnae; MDLCA23732/1-7: seven left ulnae; MDLCA23733: one left radius; MDLCA23734/1-7: seven right incomplete innominate bones; MDLCA23735/1-8: eight incomplete innominate bones; MDLCA23736/1-11: 11 right femora; MDLCA23737/1-11: 11 left femora; MDLCA23738/1-16: 16 right tibiae; MDLCA23739/1-16: 16 left tibiae.

Remarks-The insular ochotonid *Prolagus sardus* is well represented in the deposit of Sa Cona Cave with cranial and postcranial elements. *P. sardus* is a typical taxon of the Dragonara Faunal Sub-Complex (Angelone et al., 2008), and is probably the most abundant mammal in the deposits of the last part of the Middle Pleistocene-Early Holocene of Corsica and Sardinia (Vigne, 1990; Wilkens, 2000; Zoboli and Caddeo, 2016).

The observed lower third premolars (p3) show a posteriorly indented and lingually elongated anteroconid (Pl. 1, Fig. 14). This morphology suggests that the sample of Teulada is comparable with the advanced morphotypes of Monte Tuttavista (Angelone et al., 2008). Measurements of the collected p3 are reported in Tab. 3. Several bone elements collected at Sa Cona Cave are clearly attributable to young individuals.

Ord. Rodentia Bowdich, 1821
Fam. Cricetidae Fischer, 1817
Gen. ***Microtus*** Schrank, 1798
Subgen. ***Tyrrhenicola*** Major, 1905
Microtus* (*Tyrrhenicola*) *henseli (Major, 1905)
Pl. 1, Figs. 8-9

Material-MDLCA23740/1-14: 14 incomplete crania (Pl.1, Fig. 8); MDLCA23741/1-31: 31 right hemimandibles; MDLCA23742/1-32: 32 left hemimandibles (Pl. 1, Fig. 9); MDLCA23743: 34 isolated m1.

Remarks-The m1 of the Corso-Sardinian endemic cricetid *Microtus* (*Tyrrhenicola*) *henseli* shows a wide morphologic variability (Mezzabotta et al., 1995; Minieri et al., 1995). Four morphotypes of m1 of *M.* (*Tyrrhenicola*) *henseli* (Fig. 4) were recognized (Mezzabotta et al., 1995): the most primitive includes small m1 with a simple and short anterior cap, large neck and poorly developed or absent sixth triangle, the most derived includes large m1 with long asymmetrical anterior cap, developed sixth

Tab. 3 - Measurements (in mm) of the p3 of *Prolagus sardus* from Sa Cona Cave. L, length; W, width; n, number of measured elements.

n = 4	Min	Mean	Max
L	2.24	2.26	2.28
W	2.40	2.46	2.53

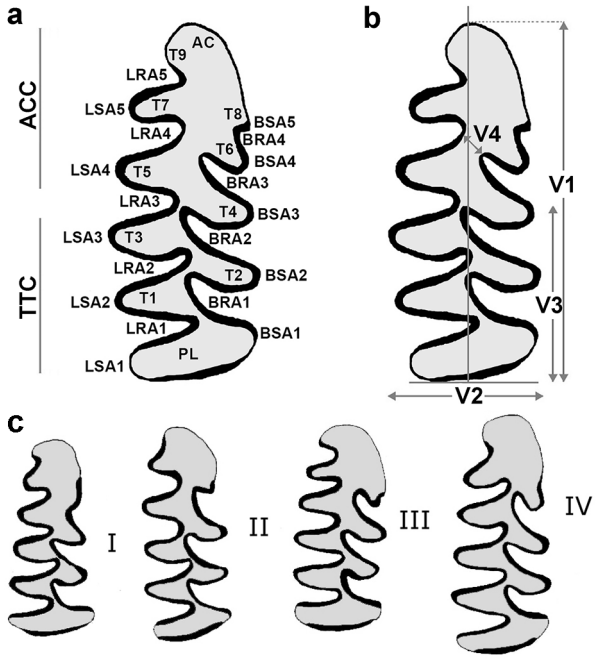

Fig. 4 - a) Terminology of the m1 occlusal surface of cricetids (modified from Van der Meulen, 1973), ACC, anteroconid complex; TTC, trigonid-talonid complex; AC, anterior cap; T, triangle; BSA, buccal salient angle; BRA, buccal reentrant angle; LSA, lingual salient angle; LRA, lingual reentrant angle; PL, posterior loop; b) sketch of measurements of the m1 of *Microtus* (*Thyrrhenicola*) *henseli*, V1, total length; V2, total width; V3, Length of posterior part of BRA2; V4, width of the neck; c) morphotypes classes of m1 (modified from Mezzabotta et al., 1995).

triangle, narrow neck and always present seventh triangle. The intermediate classes include m1 with transitional features (Fig. 4). The ancestor of *M.* (*Tyrrhenicola*) *henseli* is the archaic endemic species *M.* (*Tyrrhenicola*) *sondaari* (Marcolini et al., 2006). This taxon, reported from a fissure filling in the quarry Xg.3 "uccelli" of Mt. Tuttavista, is characterised by small dimensions (V1 min: 2.32 mm, V1 max: 3.05 mm), very slightly developed anteroconid in m1, T6 and T7 only outlined, T9 always lacking, the neck between LRA4 and BRA3 always large and T4-T5 not confluent (Marcolini et al., 2006).

The remains of the cricetid are relatively abundant in the layer B of the studied sequence of Sa Cona Cave. The majority of the analyzed m1 (about 95%, Fig. 5) are characterised by large dimensions, a narrow neck, long and asymmetrical anterior cap, developed sixth triangle, and are clearly referable to the most advanced morphotypes (Pl. 1, Fig. 9d). Data about the Schmelzband-Differenzierung-Quotient (or SQD index) of the m1 from Sa Cona are not yet available, but these will be provided via further analysis. The *M.* (*Tyrrhenicola*) *henseli* population from Sa Cona Cave is comparable with others already known from Late Pleistocene-Early Holocene Sardinian deposits (Tabs. 4, 5; Fig. 6).

Fam. Muridae Illiger, 1811
Gen. ***Rhagamys*** Major, 1905
Rhagamys orthodon (Hensel, 1856)
Pl. 1, Fig. 10

Material-MDLCA23744/1-2: two right maxillae; MDLCA23745/1-5: five left maxillae; MDLCA23746: one isolated right M1; MDLCA23747: one isolated left M1; MDLCA23748/1-12: 12 right hemimandibles (Pl. 1, Fig. 10); MDLCA23749/1-12: 12 left hemimandibles.

Remarks-The family Muridae is well represented in the Plio-Quaternary fossil record of the Sardinia-Corsica Massif. An insular lineage is documented by the presence of different taxa reported in several localities. The oldest taxon of this lineage is *Rhagapodemus azzarolii* Angelone and Kotsakis (2001). This species is reported from the Pliocene deposit of Capo Mannu (Angelone and Kotsakis, 2001; Piras et al., 2012). The second taxon of the lineage, *Rhagapodemus minor* (Brandy, 1978), is reported from Early Pleistocene localities of Sardinia and Corsica (Brandy, 1978; Abbazzi et al., 2004). The latest and most recent species of the lineage is *R. orthodon* which is reported in Middle Pleistocene-Early Holocene deposits of several Corso-Sardinian localities (e.g. among several others Comaschi Caria, 1968; Vigne, 1990, 1992; Vigne and Valladas, 1996; Zoboli and Pillola, 2016, 2017b). The transition between these two latter taxa of the lineage is marked by an increase in dimension and hypsodonty (Brandy, 1978; Piras et al., 2012).

Remains of murids are not very abundant in the deposit of Sa Cona Cave, however, features (e.g. marked hypsodonty, see Pl. 1, Fig. 10c) and dimensions of the cheek teeth (Tab. 6, Fig. 7) allow us to ascribe the remains to the most recent species *R. orthodon*.

Tab. 4 - Measurements (in mm), descriptive statistics of variables and morphological indices of the m1 of *Microtus* (*Tyrrhenicola*) *henseli* from Sa Cona Cave. V1, total length; V2, total width; V3, Length of posterior part of BRA2; V4, width of the neck; ACC, anteroconid complex; A/L, length of ACC against total length (V1-V3)/V1 *100; LAC, V4/V1; W/L, width against total length; n, number of measured elements.

n = 61	Min	Mean	Max
V1	2.82	3.45	4.05
V2	1.05	1.26	1.45
V3	1.36	1.70	1.87
V4	0.10	0.19	0.27
ACC	1.46	1.70	2.19
A/L	44.20	50.10	54.10
LAC	0.03	0.05	0.07
W/L	0.31	0.36	0.41

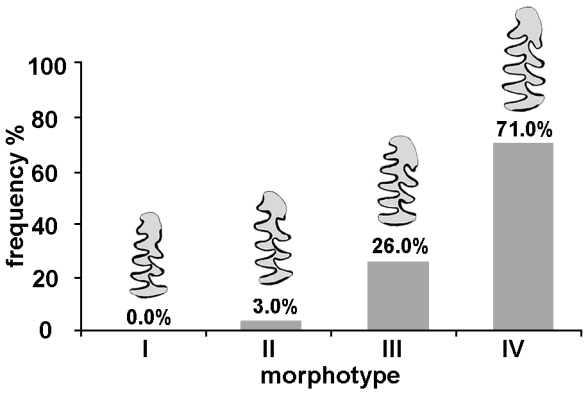

Fig. 5 - Histograms of the m1 morphotype frequencies of the Sa Cona Cave (level B) populations of *M.* (*Tyrrhenicola*) *henseli* (expressed as a percentage).

Ord. Eulipotyphla Waddell, Okada and Hasegawa, 1999
Fam. Soricidae Fischer, 1817
Gen. **"*Asoriculus*"** Kretzoi, 1959
"*Asoriculus*" *similis* (Hensel, 1855)
Pl. 1, Figs. 11-12

Material-MDLCA23750/1-5: five incomplete crania (Pl. 1, Fig. 11); MDLCA23751/1-14: 14 right hemimandibles (Pl. 1, Fig. 12); MDLCA23752/1-6: six left hemimandibles.

Remarks-Three formally described species and two undetermined species attributed to the family Soricidae are known from the Pliocene-Holocene of Sardinia (Abbazzi et al., 2004; Furió and Angelone, 2010). The oldest member of this family is reported from the Late Pliocene of Capo Mannu D1 and was attributed to the European mainland species *Asoriculus gibberodon*

Tab. 5 - Descriptive statistics of variables and morphological indices of the m1 of *M.* (*Tyrrhenicola*) *henseli* from different localities of Sardinia and *M.* (*Tyrrhenicola*) *sondaari* from Mt. Tuttavista Xg3 (data from Mezzabotta et al., 1995; Minieri et al., 1995; Turmes, 2003; Marcolini et al., 2005, 2006; Boldrini, 2008; Boldrini et al., 2010; Zoboli and Pillola 2016, 2017b). N, number of measured elements; V1, total length; A/L, length of ACC against total length; E, Early; L, Late; M, Middle; Pl., Pleistocene; Ho., Holocene.

	Age	V1				A/L			
		n	Min	Mean	Max	n	Min	Mean	Max
Sa Cona	L Pl.	61	2.82	3.45	4.05	61	44.2	50.1	54.1
Surconis	L Pl.-E Ho.	8	3.24	3.47	3.84	8	46.95	50.03	53.02
Su Concali	L Pl.	44	2.92	3.28	3.54	44	46.9	51.9	61.7
Grotta dei Fiori	M Pl.	38	2.47	3.05	3.54	38	39.87	46.21	54.05
Mt. Tuttavista Xg3	early M Pl.	36	2.32	2.72	3.05	36	39.67	44.13	48.4
Capo Figari II	M Pl.	6	2.9	3.27	3.6	6	47.4	48.55	50.6
Bonaria	M or L Pl.	39	2.9	3.32	3.7	39	46.1	51.07	54.5
Mt. San Giovanni	M Pl.	64	2.61	3.14	3.55	64	46.9	51.25	55.6
Cava Alabastro	M-?L Pl.	317	3.13	3.42	4.17	315	42	51	61
Dragonara-Medusa	L Pl.	51	2.7	3.34	3.73	50	47	51.5	56
Siniscola C	M-L Pl.	8	3.3	3.4	3.5	8	45.9	48.85	52.6
Siniscola E	M-L Pl.	4	2.9	3.25	3.5	4	48.1	49.89	51.7
Corbeddu	L Pl.-Ho.	18	2.9	3.26	3.5	18	49	52.39	55.3
Su Guanu	Ho.	24	3.1	3.54	4	24	49.2	51.96	54.6
MTV X3	M or L Pl.	92	2.3	2.72	3.07	92	36.84	45.27	60.73
MTV IX3	M or L Pl.	33	2.65	2.99	3.42	33	35.09	47.77	53.27
MTV III1	M or L Pl.	60	3	3.36	3.89	60	45.27	49.7	53.66
MTV IV14	M or L Pl.	169	3	3.36	3.93	169	46.01	50.68	65.02
MTV IV5	M or L Pl.	13	2.99	3.34	3.59	13	47.21	50.34	54.54
MTV VI6	L Pl.	87	2.95	3.32	3.77	87	36.6	51.42	59.49
MTV VII2	L Pl.	25	3.07	3.35	3.71	25	48.29	51.38	54.45

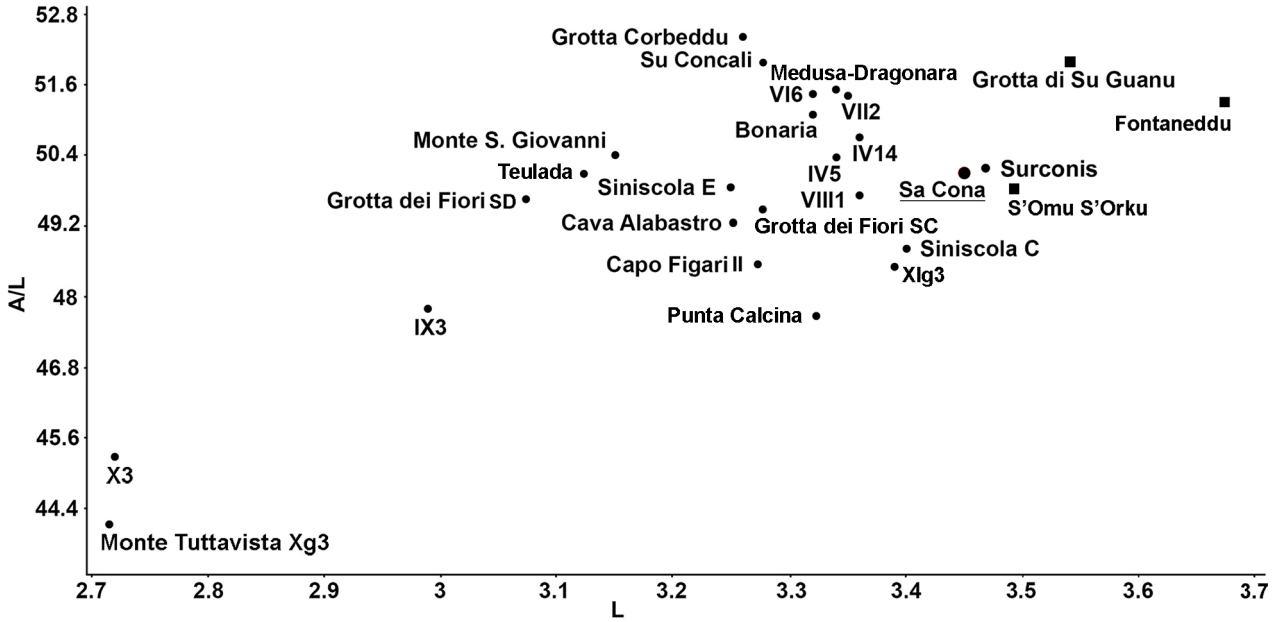

Fig. 6 - A/L (length of ACC against total length (V1-V3)/V1 *100) against L (total lenght) of m1 of *Microtus (Tyrrhenicola)* spp. from various localities of Sardinia. Dots: early Middle Pleistocene-Late Pleistocene; squares: Early Holocene (pre-Mesolitic). Monte Tuttavista Xg3 is the type locality of *M. (Tyrrhenicola) sondaari*. Data from Mezzabotta et al., 1995; Minieri et al., 1995; Marcolini et al., 2005, 2006; Boldrini, 2008; Boldrini et al., 2010; Palombo et al., 2017b; Zoboli and Pillola, 2016, 2017b.

Tab. 6 - Measurements (in mm) of the first cheek teeth of *Rhagamys orthodon* from Sa Cona Cave. L, length; W, width; n, number of measured elements.

		Min	Mean	Max
M1	L	2.58	2.72	2.85
n=8	W	1.69	1.82	1.92
m1	L	2.35	2.59	2.65
n=15	W	1.53	1.69	1.76

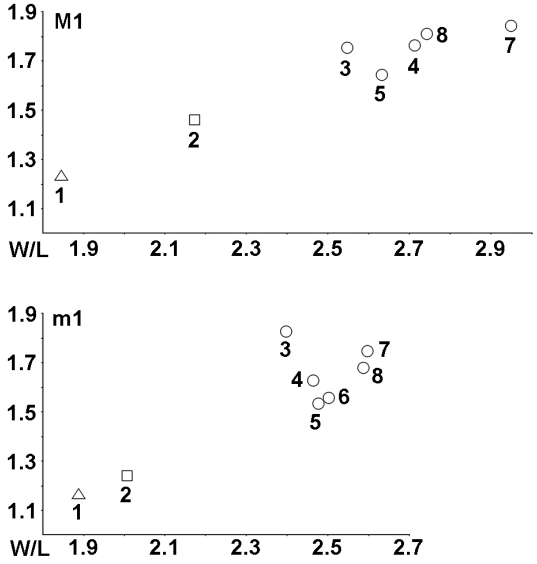

Fig. 7 - Width (W, in ordinate) against length (L, in abscissa) of the first cheek teeth of *Rhagapodemus azzarolii* (triangles), *Rhagapodemus minor* (squares) and *Rhagamys orthodon* (circles) from various localities of Sardinia and Corsica: 1, Mandriola (type locality of *R. azzarolii*); 2, Capo Figari (type locality of *R. minor*); 3, Is Oreris; 4, Corte; 5, Su Concali; 6, Surconis; 7, Tramariglio; 8, Sa Cona Cave. Data from Brandy, 1978; Gliozzi et al., 1984; Angelone and Kotsakis, 2001; Zoboli and Pillola, 2016, 2017b.

(Petényi, 1864; Furió and Angelone, 2010). Different endemic taxa that probably evolved from *A. gibberodon* of Capo Mannu D1 in an insular context during the Quaternary have been reported from the Sardinia-Corsica Massif: "*Asoriculus*" *corsicanus* (Bate, 1945), "*Asoriculus*" *similis* (Hensel, 1855), "*Nesiotites*" (= "*Asoriculus*") sp. 1 (bigger and recent form from Mt. Tuttavista) and "*Nesiotites*" (= "*Asoriculus*") sp. 2 (smaller and oldest form from Mt. Tuttavista). The large sized species "*Asoriculus*" *similis* from the Late Pleistocene-Early Holocene is the most common taxon in the Sardinian fossil record. Bate (1945) included all shrews from Corsica, Sardinia and Balearic Islands in the genus *Nesiotites*, but currently this taxon is generally used only for the Balearic species (Rofes et al., 2012; Bover et al., 2014; Palombo, 2018 and references therein). In recent works, the Corso-Sardinian shrews are either referred to "*Nesiotites*" (Abbazzi et al., 2004; Furió and Angelone, 2010) or *Asoriculus* (Rofes et al., 2012). A revision of the Sardinian material is needed and the shrews from this island could perhaps be assigned to a new endemic genus (Anglelone C., personal communication to D.Z., 2018).

The dentognathic remains collected at Sa Cona Cave allowed us to take several linear measurements (Tab. 7). Despite further comparisons with samples from other Sardinian localities are necessary, the available data suggest the presence of the largest and most recent fossil shrew of Sardinia, here provisionally indicated as "*Asoriculus*" *similis*.

5. DISCUSSION AND CONCLUSIONS

Despite the fact that fossil remains of Quaternary mammals have been reported from many localities of Sardinia, most studies on mammals and mammalian assemblages closely focus on very rich deposits (e.g. Mt. Tuttavista, Dragonara-Medusa Cave, Corbeddu Cave) or regard specific taxa or insular lineages (e.g. Malatesta,

Tab. 7 - Measurements (in mm) of the teeth of *"Asoriculus" similis* from Sa Cona Cave. Par, parameters; PE, length of the posterior emargination; LL, lingual length; BL, buccal length; AW, anterior width; PW, posterior width; L, length; W, width; TRW, trigonid width, TAW, talonid width; n, number of measured elements.

Element	n	Par	Min	Mean	Max
	8	PE	1.34	1.50	1.63
P4	8	LL	1.46	1.62	1.80
	8	BL	2.22	2.32	2.40
	8	W	1.80	1.89	1.94
	8	PE	1.63	1.69	1.78
	8	LL	1.98	2.08	2.14
M1	8	BL	2.00	2.10	2.21
	8	AW	1.91	1.97	2.03
	8	PW	2.14	2.29	2.40
	6	PE	1.42	1.51	1.58
	6	LL	1.73	1.77	1.84
M2	6	BL	1.74	1.76	1.80
	6	AW	1.90	1.98	2.13
	6	PW	2.08	2.14	2.20
M3	4	L	1.60	1.70	1.78
	4	W	0.78	0.87	0.94
I inf.	12	L	4.45	4.72	6.97
	19	TRW	1.06	1.18	1.28
m1	19	TAW	1.19	1.30	1.48
	19	L	2.05	2.20	2.34
	17	TRW	1.02	1.13	1.29
m2	17	TAW	1.07	1.20	1.34
	17	L	1.74	1.89	2.06
m3	14	W	0.84	0.91	1.00
	14	L	1.28	1.43	1.56

1970, 1977; Caloi and Malatesta, 1974; Malatesta and Willemsen, 1986; Willemsen and Malatesta, 1987; Klein Hofmeijer, 1996; Marcolini et al., 2005; Lyras et al., 2006; Van der Made and Palombo, 2006; Willemsen, 2006; Angelone et al., 2008; Boldrini, 2008; Piras et al., 2012; Madurell-Malapeira et al., 2015; Melis et al., 2016; Rook et al., 2018). However, studies on new sedimentary sequences localised in poorly known areas, are equally important to provide new data maybe useful to correlate faunal assemblages of different localities.

Among the taxa reported in the sedimentary sequence of Sa Cona Cave (*C. sardous*, *P. cazioti*, *P. sardus*, *M.* (*Tyrrhenicola*) *henseli*, *R. orthodon*, "*A.*" *similis*), the large mammals are represented by few and generally incomplete bones, and no dentognathic remains were collected, while the small mammals are very abundant. The fractures on the crania of small mammals (Pl. 1, Figs. 8, 11, 13) suggest that their accumulation was partially due to the hunting activity of birds of prey as observed in similar contexts (e.g. Andrews, 1990; Robert and Vigne, 2002; Pavia and Bedetti, 2003).

The described mammals have been previously documented in other localities of the Sardinia-Corsica Massif ranging in age from the late Middle Pleistocene to the beginning of the Holocene. The presence of *Microtus* (*Tyrrhenicola*), *Praemegaceros* and *Cynotherium* infers the "*Microtus* (*Tyrrhenicola*)" Faunal Complex and excludes the oldest "*Nesogoral*" Fauna Complex (Palombo, 2009). Despite further detailed analyses on the m1 of *M.* (*Tyrrhenicola*) *henseli* are necessary (e.g. SQD index), the preliminary morpho-dimensional data show a predominance of advanced morphotypes and suggest a probably Late Pleistocene age. Moreover, the absence of domestic fauna and taxa introduced by human activity seem to infer a pre-Mesolitic age (see discussion in Palombo et al., 2017b). In conclusion, Sa Cona Cave represents one of the most rich Late Pleistocene mammal deposits reported from the extreme south-western Sardinia.

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Pl. 1-Pleistocene mammals from Sa Cona Cave (Teulada).
1-2) *Cynotherium sardous* Studiati, 1857; 1) incomplete right humerus (MDLCA23708) in anterior (a), medial (b), posterior (c) and lateral view (d); 2) incomplete left ulna (MDLCA23709) in anterior (a), medial (b), posterior (c) and lateral view (d).
3-7) *Praemegaceros cazioti* (Depéret, 1897); 3) incomplete right humerus (MDLCA23714) in anterior (a), lateral (b) and posterior view (c); 4) left cuneiform (MDLCA23715) in anterior (a) and lateral view (b); 5) first anterior phalanx (MDLCA23717) in dorsal (a) and axial view (b); 6) second anterior phalanx (MDLCA23718) in dorsal (a) and abaxial view (b); 7) third anterior phalanx (MDLCA23719/1) in dorsal (a) and abaxial view (b).
8-9) *Microtus* (*Tyrrhenicola*) *henseli* (Major, 1905); 8) incomplete cranium (MDLCA23740/1) in dorsal (a) and lateral left view (b); 9) left hemimandible (MDLCA23742/1) in labial (a), occlusal (b) and lingual view (c), and detail of m1-m3 in occlusal view (d).
10) *Rhagamys orthodon* (Hensel, 1856), incomplete right hemimandible (MDLCA23748/1) in labial (a), occlusal (b) and lingual view (c), and detail of m1-m3 in occlusal view (d).
11-12) "*Asoriculus*" *similis* (Hensel, 1855); 11) incomplete cranium (MDLCA23750/1) in dorsal (a), ventral (b) and lateral left view (c); 12) right hemimandible (MDLCA23751/1) in labial (a), occlusal (b) and lingual view (c).
13-15) *Prolagus sardus* (Wagner, 1829); 13) incomplete cranium (MDLCA23720/1) in dorsal view; 14) left p3 (MDLCA23724/1) in occlusal view; 15) incomplete right hemimandible (MDLCA23723/1) in labial view.
Scale bar for 1-3 = 3 cm; scale bar for 4-7 = 2 cm; scale bar for 8, 9a-c, 10a-c, 11 and 12 = 1 cm; scale bar for 9d and 10d = 2.5 mm; scale bar for 13 and 15 = 1.5 cm; scale bar for 14 = 1.5 mm.