

CONTRIBUTION OF THE LATE MIOCENE MAMMALS FROM CALABRIA AND SICILY TO THE PALAEOGEOGRAPHY OF THE CENTRAL MEDITERRANEAN

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ABSTRACT. During Miocene, the paleogeography of the central Mediterranean area underwent significant modifications under control of Plate Tectonics. The area here considered occupies a southern position, roughly coincident with the Calabria-Peloritan Arc (CPA), located at the intersection between the NW/SE-trending southern Apennines and the SE-trending Sicilian Maghrebides. Land mammal assemblages can profitably be used in the paleogeographic reconstructions. The late Miocene assemblages from Central Italy and Sardinia allowed the recognition of the Tusco-Sardinia bioprovince as an insular domain for the endemic character of the fauna. The same conclusion has been reached for the Apulo-Abruzzi bioprovince, considered as an island during late Miocene. The recent studies on the mammal assemblage from Cessaniti (Calabria) revealed a continental character of the fauna, probably related to a land connection to Africa. The same datum comes from the assemblages of Gravitelli, Messinian in age, and from Monte Pellegrino (indirect datum). The Calabria-Sicily area can be considered a new bioprovince in the central Mediterranean during late Miocene.

1. Introduction

The geology of the central Mediterranean has been controlled by the complex geodynamic of Eurasia and Africa. The Sicily-Calabria area here considered occupies a southern position in the central Mediterranean and roughly coincides with the Calabria-Peloritan Arc (CPA), located at the intersection between the NW/SE-trending southern Apennines and the SE-trending Sicilian Maghrebides. The Calabria-Peloritani Terranes underwent strong tectonic forces that drastically changed the paleogeography of the area. Data sourcing from land mammal assemblages from the region since the Late Miocene can be used as an integration to geological informations and paleogeographic reconstructions.

The most significant assemblage has been recovered in the Cessaniti area (Vibo Valentia, Calabria; Fig.1), and is composed, in addition to the sirenian *Metaxytherium serresii* and cetaceans, by land mammals of Afro-Arabian and east European (Pikermian) affinities, suggesting a land connection with North Africa (Marra *et al.* 2017; Marra 2018). As a matter of facts, the mammal assemblage from Cessaniti does include continental (not endemic)



FIGURE 1. Geographic position of the sites quoted in the text.

species and can be considered a peculiar and unique central Mediterranean bioprovince, distinct from the Tusco-Sardinia and the Apulo-Abruzzi ones, characterized by marked insularity (Rook *et al.* 2006). Moreover, the stratigraphy of the Cessaniti area records a transgression event with soils and fluvial phases deposited from a near emerged land during Tortonian (Marra *et al.* 2017). A second mammal assemblage, coming from Gravitelli (Messina, Sicily; Fig.1), could have belonged to the same bioprovince (Rook *et al.* 2006), but it get lost in the 1908 earthquake and it is known only by the papers by Seguenza (1902, 1907) and tentatively attributed to Messinian age (Kotsakis *et al.* 1997; Gallai and Rook 2006). The assemblage seems do not include endemic species. After the earthquake, the site of Gravitelli has been interested by an intensive urbanization and the fossiliferous level, if not destroyed by building excavations, is no longer observable.

Evidences of Messinian faunal dispersals to Sicily are present in the Monte Pellegrino faunal assemblage, Sicily (Marra 2005, 2013, and references contained therein, Fig.1). The assemblage is dated early Pleistocene, but some endemic species have been considered evolved from European and African ancestors dispersed during the latest Miocene.

2. Late miocene mammal assemblages of the southern central Mediterranean

Cessaniti. A small albeit significant mammal assemblage has been recovered in the Late Miocene successions outcropping in the Cessaniti area (Calabria, southern Italy, Fig.1); (Ferretti *et al.* 2003; Marra *et al.* 2011; Ferretti *et al.* 2017; Marra *et al.* 2017; Marra 2018), previously known for the occurrence of marine mammals and invertebrates (Checchia

Rispoli 1925; Carone and Domning 2007; Carone *et al.* 2013; Carone and Marra 2014; Marra *et al.* 2016). The sedimentary basin of Cessaniti overlies a Paleozoic crystalline substratum and the succession of four informal units described by (Nicotera 1959) outcrops with different thickness and facies throughout the area (from the bottom to the top):

- "dark argillaceous sands with *Ostrea* and *Cerithium*", alternated to coarse sandstones, attributed to lagoonal deposition (Neri *et al.* 2005);
- "*Clypeaster* sandstones" ("*Arenarie a Clypeaster*", *sensu*, Ogniben 1973), attributed to shallow marine water deposition;
- "*Heterostegina* yellow sandstones" (Papazzoni and Sirotti 1999), deposited in frankly marine conditions;
- "*Orbulina* marls" ("*Marne a Orbulina*", Rao *et al.* 2007), deposited in hemipelagic environment.

The succession of Cessaniti is well exposed in the Gentile's Quarry (Cava Gentile, Fig.1 and Fig.2), where it has an impressive thickness and completeness. The Cava Gentile succession is newly interpreted as a transgressive event, interrupted by almost three temporary sea-falls, testified by soils and fluvial deposits (FL1, FL2, and FL3, Fig.2), within the general transgressive trend (LG to SH4, Fig.2), probably under control of tectonics (Marra *et al.* 2017). The age of the Cava Gentile succession ranges from 8,1 Ma (by the attribution of the lagoonal deposits to the Chron C4n; Marra *et al.* 2017) to 7,2 Ma (by the attribution of the "Orbulina marls" to the nannoplankton zone CNM17; Marra *et al.* 2017).

The fossils mainly comes from the *Clypeaster* sandstones (*Arenarie a Clypeaster*, *sensu* Ogniben, 1973; CG.FL1-3 and CG.SH1-3 in Marra *et al.* 2017 SH1-SH3 in Fig.2), intensively excavated for their use in buildings. The *Clypeaster* sandstones well preserves phosphate remains (Guido *et al.* 2012). The mammal assemblage does include *Stegotrabelodon syrticus* Petrocchi, 1941; *Samotherium* cf. *boissieri*; *Bohlinia* cf. *attica*; *Tragoportax* cf. *rugosifrons*, '*Ceratotherium*' *adventis*; an undertermined Anracotherid and a small bovids are still under study. (Marra *et al.* 2011, 2017; Marra 2018). Marine mammals are represented by abundant remains of *Metaxytherium serresii* (Carone and Domning 2007; Carone *et al.* 2013), and scanty fossils of Cetaceans (Carone and Marra 2014; Marra *et al.* 2016; Pandolfi *et al.* 2019). The primitive elephantoid *Stegotrabelodon* cf. *syrticus* is the only mammal present both in deposits of lagoonal marls and sands (LG) and in *Clypeaster* sandstones (SH1 to SH3) (Ferretti *et al.* 2003; Ferretti 2008; Carone *et al.* 2013; Ferretti *et al.* 2017). The *Stegotrabelodon* collection is represented by a single worn DP4 coming from the lagoonal unit (LG), and by one mandible, one incisor, one fragmentary molar, two fragmentary humeri, one right II metacarpal and one incomplete femur, coming from the shoreface sands (SH1 to SH3). The specimens from Cessaniti shows some plesiomorphic characters with respect to the fossils of the same species from As Sahabi, in Libya, dated about 6.7 Ma (Bernor and Rook 2008). The species is also recorded in the Baynunah Formation (Abu Dhabi, United Arab Emirates), in a time ranges from 8.2 to 5.3 Ma (Whybrow and Hill 1999; Bibi *et al.* 2012, 2013). Two mid-sized giraffids, are documented at Cessaniti (Cava Gentile) and in the neighbouring area (Marra *et al.* 2011). Remains attributable to *Bohlinia* cf. *attica* comes from the unit SH3 of Cava Gentile and include: an upper tooththrow, a distal radius, two astragalii, two cubo-naviculars and a distal tibia. *Samotherium* cf. *boissieri* is represented by postcranial elements: two metacarpals, two

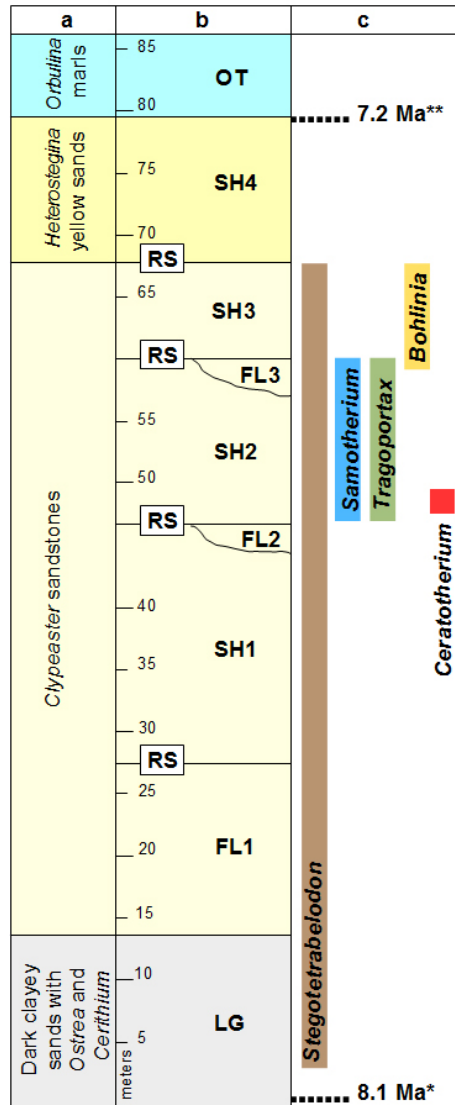


FIGURE 2. Simplified stratigraphy of Cava Gentile (Cessaniti): a) informal stratigraphy (according to Nicotera (1959), Ogniben (1973), and Rao *et al.* (2007); b) stratigraphy according to Marra *et al.* (2017) (LG: Lagoonal deposits, FL: fluvial deposits, SH: shoreface deposits, OT offshore transition); c) mammal occurrences.

metatarsals and a distal tibia comes from Cava Gentile, SH2 unit); a complete left manus, a partially preserved left ulna and a distal epiphysis of a left radius (probably belonging to the same individual), a strongly damaged humerus and other fragmentary bones comes from sediments correlatable with the SH1 unit located at Zungri. Both species are commonly found in the Greco-Iranian bioprovince and more rarely in Africa. *Bohlinia attica* is recorded in the western regions of the Greco-Iranian bioprovince, in a time span from the Tortonian to the Messinian (Geraads *et al.* 2005; Kostopoulos 2009). The presence of *Bohlinia* sp. in the Late Miocene of Chad, Africa, is still dubitable (Harris *et al.* 2010). Also *Samotherium boissieri* is a species common in the Greco-Iranian bioprovince, in some cases associated with *Bohlinia*, between 8.0 and 7.4 Ma. The species is not recorded in Africa, but the genus is represented by few remains at As Sahabi (Libya), Bou Hanifia (Algeria) and Nakali (Kenya; Harris *et al.* 2010). The occurrence of two giraffids typical of the Pikermian biome can be an evidence of the expansion through North Africa of this peculiar mammalian community inhabiting a savannah-like environment which progressively formed and spread in the Greco-Iranian bioprovince during the Late Miocene (Solounias *et al.* 1999; Marra *et al.* 2011). Moreover, the bioma could have been more extended in space than considered until now. Marra (2018) attributed a hemimandible from Cava Gentile to *Tragoptax* cf. *rugosifrons*. Postcranials of a boselaphine bovid coming from SH2-FL3 units of Cava Gentile (radius, astragalus and anterior phalanx) and from correlatable layer at Papaglioni, a locality near Cessaniti (humerus, anterior phalanx, metatarsal, posterior phalanx), are tentatively attributed to *Tragoptax* cf. *rugosifrons* (Marra 2018). The specific attribution is tentative, due to the low number of fossils, but it is significant for the wide distribution of the genus *Tragoptax* in Eurasia and Africa during Late Miocene (Kostopoulos 2009; Bibi 2011). The ecological niche of *Tragoptax* is comparable to that of the extant *Hippotragus*: a dweller of forest-savannah alternating with open spaces (Spassov and Geraads 2004). Few remains of a small bovid are still undermined (Marra 2018). An incisor and a femur from SH2 at Cessaniti are still under study and can be attributed to an Anthracotherid, rather than a hexaprotodontid hippopotamus, as previously considered (Ferretti *et al.* 2003; Marra *et al.* 2011, 2017). Rhinocerotid remains come from SH2 at Cava Gentile and are represented by a fragmentary skull, two fragmentary teeth and a few postcranial bones. Although initially referred to the genus *Diceros* Marra *et al.* 2011, they have recently been attributed to a new species, '*Cerathotherium advenientis*', having African affinities (Pandolfi *et al.* 2019). A newly recovered humerus, still under restoration, can be attributable to a Hipparionine horse.

Gravitelli. The land mammal assemblage of Gravitelli (Messina, Sicily; Fig.1) has been destroyed in the 1908 earthquake and is known only by the papers by Seguenza (1902, 1907), which emphasized similarities of the fauna with Pikermi's and Samo's species. A tentative revision of the faunal list, based on the Seguenza's papers, has been done by Kotsakis *et al.* (1997). Although all the original fossils were lost, two casts of the suid from Gravitelli have been found in the collections of the Museo di Storia Naturale dell'Università di Firenze (Gallai and Rook 2006). The specimens are represented by an upper third molar and a maxillary bone fragment bearing the fourth premolar and the first molar, both attributable to the genus *Propotamochoerus* (Gallai and Rook 2006). The teeth show a uniform morphology within the genus, so Gallai and Rook (2006) suggested only

the probable affinities with two species: *P. hysudricus* and *P. provincialis*. The mammal fauna from Gravitelli has been considered Messinian in age, and does not seem to include endemic taxa (Kotsakis *et al.* 1997; Gallai and Rook 2006). Although the later age, deeper insights are needed to investigate possible relationships with Cessaniti.

Monte Pellegrino. Although early Pleistocene in age, the faunal complex of Monte Pellegrino (Fig.1) records a dispersal of small mammals to Sicily during Messinian, whose derived species persisted on the island until Pleistocene (Marra 2005, 2007, 2009a,b, 2018, and references contained therein). Some small mammals from Monte Pellegrino can be considered an indirect evidence of Messinian faunas. The fauna, recorded in a karst fissure at Monte Pellegrino, near Palermo, is endemic, unbalanced, and poorly diversified, mainly composed by small mammals. The reconstruction of paleogeography suggests that in the Early Pleistocene Sicily was made up of two islands: a northern one, extended from west to east, represented by Peloritani, Nebrodi and Madonie Mountains; a south-eastern one represented by the Hyblean Plateau (Marra 2013, and references contained therein). A narrow sea separated the two islands, while the volcano Etna had not yet emerged (Marra 2013, and references contained therein). Also southern Calabria was divided in two small islands by narrow sea straits: a large one represented by Aspromonte and Serre Massifs; and a small one represented by Monte Poro - Cape Vaticano (Marra 2013, and references contained therein). The small mammals of the assemblage shows different degrees of endemism, mainly consisting of gigantism. In particular, *Asoriculus burgioi*, *Apodemus maximus* and *Maltamys* sp. have so marked endemic features to be considered relics of a Messinian fauna of African and/or European affinity (Marra 2013, and references contained therein). The ancestor fauna is unfortunately not documented. *Leithia* sp. from Monte Pellegrino has a long persistence on the island, being considered the precursor of *Leithia* and *Maltamys* species present in Middle and Late Pleistocene of Sicily and Malta. The ancestor of *Leithia* (and possibly of *Maltamys*) could have been a form of *Eliomys* sp. probably dispersed during Messinian (Daams and De Bruijn, 1995). *Pellegrinia panormensis* is strongly endemic and has been compared to African Ctenodactylids. *Hypolagus peregrinus* and *Mustelercta (=Pannonictis) arzilla* show moderate endemism, and are considered affine to European forms, dubitatively related to an Early Pleistocene dispersal (Marra 2013, and references contained therein). The assemblage is composite, and its find in a karst fissure makes doubtful the real coexistence of the mammal species. The relevant information of the assemblage is the derivation from African forms of the taxa evolved from Messinian immigrants, and the European affinities of later forms.

3. Discussion

The mammal assemblages of Sicily and Calabria clearly differ from the other bioprovince of the central Mediterranean during Miocene: the Tusco-Sardinian and the Apulo-Abruzzi bioprovinces (Fig.1). The fossil record from the Tusco-Sardinian bioprovince is strongly endemic and impoverished, condition this latter related to a long persistence of insular conditions. The area was probably part of an island or an archipelago in the Early Tortonian. The emersion of lands in the Tuscan portion probably can be probably dated at the beginning of Late Miocene, as also testified by the occurrences of endemic taxa derived from ancestors present in continental Europe during Late Miocene (i. e. *Oreopithecus bambolii*; some of

the endemic glirids and lagomorphs; (Cirilli *et al.* 2016; C. *et al.* 2017)). Another dispersal event from mainland is testified in the succession of Baccinello (Grosseto, Tuscany) about 7,55 Ma B.P. and is also recorded in Sardinia, suggesting that the Tyrrhenian sea was still narrow enough to be crossed by land mammals (Abbazzi *et al.* 2008). A consistent dispersal event of European mammals interested the Tuscan area during Messinian, while the Corso-Sardinian area was completely separated by a wider Tyrrhenian sea (Rook *et al.* 2006). This last phase occurs in a paleogeographic context where Tuscany was definitively in continuity with the Apennines, a newly formed orogen (Rook *et al.* 2006). The Apulo-Abruzzi area is characterized by strongly endemic Hoplihomerycidae during Early Tortonian, represented by eighth morphotypes and probably derived by pre-Pecora taxa (Mazza and Rustioni 1996; Rook *et al.* 2006; Mazza and Rustioni 2008; Hoek Ostende *et al.* 2009). After the early Tortonian, the Apulo-Abruzzi bioprovince lost the Abruzzi area involved in the Apennine orogenesis, while the Gargano-Murge foreland maintained its character of island until Early Pliocene, experiencing a dispersal event from mainland during Messinian. The island's area get dramatically reduced during the Pliocene marine ingression and the lack of fossils suggests that the residual endemic fauna underwent a rapid extinction (Rook *et al.* 2006). While the Tusco-Sardinia and the Apulo-Abruzzi areas were two distinct insular domains, the southern assemblages were in close connection to North Africa and did not evolved insular fauna. The mammal assemblage from Cessaniti is sufficiently documented to allow circumstantial discussions. The proboscidean specimens from Cessaniti have some plesiomorphic characters with respect to the sample referred to *S. syrticus* from As Sahabi, an Upper Miocene locality from Northern Libya which released the type material (Ferretti *et al.* 2003, 2017). At present, the finding in Cessaniti is the only record of this species outside the Afro-Arabian province and is interpreted as an evidence of a land connection of a portion of Calabria to North Africa (Ferretti *et al.* 2003, 2017). The occurrence of *Bohlinia* cf. *attica* and *Samotherium* cf. *boissieri* at Cessaniti suggests a westward expansion of the Pikermian biome, a peculiar mammal community spread in the Greco-Iranian bioprovince during the Late Miocene. This expansion could have been more relevant in time and space that considered before and the data from Cessaniti confirms this supposition. Unfortunately, the occurrence in Africa of the two giraffid species is uncertain due to the scanty fossil record (Marra *et al.* 2011, 2017). The presence of *Tragoportax* cf. *rugosifrons* seems to confirm the wide distribution of Tragoportacini throughout the Late Miocene of Europe and Asia. Tragoportacini (mainly referring to the genus *Tragoportax*) have been found in the Late Miocene of Africa (As Sahabi, Lothagam, Middle Awash, Samburu Hills and Langebaanweg), and Arabian peninsula (Abu Dhabi; Baynunah Formation) (Bibi 2011). Bibi (2011) considers the similarity of African and European/Asian tragoportacins as evidence for a great degree of biotic exchange between Africa and Eurasia during the Late Miocene or even later in time. The occurrence of *T. cf. rugosifrons* at Cessaniti confirms that the assemblage from Cessaniti includes North African species associated with Greco-Iranian ones. The new species '*Ceratotherium*' *advenientis* can be located within Rhinocerotina, and related to the African genera *Diceros* and *Ceratotherium*. The palaeoecology of the mammal association indicates a mosaic environment with open spaces, probably similar to the modern savannah but less arid. The environment must have been similar to that of the Pikermian biome. The mammals from Cessaniti probably inhabited a land in terrestrial continuity with Afro-Arabia and did not have relationships with the insular bioprovinces of

Tusco-Sardinian and Apulo-Abruzzi areas. The possibility that the assemblage could have been accumulated by the casual sinking of carcasses after a long floating in open sea has been considered by Marra *et al.* (2011). However, the distribution of bones in layers related to transgression events and the evidences of fluvial intercalations (Marra *et al.* 2017) force to suppose the existence of nearby emerged land whose position and areal extension, as well as possible connections to North Africa, need more investigations. The position and extension of the emerged land of Cessaniti are not still not fully elucidated by geological studies. Gravitelli represents a doubtful datum, due to the loss of the fossils and the impossibility in recovering the original outcrop. However, the assemblage does include continental forms and is considered a continental, not insular, domain (Gallai and Rook 2006, and references contained therein). The endemic species of the Monte Pellegrino mammal assemblage reveal ancestor of European and African origin. Data seems according to an African origin for the taxa evolved from Messinian immigrant forms and a European origin for taxa evolved from Plio-Pleistocene immigrant forms. Fauna evolved from Messinian ancestors is an indirect evidence of spreadings occurred during late Miocene. The island of Sicily had different endemic faunas during the Plio-Pleistocene spread from the Italian peninsula trough Calabria (Marra 2005, 2007; Marra and Bellomo 2008; Marra 2009a,b). The land mammal record of the southern area of Central Mediterranean shows close relations with Africa during the late Miocene, while from the Plio-Pleistocene the area is more closely related to the Italian peninsula and its European faunas (Marra 2005, 2007; Marra and Bellomo 2008; Marra 2009b).

4. Conclusions

At the light of data sourcing from the land mammal assemblages, the Calabria-Sicily area can be considered a new bioprovince in the late Miocene of Central Mediterranean. The continental character of the fauna from Cessaniti implicates land connections with Africa, as well as the existence of an emerged land whose position and extension is not clear by the geological context. A similar consideration can be done for the assemblage from Gravitelli, later in age than Cessaniti one. In this latter case, caution is due for the loss of the assemblage and the possibility to know it only from the paper by Seguenza (1902) and two casts re-discovered in Florence (Gallai and Rook 2006). The assemblage from Monte Pellegrino is doubtful for its occurrence in a karst fissure, whose fillings could have not been coeval. Part of the fossils shows a strong endemism probably evolved by African and or European ancestors, probably spread during Messinian. This is an indirect evidence of a Messinian land mammal assemblage. Obviously, the Messinian spreadings of mammals that reached Gravitelli and western Sicily (M. Pellegrino) can be explained with the consistent fall of the sea level induced by the Salinity Crisis and implies emersion of lands in Sicily at that time. The existence of an emerged land in Calabria during late Miocene, suggested by the mammal assemblage of Cessaniti, and the possible relations with Sicily introduce a new intriguing sight to the southern part of the Central Mediterranean during late Miocene.

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