

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

**Stratigraphic framework of the type-locality of PirroNord
mammal Faunal Unit (Late Villafranchian, Apricena, southeastern
Italy)**

This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/129476> since 2015-11-24T22:09:15Z

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)



UNIVERSITÀ DEGLI STUDI DI TORINO

This is an author version of the contribution published on:

Questa è la versione dell'autore dell'opera:

Palaeontographica Abteilung A, 298, 1-6, 2013, DOI:10.1127/pala/298/2013/5

definitive version is available at:

La versione definitiva è disponibile alla URL:

<https://www.schweizerbart.de/journals/pala>

Stratigraphic framework of the type-locality of Pirro Nord mammal Faunal Unit (Late Villafranchian, Apricena, south-eastern Italy)

CARLO BERTOK ⁽¹⁾, FEDERICO MASINI ⁽²⁾, LUCA MARTIRE ⁽¹⁾, MARCO PAVIA ⁽¹⁾, MARTA ZUNINO ⁽¹⁾,
GIULIO PAVIA ⁽¹⁾

⁽¹⁾ Dipartimento di Scienze della Terra, Università di Torino, Italy (carlo.bertok@unito.it)

(Corresponding author)

⁽²⁾ Dipartimento di Scienze della Terra, Università di Palermo, Italy (fmasini@unipa.it)

(3 Figs.)

Summary

The fossiliferous karst deposits of the typical Pirro Nord Faunal Unit recently revived interest for the lithic tools documenting the human occurrence in southern Italy at Early Pleistocene.

Therefore, a revision of the Pliocene to lowermost Pleistocene stratigraphic succession was needed. It was carried out with a twofold aim: to detail the stratigraphic architecture and the structural-depositional evolution of the “Apricena horst”, and to verify the chronostratigraphic constraints for the Pirro Nord F. U. in the type-locality of Apricena. The stratigraphic record has been subdivided in four units bounded by ubiquitous unconformity surfaces, often associated to evidence of subaerial exposure. Facies changes and unconformity surfaces reflect the activity of the E-W trending normal faults bounding the study area which, since late Early Pliocene, was a submerged horst characterized by highly variable sedimentation rates, repeated episodes of no sediment supply and a significant synsedimentary seismic activity. The southern fault of the Apricena horst assumes particular significance because the karstification preferentially developed along the fractured fault core-zone; the resulting hypogenous features were filled up by sediments bearing late Villafranchian biogenic remains whose age is confirmed within the Early Pleistocene (sensu pre-IUGS recommendation). At present no more precise age information is available, except for the one derived from biochronological data based on the vole *Allophaiomys ruffoi*.

Key-words: Facies analysis – Synsedimentary faulting – Pliocene – Pleistocene – Pirro Nord – W Gargano.

Table of Contents

1. Introduction, pag. 3
2. Geological Setting, pag. 4
3. The Plio-Pleistocene marine succession, pag. 6
4. Stratigraphic correlations and evidence of syndepositional tectonics, pag. 11
5. The continental palaeontological record, pag. 14
6. Discussion and Conclusions, pag. 18
7. Acknowledgements, pag. 21
8. References, pag. 22

1. Introduction

The interest on the fossiliferous karst deposits delivering the vertebrate type-assemblages of the Pirro Nord Faunal Unit (late Villafranchian Mammal Age, Early Pleistocene: ABBAZZI *et alii*, 1996; GLIOZZI *et alii*, 1997, and references therein) recently revived after discovery of lithic tools from the infillings of the karst network exposed in the Apricena-Lesina-Poggio Imperiale quarrying district. The association of vertebrate fossils and flint artefacts document the human occurrence in southern Italy in the Matuyama post-Olduvai palaeomagnetic Chron, in the Early Pleistocene between 1,3 and 1,7 Ma, and testify that the genus *Homo* spread in Europe earlier than previously supposed (ARZARELLO *et alii*, 2007). The importance of such findings calls for a revision of the Pliocene to lowermost Pleistocene stratigraphic succession in which the fossiliferous karst structures are developed. The quarry works have recently exposed new large transects, showing a stratigraphic architecture quite different from those discussed even in recent

papers (ABBAZZI *et alii*, 1996; CASOLARI *et alii*, 2000), and revealing the strong influence of synsedimentary tectonics on the deposition of the Pliocene to lowermost Pleistocene sediments (PAVIA *et alii*, 2010).

The aim of the present work is thus manifold, namely (1) to detail the stratigraphic context in which the Pirro Nord F.U. is inserted, (2) to summarize the depositional evolution of the northwestern Gargano Pliocene to lowermost Pleistocene stratigraphic succession, (3) to verify the earliest Pleistocene chronological constraint to the type Pirro Nord F.U., (4) to characterize the Pliocene synsedimentary faults, providing chronostratigraphic constraints to their activity and documenting their role in controlling the geometry of the sedimentary bodies, (5) to document that the Pliocene faults acted as structural constraints to the development of the Lower Pleistocene karst network and its fossiliferous deposits.

As regards the chronostratigraphic/chronologic terms used in this paper, it is worth noting that Pliocene Series/Epoch, Pleistocene Series/Epoch and Gelasian Stage/Age are reported with the former meaning preceding 2009 IUGS's recommendation (see also GIBBARD & HEAD, 2009). Thus, in the following, we consider the Gelasian Stage/Age as the uppermost Pliocene term and the Pleistocene lower boundary placed at 1,8 Ma.

2. Geological Setting

The former Pirro Nord quarry sector is located north-west of the Gargano Promontory on a E-W elongated topographic belt constituting the so-called Apricena horst, a positive structure connected to E-W to WNW-ESE trending regional faults, the most known of which is the normal Apricena Fault. The latter is a normal fault with a cumulative displacement of about 500 m, and is considered the westernmost branch of the Mattinata fault system, a complex crustal-scale E-W trending wrench zone crossing the whole southern Gargano promontory and continuing offshore

in the Adriatic sea for more than 130 km (PATACCA & SCANDONE, 2004, and references therein). BRANCKMAN & AYDIN (2004) proposed that the interaction with another E-W trending strike-slip fault zone bounding the Gargano to the North caused the uplift of the Gargano area since Late Miocene.

Consequently, the Neogene succession in north-western Gargano is extremely complex due to the palaeotopography articulated in a pattern of structural highs and lows, that resulted in palaeoenvironments repeatedly changing in space and time. In short, during the Miocene a marine sedimentation, although irregular and discontinuous, took place in the Gargano area (D'ALESSANDRO *et alii*, 1979; BOSELLINI *et alii*, 1994; CASOLARI *et alii*, 2000), whereas the Apricena-Poggio Imperiale block formed an emerged horst elongated in E-W direction. During the Pliocene the Gargano Promontory was uplifted and became an elongated island, whereas the Apricena horst subsided and was flooded.

The Plio-Pleistocene marine succession cropping out in the Apricena-Lesina-Poggio Imperiale quarrying district is composed of carbonate to siliciclastic terms unconformably resting on the Mesozoic limestones of the Calcere di Bari Fm. (SPALLUTO & PIERI 2008). Two sets of continental deposits also occur: the residual Terre Rosse characterized by the Late Miocene to Early Pliocene “*Mikrotia* fauna”, and the sandy pelites of the Early Pleistocene Pirro Nord Fauna Unit. The Plio-Pleistocene marine succession has been investigated by several authors in the last century (ABBAZZI *et alii*, 1996, and references therein). Recently, however, Pavia *et alii* (2010) proposed a quite different lithostratigraphic setting, and stressed the fundamental role of tectonics in controlling both facies and geometry of the Pliocene sedimentary units.

3. The Plio-Pleistocene marine succession

The Plio-Pleistocene marine succession is arranged in two lithologic bodies separated by a discontinuity: a lower carbonate complex, spanning the Lower to Upper Pliocene, and an upper siliciclastic unit, latest Pliocene to Early Pleistocene in age.

In literature, the lower carbonate complex has been referred on the whole to the Calcarenite di Gravina Formation (D'ALESSANDRO *et alii*, 1979; CASOLARI *et alii*, 2000; PAMPALONI, 2001). Only the upper part of the Pliocene carbonate complex, however, corresponds to the Calcarenite di Gravina bio- and lithofacies, whereas the lower part shows peculiar features which markedly differ from the Gravina Formation. For this reason, two lithostratigraphic units with formational meaning have been distinguished: the Lago di Varano Fm. (CREMONINI *et alii*, 1971) for the lower part, and the Calcari a Briozoi Fm. (MERLA *et alii*, 1969) for the upper part.

The upper siliclastic unit is referred to the Serracapriola Fm. (CAPUANO *et alii*, 1996, and references therein).

The Apricena-Lesina-Poggio Imperiale quarrying district succession has been described in nine sections cropping out in adjacent quarries located in an area of around 1.5 km² (Fig. 1). Seven of these sections are represented in Fig. 2, where the main facies distinguished in the succession are correlated. A large amount of data has been elaborated on invertebrate and microfossil assemblages, that allowed fine biostratigraphic and palaeoenvironmental definitions of the units (see also in PAVIA *et alii*, 2010).

Lago di Varano Formation

Several lithozones have been distinguished within the Lago di Varano Fm. on the basis of their facies associations and palaeontological content. They are described in the following with the acronyms reported in Fig. 2.

Limestone-clay (LC) and calcarenite (CL) lithozones

This set of lithozones lies on an erosional surface cutting the Terre Rosse and the Calcare di Bari Fm. with a marked angular unconformity (Fig. 3a). Its thickness ranges from 3.7 to 9.4 m, being controlled by the jagged morphology of the stratigraphic top of Calcare di Bari Fm. At the base the limestone-clay lithozone (LC, 1 metre-thick) is composed of medium to thick whitish mudstones alternating with thin to medium greenish clay beds; carbonate beds are crossed by thin and irregular fissures, possibly related to plant roots. The overlying calcarenite lithozone (CL) is composed of well-sorted fine- to coarse-grained peloidal and bioclastic grainstones, organized in medium to thick beds showing parallel lamination or ripple cross-bedding, alternating with subordinated coarser-grained thin to medium beds.

As to depositional aspects, the limestone-clay lithozone reflects sedimentation in a transitional lagoonal environment, with periodic episodes of subaerial exposure, whereas the calcarenite lithozone indicates the transition to an open marine setting.

Megabreccia lithozone (ML)

This lithozone rests on the calcarenite lithozone with an erosional contact and consists of a megabreccia single bed 4 to 6 metres thick (Fig. 3b), showing peculiar and quite ubiquitous features: (a) erosional base with dm- to m-scale relief; (b) clast-supported and chaotic texture, without any internal partition; (c) occurrence of water escape structures and soft sediment deformation structures; (d) extremely poor sorting, with angular to poorly rounded clasts ranging up to m-sized boulders and portions of strata; (e) diverse nature of the clasts: most clasts consist of lithologies occurring in the local underlying succession, but also exotic clasts occur (e.g. wackestones with Middle Eocene planktonic foraminifera); (f) a marly matrix with planktonic foraminifers (e.g. *Globorotalia puncticulata*) pointing to the late Early Pliocene; (g) a very sharp

upper surface corresponding to the top unconformity, with an abrupt transition to the overlying deposits.

Such features indicate a single *en-masse* deposition from a hyperconcentrated flow moved by a particularly high-energy process that could remove and transport unconsolidated sand, gravel, boulders and portions of strata, and to scour up to 1 metre down into sea-bottom sediments. The only reliable causative phenomenon seems to be a tsunami; comparable examples could be found in EINSELE (1998), MASSARI & D'ALESSANDRO (2000), HARTLEY *et alii* (2001), CANTALAMESSA & DI CELMA (2005), LE ROUX & VARGAS (2005). It is thus suggested that during the late Early Pliocene a tsunami wave passed across the Apricena-Poggio Imperiale area and triggered a strong backwash current that deeply eroded upper shoreface and foreshore sediments, generating a seaward-directed hyperconcentrated debris flow that, after a short distance, quickly froze and deposited its charge.

Isognomon *biostromal lithozone* (IB)

This unit consists of a single, massive bed 0,80 to 1,60 m in thickness. It lies on the unconformity surface corresponding to the megabreccia lithozone top (Fig. 3c) and ends with an undulated hard ground surface with *Lithophaga* borings. At the base, the bed is matrix-supported and bears medium-sized specimens of *Isognomon* (*Hippochaeta*) *maxillatus* whose scaly shells lie sub-horizontal; at the top, the texture is shell-supported and fossils are large, both univalve and bivalve, randomly oriented. The biostrome is dome-shaped in a sort of patch reef structure.

The environmental meaning of such a biostromal unit derives from the autoecological characters of *I. maxillatus*, which is a marine soft-bottom dweller with semi-infaunal habitus on unconsolidated medium-energetic bottom in the proximal part of the infralittoral zone (SAVAZZI, 1995; FERRERO & PAVIA, 1996). As to chronostratigraphic constraints, the most recent occurrence of *I. maxillatus* is from the earliest Piacenzian (MONEGATTI & RAFFI, 2001).

Barnacle-coral biostromal lithozone (BC) and barnacle horizon (BH)

It consists of rudstones with a shell-supported texture (BC); palaeobiological elements are represented by large, mainly coalescent and mostly entire carapaces of *Balanus* sp., and by internal molds of solitary, ahermatipic corals such as *Balanophyllia*, *Caryophyllia*, *Flabellum*, plus invertebrate tests and undeterminable benthic and planktonic foraminifera. Barnacles and corals do not show any sorting, being represented by specimens ranging from few mm to more than 10 cm for barnacles, and lie both in growth position or differently displaced to overturned. As to palaeoenvironmental definition, the coral families Cariophylliidae, Dendrophyllidae (*Balanophyllia* ap.) and Flabellidae are referred to relatively deep bottoms, below the infralittoral/circalittoral transition (cf. CHAIX *et alii*, 1999).

At the top of the lithozone, a 20-40 cm-thick bed occurs (Fig. 3d), which is composed of coalescent barnacle carapaces of *Balanus* sp. and very scattered corals (BH). Most fossils are dimensionally selected (barnacle carapaces 6-10 cm high) and preserved in life position or little displaced and laying down; the fossil horizon represents a residual, size-selected barnacle community. The scarcity of circalittoral corals and the homogeneous large size of barnacles point to an increase in hydrodynamic energy compared to that inferred for the underlying barnacle-coral biostrome.

Calcari a Briozoi Formation (CB)

It consists of yellowish, medium to coarse bioclastic packstones, organized in ill-defined dm- to metre-thick beds; the appearance is lumpy because of localized cementation and of algal nodules. The lower boundary is erosional on the upper terms of the Lago di Varano FM. The formation is thinner in the central horst sector of the study area, whereas it can reach thickness of

several tens of metres on the downthrown blocks of the main synsedimentary normal faults (fig. 2, sect. 1). Moving westward, the Calcari a Briozoi Fm. progressively reduces its thickness and finally pinches out. The fossil assemblages are dominated by colonial Cheilostomata and subordinately Tubuliporata bryozoans; corallinae algae are common both as encrusting structures and pluricentimetric spheroids. Fossil tests belong to different invertebrates among which brachiopods that indicate deposition on circalittoral bottoms approximating the "Coastal Detritic Biocenosis" of the modern Mediterranean platform (PÉRÈS & PICARD, 1964). As to biostratigraphy, *Globorotalia inflata* allows the fossil assemblage to be referred to the subzone MP16 of SPROVIERI (1992) corresponding to the Gelasian Stage; moreover, the base of this formation can not be older than the Gelasian Stage due to the presence of *Joania cordata* which is known to be distributed from Late Pliocene to Recent.

The top of the Calcari a Briozoi Fm. corresponds to an erosional unconformity surface marked by a hard, decimetre-thick layer mainly resulting from the lateral coalescence of encrusting coralline algae colonies. Rounded, encrusted and bored pebbles of different lithologies (Calcare di Bari limestones, barnacle-coral biostromal limestones, various kinds of calcarenites) occur and document intense current activity and a prolonged interruption of sediment accumulation. Macro- and microfossil assemblages, occurring just below the hardened layer, are referable to one of the shallow communities described by PÉRÈS & PICARD (1964) among the mediolittoral "Hard Bottoms" biocenoses of the Mediterranean Sea.

Serracapriola Formation (SE)

The Serracapriola Fm. is mainly developed in the western sector of the studied area (Fig. 3e), where two parts can be distinguished: the lower one is made up of about 10 metres of silty sands with planar lamination; in the upper part, about 30 m thick, siliciclastic sands show large scale

cross-bedding structures that indicate a fan-delta environment and a clastic influx supplied by a NW source (CAPUANO *et alii*, 1996; ROBUSTELLI & AUCELLI, 2001). In the eastern sector, the formation is much more reduced in thickness, and shows lithological and palaeontological features pointing to shallower depositional environments. The lower part provided abundant microfossils and sparse clusters of the circalittoral *Terebratula scillae*. Benthic foraminifera assemblages are constituted by both infralittoral species and taxa commonly occurring, in the Mediterranean Sea, from circalittoral to deeper environments (SGARRELLA & MONCHARMONT-ZEI, 1993; MORIGI *et alii*, 2005). As to chronostratigraphy, the occurrence of *Globorotalia inflata* indicates an age not older than the Gelasian; more precise information derives from some ostracods (e.g. *Aurila punctata*, *Echinocythereis postulata*, *Loxoconcha turbida*) which point to an Early Pleistocene age, as also suggested by the presence of left coiled specimens of *N. pachyderma* and by the brachiopod *T. scillae*.

4. Stratigraphic correlations and evidence of syndepositional tectonics

Areal distribution and geometric relationships of the above-described lithological units are complex and hardly predictable. Almost all the sedimentary bodies are characterized by strong variations in thickness. This is mainly due to the peculiar morphostructural setting of the Apricena high, which, starting at least from the end of the megabreccia deposition, was a submerged horst bounded by major E-W trending normal faults, characterized by highly variable sedimentation rates, repeated episodes of no sediment supply, and a significant synsedimentary seismic activity.

The Plio-Pleistocene stratigraphic record is characterized by the presence of four main discontinuity surfaces (fig. 2):

- **D1**, at the lower boundary of the Lago di Varano FM (Fig. 3a).

- **D2**, at the upper boundary of the megabreccia lithozone (Fig. 3c). The sharpness and the common occurrence of *Lithophaga* borings, and locally of Fe-oxide coatings, clearly show that the D2 was a rock ground. Within the megabreccia lithozone, several macroscopic and microscopic features suggest an early diagenesis in a meteoric environment and hence an episode of subaerial exposure during the time interval corresponding to the D2 unconformity.

- **D3**, at the lower boundary of the Calcari a Briozoi Fm. Its physical expression is a sharp erosional surface extensively bored by *Lithophaga*, associated to onlap geometries of the overlying sediments.

- **D4**, at the lower boundary of the Serracapriola Fm. The D4 was a hard ground surface, as testified by the erosional geometries and the local occurrence of *Lithophaga* borings. The presence of cm-sized cavities geopetally filled with reddish fine-grained sediments and calcite spar cements within the underlying sediments suggests subaerial exposure.

By combining biostratigraphic data with the occurrence of such discontinuity surfaces, that at the scale of the study area can be considered as time-lines, it is possible to subdivide the succession in four unconformity-bounded intervals that may be also related to important stages in the tectono-sedimentary evolution of the study area. The first one, comprised between D1 and D2 is referable to the Zanclean. The second interval, comprised between D2 and D3, on the whole refers to the late Zanclean. The third interval, comprised between D3 and D4, corresponds to the Calcari a Briozoi Fm. and spans the Gelasian. The complex of sediments encompassing the second and third intervals shows the most relevant changes in thickness and facies and may be even completely lacking where D2, D3, and D4 merge in a single, complex discontinuity at the top of the megabreccia. This is the result of a locally important tectonic activity that deeply affected the stratigraphic record and that will be discussed in the following section. Finally, the

fourth interval, overlying the D4, corresponds to the Serracapriola Fm. and dates to Early Pleistocene, though a late Gelasian age can not be excluded.

The favourable outcrop conditions of the Apricena-Lesina-Poggio Imperiale quarrying district allow to directly observe the fault planes directly related to the Pliocene synsedimentary tectonics recorded. In particular, two E-W trending main tectonic surfaces, bounding the Apricena horst respectively northward and southward, have been recognized. The southern fault runs close to the Pirro Nord 10 and 13 sites: it has therefore been investigated in detail in order to reconstruct its evolution and the possible structural constraints to the formation of the lower Pleistocene karst cavities.

The best exposure of the southern fault is on section 1 that corresponds to a 50 metres deep artificial trench which is N-S trending, insofar providing a beautiful section across the fault (Fig. 3f). The fault displacement is not measurable, but it surely exceeded 40 metres, i.e. the thickness of sediments on the hangingwall. The footwall is entirely composed of sub-horizontal Calcare di Bari limestones. The core-zone of the fault is represented by a subvertical 4-6 metres thick breccia body: the clasts are all composed of Calcare di Bari limestones, whereas the matrix is a wackestone/packstone with cm-sized barnacle and coral fragments. Some 20-30 metres southward from the fault a second-order antithetic high-angle normal fault is visible, showing the same strike but opposite dipping direction; its footwall wall is composed of the *Isognomon* biostromal lithozone. The morphological depression, bordered by the main fault and its antithetic fault, is filled up with resedimented deposits among which two bodies are recognizable. The lower body (B in Fig. 2, section1, and Fig. 3f) is composed of greenish bioclastic packstones with large, cm-sized, barnacle carapaces, organized in dm-thick ill-defined beds with a concave-upward geometry, quickly steepening approaching the fault; on the whole, its geometry is wedge-shaped with the depocentre close to the main fault. This lower sedimentary body is abruptly

crosscut by a matrix-supported breccia (BB in Fig. 2, section1, and Fig. 3f) with clasts made up of a packstone with fragments of barnacles and corals. The breccia body is massive, highly irregular in shape and thickness (from decimetres to 3-4 metres thick), sub-vertical in the lower part of the outcrop but gradually turning to horizontal in the upper part, where it abuts against the main fault. These two sedimentary bodies, as well as the breccia of the main fault core-zone, are sharply overlain by the yellow calcarenites of the Calcari a Briozoi Fm., which unconformably rest on them with onlap relationships (Fig. 3f).

All the described stratigraphic and geometrical features allow to define the timing of the southern fault activity as well as its effects on sedimentation. The main synsedimentary activity is chronologically constrained by the age of the youngest unit displaced by the faults (*Isognomon* biostromal lithozone) and the oldest unit sealing the fault planes (Calcari a Briozoi Fm.) i.e. between late Zanclean and Gelasian. During this time span, the accommodation space created by the displacement of the southern block was filled up by rock falls and debris flows activated along the unstable edge of the footwall of the normal fault. Two gravitational flow events have been documented: the oldest (B) was sourced from the horst edge where the barnacle palaeocommunity (BH) was thriving; the youngest (BB) is a lithoclastic breccia deriving from collapse of the barnacle-coral biostromal lithozone (BC).

5. The continental palaeontological record

The vertebrate fossil assemblages from the Gargano Neogene to Lower Pleistocene continental deposits raised in the sixties of the past century owing to the widespread exposure of morphological traps (karst structures) frequent on the Apricena horst, and particularly in the Apricena-Poggio Imperiale quarrying district. The first report is by FREUDENTHAL (1971) who pointed out the occurrence of a very diversified Miocene to Pliocene *Mikrotia* endemic fauna

from the Terre Rosse fissure infillings, and of a younger, not endemic fauna “with *Allophaiomys*” well documented in the karst deposits of some quarries localized in the central sector of the quarrying district, the present Dell’Erba quarries complex (Fig. 1).

The karst history of the Apricena area gets in the karstification scheme proposed by GRASSI *et alii* (1982) (see also ABBAZZI *et alii*, 1996, and references therein) who distinguished a “Tertiary palaeokarst cycle” developed at various time in relatively stable climatic and tectonic conditions, and a “Quaternary neokarst cycle” started after the Pleistocene regression and developed under more disturbed morphologic and tectonic conditions.

The palaeokarst cycle produced the Terre Rosse; their related infilling sediments with the endemic mammal remains were derived by soils (oxisoils). These residual deposits formed during a very long phase of emersion and deposited into well developed superficial morphologies, that are the result of repeated dissolution activities (ABBAZZI *et alii*, 1996).

The neokarst cycle is documented by morphostructures containing the Lower Pleistocene deposits with late Villafranchian vertebrate assemblages which are found in silty-sandy sediments that occur in the very restricted area of the present Dell’Erba quarries. Karstic features include both superficial (e.g. sinkholes) and hypogene forms, and were opened within the Pliocene cover (Fig. 3e), down to the boundary between the Pliocene cover and the Mesozoic limestones of the Calcare di Bari Fm., and even within the Calcare di Bari Fm. itself. Among the hypogeous structures, common karst conduits could exceed 5 m in diameter, at the contact with the Pliocene bioclastic cover the vadose phase of excavation eroded the substrate and partly removed the Terre Rosse, so that polyphasic infillings are recorded with superimposed or mixed deposits (ABBAZZI *et alii*, 1996). The recent quarry works in the southern margin of the quarrying district exposed spectacular and different karst structures: the broad sinkhole of Pirro 13 (ARZARELLO *et alii*, 2007) and the large cavity of Pirro 10 developed inside the Calcare di Bari Fm. (Figs. 3g-h)

The endemic faunas from the Terre Rosse

The fossil assemblages of the palaeokarst cycle are named by the ubiquitous occurrence of the very peculiar endemic murid *Mikrotia* (formerly *Microtia*, see FREUDENTHAL, 2006). These fossil assemblages include mammals (mostly small mammals), birds, reptiles, amphibians and document subsequent population phases of an isolated endemic district, possibly an island in an archipelago (see MASINI *et alii*, 2008, with references therein). During the time interval documented by the fissure deposits, the faunal diversity changed and several taxa underwent significant evolutionary changes and radiations. On the basis of their fossiliferous content, the fissure infillings can be arranged in a chronological sequence that includes at least four different phases characterized by changed taxonomical composition and evolutionary stage (FREUDENTHAL 1976; DE GIULI *et alii*, 1987b, 1990). The range of possible ages for the *Mikrotia* faunas is fairly well constrained and a Messinian-Early Pliocene age is considered likely by several authors (e.g. MAZZA & RUSTIONI, 2008). Details on faunal content and palaeobiogeographical meaning of the *Mikrotia*-bearing sediments can be found in ROOK *et alii* (2006), MASINI *et alii* (2008), MAZZA & RUSTIONI, 2008.

The Late Villafranchian fauna of Pirro Nord F. U.

The “Pirro Nord” term derives from the family name of Pirro, the quarry agent operating in the seventies on the central Apricena horst, and from the fissures opened in the northern corner of Pirro’s quarry. Excavations went on very quickly in the last decade, so that the quarrying area extends southwards and reaches the margin of the Apricena horst. Though this area nowadays is exploited by Franco Dell’Erba and Gaetano Dell’Erba factories, the use of the “Pirro Nord” term is too deeply adopted by literature to be changed.

After a short quotation by FREUDENTHAL (1971), DE GIULI & TORRE (1984) is the first paper where the small mammal findings from a fissure named as Pirro Nord are described. In 1985 the new fossil assemblage (large and small mammals) was introduced to the scientific community at the Fifth Palaeontological Colloquium in Weimar and a report was then published by DE GIULI *et alii* (1987a). In few years the fauna gained more and more importance and the former Pirro Nord quarry was proposed (and accepted) as the type locality of the youngest faunal unit of the late Villafranchian (macro-) Mammal Age (Pirro Nord F.U.): i.e., it was considered as representative of a distinct phase of mammalian population of the Italian peninsula (GLIOZZI *et alii*, 1997). Meanwhile, new studies were carried out and new fossil material was recovered (ABBAZZI *et alii*, 1996, with references therein).

From 2007 to 2009, systematic excavations have been carried out in two large fissures of new discovery, named Pirro 10 and Pirro 13 (PAVIA *et alii*, 2011). At present we can just document that the infillings of these broad karstic features underwent subsequent and alternate phases of sediment supply and channelized erosion, so that a succession in both localities could be described and provide elements useful for palaeomagnetic interpretation and taphonomic studies (ARZARELLO *et alii*, 2009b; PAVIA *et alii*, 2009). Such a situation is particularly evident at Pirro 10 where a 7 meters thick succession has been sampled and tested (Fig. 3h).

An updated faunal list is in ARZARELLO *et alii* (2009a). The fossil assemblages have totalized nearly 110 vertebrate taxa: 20 amphibians and reptiles, 47 birds, over 40 mammals. Some details for the faunal association: a large number of carnivores among which *Pachycrocuta brevirostris*, *Megantereon withei*, *Lycaon lycaonoides*; several herbivores among which *Bison (Eobison) degiulii*, *Equus altidens* and *E. sussenbornensis*; many Cervidae; the large porcupine *Hystrix refossa*; different species of bats and other micromammifers among which the biochronologically important *Allophaiomys ruffoi*; a palaeoenvironmentally significant stock of birds like *Otis tarda*,

Tetrax tetrax, *Pterocles orientalis*. General palaeobiogeographic remarks concern the absence of any signal of insular endemism. This observation, coupled with the occurrence of a balanced, high diversified, vertebrate association (ARZARELLO *et alii*, 2009A), evidences that at the time of the neokarst infillings the Gargano area should definitely have been in full geographical connection with the Italian peninsula.

The macrofauna includes several taxa that also occur in other Italian late Villafranchian localities (e.g. Pietrafitta, Cava Liberatori) referred to the Farneta F.U., the biochronological unit just preceding the Pirro Nord F.U. However, at Pirro Nord some new taxa are found, which also occur in localities definitely younger; the best known taxon is *Bison degiulii* which is absent within the Farneta F. U. (GLIOZZI *et alii*, 1997; MASINI & SALA, 2007). The most significant element for biochronological dating is the vole *Allophaiomys ruffoi* (MASINI *et alii*, 1998), which is indicative of the Early Biharian (micro-) Mammal Age (cf. GLIOZZI *et alii* , 1997; SALA & MASINI, 2007). In synthesis, the Pirro Nord F.U. is considered as younger than the Farneta F.U. and as older than the Colle Curti F.U. of earliest Galerian Mammal Age (cf. MASINI & SALA, 2007, with references therein).

6. Discussion and Conclusions

On the basis of biochronostratigraphic, palaeoecological and sedimentological data, genetic interpretation of discontinuity surfaces, and the geometrical relationships of sedimentary bodies the following steps in the Pliocene to Early Pleistocene evolution of the Apricena-Poggio Imperiale area may be sketched:

a) After the prolonged period of subaerial exposure which led to production of the residual Upper Miocene-Lower Pliocene Terre Rosse, marine sedimentation started again during the Zanclean in a lagoonal depositional environment (LC), rapidly evolving to a middle to upper shoreface setting

(CL). The occurrence of a 4-6 metres-thick tsunamite megabed (ML) testifies for a very large seismic shock in the proximity of the Apricena-Poggio Imperiale area, possibly related to the activity of some major faults (e.g., the Mattinata Fault system).

b) The megabed deposition was followed by a subaerial exposure episode, which determined a widespread and intense early meteoric diagenesis of sediments. The subsequent marine depositional phase, spanning the Late Zanclean, was strongly controlled by synsedimentary tectonics that originated a highly irregular sea floor topography. The activation of km-scale E-W trending normal faults provoked the uplift of a horst sector, elevated on the surrounding areas by several tens of metres. Marine transgression was rapid, so that the central horst was placed below the infralittoral/circalittoral transition, and sedimentation was represented exclusively by the growth of barnacle-coral biostromes and barnacle communities (BC and BH). The edges of the horst, close to the boundary faults, were repeatedly affected by gravitational collapse phenomena (B and BB). All these gravitational deposits filled the morpho-structural depression bordering the southern fault.

c) Another discontinuity testifies for an ubiquitous erosional phase and is overlain with onlap geometries by the calcarenites of the Calcari a Briozoi Fm. The latter fill up the remaining tectonic depressions, and seal the horst boundary faults. The Calcari a Briozoi Fm., dated to the Gelasian, marks the end of the main synsedimentary tectonic phase within the Apricena-Poggio Imperiale area.

d) The Serracapriola Fm. Rests on a discontinuity that shows diagenetic evidence for a prolonged subaerial exposure. The Serracapriola Fm. Marks an abrupt change in sedimentation: the sudden siliciclastic sediment supply from the north-western sector (ROBUSTELLI & AUCELLI, 2001) documents the approaching of the Apennines and the involvement of the Apricena-Poggio Imperiale area within the southern Adriatic foredeep.

e) The final emersion of the area was followed by the development of an extensive karst network, which was much more branched and developed in the morphologically highest sectors of the Apricena horst, i.e. in the present Dell'Erba quarries where the calcarenitic-siliciclastic cover is reduced or absent (ABBAZZI *et alii*, 1996, fig. 4). The hypogeous mechanisms developed (1) after reactivation of the pre-Pliocene palaeokarst structures or (2) by new conduits that passed through the Pliocene carbonates to reach the basal boundary with the Calcare di Bari Fm. In both cases, the meteoric dissolution connected with the neokarst cycle was more effective along the highly-fractured core-zones of the synsedimentary Pliocene faults, leading to the opening of large karstic features (sinkholes and funnel-like depressions) like those of Pirro 10 and Pirro 13 (Figs. 3g-h). The water flows circulating along such cavities led to their infilling by sandy-clayey sediments, clasts and biogenic products, among which the recently recovered human artefacts are the most impressive (ABBAZZI *et alii* 1996; ARZARELLO *et alii*, 2009a).

f) The composition of the faunal assemblage contained in the deposits infilling the cavities includes birds, amphibians, reptiles and mammals among which a very rich and diversified community of herbivores, and particularly of carnivores. The taxa have a wide European Mediterranean distribution. Such a rich fauna documents a well developed trophic chain, and indicates that at the time of the deposition of the fissure deposits the Gargano area was already a part of the north eastern side of the peninsula, and that no important palaeogeographical barrier was in existence to separate the Gargano from the Apennine sector. The spread of the siliciclastic Serracapriola deltaic system marks the approaching of the Apennine to the Gargano insular system, and the subsequent emersion represent the definite breakdown of the palaeogeographic barrier, thus permitting to the faunal elements from the continental peninsula to colonise the area.

g) The late Villafranchian age of the vertebrate Pirro Nord F.U. fits well with the late Gelasian (?)-Early Pleistocene age of the Serracapriola Fm. No more precise chronostratigraphic

constraints are presently available. Also the palaeomagnetic results are limited; according to the measured reversed polarity, only the Matuyama Chron is testified (TEMA *et alii*, 2009), i.e. the Pirro fissure infillings should be considered definitely younger than the Olduvai and older than the Jaramillo submagnetochrones (MASINI & SALA, 2007). Further information could derive from two in-progress analyses: the U/Th-ESR-combined radiometric tests in progress on the mammal tooth enamel, from which an absolute age is expected; the tests on the floatstones present at the base of the Villafranchian deposits at Pirro 10 fissure, or on the speleothem clasts reworked at different levels within the karst deposits of both Pirro 10 and Pirro 13, which could give at least a maximum age of the sampled layers.

In conclusion, at present only biochronological data serve to frame the chronological position of the Pirro Nord fauna in the type-locality. In this respect, it is worth noting the chronological constraint provided by the primitive form of *Allophaiomys ruffoi* common in Apricena outcrops; this form results to be more archaic than the type population of Cava Sud (Soave, Verona), i.e. it can not be younger than 1,3 Ma (MASINI & SALA, 2007). On the other hand, the occurrence of *Bison* (*Eobison*) at Pirro indicates an age younger than Pietrafitta, i.e. not older than 1,6 Ma (MASINI & SALA, 2007).

7. Acknowledgements

Field works were financially supported by University Ministry grants 2006044074_002 (resp. G. Pavia, Torino), by Italcementi Groups and by the Cassa di Risparmio and San Paolo foundations of Torino. We are grateful to many colleagues who joined us in field inspections: Gaetano Robustelli (Calabria University), Pietro Aucelli (Molise University), Valentino Di Donato and Nicoletta Santangelo (Napoli University), Mauro Coltorti (Siena University). Special

thanks to the cave agents of the former Pirro Nord quarries, Franco and Gaetano Dell'Erba, and to Vito Zuccarino (Mayor of Apricena) for assistance during field activity.

8. References

- ABBAZZI, L., BENVENUTI, M., BOSCHIAN, G., DOMINACI, S., MASINI, F., MEZZABOTTA, C.,
PICCINI, L., ROOK, L., VALLERI, G. & TORRE, D. (1996): Revision of the Neogene and
Pleistocene of the Gargano region (Apulia, Italy). The marine and continental successions and
the mammal faunal assemblages in an area between Apricena and Poggio Imperiale (Foggia).
– Mem. Soc. Geol. It., **51**: 383-402.
- ARZARELLO, M., MARCOLINI, F., PAVIA, G., PAVIA, M., PETRONIO, C., PETRUCCI, M., ROOK, L. &
SARDELLA, R. (2007): Evidence of earliest human occurrence in Europe: the site of Pirro
Nord (Southern Italy). – *Naturwissenschaften*, **94**: 107-112.
- ARZARELLO, M., MARCOLINI, F., PAVIA, G., PAVIA, M., PETRONIO, C., PETRUCCI, M., ROOK, L. &
SARDELLA, R. (2009A): L'industrie lithique du site pléistocène inférieur de Pirro Nord
(Apricena, Italie du sud): une occupation humaine entre 1,3 et 1,7 Ma. – *L'Anthropologie*,
113: 47-58.
- ARZARELLO, M., PAVIA, G. & SARDELLA, R. (2009b): Evidence on an Early Pleistocene human
presence at Pirro Nord (Apricena, Foggia, South Italy): P13 site. – VII Forum FIST, Epitome
2009: 288.
- BOSELLINI, A., NERI, C. & LUCIANI, V. (1994): Platform margin collapses and sequence
stratigraphy of slope carbonates (Cretaceous-Eocene, Gargano Promontory, Southern Italy). –
Guide to excursion A7, 15th IAS Regional Meeting, April 1994, Ischia, Italy.

- BRANCKMAN, C. M. & AYDIN, A. (2004) - Uplift and contractional deformation along a segmented strike-slip fault system: the Gargano Promontory, southern Italy. – *Journ. Struct. Geol.*, **26**: 807-824.
- CANTALAMESSA, G. & DI CELMA, C. (2005): Sedimentary features of tsunami backwash deposits in a shallow marine Miocene setting, Majillones Peninsula, northern Chile. – *Sed. Geology*, **178**: 259-273.
- CAPUANO, N., PAPPAFICO, G. & AUGELLI, G. (1996): Ricostruzione dei sistemi deposizionali plio-pleistocenici del margine settentrionale dell'avanfossa pugliese. – *Mem. Soc. Geol. It.*, **51**: 27-292.
- CASOLARI, E., NEGRI, A., PICOTTI, V. & BERTOTTI, G. (2000): Neogene stratigraphy and sedimentology of the Gargano Promontory (southern Italy). – *Ecl. Geol. Helv.*, **93**: 7-23.
- CHAIX, C., CAHUZAC, B. & CLUZARD, A. (1999): Les scléractiniaires du serravallien de Pessac (nord-aquitaine, France); approche paléoécologique. – *Geobios*, **32**: 33-62.
- CREMONINI, G., ELMI, C. & SELLI, R. (1971): Note Illustrative della carta Geologica d'Italia alla scala 1:100000. Foglio 156: S. Marco in Lamis. – *Serv. Geol. Italia*, 64 p., Roma.
- D'ALESSANDRO, A., LAVIANO, A., RICCHETTI, G. & SARDELLA, A. (1979): Il Neogene del Monte Gargano. – *Boll. Soc. Pal. It.*, **19**: 9-116.
- DE GIULI, C. & TORRE, D. (1984): Species interrelationships and evolution in the Pliocene endemic faunas of Apricena (Gargano Peninsula, Italy). – *Geobios, Mém. Spec.*, **8**: 379-383.
- DE GIULI, C., MASINI, F. & TORRE, D. (1987a): The latest Villafranchian faunas in Italy: the Pirro Nord Fauna (Apricena, Gargano). – *Paleontogr. It.*, **74**: 52-62.
- DE GIULI, C., MASINI, F., TORRE, D. & BODDI, V. (1987b): Endemism and bio-chronological reconstructions: the Gargano case history. – *Boll. Soc. Pal. It.*, **25**: 267-276.

- DE GIULI, C., MASINI, F. & TORRE, D. (1990): Island endemism in the eastern Mediterranean mammalian paleofaunas: radiation patterns in the Gargano paleo-arcipelago. – Atti Acc. Naz. Lincei, **85**: 247-262.
- EINSELE, G. (1998): Event Stratigraphy: Recognition and Interpretation of Sedimentary event Horizons. In: Doyle, P. and Bennet, M.R. (Eds.): Unlocking the Stratigraphical Record: Advances in Modern Stratigraphy. John Wiley & Sons Ltd.: 145-193.
- FANFANI, F. (2000): Revisione degli insettivori (Mammalia) tardo neogenici e quaternari dell'Italia peninsulare. – Ph.D. Thesis, 282 p., Dept. Geological Sciences Bologna-Firenze-Modena-Roma “La Sapienza”.
- FERRERO, E. & PAVIA, G. (1996): La successione marina pre-villafranchiana. In Carraio, F. (Ed.): Revisione del Villafranchiano nell’area-tipo di Villafranca d’Asti. – Il Quaternario, **9**: 36-38.
- FREUDENTHAL, M. (1971): Neogene vertebrates from the Gargano Peninsula, Italy. – Scripta Geol., **3**: 1-10.
- FREUDENTHAL, M. (1976): Rodent stratigraphy of some Miocene fissure fillings in Gargano (prov. Foggia, Italy). – Scripta Geol., **27**: 1-23.
- FREUDENTHAL, M. (2006): *Mikrotia* nomen novum for *Microtia* Freudenthal 1976 (Mammalia, Rodentia). – J. Vertebr. Paleontol., **26**: 784-784.
- GIBBARD, P. & HEAD, M.J. (2009): The definition of the Quaternary System/Era and the Pleistocene Series/Epoch. – Quaternaire, **20**: 125-133.
- GLIOZZI, E., ABBAZZI, L., AZZAROLI, A., CALOI, L., CAPASSO BARBATO, L., DI STEFANO, G., ESU, D., FICCARELLI, G., GIROTTI, O., KOTSAKIS, T., MASINI, F., MAZZA, P., MEZZABOTTA, C., PALOMBO, M.R., PETRONIO, C., ROOK, L., SALA, B., SARDELLA, R., ZANALDA, E. & TORRE, D. (1997): Biochronology of selected mammals, molluscs and ostracods from the Middle

- Pliocene to the Late Pleistocene in Italy. The state of the art. – Riv. It. Pal. Strat., **90**: 369-388.
- GRASSI, D., ROMANAZZI, L., SALVEMINI, A. & SPILOTRO, G. (1982): Grado di evoluzione e ciclicità del fenomeno carsico in Puglia in rapporto all'evoluzione tettonica. – Geol. Appl. Idrogeol., **17**: 55-73.
- HARTLEY, A., HOWELL, J., MATHER, A.E. & CHONG, G. (2001): A possible Plio-Pleistocene tsunami deposit, Hornitos, northern Chile. – Rev. Geol. Chile, **28**: 117-125.
- LE ROUX, J.P. & VARGAS, G. (2005): Hydraulic behavior of tsunami backflows: insights from their modern and ancient deposits. – Environ. Geol., **49**: 65-75.
- MASINI, F. & SALA, B. (2007): Large- and small-mammal distribution patterns and chronostratigraphic boundaries from the Late Pliocene to the Middle Pleistocene of the Italian peninsula. – Quatern. Intern., **160**: 43-56.
- MASINI, F., ABBAZZI, L., SALA, B., & TORRE, D. (1998): Review and new finds of *Microtus (Allophaiomys)* (Rodentia, Arvicolidae) from the Early Pleistocene of the Italian peninsula. – Paludicola, **2**: 78-90.
- MASINI, F., PETRUSO, D., BONFIGLIO, L. & MANGANO, G. (2008): Origination and extinction patterns of Mammals in three Central Western Mediterranean Islands in the Late Miocene to Quaternary. – Quatern. Intern., **182**: 63-79.
- MASSARI, F. & D'ALESSANDRO, A. (2000): Tsunami-related scour-and-drape undulations in Middle Pliocene restricted-bay carbonate deposits (Salento, southern Italy). – Sed. Geology, **135**: 265-281.
- MAZZA, P. & RUSTIONI, M. (2008): Processes of island colonization by Oligo-Miocene land mammals in the central Mediterranean: new data from Scontrone (Abruzzo, Central Italy) and Gargano (Apulia, Southern Italy). – Palaeogeogr., Palaeoclim., Palaeoecol., **267**: 208-215.

- MERLA, G., ERCOLI, A. & TORRE, D. (1969): Note Illustrative della Carta Geologica d'Italia alla scala 1:100000. Foglio 164 Foggia. – Serv. Geol. Italia, 22 p., Roma.
- MONEGATTI, P. & RAFFI, S. (2001): Taxonomic diversità and stratigraphic distribution of Mediterranean Pliocene bivalves. – *Palaeogeogr., Palaeoclimat., Palaeoec.*, **165**: 171-193.
- MORIGI, C., JORISSEN, F.J., FRATICELLI, S., HORTON, B.P., PRINCIPI, M., SABBATINI, A., CAPOTONDI, L., CURZI, P.V. & NEGRI, A. (2005): Benthic foraminiferal evidence for the formation of the Holocene mud-belt and bathymetrical evolution in the central Adriatic Sea. – *Marine Micropal.*, **57**: 25–49.
- PAMPALONI, R. (2001): Formazione del Lago di Varano. In Delfrati et al. (coord.): Carta Geologica d'Italia 1:50000, Catalogo delle Formazioni, Fascicolo II, Unità non validate. – Quad. Serv. Geol. Italia, SELCA, **7**: 144–148.
- PATACCA, E. & SCANDONE, P. (2004): The 1627 Gargano earthquake (Southern Italy): identification and characterization of the causative fault. – *Journ. Seism.*, **8**: 259-273.
- PAVIA, G., ANGELONE, C., ARZARELLO, M., AURELI, D., BAGNUS, C., BELLUCCI, L., BUONSANTO, C., COLOMBERO, S., MANZI, G., PAVIA, M., PERETTO, C., PETRONIO, C., PETRUCCI, M., SARDELLA, R., VILLIER, B., ZUCCARINO, V. & ZUNINO, M. (2009): Paleontological researches of the Early Pleistocene Pirro Nord site (western Gargano): 2007 and 2008 systematic excavations. – VII Forum FIST, Epitome 2009: 290.
- PAVIA, G., BERTOK, C., CIAMPO, G., PAVIA M., DI DONATO, V., MARTIRE, M., MASINI, F., SANTANGELO, N., TADDEI RUGGIERO, E. & ZUNINO, M. (2010): Tectono-sedimentary evolution of the Pliocene to Lower Pleistocene succession of the Apricena-Lesina-Poggio Imperiale quarrying district (western Gargano, southern Italy). – *Boll. Soc. Geol. It.*, **129**: 132–155.

- PAVIA, M., ZUNINO, M., COLTORTI, M., ANGELONE, C., ARZARELLO, M., BAGNUS, C., BELLUCCI, L., COLOMBERO, S., MARCOLINI, F., PERETTO, C., PETRONIO, C., PETRUCCI, M., PIERUCCINI, P., SARDELLA, R., TEMA, E., VILLIER, B. & PAVIA, G. (2011): Stratigraphical and palaeontological data from the Early Pleistocene Pirro 10 site of Pirro Nord (Puglia, south eastern Italy). – *Quat. Int.*, doi:10.1016/j.quaint.2010.12.019
- PERES, G.M. & PICARD, J. (1964): Nouveau manuel de bionomie benthique de la Mer Méditerranée. – *Rec. Trav. Stat. Marine Endoume*, **31/47**, 137 p.
- ROBUSTELLI, G. & AUCELLI, P.P.C. (2001): I termini di chiusura del bacino pugliese (Avanfossa sud-appenninica nell'area di Poggio Imperiale (Foggia): caratteri stratigrafici ed implicazioni paleogeografiche. – *Il Quaternario*, **14**: 173-186.
- ROOK, L., GALLAI, G., TORRE, D. (2006): Lands and endemic mammals in the Late Miocene of Italy: Constrains for paleogeographic outlines of Tyrrhenian area. – *Palaeogeogr., Palaeoclim., Palaeoecol.*, **238**: 263-269.
- SALA, B. & MASINI, F. (2007): Late Pliocene and Pleistocene small mammal chronology in the Italian peninsula. – *Quatern. Intern.*, **160**: 4-16.
- SAVAZZI, E. (1995): Parasite-induced teratologies in the Pliocene bivalve *Isognomon maxillatus*. – *Palaeogeogr., Palaeoclimat., Palaeoec.*, **116**: 131-139.
- SGARRELLA, F. & MONCHARMONT-ZEI, M. (1993): Benthic foraminifera of the Gulf of Naples (Italy): systematics and autoecology. – *Boll. Soc. Pal. It.*, **32**: 145-264.
- SPALLUTO, L. & PIERI P. (2008): Evidenze di neotettonica (Pliocene medio - Pleistocene superiore) nel settore occidentale del promontorio del Gargano (Italia meridionale). – *Journ. Quatern. Sciences*, **19**: 147-176.

SPROVIERI, R. (1992): Mediterranean Pliocene biochronology: a high resolution record based on quantitative planktonic foraminifera distribution. *Riv. Ital. Paleont. Strat.*, **98**: 61-100.

TEMA, E., LANZA, R. & PAVIA, G. (2009): Paleomagnetic study of the Pirro Nord sedimentary fill.
– VII Giornate di Paleontologia 2009, S. Marco in Lamis, Abstract vol.: 56.

Figure captions

Fig. 1. Geographic location and aerial photograph of the Apricena horst. Numbers 1-9 refer to the measured stratigraphic sections. Black lines are the traces of faults bordering the Apricena horst. In the close up view (top right) the location of sites with Villafranchian faunas is reported. White circles refer to historical studied sites, nowadays cancelled by quarrying activities; white squares indicate active sites (Pirro 10 and Pirro 13 in fig. 3g).

Fig. 2. Lithostratigraphic logs of seven sections described in the Apricena quarrying district (see Fig. 1 for location). D1-D4, unconformity surfaces. Correlation plane at the unconformity D2. B, barnacle-bearing lithozone. BB, barnacle-coral biostromal breccia lithozone. BC, barnacle-coral biostromal lithozone. BH, barnacle horizon. CB, Calcari a Briozoi Fm.. CBa, Calcare di Bari Fm.. CL, calcarenite lithozone. IB, Isognomon biostromal lithozone. LC, limestone-clay lithozone. ML, megabreccia lithozone. SE, Serracapriola Fm. tr, Terre Rosse. Thicknesses of BC, BH, IB and LC are not on scale.

Fig. 3. (a) Angular unconformity between the Calcare di Bari Fm. (CBa) and the Lago di Varano Fm. (LV). Note the karstified top of the CBa, with the fissures filled with Terre Rosse sediments (tr). (b) The 4 metres-thick megabed of the megabreccia lithozone (ML) in the upper part of the quarry wall at section 8, resting on the limestone-clay (LC) and calcarenite (CL) lithozones. (c) Planar unconformity surface at the basal boundary of the Isognomon biostromal lithozone (IB) few hundreds of metres south of section 1, overlying the megabreccia lithozone (ML). (d) In section 7 the barnacle horizon is composed of a 10-15 cm thick shell-supported layer just overlying a massive bed of the barnacle-coral biostromal lithozone. (e) General view of section 9 which is composed of the Calcare di Bari Fm. (CBa), the Lago di Varano Fm. with the

calcarenite (CL) and the megabreccia (ML) lithozones, and finally of the siliciclastic Serracapriola Fm (SE). Note the presence of karstic tunnels inside the Varano carbonates (white arrows). (f) Panoramic view of the southern fault (unbroken line) at section 1, from section 2. On the left the Calcare di Bari Fm. limestones (CBa) making up the footwall and the thick breccia body along the fault (FB); on the hanging wall to the right, the two resedimented bodies (B and BB), and the yellow calcarenite of the Calcari a Briozoi Fm. (CB). (g) Frontal view of Gaetano Dell'Erba quarry wall, with the location of Pirro 13 and Pirro 10 sites. (h) Close up view of the Pirro 10 site, during the summer 2009 excavation campaign.

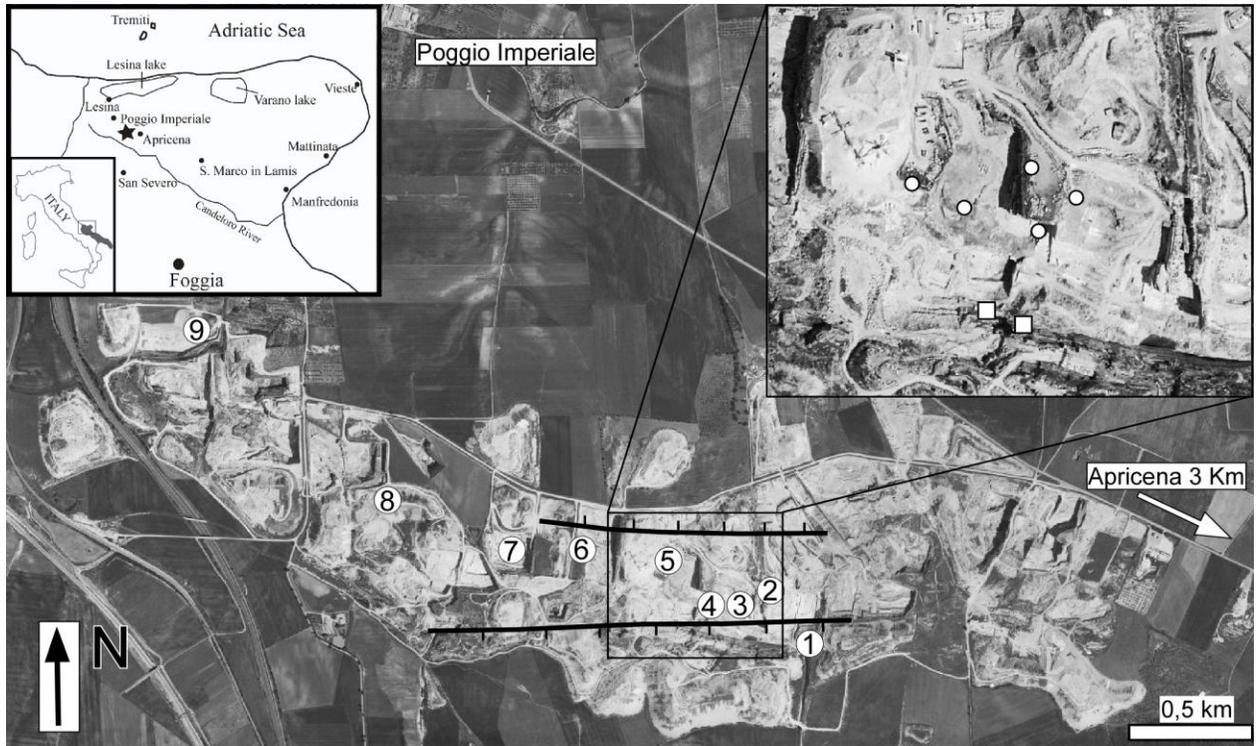


Figure 1

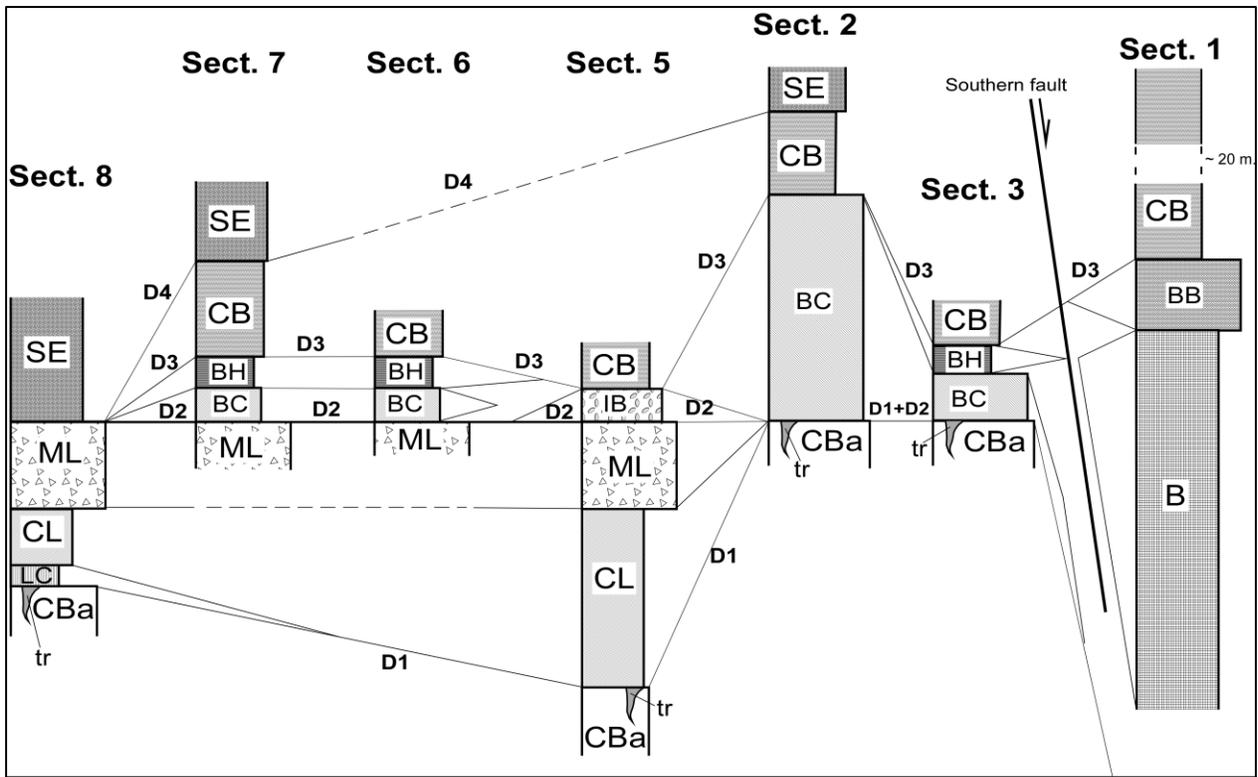


Figure 2

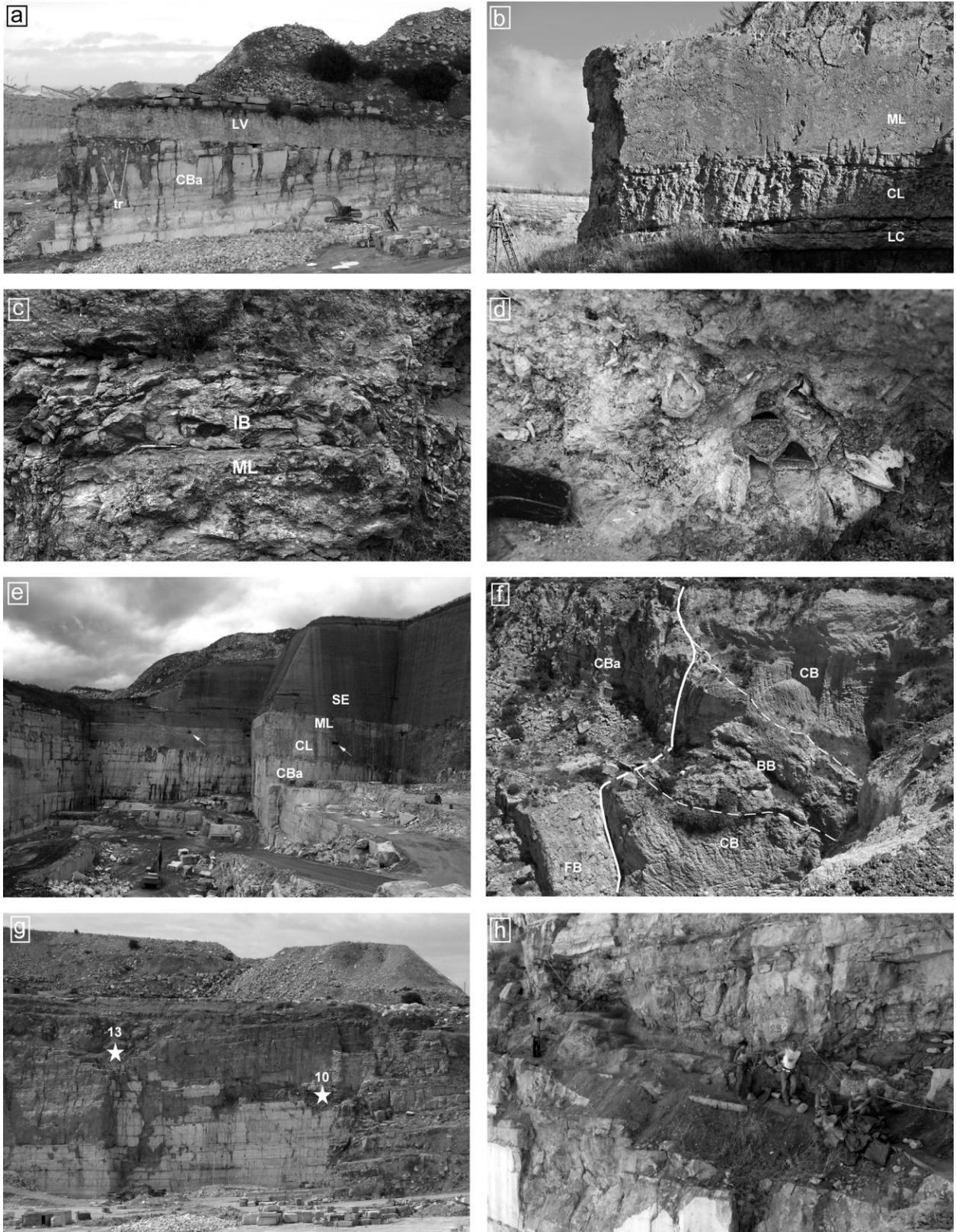


Figure 3