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EARLY MIOCENE INSULAR VERTEBRATES FROM LAERRU (SARDINIA, ITALY): PRELIMINARY NOTE

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Abstract. A new vertebrate assemblage was discovered in an Early Miocene lacustrine deposit near the village of Laerru (northern Sardinia, Italy). The assemblage is composed by mammals, reptiles and a bird. The mammals are represented by three ruminants (cf. *Sardomeryx oschiriensis*, Pecora indet. small size and Pecora indet. very small size) and one dormouse (*Peridyromys* aff. *murinus*) while reptiles are represented by turtles (Trionychidae?) and crocodiles (cf. *Diplocynodon* sp.). A bird bone fragment is also reported and referred to *Palaeortyx* cf. *brevipes* (Galliformes). The assemblage can be related to the "Oschiri fauna", one of the oldest endemic insular fauna known in the Mediterranean. The age of the Laerru vertebrates is early-middle Burdigalian, between 18.8 and 18.3 Ma, corresponding to the mammal unit of the main land MN3. The predominance of ruminants confirms the good capacity of these mammals to colonize insular environments.

Introduction

In the early 1990ies some vertebrate bone fragments were discovered near the village of Laerru (Anglona subregion, northwestern Sardinia, Fig. 1) by the student Leonarda Cascioni. The fossils were collected from an outcrop of lacustrine deposit of the lower part of the Perfugas Formation (Sowerbutts 2000). Furthermore, during the year 2005 a team of the University of Cagliari found there several teeth and bone fragments and took a few cubic meters of sediment for further investigation. Within these sediments, other more relevant palaeontological materials were identified (Zoboli 2013).

Geological setting

Lacustrine deposits ("Formazione Lacustre" or "Lacustre" Auct., Vardabasso 1962; Cherchi 1985), often associated with conglomerates and volcanic products, have been localized in various Sardinian subregions: Nurra, Anglona, Barigadu, Sarcidano, Arburese (Vardabasso 1962). These continental sediments represent the first filling of the Sardinian Oligo-Miocene extensional basins (Cherchi 1985; Faccenna et al. 2002; Oudet et al. 2010).

The tectono-stratigraphic history of the Anglona subregion is complex. A complex facies architecture involving clastic, carbonate and volcanic rocks was generated during a multiphase rifting (Sowerbutts 2000). The continental lacustrine deposits of this subregion have been included into the lower part of the Perfugas Formation (Sowerbutts 2000) (Fig. 2). This formation is generally represented by finely bedded limestones, marlstones, cherts and tuffs interpreted as lacustrine deposits. The presence of petrified tree trunks with growing up concentric algal coats denote a change from continental to lagoonal environment ("petrified forest of Carrucana", Martis, Fig. 3). Occasionally, these trunks are still found in their lifetime position. In the eastern sectors, the Perfugas Formation comprises finely laminated limestones and cherts with abundant oogones, algal oncolites, monospecific gastropods plus thin mass flow deposits. These rocks are interpreted as the deposits of a quiet, carbonate-producing, deeper lacustrine environment (Sowerbutts 2000). The age of this lacustrine deposit is

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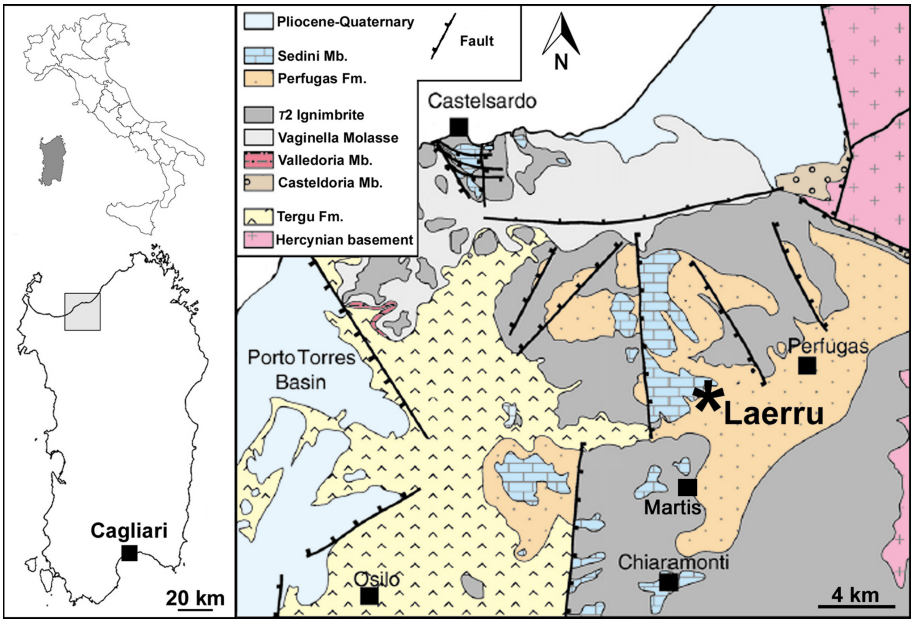


Fig. 1 - Geological map of the Anglona area and location of the village of Laerru. Modified from Oudet et al. (2010).

early-middle Burdigalian, between 18.83 +/- 0.13 and 18.29 +/- 0.13 Ma (age of the underlying and overlying volcanic marker, Oudet et al. 2010).

The Laerru fossiliferous outcrop is represented by an epiclastic pomiceus-cineritic level underlying selciferous carbonates in the lower part of the Perfugas Formation. This level is divisible into three different layers or units (A, B and C shown in Fig. 4). The majority of fossils yielded by the top of the lower layer A.

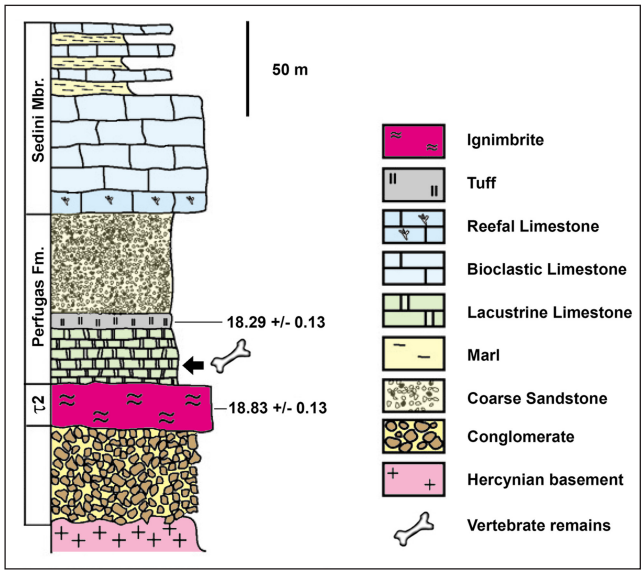


Fig. 2 - Stratigraphic sketch of the Miocene deposits in the Perfugas and Laerru area and approximate level with vertebrate remains (modified from Oudet et al. 2010).

Materials and methods

We used an air-engraving pen (3400BPM) in order to prepare the macrovertebrate remains (Fig. 5). Afterwards, the most fragile samples were consolidated using Paraloid B-72. Subsequently, we measured the macrovertebrate fossils with a Rupac 0-150 mm/0.01 ABS digital caliper. Photographs and measurements of the microvertebrate remains were performed using a Nikon D5000 digital camera mounted on a Leica MS5 stereomicroscope and an Environmental Scanning Electron Microscope (ESEM QUANTA 200, FEI).

The nomenclature of ruminant teeth follows Bärmann & Rössner (2011). The measurements (in mm) taken according to Van der Made (2012) and Wang et al. (2015) are indicated with the following abbreviations: Hm: height at the metaconid, He: height at the entoconid, DAP: antero-posterior diameter or length of a tooth, DAPb: DAP at the base of the crown of a tooth, DTa: transverse diameter of the anterior lobe of a tooth or width at the 1st lobe, DTp: transverse diameter of the posterior lobe of a tooth or width of a 2nd lobe, DTpp: transverse diameter of the 3rd lobe (in M_3 and DP_4) (Fig. 6). The nomenclature and measurements methods of the Gliridae cheek teeth follow Daams (1981); measurements are given in units of 0.1 mm.

The studied material is stored at the Museo Sardo di Geologia e Paleontologia Domenico Lovisato (acronym MDLCA) of the Dipartimento di Scienze Chimiche e Geologiche of the University of Cagliari.

The vertebrate assemblage

The following vertebrates are reported herein: Reptilia: cf. *Diplocynodon* sp., Chelonii indet. (Trionychidae?); Aves: *Palaeortyx* cf. *brevipes*; Mammalia: cf. *Sardomeryx oschiriensis*, Pecora indet. small size, Pecora indet. very small size, *Peridyromys* aff. *murinus*.

Reptilia

Four tiny isolated and incomplete teeth

Fig. 3 - Concentric algal coats grown up around tree trunks, "petrified forest of Carrucana" (Martis).

(MDLCA 14114a-d) are referable to a small crocodilian (Pl. 1, fig. 2). The crown length of the biggest tooth is 0.9 cm and its bucco-labial diameter is 0.3 cm. The shapes are conical, not slender and generally laterally compressed. Two smooth carinae are present on the posterior and anterior parts of the teeth. Ridges and marked striations are not present in the enamel. In terms of shapes and dimensions, the Laerru crocodilian remains are very similar to the small alligatoroid *Diplocynodon* Pomel, 1847, a typical faunal element in the Paleocene-Middle Miocene of Europe (Antunes 2003; Martin & Gross 2011). The specimen of Laerru represents the most ancient crocodile reported in the fossil record of Sardinia, and at the moment, it is assigned to cf. *Diplocynodon* sp. In addition, an incomplete right humerus (MDLCA 14115, Pl. 1, fig. 1) could belong to a crocodile or a turtle.

An ornamented-surface bone fragment (MDLCA 14116, Pl. 1, fig. 3) could be associated to a turtle carapace element. The ornamentation of the bone is similar to the one seen in Trionychidae. "Softshell turtles" were reported in Sardinia from Eocene to Upper Miocene (Portis 1901; Comaschi Caria 1958; Kotsakis 1985).

Aves

A proximal part of a right humerus (MDLCA 14113a) is the only bone fragment certainly ascribed to a small bird (Pl. 1, fig. 4). The humerus is characterized by a deep fossa pneumotricipitalis dorsalis and a deep fossa pneumotricipitalis ventralis. The general morphology is referable to *Palaeortyx* Milne-Edwards, 1869 (Galliformes, Phasianidae). In addition, its proximal width (8.8 mm) is comparable to the Upper Oligocene-Middle Miocene species *Palaeortyx brevipes* Milne-Edwards, 1869 from France and Germany (Göhlich & Mourer-Chauviré 2005). Pending further data, we refer the bird of Laerru to *Palaeortyx* cf. *brevipes*. The Burdigalian Phasianidae of Laerru represents the most ancient bird reported in the fossil record of Sardinia.

Mammalia

Ruminants are the most represented mammal group of least three types of size: medium, small and very small.

Pecora medium size (cf. *Sardomeryx oschiriensis*) - The fossils of the biggest ruminant are the most

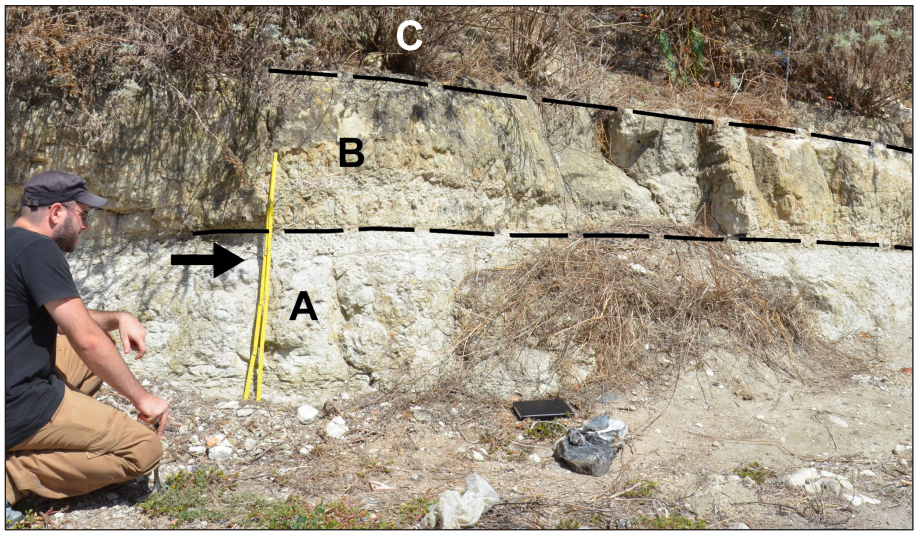


Fig. 4 - Epiclastic level where the vertebrate fossils has been collected. The level has been divided into three layer A, B and C. The majority of fossils has been provided by the top of layer A (black arrow).

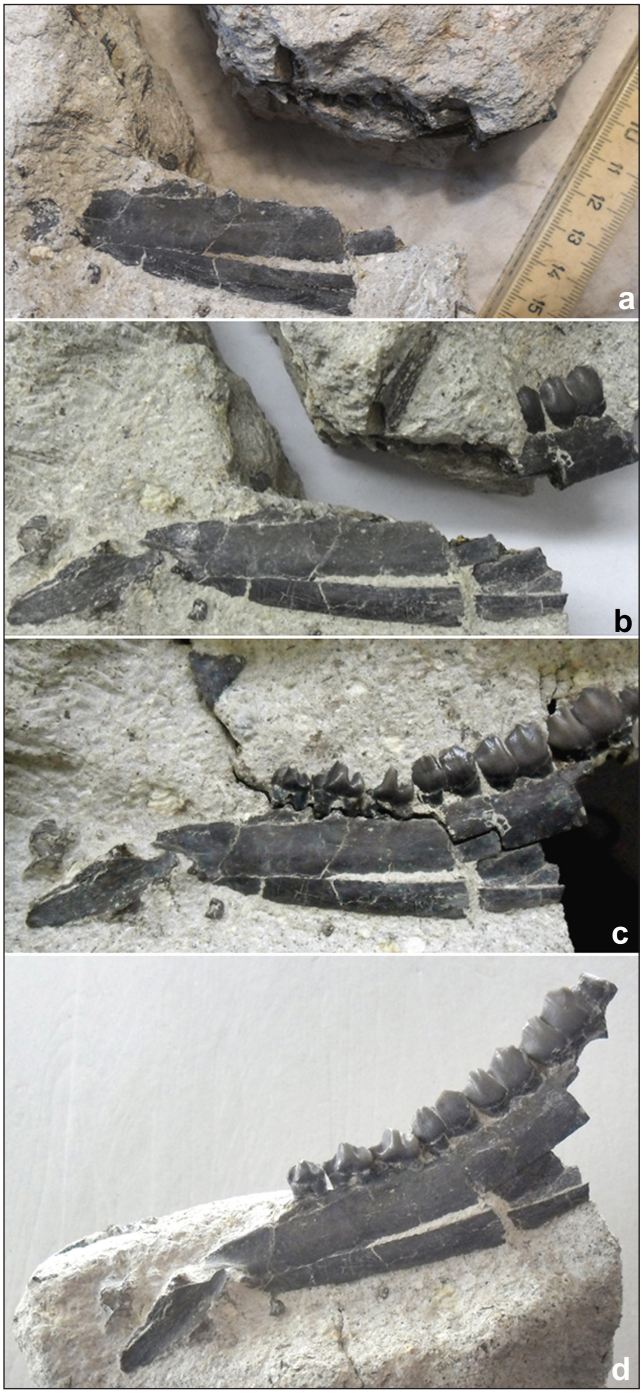


Fig. 5 - Preparation and restoration phases of a ruminant mandible (MDLCA 14118).

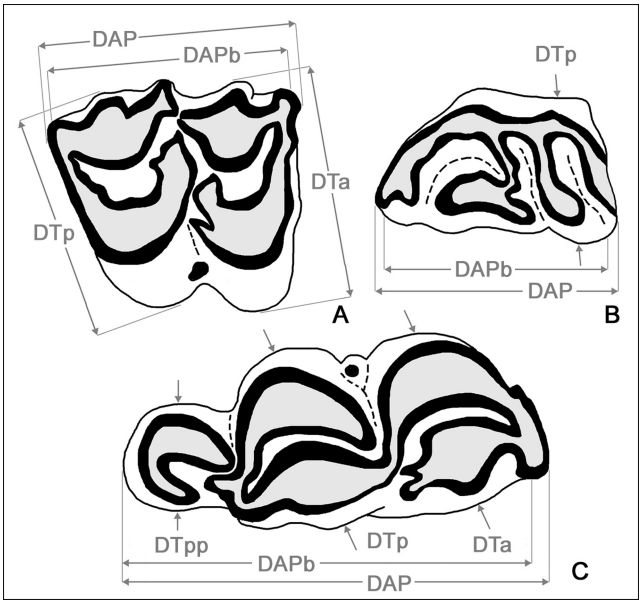


Fig. 6 - Sketch of measurements of ruminant teeth. A: upper molar, B: lower premolar, C: lower molar (modified from Van der Made 2012).

abundant, several teeth and poorly preserved cranial and post-cranial bones were found. The upper molars are subrectangular and have relatively high crowns. The parastyles and mesostyles are prominent, the paraconi have very strong labial ribs and the metaconi have flat labial faces. The postmetaconulecrista of M^1 has a lingual bifurcation. The internal postprotocrista and the premetaconulecrista do not reach the buccal walls, and the external protopostcrista (or "pli-protoconal") is not present. Lingual cingula and tiny entostyle-like structure may be present. The upper premolars have many well-developed cingula, with the exception of P^4. The anterior styles are well-developed. A peculiar sabre-like upper canine (Pl. 1, fig. 11) is referred to a male individual. This tooth is slightly curved backwards and its cross-section changes from proximal to distal, from drop-shaped to triangular. A strong wear streak is visible in the relatively flat lingual side. A similar morphology is also present in another left canine (Pl. 1, fig. 12) probably belonged to a female individual given its small dimensions. The lower molars have fine-striated enamel, a relatively flat lingual face and not well-marked lingual ribs. The external postprotocristid (or "*Palaeomeryx*-fold") and the external postmetacristid are not present (Fig. 7). Low anterior ectostylids are present and there are no trace of posterior ectostylids. The P_4 is high, short and wide compared to the other premolars, presenting a faint labial incision. The antero-lingually directed anterior conid is simple and not bifurcated. The mesolingual and the posterolingual conids are parallel and postero-lingually directed. The posterior stylid and the posterior valley are weak-developed. The P_3 (Pl. 1, fig. 8) and P_2 have the same morphology of P_4 but they are relatively elongated and narrow, and the posterior stylids are lacking. The P_1 was present, as attested by the oc-

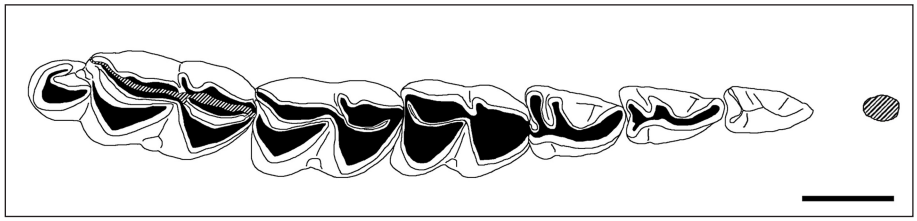


Fig. 7 - Occlusal view of the lower dentition (P_2-M_3 and position of P_1) of cf. *Sardomeryx oschiriensis* (MDLCA 14118) from Laerru. Scale bar: 1 cm.

currence of its alveola near the P_2. An isolated third right incisive is shovel-like and shows a lateral wear surface. In the preliminary morphological analysis of the upper teeth, this medium sized ruminant is similar to the Giraffoidea? *Sardomeryx oschiriensis* Van der Made, 2008 of the Oschiri basin. However, there are some morphologic differences, such as the fact that the Laerru ruminant is smaller than the type material of *S. oschiriensis* (Tab. 1). Pending a more comprehensive study, the medium size Pecora of Laerru is temporarily referred to cf. *Sardomeryx oschiriensis*.

Pecora indet. small size - A right upper molar, probably an M^3, attested the presence of a small size ruminant (Pl. 1, fig. 7). The tooth is incompletely preserved and shows protocone and metaconule. The protocone is slightly larger than the metaconule. There are no entostyle and external postprotocrista. The anterior cingulum is present. The tooth dimensions are close to those of the sample of *Pomelomeryx gracilis* (Pomel, 1853) from the Lower Miocene of Cetina de Aragón (Ginsburg et al., 1994). According to Rössner & Rummel (2001), the sample from Cetina de Aragón should be included in *Pomelomeryx boulangeri* (Pomel, 1853). The small sized ruminant of Laerru is probably a new insular taxon and it can be associated to the same forms of Oschiri ("*Amphitragulus*" sp.) (Van der Made 2008) and Sardara ("*Amphitragulus boulangeri*") (Comaschi Caria 1953). The poorly preserved remains of Laerru are temporarily reported to Pecora indet.

Upper dentition		P2	P3	P4	M1	M2	M3
MDLCA14130a-c	DAP	10.1	12.0	11.2			
	DAPb	9.5		10.0			
	DTp	9.1	13.1	13.6			
MDLCA14123	DAP				16.9	⩾17.1	
	DAPb				14.0	⩾14.0	
	DTa				15.9		
	DTp				16.9		
Lower dentition		p2	p3	p4	m1	m2	m3
MDLCA14127a	DAP		10.4				
	DAPb		8.8				
	DTp		5.5				
MDLCA14119	DAP					16.6	21.9
	DAPb					15.6	20.0
	DTa					11.1	11.1
	DTp					11.9	11.0
	DTpp						6.3
MDLCA14118	DAP	9.0	11.1	11.0	13.9	16.7	23.4
	DAPb	8.2	9.3	10.0	13.0	15.6	22.4
	DTa				10.5	12.0	12.0
	DTp	4.9	6.4	8.4	11.3	12.0	11.8
	DTpp						7.0

Tab. 1 - The measurements of the teeth of cf. *Sardomeryx oschiriensis* from Laerru.

Pecora indet. very small size - A very small ruminant is reported (Pl. 1, fig. 6). The only sample is represented by an incomplete left mandibular ramus with a complete and unworn DP_4. The tooth is elongate and shows three labial and three lingual conids. There are no trace of external postprotocristid (or "*Palaeomeryx*-fold") and external postmetacristid (or "*Dorcatherium*-fold"). The absence of "*Dorcatherium*-fold" excluding Tragulidae and almost all of Tragulina (Mennecart 2012). The "*Palaeomeryx*-fold" is variably present in some small-sized Miocene Pecora. *Hispanomeryx* does not have this fold but it appears in Europe in the Middle Miocene (MN6) (Sánchez et al. 2010). The Eurasian Moschidae *Micromeryx flourensianus* (recorded from the early Middle Miocene to the Late Miocene, MN5-MN9) shows the "*Palaeomeryx*-fold" in the DP_4 (Aiglstorfer et al. 2014; Wang et al. 2015). This fold is also present in two very small Pecora from the Lower Miocene of Europe: *Pomelomeryx gracilis* (MN1 to MN3) and *Lagomeryx parvulus* (MN3? to early MN6). *P. gracilis* has a bad-developed "*Palaeomeryx*-fold" in the DP_4, whereas in *L. parvulus* this fold is well-developed (Rössner 1999; Rössner & Rummel 2001). It is likely that the very small-sized ruminant of Laerru may be a new insular taxon probably related to the continental form *P. gracilis*. The measurements of the DP_4 are reported in Tab. 2.

Rodentia - Scarce micromammal remains were recorded. The sample is represented by generally well-preserved isolated teeth and a mandible fragment containing one tooth. This material is clearly attributable to Gliridae. The recorded M_{1-2}

		DAP	DTa	DTp	DTpp	Hm	He
MDLCA14136	dp4	8.0	2.5	3.0	3.5	3.0	3.1

Tab. 2 - The measurements of the DP_4 of the Pecora indet. very small size from Laerru.

show an anterolophid not separated from the protoconid. The anterolophid, metalophid and centrolophid meet at the metaconid. The mesolophid and posterolophid form a continuous U-shaped ridge. An extra ridge (posterotropid) is present in the posterior valley, while in the anterior valley the anterotropid is not present. The morphological characteristics of the teeth clearly designate the Late Oligocene - Middle Miocene genus *Peridyromys* Stehlin & Schaub 1951. The presence of posteroprotid and the absence of anteroprotid are features showed in the morphotype 2 recognized by Daams (1981). Bruijn & Rümke (1974) described *Myomimus* sp. of the Lower Miocene of Oschiri. Since the lower molars of this species are two-rooted, these teeth have been assigned to *Peridyromys* aff. *murinus* by Daams (1981). The Oschiri specimens differ from the continental *P. murinus* only by their larger size and by the high frequency of fused centrolophs in the upper molars. According to Daams, the variation in the relative length of the centrolophs in the M^{1-2} of the insular *Peridyromys* of Oschiri suggests a close relationship with *P. murinus* from France. The sample of Laerru is larger than the average of the continental record of *Peridyromys murinus* and is more similar to the biggest Oschiri sample (Tab. 3). The material of Laerru is also reported to *Peridyromys* aff. *murinus*.

		Length			Width		
Laerru	N	min.	mean	max.	min.	mean	max.
m1	1		11.3			11.1	
m2	2	11.0	11.8	12.5	10.5	11.3	12.0
Oschiri							
m1	4	11.1	11.4	11.7	9.8	10.6	11.1
m2	6/7	11.5	12.0	12.5	10.5	11.0	11.4

Tab. 3 - Length and width synthetic measurements for the lower molars of *Peridyromys* aff. *murinus* from Laerru and Oschiri (data from Bruijn & Rümke 1974).

Discussion and conclusions

The "Oschiri fauna" is one of the oldest known endemic insular fauna of the Mediterranean (Bruijn & Rümke 1974; Van der Made 2008). In literature, this fauna is reported in two Sardinian localities: Oschiri and Sardara (Comaschi Caria 1953; Bruijn & Rümke 1974; Van der Made 2008). In the early 20th century, the first vertebrate fossils were found in Oschiri, such as two maxilla fragments of ruminant. These fossils, stored in the Natural History Museum of London, were studied by Van der Made (2008) and assigned to the new taxon *Sardomeryx oschiriensis* (Giraffoidea?). In addition, Comaschi Caria (1953) reported the first terrestrial mammal fossil of the Lower Miocene of Sardinia. This fossil, found in the marine marls of Sardara (northern Campidano), consists of an incomplete left mandible with P_4-M_3 assigned to the small moschids (or Palaeomerycidae) *Amphitragulus* (=*Pomelomeryx*) *boulangeri*. The ruminant from Sardara has been briefly and marginally described by Comaschi Caria, and probably represents a new insular taxon.

In the early 1970ies, a team from Utrecht collected many mammal bones and teeth from a small exposure of lacustrine clay in a road cut near the village of Oschiri (Bruijn & Rümke 1974). The collected material allowed to describe three Eulipotyphla: *Crocidosorex* (=*Oligosorex*) *antiquus*, *Geotrypus*

PLATE 1

Burdigalian vertebrate remains of Laerru (Sardinia, Italy).

Fig. 1 - Crocodylia/Chelonii? MDLCA 14115 - incomplete right humerus in dorsal (a) and ventral view (b).

Fig. 2 - cf. *Diplocynodon* sp., MDLCA 14114b - isolated tooth in lingual (a), buccal (b) and lateral view (c).

Fig. 3 - Trionychidae? MDLCA 14116, possible fragment of carapace.

Fig. 4 - *Palaeortyx* cf. *brevipes*, MDLCA 14113a, incomplete right humerus (plaster cast).

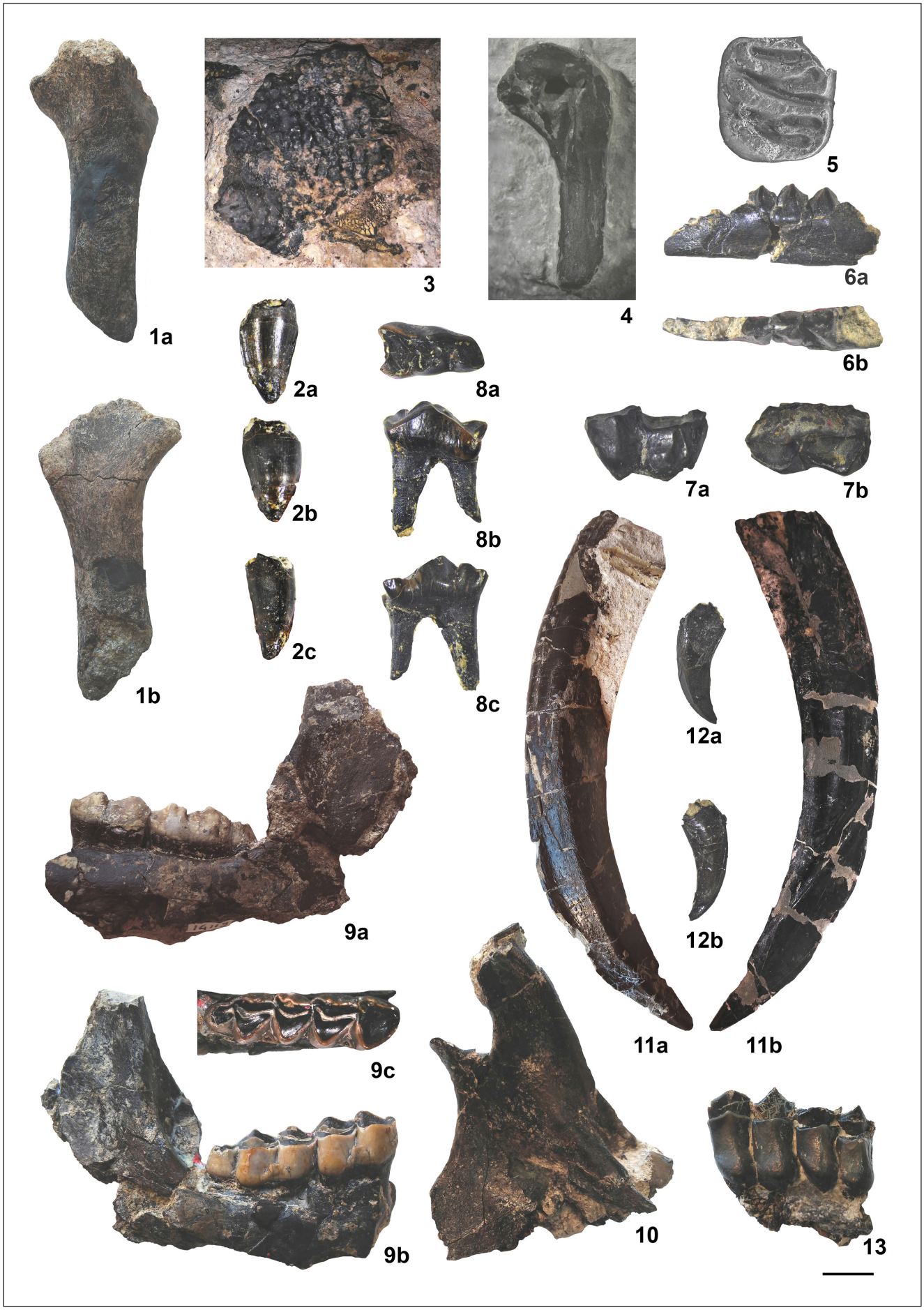
Fig. 5 - *Peridyromys* aff. *murinus*, MDLCA 14142a, left M_2 in occlusal view.

Fig. 6 - Pecora indet. very small size, MDLCA 14136, left mandible with DP_4 in buccal (a) and occlusal view (b).

Fig. 7 - Pecora indet. small size, MDLCA 14135a, incomplete right upper molar (M^3?) in lingual (a) and occlusal view (b).

Figs 8-13 - cf. *Sardomeryx oschiriensis*, 8) MDLCA 14127a, left P_3 in occlusal (a), buccal (b) and lingual view (c); 9) MDLCA 14119, incomplete right mandible with M_{2-3} in lingual (a), buccal (b) and occlusal view (c); 10) MDLCA 14120, incomplete right mandible with M_3 fragment, buccal view; 11) MDLCA 14131, male left upper canine in buccal (a) and lingual view (b); 12) MDLCA 14132, probably female left upper canine in buccal (a) and lingual view (b); 13) MDLCA 14123, right M^{1-2} in lingual view.

Scale bar: fig. 1 = 2 cm; figs 2, 4, 6-8 = 0.5 cm; fig. 5 = 0.5 mm; figs 3, 9-13 = 1 cm.


1a
3
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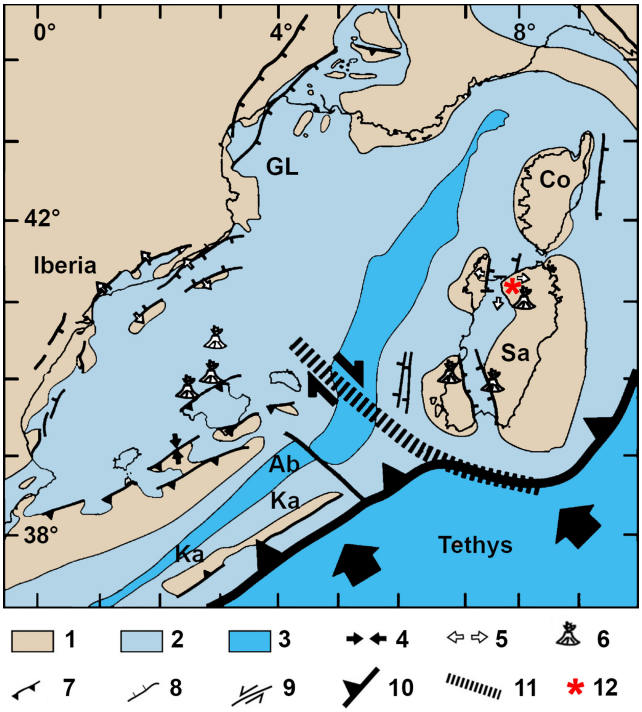

Fig. 8 - Palaeogeographic and syn-kinematic sketch of the North-West Mediterranean Basin during the early-middle Burdigalian. GL: Golfe du Lion, Co: Corsica, Sa: Sardinia, Ka: Kabylies, Ab: Algerian basin, 1: emerged land, 2: shallow and deep marine deposits, 3: basins area floored by oceanic crust, 4: active compression, 5: active extension, 6: active volcanism, 7: thrust fault, 8: normal fault, 9: strike-sleep fault, 10: oceanic subduction, 11: transform fault zone, 12: Anglona subregion (simplified from Oudet et al. 2010).

oschiriensis, *Nuragha schreuderae*, and six Rodentia: *Sardomys dawsonae*, *Sardomys antoniettae*, *Pireddamys rayi*, *Myomimus* sp. (=*Peridyromys* aff. *murinus*), *Microdyromys* aff. *koenigswaldi* and *Glis major*. In addition, some macromammal bones have been collected. Afterwards, this material has been studied by Van der Made (2008), who reported the following taxa: *Hyotherium*? *insularis*, *Bachitherium sardus*, "*Amphitragulus*" (=*Pomelomeryx*) sp., Moschidae? indet., *Sardomeryx oschiriensis*, and possibly a perissodactyl. Furthermore, some amphibians and reptiles from Oschiri have been reported by Venczel & Sanchíz (2006): *Salamandrina* sp., *Discoglossus* sp., *Lacerta* sp., Gekkonidae indet., Scincidae indet., *Ophisaurus* cf. *fejfari*, *Blanus gracilis*, *Eoanilius oligocenicus*, Natricinae indet. and *Vipera* sp. 'aspis group'.

Various authors have inferred the age and the origin of the "Oschiri fauna" and its possible relationship with the continental ancestral forms: Bruijn & Rümke 1974, Azzaroli & Guazzone 1979, Kotsakis & Palombo 1979, Esu & Kotsakis 1983, Kotsakis 1984, Van der Made 1999, Van der Made 2008. The advanced endemism in Ctenodactylidae and the contemporary presence of taxa very similar to the main land forms suggest different colonizing phases of Sardinia. According to Kotsakis (1984), a Late Oligocene origin for the Sardinian Ctenodactylidae is proposed. Sorcidae, Talpidae, Gliridae and Artiodactyla are not very different from the main land forms and indicate a more recent immigration, not less than 20 Ma. The palaeogeographical context suggests that the latest additions to the association arrived in Sardinia during European Land Mammal Unit MN3, which is coincident with the early Burdigalian marine regression, around 20 Ma ago (Van der Made 2008). The age and the faunal assemblage of Laerru seems to confirm this scenario. A palaeogeographic reconstruction of the North-West Mediterranean Basin during the early-middle Burdigalian is reported in Fig. 8.

The ability to colonize island environments by ruminants and rodents (and other micromammals) is further confirmed by the Laerru association. These groups are good colonizer of islands and we have some examples of this attitude in the Sardinian and other insular fossil records (e.g. Balearic Islands, Crete, Gargano palaeo-isla, "Tusco-Sardinian palaeobioprovince"). The oldest Sardinian assemblage is represented by the already discussed "Oschiri Fauna" (Upper Oligocene - Lower Miocene). The "Tusco-Sardinian palaeobioprovince" existed during the Late Miocene (Abbazzi et al. 2008; Casanovas-Vilar et al. 2011) and finally, during the Plio-Pleistocene, various "faunal-complexes" are recognized (Palombo 2006, 2009). Furthermore, a predominance of ruminants and micomammals have been reported in all of these palaeo-insular ecosystems. These data confirm the fact that, independently of the initial faunal assemblages or geological context, the insular palaeo-ecologies result in similar features.

An updated list of the continental vertebrate taxa of the Lower Miocene of Sardinia is reported in the Tab. 4.

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TAXA	Oschiri 1	Oschiri 2	Laerru	Sardara
Salamandrina sp.	x			
Discoglossus sp.	x			
Lacerta sp.	x			
Gekkonidae indet.	x			
Scincidae indet.	x			
Ophisaurus cf. *fejfari*	x			
Blanus gracilis	x			
Eoanilius oligocenicus	x			
Natricinae indet.	x			
Vipera sp. 'aspis group'	x			
cf. *Diplocynodon* sp.			x	
Chelonii indet. (Trionychidae?)			x	
Palaeortyx cf. *brevipes*			x	
Oligosorex antiquus	x			
Geotrypus oschiriensis	x			
Nuragha schreuderae	x			
Sardomys dawsonae	x			
Sardomys antoniettae	x			
Pireddamys rayi	x			
Peridyromys aff. *murinus*	x		x	
Microdyromys aff. *koenigswaldi*	x			
Glis major	x			
Hyotherium ? insularis	x			
Bachitherium sardus	x			
"*Pomelomeryx* sp."	x			
"*Pomelomeryx boulangeri*"				x
Moschidae? indet. small size	x			
Sardomeryx oschiriensis	x?	x		
cf. *Sardomeryx oschiriensis*			x	
Pecora indet. small size			x	
Pecora indet. very small size			x	

Tab. 4 - Continental vertebrate taxa reported in the Early Miocene of Sardinia. Data from: Comaschi Caria (1953), Bruijn & Rümke (1974), Venczel & Sanchíz (2006) and Van der Made (2008).

References

Abbazzi L., Delfino M., Gallai G., Trebini L. & Rook L. (2008) - New data on the Vertebrate assemblage of Fiume Santo (North-West Sardinia, Italy), and overview on the late Miocene Tusco-Sardinian palaeobioprovince. *Palaeontology.*, 51: 425-451.

Aiglstorfer M., Rössner G.E. & Böhme M. (2014) - *Dorcatherium naui* and pecoran ruminants from the late Middle Miocene Gratkorn locality (Austria). *Palaeobiodiv. palaeoenv.*, 94: 83-123.

Antunes M.T. (2003) - Lower Paleogene crocodilians from Silveirinha, Portugal. *Palaeovertebrata*, 32: 1-26.

Azzaroli A. & Guazzone G. (1979) - Terrestrial mammals and land connections in the Mediterranean before and during the Messinian. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 29: 155-167.

Bärmann E.V. & Rössner G.E. (2011) - Dental nomenclature in Ruminantia: Towards a standard terminological framework. *Mammal. Biol.*, 76: 762-768.

Bruijn de H. & Rümke C.G. (1974) - On a peculiar mammalian association from the Miocene of Oschiri (Sardinia). *Proc. Kon. Ned. Akad. Wetensch.*, 77: 46-79.

Casanovas-Vilar I., van Dam J. A., Trebini L. & Rook L. (2011) - The rodents from the Late Miocene *Oreopithecus*-bearing site of Fiume Santo (Sardinia, Italy). *Géobios*, 44: 173-187.

Cherchi A. (1985) - Oligo-Miocene Basin. "19th European Micropaleontological Colloquium-Guide Book", AGIP Sardina, October 1-10, 1985, 87-101.

Comaschi Caria I. (1953) - L' *Amphitragulus boulangeri* Pomel, primo mammifero terrestre segnalato nel Miocene della Sardegna. *Riv. Ital. Paleont. Strat.*, 59: 91-99.

Comaschi Caria I. (1958) - Nuovi resti di cheloni nel Miocene della Sardegna. *Boll. Soc. Geol. It.*, 78: 37-44.

Daams R. (1981) - The dental patten of the dormice *Dryomys*, *Myomimus*, *Microdyromys* and *Peridyromys*. *Utrecht Micropal. Bull.*, 3: 1-115.

Esu D. & Kotsakis T. (1983) - Les vertébrés et les mollusques continentaux du Tertiare de la Sardaigne: paléobiogéographie et biostratigraphie. *Geol. Romana*, 22: 177-206.

Faccenna C., Speranza F., D'Ajello Caracciolo F., Mattei M. & Oggiano G. (2002) - Extensional tectonics on Sardinia (Italy): insights into the arc–back-arc transitional regime. *Tectonophysics*, 356: 213-232.

Ginsburg L., Morales J. & Soria D. (1994) - The ruminants (Artiodactyla, Mammalia) from the Lower Miocene of Cetina de Aragón (Province de Zaragoza, Aragón, Spain). *Proc. Kon. Ned. Akad. Wetensch.*, 97, 141-181.

Göhlich U.B. & Mourer-Chauviré C. (2005) - Revision of the phasianids (Aves: Galliformes) from the Lower Miocene of Saint-Gérard-Le-Puy (Allier, France). *Palaeontology*, 48: 1331-1350.

Kotsakis T. (1984) - Problemi paleobiogeografici dei mammiferi fossili italiani: le faune mioceniche. *Geol. Romana*, 23: 65-89.

Kotsakis T. (1985) - Les Trionychidae (Testudinata, Reptilia) fossiles de l'Italie. *Boll. Soc. Paleontol. It.*, 24: 161-168.

Kotsakis T. & Palombo M.R. (1979) - Vertebrati continentali e paleogeografia della Sardegna durante il Neogene. *Ann. Géol. Pays Hélléniques*, 2: 621-630.

Martin J.E. & Gross M. (2011) - Taxonomic clarification of *Diplocynodon* Pomel, 1847 (Crocodylia) from the Miocene of Styria, Austria. *N. Jb. Geol. Paläont. Abh.*, 261: 177-193.

Mennecart B. (2012) - The Ruminantia (Mammalia, Cetartiodactyla) from the Oligocene to the Early Miocene of Western Europe: systematics, palaeoecology and paleobiogeography. *Geo Focus*, 32: 1-258.

Milne-Edwards A. (1867-1871) - Recherches anatomiques et paléontologiques pour servir à l'histoire des oiseaux fossiles de la France, vol. 1 (1867-1868), vol.2 (1868-1871, see *Zoological Record*, vol. 5-8), 632 pp., Atlas 1+2 pls. 1-96 + pl. 97-200 [date of publication of *Palaeortyx gallica*, and *P. brevipes* is 1869, see *Zool. Record*, vol. 6. p. 93].

Oudet J., Münch Ph., Verati C., Ferrandini M., Melinte-Dobrinescu M., Gattacecca J., Cornée J.-J., G. Oggiano G., Quillévéré F., Borgomano J. & Ferrandini J. (2010) - Integrated chronostratigraphy of an intra-arc basin: $^{40}Ar/^{39}Ar$ datings, micropalaeontology and magnetostratigraphy of the early Miocene Castelsardo basin (northern Sardinia, Italy). *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 295: 293-306.

Palombo M.R. (2006) - Biochronology of the Plio-Pleistocene terrestrial mammals of Sardinia: the state of the art. *Hellenic J. Geosc.,* 41: 47-66.

Palombo M.R. (2009) - Biochronology, paleobiogeography and faunal turnover in western Mediterranean Cenozoic mammals. *Integr. Zool.*, 4: 367-386.

Pomel A. (1847) - Note sur les animaux fossiles découverts dans le département de l'Allier. *Bull. Soc. Géol. Fr.*, 4: 378-385.

Pomel A. (1853) - Catalogue méthodique et descriptif des vertébrés fossiles découverts dans le bassin hydrographique supérieur de la Loire, et surtout dans la vallée de son affluent principal l'Allier. Cataluge des vertébrés fossiles (suite et fin). *Ann. scient. litt. indus. Auv.*, 24: 81-229.

Portis A. (1901) - Il *Procyclanorbis sardus* Port. nuovo Trionichide fossile della Sardegna. *Boll. Soc. Geol. It.*, 20: 51-79.

Rössner G.E. (1999) - Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich): 9. Ruminantia (Mammalia). *Ann. Naturhist. Mus. Wien*, 99: 169-193.

Rössner, G.E. & Rummel M. (2001) - *Pomelomeryx gracilis* (Pomel, 1853) (Mammalia, Artiodactyla, Moschidae) from the Lower Miocene karstic fissure filling complex Rothenstein 10/14 (Germany, Bavaria). In: I. Horacek & J. Mlìkovsky (Eds) - Papers in paleomammalogy honouring Prof. Dr. Oldrich Fejfar. *Lynx*, 32: 323-353.

Sanchèz I.M., Domingo M.S. & Morales J. (2010) - The genus *Hispanomeryx* (Mammalia, Ruminantia, Moschidae) and its bearing on musk deer phylogeny and systematics. *Palaeontology*, 53: 1023-1047.

Sowerbutts A. (2000) - Sedimentation and volcanism linked to multiphase rifting in an Oligo-Miocene intra-arc basin, Anglona, Sardinia. *Geol. Mag.*, 137: 395-418.

Stehlin H.G. & Schaub S. (1951) - Die Trigonodontie der Simplicidentaten Nager. *Schweiz. Pal. Abh.*, 67: 1-385.

Van der Made J. (1999) - Biogeography and stratigraphy of the Mio-Pleistocene mammals of Sardinia and the description of some fossils. In: J.W.F. Reumer & J. de Vos (Eds) - Elephants have a snorkel! Papers in honour of P.Y. Sondaar. *Deinsea*, 7: 337-360.

Van der Made J. (2008) - New endemic large mammals from the Lower Miocene of Oschiri (Sardinia): Observations on evolution in insular environment. *Quat. Int.*, 182: 116-134.

Van der Made J. (2012) - The latest Early Pleistocene giant deer *Megaloceros novocarthaginiensis* n. sp. and the fallow deer *Dama* cf. *vallonnetensis* from Cueva Victoria (Murcia, Spain). *Geol. Paleontol. Cueva Victoria*, 11: 269-323.

Vardabasso S. (1962) - Questioni paleogeografiche relative al Terziario antico della Sardegna. *Mem. Soc. Geol. It.*, 3: 655-673.

Venczel M. & Sanchíz B. (2006) - Lower Miocene Amphibians and Reptiles from Oschiri (Sardinia, Italy). *Hantkeniana*, 5: 72-75.

Wang S., Shi Q., Hui Z., Li Y., Zhang J. & Peng T. (2015) - Diversity of Moschidae (Ruminantia, Artiodactyla, Mammalia) in the Middle Miocene of China. *Paleontol. Res.*, 19: 143-155.

Zoboli D. (2013) - I vertebrati del Miocene inferiore di Laerru (Sardegna settentrionale). Unpublished undergraduate thesis of the University of Cagliari, 121 pp.