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PALEOGEOGRAPHIC EVOLUTION OF THE ADRIATIC AREA SINCE OLIGOCENE TO PLEISTOCENE

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Riassunto. Un riesame dei dati geologici e geofisici di tutta l'area peri–Adriatica meridionale e l'analisi delle caratteristiche delle faune continentali a Mammiferi del Gargano hanno permesso di ricostruire una serie di schemi paleogeografici, riguardanti il Dominio Apulo-Dalmatico, dal Miocene al Pleistocene.

Abstract. The paleogeographic evolution of the Apulo–Dalmatic Realm, since Oligocene to Pleistocene, has been reconsidered according to the geology of the South Adriatic area and the characters of the mammalian continental faunas of the Gargano Peninsula.

Introduction.

In the western foothill of the Gargano Peninsula (Foggia Province, southern Italy), fossil mammals have been recovered. A few were found in fluviatile gravels (Palma di Cesnola, 1967). The greatest part of the fossils occurs in the fillings of karstic structures (fissures, sinkholes and larger cavities) cut by quarry works in the surroundings of the village Apricena and along the road from Apricena to Poggio Imperiale.

Most of the quarries are located along an E to W oriented horst structure in Mesozoic limestones. These limestones are discontinuously and alternately capped by calcarenites, crystalline pink limestones or shelly limestones and bordered by calcarenites and by sandy clays. An angular unconformity separates these units from the Mesozoic substratum.

Up to present the capping sediments did not yield significant fossils and were therefore dated with correlation to nearby units. D'Alessandro et al., (1979), referred the crystalline and shelly limestones to the Tortonian. The data

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of the Cava dell'Erba section (Valleri, 1984), located in a small minor graben, suggest a Pliocene age.

Both the Mesozoic and the capping limestones are karstified. The fossil mammals can be grouped into three distinct faunal complexes. Also the sediments filling the cavities are different.

Characters of mammal faunas.

The oldest faunal complex is represented by the well known endemic fossil assemblage characterized by the murid *Microtia.* These fossils were recovered in fissures of the Mesozoic limestones filled by a typical «terra rossa». After the first pubblication of Freudenthal (1971), only some taxa were the object of taxonomical analyses (Freudenthal, 1973, 1985; Ballmann, 1973, 1976; Willemsen, 1983; Leinders, 1984; Daams & Freudenthal, 1985; Mazza. 1987, Some researches dealt with chronologic reconstructions and evolutionary aspects of the fauna (Freudenthal, 1976; De Giuli & Torre, 1984a; De Giuli et al., 1985b, 1985c, 1985d; De Giuli et al., in press). A chronologic succession of the fissures was outlined; the peculiar endemic character of the faunas was interpreted as the result of the occurrence of an archipelago; the overall Miocene affinity of the fauna and the occurrence of two phases of major faunal dispersal were recognized. The age of the actual fissure fillings is somewhat discussed: Late Vallesian according to Freudenthal (1971); post Turolian according to De Giuli and Torre (1984b). Freudenthal (1985) suggests, mainly on the basis of cricetid affinities, that no migration did occur before the Late Turolian. We will deal later with this problem.

The second fossil assemblage is characterized by the occurrence of *Allophaiomys pliocaenicus* and was collected in yellow and gray sands filling large karst cavities, excavated in the limestones unconformably overlying the Mesozoic basement, and some fissures which reach also the uppermost part of the Mesozoic limestones. The fauna is a quite peculiar one with a clear Villafranchian pattern (De Giuli & Torre, 1984b), but with the occurrence of taxa not previously known in Italy (De Giuli et al., 1985a). It can be referred to a latest Early Pleistocene age.

The youngest assemblage is characterized by the occurrence of *Allocricetus bursae.* The sediments are reddish brown sands. In the Apricena area, this fauna was yielded by only one large fissure, located in the Mesozoic limestones. Large horses, bovids, cervids and *Microtus* are present. In the nearby Paglicci Cave a very similar fauna has been collected (Mezzena & Palma di Cesnola, 1971). The fauna is Middle Pleistocene. In the Paglicci Cave pre–Musterian stone implements also support this age (Bartolomei, 1975, 1980).

Paleogeographic evolution.

A reconstruction of the paleogeographic history of the area during the

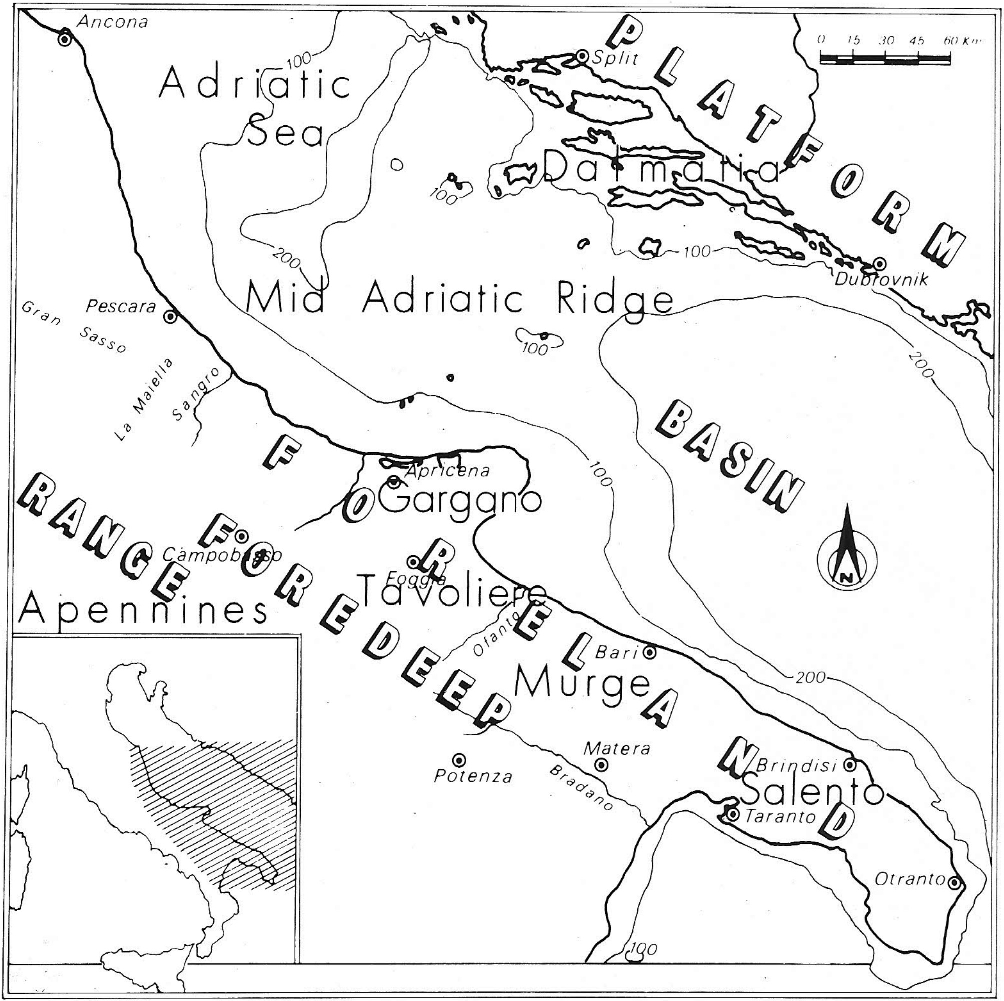

Fig. 1 — Sketch of the Apulo–Dalmatic Area.

Neogene has been made by De Giuli et al. (1985d; in press). In the southern Adriatic region an area was evidenced formed by structural high blocks, often emerged and discontinuously connected. This area has been named Apulo–Dalmatic Realm. The main elements of the Realm (Fig. 1) were: the Murge highlands, the Salento Peninsula, the Apulian Tavoliere extending to the north in the Fortore–Sangro area, the Gargano Peninsula and the shallow–sea area between the Gargano and the Split–Dubrovnik region (Mid–Adriatic Ridge). The eastern borders of the Realm could not be defined but the characters of the land faunas suggest a strong isolation from neighbouring continental areas.

An ingressive phase started during the Early Miocene on the Apulo–Dal-

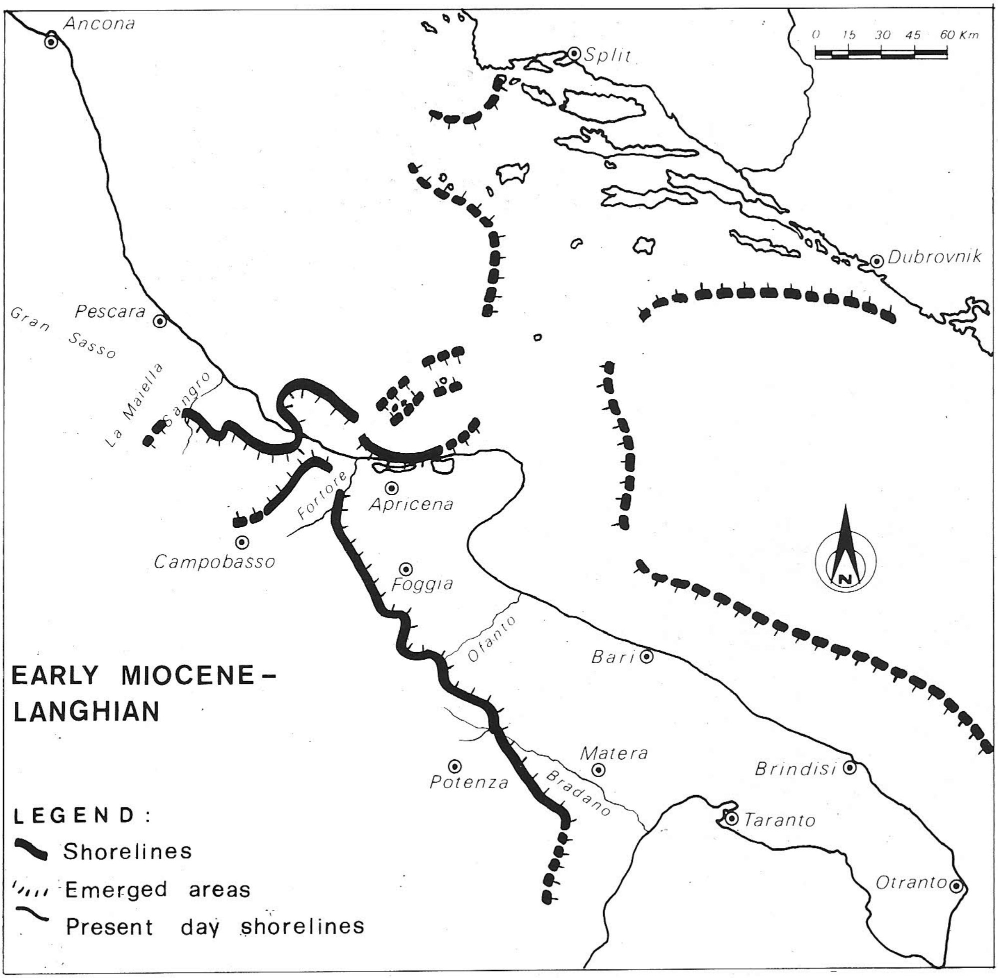

Fig. 2 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the Early Miocene–Langhian.

matic Realm which was already widely emerged during the Oligocene. The sea–shore progressively approached to the present western border of the Murge and gave rise to narrow and more or less deep gulfs in the Tavoliere area (Fig. 2). Widely emerging zones probably persisted in the Mid–Adriatic Ridge.

A stronger disruption of the Apulo–Dalmatic foreland took place in the Tortonian and caused a significant decrease of emerged areas. This is clearly evidenced along the northern part of the Realm and in the Salento Peninsula (Fig. 3). Possibly also the Mid–Adriatic Ridge was largely submerged.

The Messinian was characterized by a strong enlargment of emerged areas. This feature is more evident in the Murge rather than in the Tavoliere (Fig. 4).

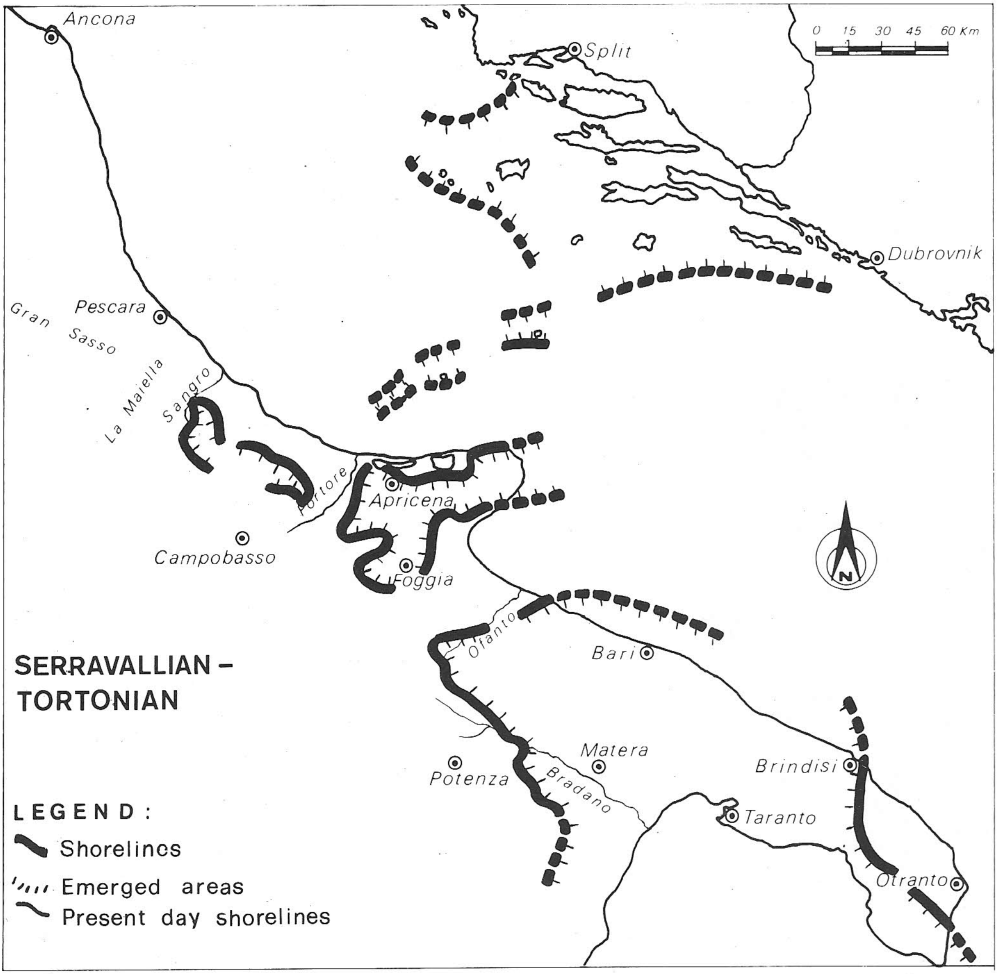

Fig. 3 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the Serravallian–Tortonian.

Many areas formerly isolated were connected. To the north–west it is possible for the first time to recognize the effects of the emerging Apennines which approached the northern part of the Fortore–Sangro area (Ricci Lucchi, 1975). However the Apulo–Dalmatic Realm remained bordered to the north–west and to the west by deep sea basins.

Hamor (1984) recognized three orogenetic phases in the Paratethys during the Miocene with a major distensive phase during the Early Badenian and the Pannonian (i.e. Tortonian). Even in the Apulo–Dalmatic Realm the Tortonian was the period of maximal sea–spreading and of fragmentation of the foreland during the Miocene.

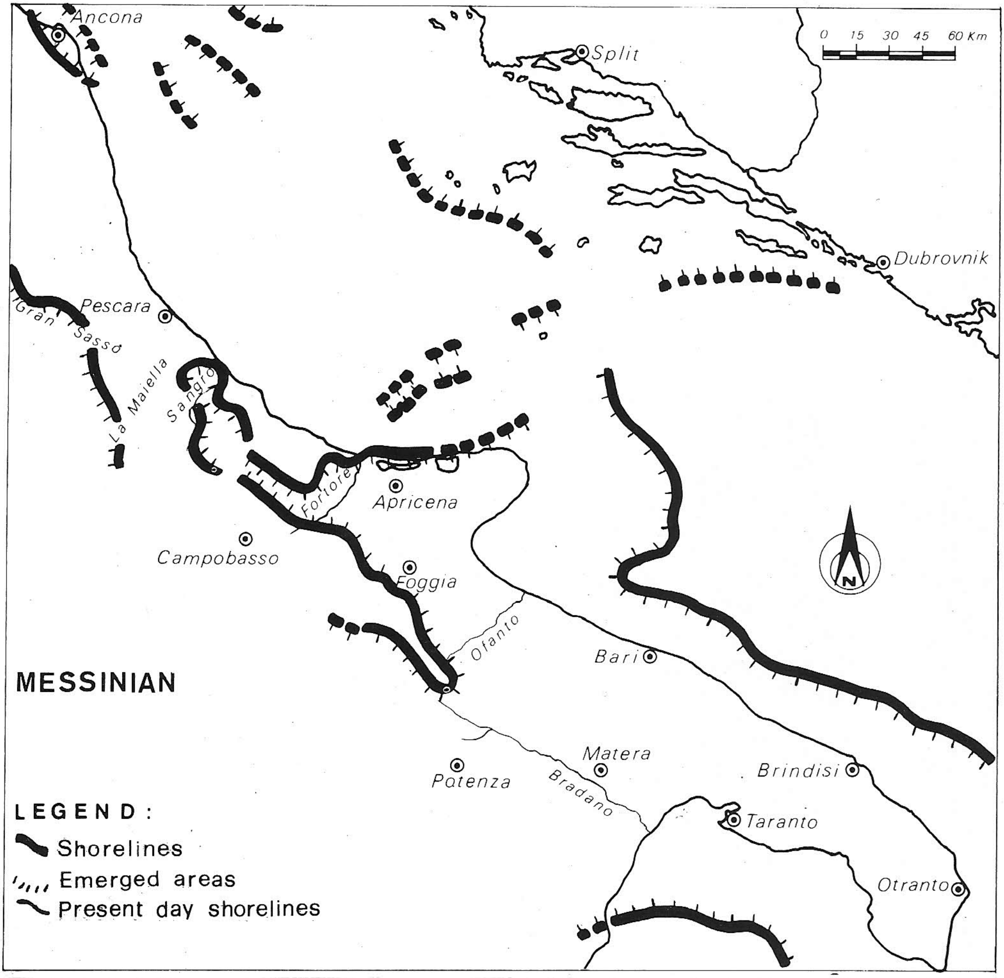

Fig. 4 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the Messinian.

During the Pliocene a new ingressive phase started and progressed till the Early Pleistocene. In the lower part of the Pliocene (*Sphaeroidinellopsis* – *G. margaritae* Zones) (Fig. 5) it appears that the area was still widely emerged, while the ingressive phase is evidenced by the flooding of the Fortore–Sangro area during the *G. puncticulata* Zone (Fig. 6). In the Middle Pliocene (*G.* gr. *crassaformis* Zone) the sea widely covered the Tavoliere, approached the present day Murge border and spread over the Salento Peninsula (Fig. 7). During the latest Pliocene (Fig. 8) and the Early Pleistocene (Fig. 9) the sea reached its major extent in the whole Adriatic area.

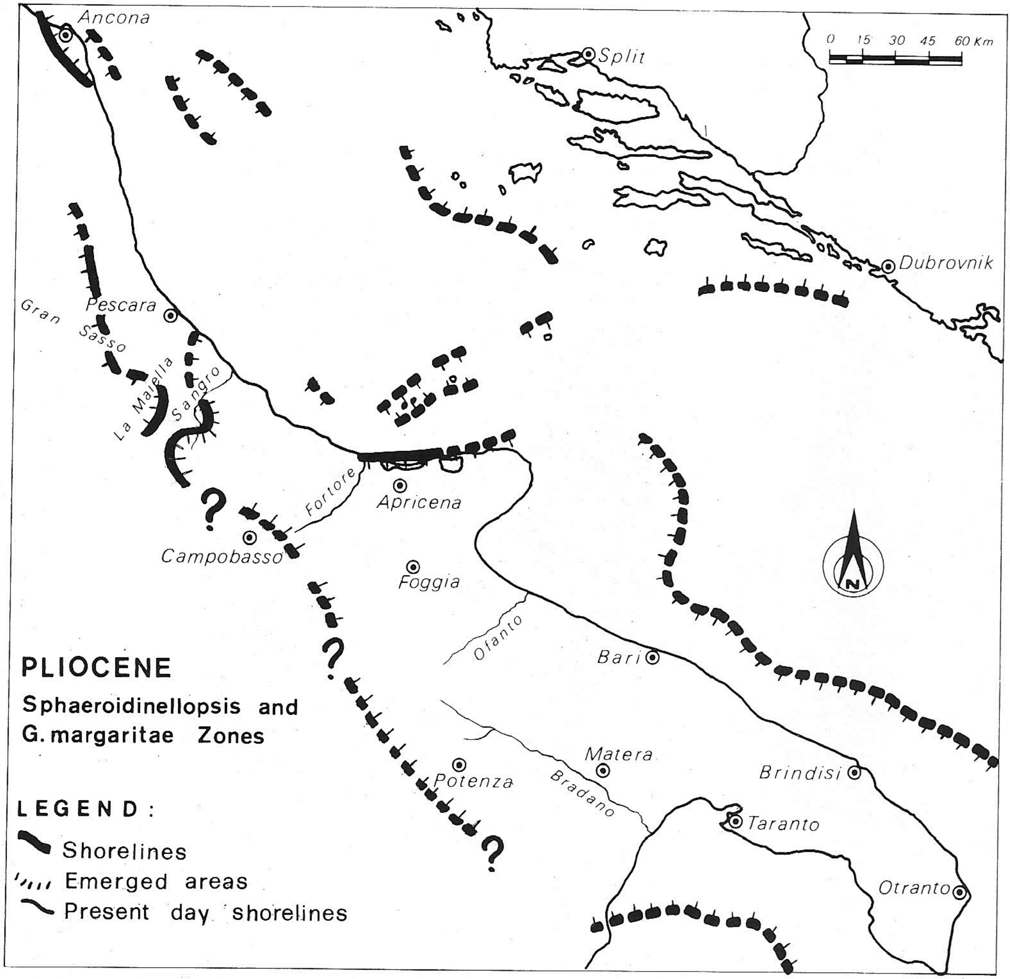

Fig. 5 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the *Sphaeroidinellopsis* and *G. margaritae* Zones.

Now the Pliocene and Pleistocene paleogeographic reconstruction needs to be better defined.

To start with, a geologic and tectonic outline can be useful.

In the southern Adriatic area Ciaranfi et al. (1983), recognized the following structural sectors from east to west: a) the Dalmatic platform; b) the meso – Adriatic basin; c) the Apulian foreland; d) the Apennines foredeep; e) the Apennines Range (Fig. 1).

Except for the Apennines Range, these structural blocks roughly correspond to the detectable remains of the Apulo–Dalmatic Realm. In this area the

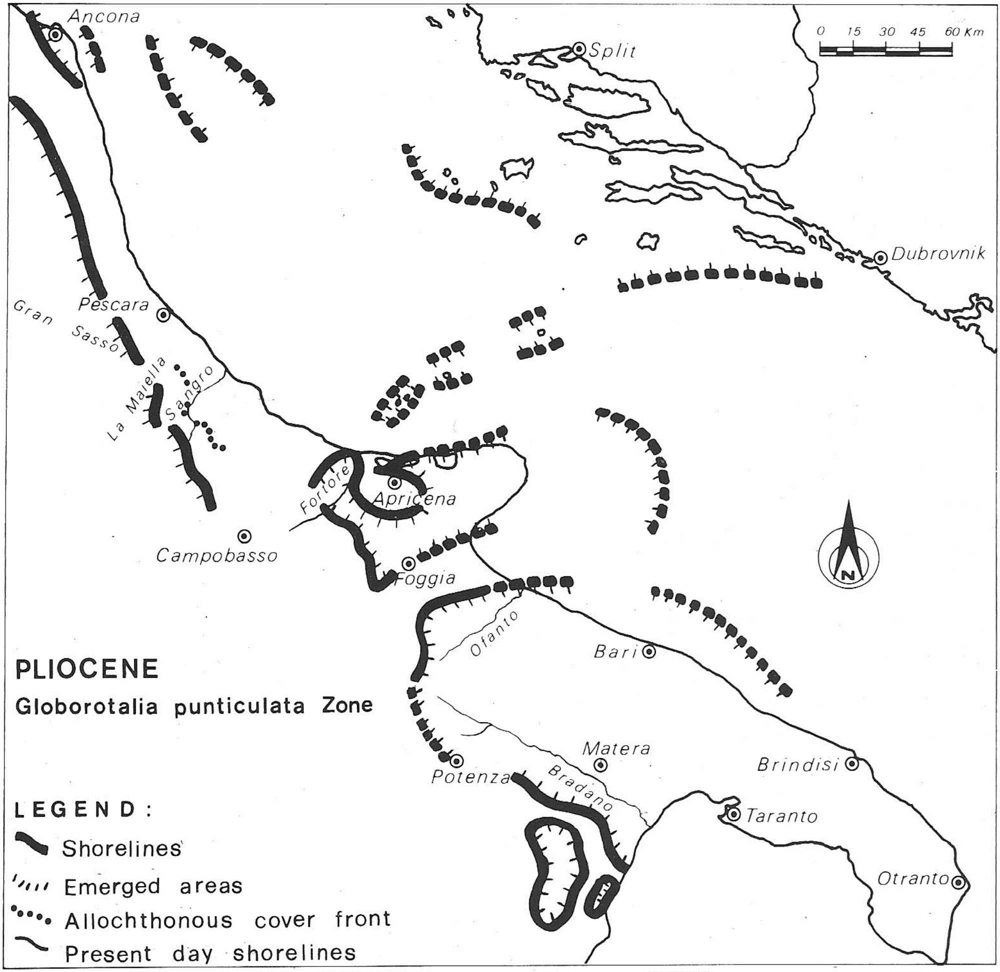

Fig. 6 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the *G. puncticulata* Zone.

Apennines have been affected by uplifting since the Early Pliocene while to the north, outside the Apulo–Dalmatic Realm, they have been emerging since the Messinian.

The sectors evolved in different ways. The evolution of the foredeep in respect to tectonics and sedimentation is the best known.

To the north (Marche and Abruzzo basins, Valleri et al., in press) the sedimentation in the infra–Pliocene basins (*Sphaeroidinellopsis* and *G. margaritae* Zones) (Fig. 5) took place uninterruptedly over the Messinian deposits, often turbiditic. On the contrary, the marine ingression started to the south

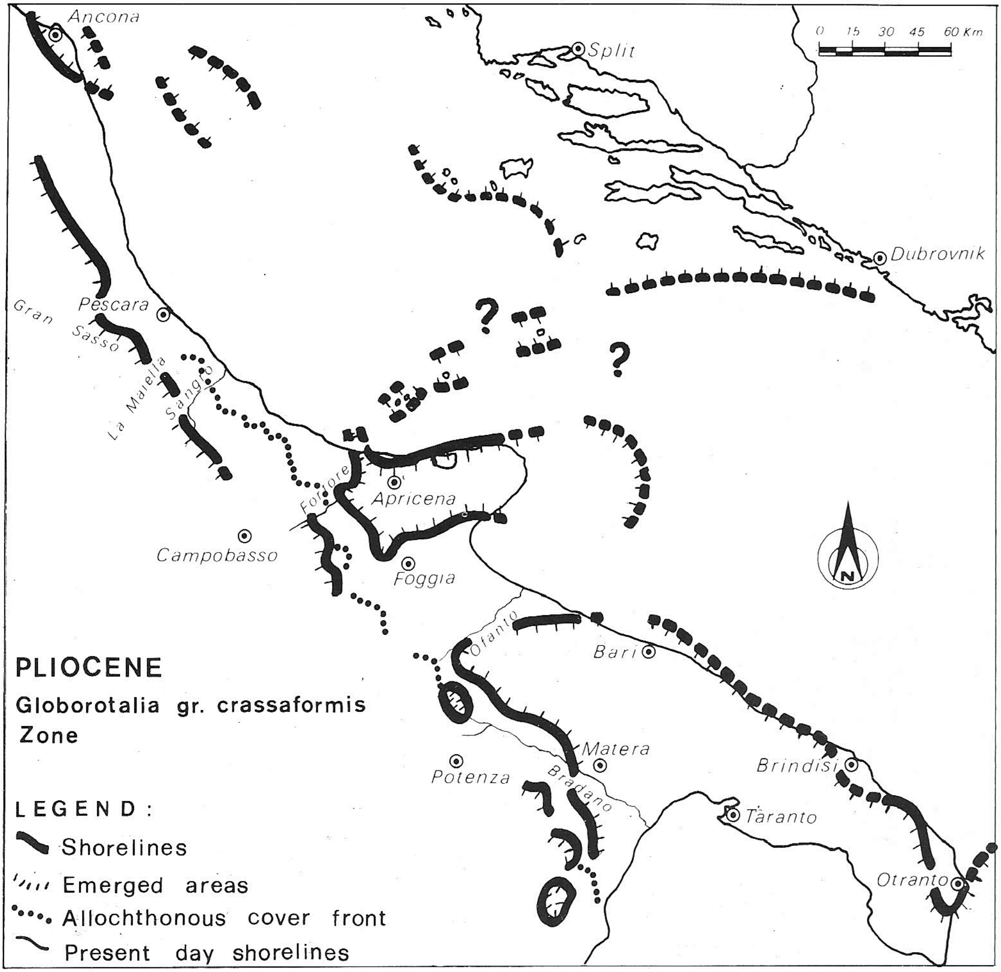

Fig. 7 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the *G.* gr. *crassaformis* Zone.

during the *G. puncticulata* Zone on a substratum, of progressively older age from north to south, from the Middle Miocene to the Cretaceous (Fig. 6).

The widening of the marine environment went on till the end of the Early Pleistocene. As a general trend the Pliocene transgression rejuvenates southward starting from the Marche and Abruzzo basins (Casnedi et al., 1982) through the Apulia basin to the Lucania basin (Balduzzi et al., 1982a).

The tectonic evolution of the margins of the foredeep (the Apennines to the west and the Apulian platform to the east) was different. The western margin is characterized by compressive tectonics starting at the end of the Tor-

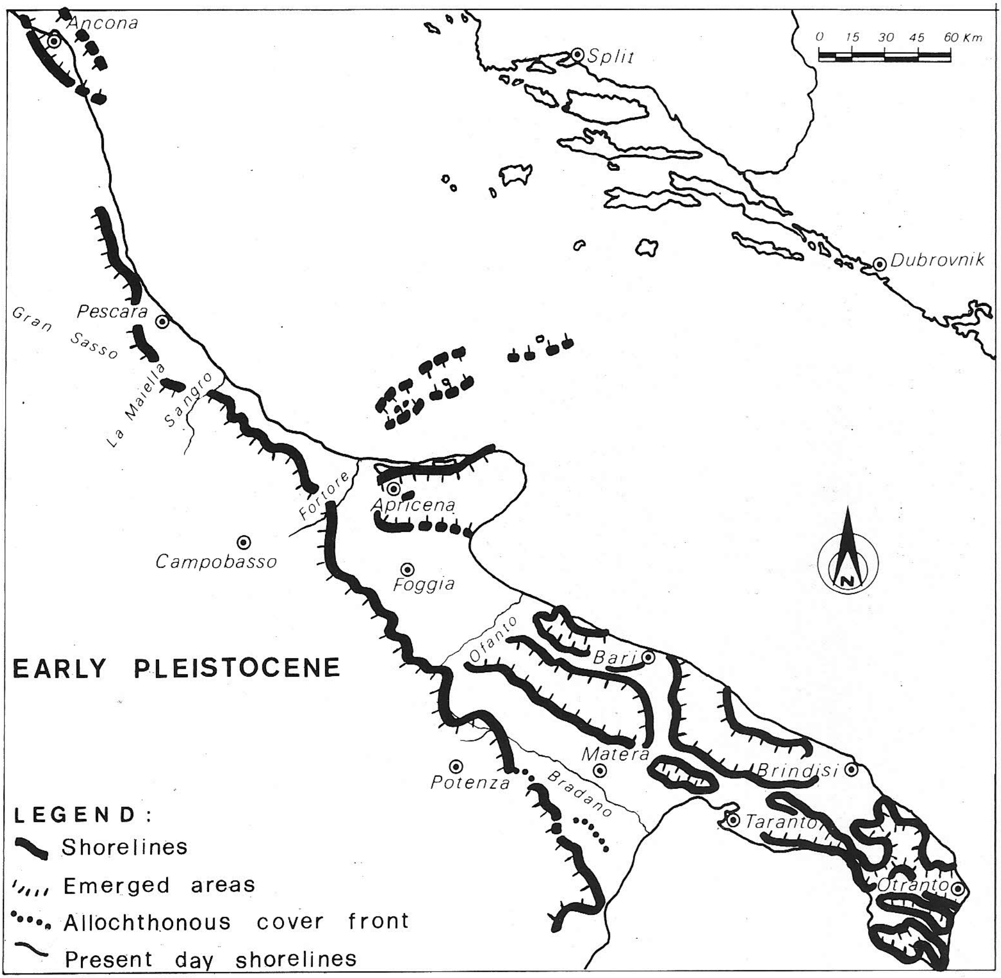

Fig. 9 – Paleogeographic sketch of the Apulo–Dalmatic Realm during the Early Pleistocene.

emerged in the later part of the Early Pleistocene and the present coasts were reached by stepwise regressions during the Middle–Late Pleistocene. The eastern margin of the foredeep was uplifted as an average about 350 m, the western one about 700 m (Ciaranfi et al., 1983; Segre, 1978). After the late Early Pleistocene no sufficient data are available to draw detailed paleogeographic maps.

The Pliocene, exclusive of the very beginning, and the Early Pleistocene were characterized by a general transgressive trend, but during the Middle Pliocene (G. gr. *crassaformis* Zone) an extensive faulting generated extremely variable local conditions (Fig. 7). Sedimentary gaps or reduced series, usually

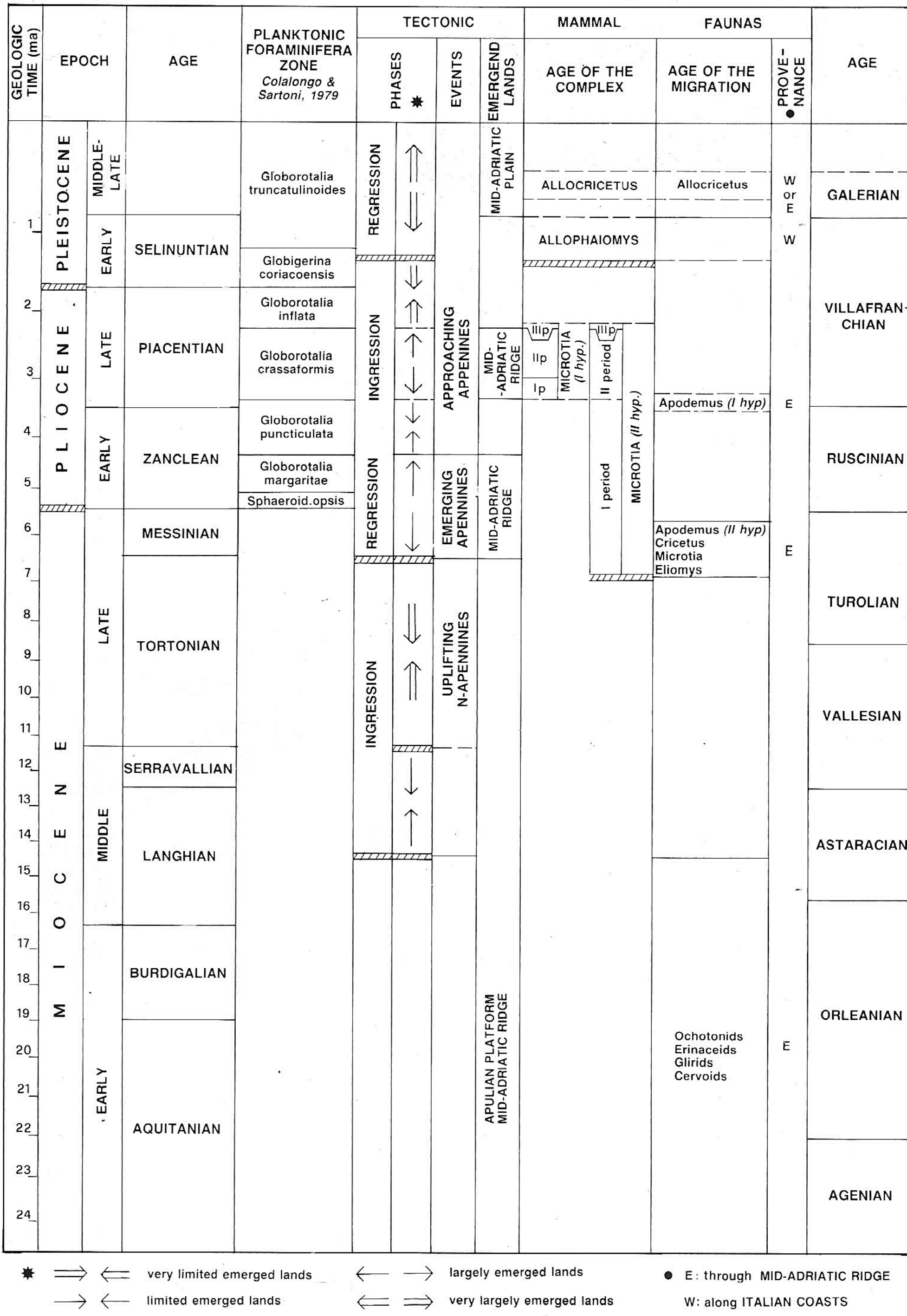

Fig. 10 – Geologic and biologic events in the Apulo–Dalmatic Realm.

in correspondence of the *G.* gr. *crassaformis* Zone, occur on structurally high blocks. This is observed in the eastern border of the Molise basin (Crescenti, 1975), in the Apulia basin (Balduzzi et al., 1982b; Valleri, 1984), in the southern border of the Lucania basin (Balduzzi et al., 1982a). Crescenti (1975) suggested a Middle Pliocene regression–transgression cycle which can also be appreciated in the Marche–Abruzzi basin (Crescenti, 1971; Crescenti et al., 1980). The tectonic phase, causing the regression–transgression phenomena and the advancement of the allochthonous covers from the west, led to the maximal narrowing of the foredeep.

In the northern Adriatic area a thick sequence with anoxic sediments was deposited during the *G.* gr. *crassaformis* Zone (Colalongo et al., 1982; Berardi & Nanni, 1985). The sapropels yielded endemic fishes of Miocene affinities (Sorbini, 1982 and personal communication, 1985). Thus a low exchange rate of the northern Adriatic with the Mediterranean sea has to be envisaged. This agrees with the temporary limited water circulation through the foredeep and implies an uplift of the Mid–Adriatic Ridge.

Paleogeography and mammal faunas.

Paleogeographic reconstructions provide evidence that migrations of the ancestors of the species forming the *Microtia* complex to the Apulo–Dalmatic Realm most likely were accomplished during two periods in the Miocene. The Tortonian sea spreading divides these two periods (Fig. 10).

The direct ancestors of most of the mammals of *Microtia* complex are still unknown, and therefore only hypotheses are possible.

The most likely ancestors of the small glirids, ochotonids, cervoids and of at least the largest erinaceid suggest that the migrations of these forms occurred during the first period covering the Early Miocene and part of the Middle Miocene. Leinders (1984) points out a connection of *Hoplitomerycidae* with Early Miocene antlerless cervoids, while Butler (1980) suggests that the ancestor of *Deinogalerix* was a still unknown *Echinosoricinae* which possibly migrated during the Early Miocene together with other members of the subfamily, from an Asiatic dispersal center. The small glirids appear to be related to the Early–Middle Miocene *Peridyromys* group and the *Prolagus* to *Prolagus oenigensis*, not recorded later than the Vallesian.

On the other hand, the ancestors of the cricetids, of *Eliomys, Microtia* and *Apodemus* presumably did not arrive before the second period, covering the Messinian and the earliest Pliocene. Freudenthal (1985) suggests that the ancestor of the cricetids were *Cricetulodon* and a form closely related to *Cricetus kormosi* both of Late Miocene age. The genus *Elyomys* has not been recorded before the Late Miocene. The hypsodont and stephanodont murids that could have originated *Microtia* occurred during the latest Miocene.

Apodemus needs discussion. Its morphology and its evolutionary degree are very similar to those of *Apodemus dominans* of the Csarnota 2 site. This similarity could be due either to a clear phylogenetic relationship of these two species or to convergence phenomena that involved the ancestor of the «Gargano *Apodemus*». In the latter case, suitable ancestors for the «Gargano *Apodemus*» could have migrated during the Messinian—earliest Pliocene regression. In the former case, on the contrary, the migration of *Apodemus* to the Apulo—Dalmatic Realm should have occurred in an age not much different from that of Csarnota 2 (referred to the Late Ruscinian = Late *G. puncticulata* Zone). We consider this hypothesis more probable (Fig. 10).

If this is true, as *Apodemus* occurs in all fissures with *Microtia* fauna, the «terra rossa» fillings are late Early Pliocene in age. Also the evolutionary radiation of *Microtia* does not oppose this hypothesis. If we consider the ancestor of *Microtia* to have migrated in the Messinian, as several authors suggest, the best conditions for radiation of the genus, supported by an archipelago condition, would have occurred during the fragmentation phase of the Realm in correspondence of the *G. puncticulata* Zone. *Apodemus*, on the contrary, does not show any radiation.

The age of the capping sediments does not oppose this conclusion. During the Pliocene two ingressive phases, in the *G. puncticulata* Zone and in the *G. inflata* Zone, are recognized in the Apricena area (Valleri, 1984). Emerged land conditions are thus testified not only in the Messinian—earliest Pliocene but also during the time span of the *G. crassaformis* Zone.

De Giuli et al. (1985c) interpreted the variation of relative abundance of taxa and the development of peculiar morphologies, in the samples of the *Microtia* complex, as due to environmental changes related to the variations in climate and in emerged land surface. The authors divided the history of the *Microtia* complex into three periods. A progressive drying up of the climate and a strong isolation of the emerged lands were envisaged in the first period. During the second phase, the climate was still dry but communications among islands were easier and the environment allowed the coexistence of several sister species; this fact suggests a widening of the emerged areas. Several taxa became extinct during the third period, characterized by a deterioration of the environmental conditions.

During the Pliocene, on the base of marine data (Valleri et al., in press), a climate with sub—tropical affinity may be recognized until around 3.2—3.0 M. A., when a temporary cooling event took place. The strongest climatic cooling occurred around 2.6—2.4 M.A. (Valleri et al., in press). On the emerged lands these climatic coolings could have resulted in a drying up; on the continents climatic fluctuations often correspond to migration events but on the islands these do not necessarely leave a discernible mark.

The reconstruction of the history of the *Microtia* complex can fit this climatic evolution in two different ways, according to which interpretation of the *Apodemus* arrival is accepted. If we interpret the «Gargano *Apodemus*» as having migrated during the Messinian–earliest Pliocene, then the first period with radiations would correspond to the *G. puncticulata* transgression; the second period, characterized by easier inter–island communications and wide emerged areas, would correspond to the *G. crassaformis* regression; the final period, as well as the extinction of the *Microtia* complex, would correspond to the *G. inflata* ingression.

On the other hand, if we accept the hypothesis of a migration of a Csarnota–like *Apodemus*, all the recorded phases of the history of the *Microtia* complex must have occurred during the *G. crassaformis* regression. The first phase would correspond to the beginning of the sea regression, the second to the full emersion, and the third to the final flooding (Fig. 10).

It is evident that the interpretation of *Apodemus* is the key to a definite chronological setting of the *Microtia* fauna. A latest Miocene non–endemic fauna has been recently discovered near Brisighella in the Northern Apennines (Costa et al., 1985). The study of the rich murids assemblage in this fauna (De Giuli, in progress) and the comparisons with the murids of the Gargano will possibly contribute to a better understanding of where in the geologic time scale the *Microtia* history should be placed.

As we have seen, the paleogeographic reconstructions, and the interpretations of faunal evolution, are essential to the hypothesis of the migrations of the members of the *Microtia* complex through the Mid–Adriatic Ridge.

On the contrary, suitable data are not available for detailed paleogeographic reconstructions from the later part of the Early Pleistocene onwards. The *Allophaiomys* and the *Allocricetus* faunas have no endemic features, and elements with eastern affinities inside these faunas are shared by a number of European sites.

The simplest hypothesis for the arrival of the *Allophaiomys* fauna is through the Italian Peninsula. Thus, as data on the marine series are not available, the migration of this fauna marks the definite closing of the northern part of the foredeep.

Bartolomei (1980) pointed out the eastern affinities of the *Allocricetus* fauna. As a matter of fact *Allocricetus* is documented only in the area around Trieste in the continental part of Italy. On the other hand, few Middle Pleistocene sites are known in the peninsula and, at the moment, none were found along the Adriatic coast. As this fauna is placed in a time when glacial eustatic variations occurred, a migration through the Mid–Adriatic Ridge or one along the coasts of the Northern Adriatic Sea are equally possible.

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