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LATEST MESSINIAN VERTEBRATE FAUNA PRESERVED IN A PALAEOKARST - NEPTUNIAN DYKE SETTING (Brisighella, Northern Apennines)

RIASSUNTO - Viene segnalata una nuova fauna a vertebrati continentali, ricca, ben preservata, anche se con ossa disarticolate e trasportate, e assai varia, trovata nella parte superiore della Formazione a Colombacci, di età messiniana terminale. Le ossa, che inizialmente erano inserite in fanghi di piana alluvionale, sono state dapprima disarticolate e concentrate ad opera di torrenti effimeri e quindi rideposte in ambiente salmastro, dove, in parte, si trovano fossilizzate. La maggior parte, però, ha subito un ulteriore processo di concentrazione durante l'infiltrazione come riempimenti tardo messiniani di filoni sedimentari.

Questi filoni intersecano la Formazione Gessoso-solfifera già piegata, e sono orientati prevalentemente N 20° E secondo uno dei principali sistemi regionali di faglie. Il riempimento dei filoni avviene con una prima fase iniettiva, condizionata da movimenti trascorrenti che smembrano le evaporiti incassanti, e con una fase tardiva a sedimentazione puramente gravitativa. La prima fase è preceduta da modellamento carsico, a scala minore, lungo i sistemi regionali di frattura. L'età di questo processo paleocarsico corrisponde alla fase di piegamento ed emersione intramessiniana.

La successione stratigrafica locale è composta da: 1) Formazione Gessoso-solfifera (Messiniano inferiore) ricoperta in discordanza angolare da 2) Formazione a Colombacci assai sottile (0 - 1,5 m) (Messiniano terminale) e da 3) argille marnose grigio azzurre (Pliocene iniziale, Zona a *Sphaeroidinellopsis*).

La fauna è costituita da due forme di insettivori, da un probabile *Mesopithecus,* da due carnivori (*Plioviverrops orbignyi* e un procionide), da *Dicerorhynus* cf. *megarhynus*, da un *Hipparion*, da varie forme di artiodattili fra cui un probabile *Parabos*, da alcuni muridi, da un *Prolagus* cf. *michauxi* e da una forma di *Trischizolagus*, oltre che da alcuni resti di rettili e uccelli. Le peliti paraconglomeratiche contenenti le ossa, sia nei filoni sedimentari, che all'interno della successione non alterata nel suo ordine di sovrapposizione stratigrafica, appartengono alla Formazione a Colombacci e contengono *Dreissena, Melanopsis, Melanoides, Limnocardium* e *Cyprideis* di ambiente marino salmastro. Evaporiti, filoni e Formazione a Colombacci sono saldate dal Pliocene iniziale della Zona a *Sphaeroidinellopsis*.

La nuova fauna dovrebbe fornire elementi chiave per calibrare le correlazioni fra le scale stratigrafiche del dominio continentale e paratetideo, di quello marino (Mediterraneo) e di quello oceanico.

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ABSTRACT - A rich, diverse and good preserved, though fragmentary, continental vertebrate fauna was found within the uppermost Colombacci Fm. of terminal Messinian age. The bones, originally preserved within alluvial plain muds, were first disarticulated and enriched by means of torrential streams and subsequently redeposited in a brackish environment. Part of them, however, were further concentrated and stored within late Messinian neptunian dyke fillings.

The sedimentary dykes cutting across the folded Gessoso-solfifera Fm. trend about N 20° E according to the main regional faulting system. The polyphase dyke filling shows prevailing injection structures controlled by strike-slip movement of the enclosing evaporites; gravitative structures are also found. The strike-slip dyke-filling phase is predated by a minor karst-hole development along the same joint system. This palaeo-karst process took place during the intra-Messinian folding and emersione phase.

The local stratigraphic sequence is made up by: 1) Gessoso-solfifera Fm. (lower Messinian) unconformably overlain by 2) a very thin (0 to 1.5 m) Colombacci Fm. (uppermost Messinian) and 3) light-grey marly clays (lower-most Pliocene, *Sphaeroidinellopsis* Zone). The fauna consists of two insectivors, a possible *Mesopithecus,* two carnivors (*Plioviverrops orbignyi* and a procionid), *Dicerorhynus* cf. *megarhynus* and *Hipparion* sp., several form of artiodactyls with a possible *Parabos*, some murids, *Prolagus* cf. *michauxi* and a *Trischizolagus*, as well as birds and reptiles. The mudstone containing the bones yields *Dreissena, Melanopsis, Melanoides, Limnocardium* and *Cyprideis* of uppermost Messinian age and of brackish environment; it is posdated by the lowermost (*Sphaeroidinellopsis*) Pliocene.

The new vertebrate fauna is expected to provide critical insights to the correlation between the continental (and Paratethyan), marine (Mediterranean) and oceanic stratigraphic scales.

INTRODUCTION

Recent growing progress made in biostratigraphy, event stratigraphy, physical stratigraphy and seismostratigraphy have enhanced the need to bridge the correlation gap between isochronous, different magnafacies. This need resulted in an increasing use of the ecostratigraphic approach, especially in the areas of potential interfingering of different magnafacies.

Classical examples of such problems are represented by the puzzling correlation between the Old Red and the Rhenish (or even Bohemian) Devonian stages (MARTINSSON, 1977, 1980), or between Mediterranean and Paratethys Neogene sequences (RÖGL and STEININGER, 1984). In both cases, the critical point is given by the apparent disconnection between vertebrate (mainly continental) and marine invertebrate zonations. This fact brings in turn difficulties in defining boundaries of standard chronostratigraphic units (at whatever hierarchical level) and in perfoming reliable chronologic correlations.

We had the chance, through an amateur palaentologist (Tonino Benericetti from Zattaglia), to find a rich continental vertebrate fauna of uppermost Miocene age associated with many Paratethys genera and species and capped by marine, Mediterranean fauna.

Aim of this paper is to report shortly about the new fauna, its taphonomy and biostratinomy, and to discuss its stratigraphic, geologic and palaeoenvironmental implications.

STRATIGRAPHY AND DEFORMATION PHASES

The new vertebrate fauna was found inside the Monticino gypsum quarry near Brisighella, within the Northern Apenninic Vena del Gesso Basin (VAI and RICCI LUCCHI, 1977) that represents a stage of the Periadriatic Foredeep development (RICCI LUCCHI, 1975). A recent account on local mapping, facies analysis, and structural geology was done by MARABINI and VAI (1985). Updated reviews of regional Neogene to Quaternary stratigraphy and synsedimentary tectonics (RICCI LUCCHI *et al.*, 1982) and of regional structural setting (CASTELLARIN *et al.*, 1985) can act as useful introduction to the geology of the Northern Apennine margin.

A simplified tectono-stratigraphic scheme of the Vena del Gesso area is represented on Fig. 1. The vertebrate fauna is always supported by slightly different lithotypes of the Colombacci Formation. This unit, upper Messinian in age, is regionally underlain by the Gessoso-solfifera Formation (evaporites of lower Messinian age) and overlain by the light, blue-grey, « Trubi »-like clay (lower Pliocene).

The thickness of the Colombacci Fm. in the Vena del Gesso area (western Romagna) never exceeds 30 m, whereas in eastern Romagna it usually reaches some hundreds of metres (CASATI et al., 1978; COLALONGO et al., 1978). In the surroundings of Brisighella, however, the thickness of the Colombacci Fm. is even lower (4 to 2m) so that in the southwestern part of the Monticino quarry the unit disappears (CREMONINI and MARABINI, 1982).

Peacks in a continuous process of tectogenic and orogenic deformation are reached at different times in the area (MARABINI and VAI, 1985). An important angular unconformity is very common at or near the base of the Colombacci Fm.; it is connected to compressive thrustings and strike-slip N 20° E trending faults. More scattered evidences of angular unconformity or of simple disconformity are found at or near the top of the Colombacci Fm. Slight unconformity and/or disconformity (biostratigraphic gap) are commonly found somewhere in a late lower to upper Pliocene interval; they are also related to compressional and strike-slip movements. The last angular unconformity is found above the lower Pleistocene.

TAPHONOMY AND BIOSTRATINOMY

The vertebrate bones, usually disarticulated, are preserved into two quite different settings: the first, more common, as sedimentary dyke fillings reactivating previous, minor karst clefts; the second one as pocket-like bone beds.

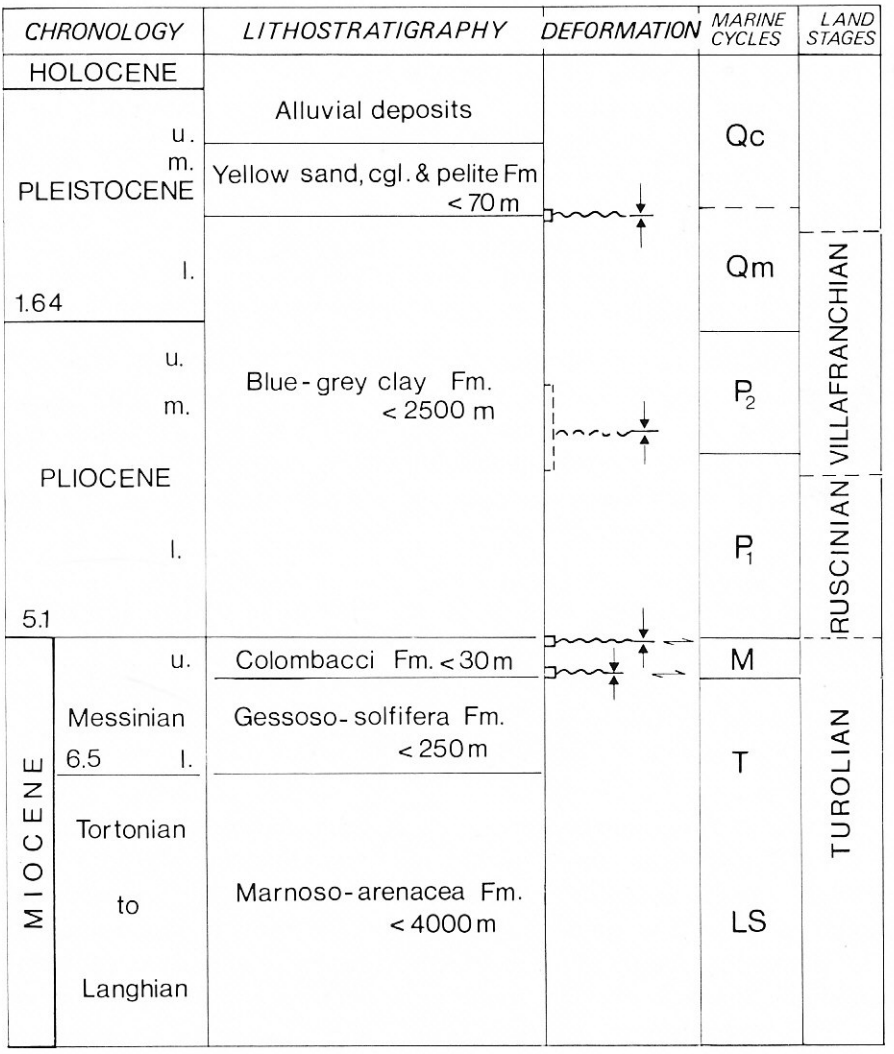


Fig. 1 - Stratigraphy, deformation phases and sedimentary cycles (depositional sequences) in the Vena del Gesso Basin (Northern Apennines) related to the Standard Stratigraphic Scales and to the continental stages. Simplified after Vai and Ricci Lucchi (1977), Ricci Lucchi *et al.* (1982) Marabini and Vai (1985).

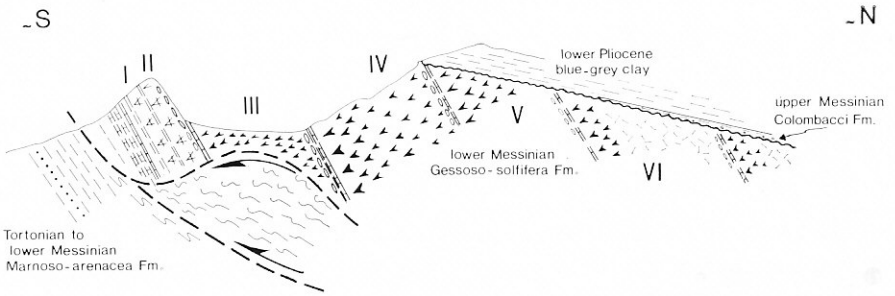


Fig. 2 - Geologic section across the Monticino quarry area, Brisighella, Northern Apennines. The major intra-Messinian deformation with sharp angular unconformity is shown. Notice the southward onlap of the thin Colombacci Fm. and the rapid lowermost Pliocene transgression. Roman numbers refer to the major evaporite cycles (VAI and RICCI LUCCHI, 1977).

Sedimentary dyke fillings (Fig. 3, 5, 7, 8).

A dense, irregular net of medium (meter-size) to fine (cm-size) sedimentary dykes, statistically trending as the main strike-slip fault systems, intersects the thick-bedded evaporites of the Gessoso-solfifera Fm. from the erosional top to its bottom. The infilling occurs in two phases (Fig. 5).

The first phase is characterized by isoclinally folded to chaotic structure of the infilled material, with banding markedly parallel to the dyke walls. This setting, emphasized by the different lithotypes swallowed in the dykes, suggests an emplacement by injection (underpressure in the opening dyke holes plus hydrostatic and lithostatic load) (CASTELLARIN, 1982). The infilling material of this phase, besides a few gypsum fragments scraped off the walls, consists exclusively of all different lithotypes of the Colombacci Fm., which unconformably overlies the evaporites in the same Monticino quarry (Fig. 3, 4, 6). The main local lithotypes are: olive-green silty clay, calcrete-rich light-green clay, limestone paraconglomerate, brown *Melanopsis* and *Dreissena* clay, blue-green clay, dark *Cyprideis* clay. Paraconglomerates are more abundant in the infilled material than in the *in situ* preserved Colombacci Fm. This can be explained by both the original setting of the conglomerates and their subsequent mechanical sorting and concentration; it can be achieved during the injectional filling process and by a filtering effect linked by the variable mesh of the irregular dyke net. The location of primary shoe-string-like paraconglomerate bodies, commonly recognized in the Colombacci Fm., seems to be directly controlled by the major transversal strike-slip faults, which are also responsi-

ble for development of sedimentary dykes, at least in the Vena del Gesso area (MARABINI and VAI, 1985).

The second phase filling is characterized by a flat lying, gravitative, fine bedded, fining-upward sequence made up by alternating yellowish sand and grey silty clay of still undetermined (possibly Pleistocene) age.

The vertebrate fauna is limited to the first filling phase. It is exclusively associated with the Colombacci Fm. lithotypes, mainly the paraconglomerates and the concretion-rich light-green clay. The state of preservation of disarticulated bones is usually excellent, due to their mud-supported setting.

The dyke walls are usually plane, almost parallel each other. However, dm-size (exceptionally m-size, see Fig. 5) hemispherical depressions can often be observed. They suggest a karst-modeling phase enlarging previous fracture systems, and predating the major sedimentary dyke development.

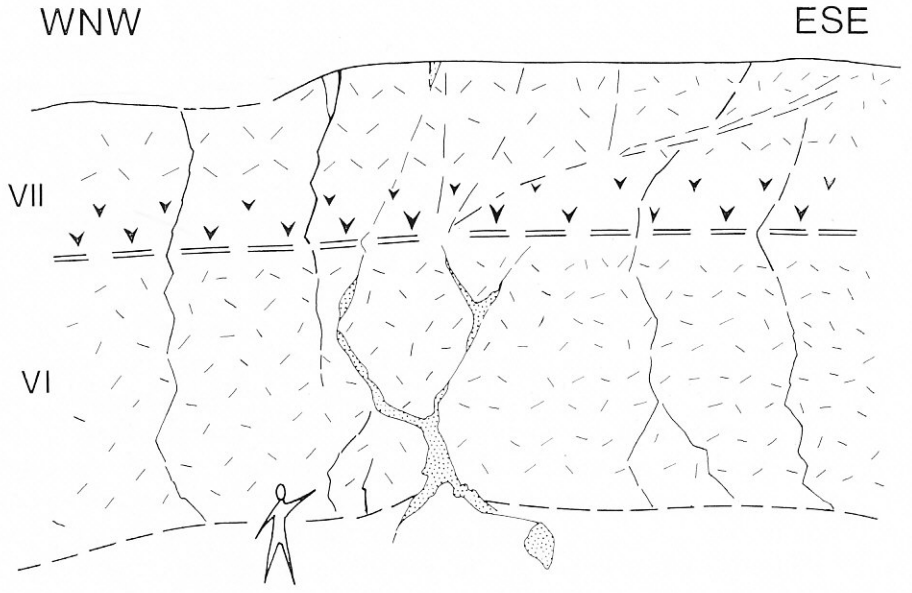


Fig. 3 - North-eastern front of Monticino quarry. Irregular, anostomosed net of sedimentary dykes cutting across the Lower Messinian evaporites (numbered according to the major evaporitic cycles). Dotted areas represent major, bone-rich Colombacci Fm. bodies filling the sedimentary dykes.

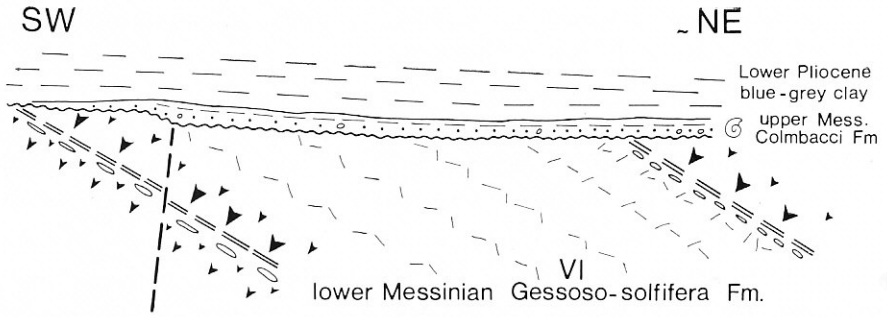


Fig. 4 - North-western front of Monticino quarry, showing angular unconformity between gypsum evaporites and the Colombacci Fm. housing pocket-like concentration of small vertebrate bones.

Pocket-like bone beds (Fig. 4)

In this setting, too, the disarticulated vertebrate bones are associated with the Colombacci Fm., which, however, occurs *in situ*, unconformably overlying the folded Gessoso-solfifera Fm. Only very fine (mm- to cm-size) bones of vertebrates have been found so far, usually in thin lenses of the olive-green silty clay.

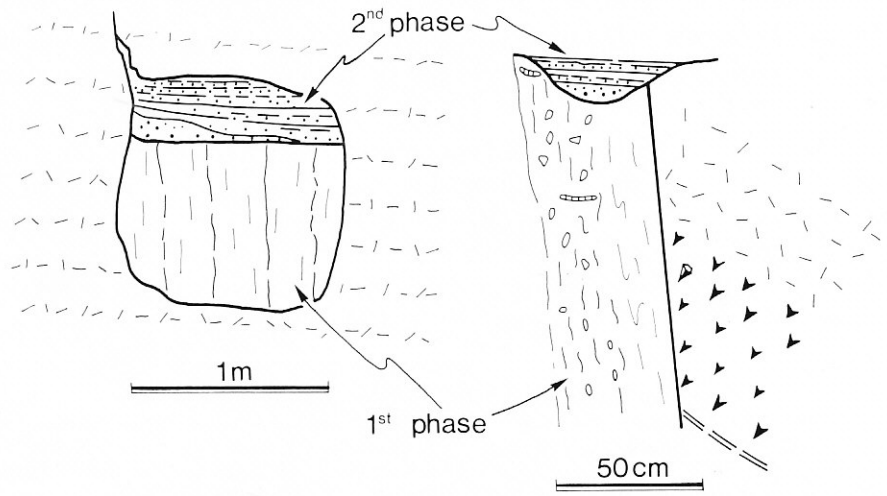


Fig. 5 - Two-phase infilling of sedimentary dykes cutting across the gypsum evaporites (Lower Messinian). Infilled material consists of Upper Messinian Colombacci Fm. (1st phase) and Pleistocene sandy clay (2nd phase).

The stratigraphic sequence encompassing these lenses can be summarized as follows from the bottom upwards.

1) Gessoso-solfifera Fm. (lower Messinian). The evaporite sequence is folded and sharply truncated by the angular unconformity surface at the base of the overlying Colombacci Fm. Open air exposures of the truncated evaporite top surface show irregular, wavy structure of possible erosional, karstic origin (Fig. 6b).

2) 20 to 30 cm of yellow-grey *Limnocardium* sand, with a discontinuos horizon of pedogenetic, « terra rossa » - like pockets at its very base (Colombacci Fm., upper Messinian). The basal horizon supports an emersion interval followed by the transgression of the Colombacci Fm. The *Limnocardium* sand suggests a flat, brackish environment, not far from a distributary channel.

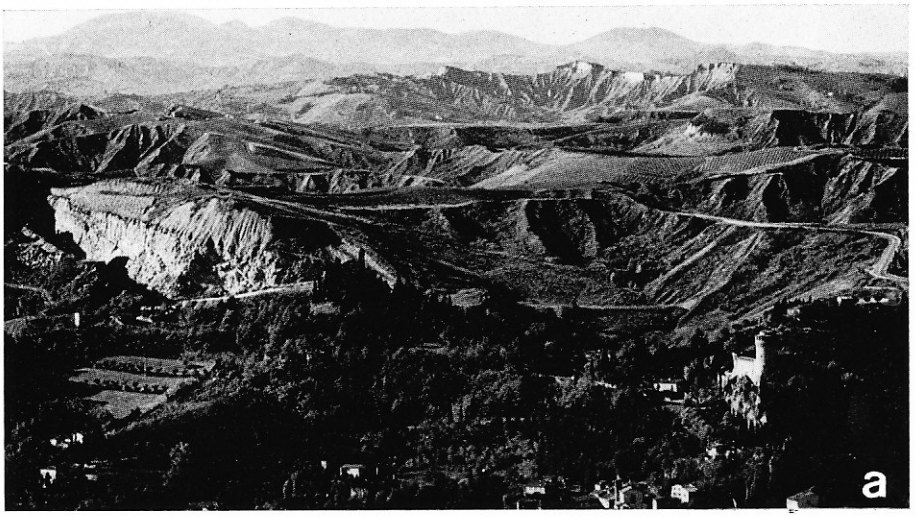
3) 0 to 20 cm of olive-green silty clay with rare *Cyprideis* and frequent bones of micro-vertebrates (Colombacci Fm., upper Messinian). Same brackish flat, almost isolated or far from distributary channels. This environment might explain the mechanical concentration and the good preservation of small, porous, quite light bones.

4) 30 to 50 cm of brackish, nodule-bearing bioturbated dark clay with abundant *Dreissena* fauna (Colombacci Fm., upper Messinian). Same brackish flat environment.

5) more than 5 m of « trubi » - like, light-grey clay of lowermost Pliocene (*Sphaeroidinellopsis* Zone). *Sphaeroidinellopsis* sp.p. are common at the base of the interval, whereas the *G. margaritae* onset occurs a few metres above the top.

The transition from unit 4 (uppermost Messinian) to unit 5 (lowermost Pliocene) is sharp but conformable and continuous. It is marked by spectacular bioturbation, as common in the Vena del Gesso Basin (Vai and Ricci Lucchi 1976). The tectonic phase with angular unconformity and strike-slip dextral movement occurring in the Santerno River area (Marabini and Vai, 1985) near the top of the Colombacci Fm. is probably coe-

Fig. 6 - *a*: The Monticino quarry (left) with lower Messinian evaporites, steeply dipping to the right, unconformably overlain by very thin Colombacci Fm. (disappearing at the left end of the quarry) and very thick Pliocene clay with minor sandy bodies (up to the right sky-line). Monticino Church (middle) and Brisighella Castle (right). *b*: Wavy top surface of the lower Messinian evaporites unconformably overlain by thin (about man-size) Colombacci Fm. continuously followed by « Trubi »-like lowermost Pliocene clay.
c: Disarticulated bone floating within Colombacci Fm. green clay (bar is 3 cm).


a


b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val with the development and infilling of sedimentary dykes found here and in the Castelnuovo area, a few Km to the W (MARABINI and VAI, 1985).

Interpretation of the data

The first, intra-Messinian deformation phase (Fig. 1) was responsible for folding and thrusting of the lower Messinian evaporites (MARABINI and VAI, 1985). It led to local emersion enabling erosional truncation (Fig. 2,6) and development of small-scale karst morphology following the paths of regional fracturing systems (evidences of Messinian palaeokarst are reported also from DUBLJANSKY and KLIMCHOUK, this volume). It suggest a short emergence interval followed by rapid onset of alluvial plane environment, with warm, semiarid climate and ephemeral stream deposits (paraconglomerates). This is the environment allowing a first mechanical disarticulation, concentration and reworking of vertebrate bones from the alluvial plain to the slowly transgressing brackish (deltaic) flat (upper Messinian).

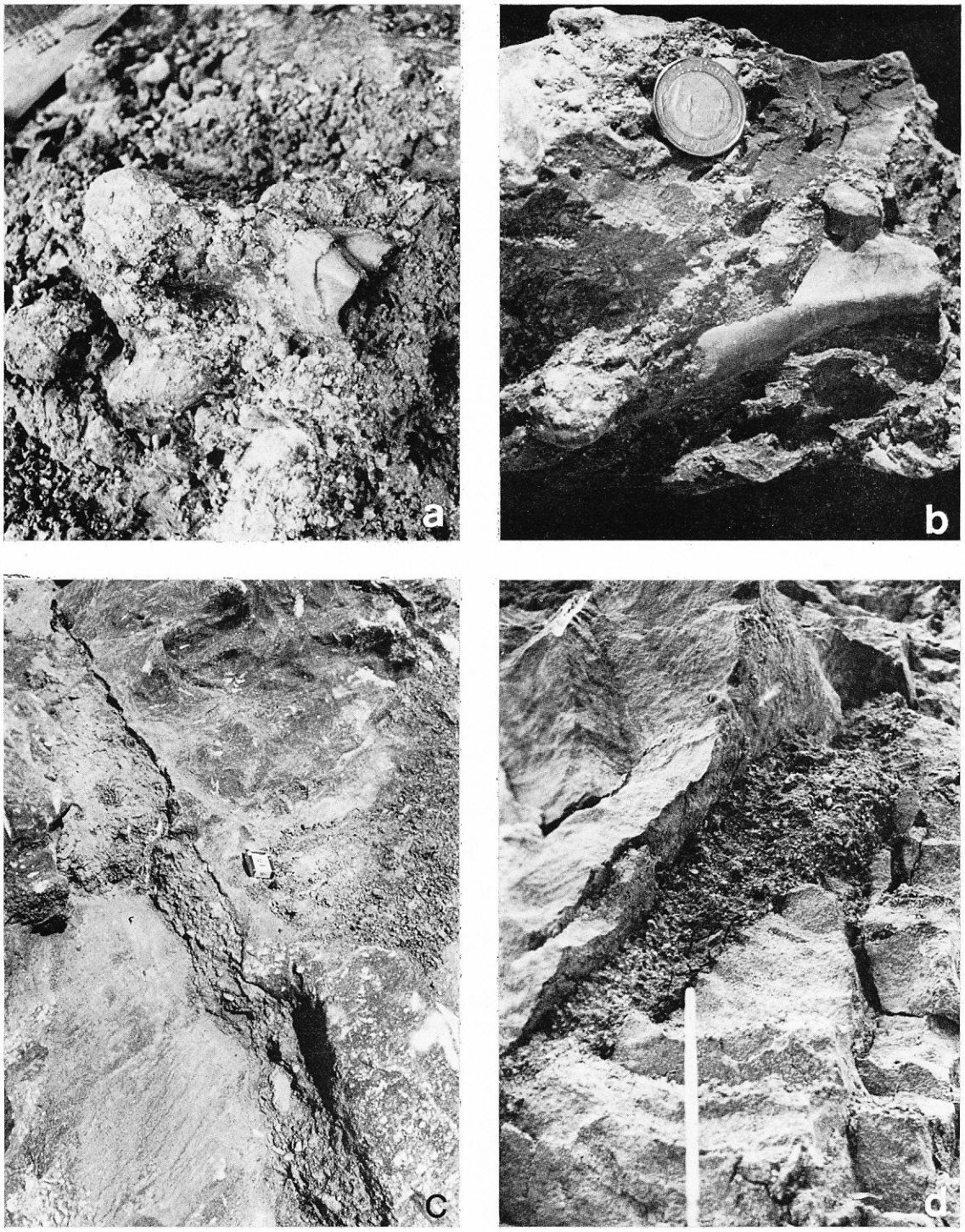
At this time the second deformation phase occured, as a minor strike-slip reactivation along the regional transverse fracture systems. The major deformative effect in the Brisighella area is represented by transcurrent rejuvenation of the previously karstified fracture systems. It produced a complex net of sedimentary dykes inside the early lithified evaporites; the dykes were filled by swallowing of the owerlying not-lithified, bone bearing paraconglomerates, sands and brackish pelites, under injection conditions.

A thin blanket of brackish sand and pelite sealed the already infilled sedimentary dyke system and was conformably followed by the sharp transgressive Pliocene clay (Fig. 4). Slow diagenetic compaction of the first phase dyke filling allowed a second phase infilling of the newly formed interstices by Pleistocene sediments under pure gravitative conditions (Fig. 5).

VERTEBRATE FAUNA

The rich, higly diverse, though disarticulated or fragmentary fauna is presently being studied by palaeontologists of Florence University co-authoring this paper.

Fig. 7 - *a*: *Dicerorhynus* cf. *megarhynus* tooth within muddy paraconglomerate (trowel for scale).
b: Porcupine bone within muddy paraconglomerate.
c and *d*: sedimentary dykes cut across gypsum layers and filled by bone-bearing paraconglomerates (bar in *d* is 1 m).


a
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The vertebrate finds pertain mostly to mammals; but reptiles and birds are also reseprented. Eighteen different mammal genera have been determined so far. The provisional faunal list is as follows:

INSECTIVORA
- Soricidae indet.
- Echinosoricinae cf. *Galerix*

PRIMATES
- Colobinae cf. *Mesopithecus*

CARNIVORA
- *Plioviverrops orbignyi*
- Procyonidae indet.

PERISSODACTYLA
- *Dicerorhynus* cf. *megarhynus*
- *Hipparion* sp.

ARTIODACTYLA
- Suidae indet.
- Cervidae indet.
- Bovinae cf. *Parabos*
- *Gazella* sp.
- Bovidae indet.

RODENTIA
- *Stephanomys* cf. *ramblensis*
- *Occitanomys* sp.
- Murinae cf. *Paraethomys*
- Murinae cf. *Apodemus*

LAGOMORPHA
- *Prolagus* cf. *michauxi*
- *Trischizolagus* sp.

DISCUSSION

The Monticino fauna near Brisighella can be compared with the Spanish and Freanch faunas reported as unit MN 13 by MEIN (1981)

Fig. 8 - *a*: Detail of Fig. 7c showing chaotic (injection) structure of the paraconglomerate filling.
b: Sphaerical hole connecting different segments of sedimentary dykes.
c: Small-scale (dm-size) palaeokarst depressions preserved on the straight wall of a sedimentary dyke.


a


b


c

(equivalent to E by AGUILLAR, 1982; AGUILLAR and MICHAUX, 1983). A similar association was known in Italy only from layer V3 of Baccinello near Grosseto described by HURZELER and ENGESSER (1976) and stored in the Basel Museum of Natural History and from Gravitelli near Messina (SEGUENZA, 1902-1907); unfortunately, this material of Gravitelli was lost during the Messina earthquake, 1908.

These faunas represent transitional associations between typical Turolian (upper Miocene) and Ruscinian (lower Pliocene) vertebrate faunas (DE GIULI *et al.*, 1983); therefore, they suggest a distinct step in the evolution of mammal assemblages. The new Monticino findings may become crucial for increase the knowledge of this intermediate population.

It is also worth mentioning the combined occurrence of both micro- and macrovertebrates, which is rarely observed. A careful study of the Brisighella fauna might allow a direct correlation band between the two still separated biostratigraphic scales.

The outstanding importance of the new fauna, however, is the clear stratigraphic position inside the Colombacci Fm. between the Messinian salinity crisis and the very base of the marine Pliocene (*Sphaeroidinellopsis*-Zone). This position is a unique tool able to solve definitely a major time-correlation problem between continental, brackish an marine domains (the European, Paratethys and Mediterranean respectively) having a series of implications at stratigraphic, palaegeographic and geodynamic level. In fact this problem is far from being cleared up, as recently pointed out by HSÜ (1983).

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