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Depositional environments and microfaunal associations in the Sicilian of the Periadriatic Marche Basin (Central Italy) *

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ABSTRACT - A detailed stratigraphic-sedimentologic study was carried out on the top sediments of the Plio-Pleistocene marine cycle in the southern Marche. The identification, in most of the study area, of an unconformity surface in the upper part of the Plio-Pleistocene marine succession, correlatable to the Emilian regression of Ruggieri (1980), allowed these sediments to be attributed to the Sicilian. Only in a small part of the study area was it possible to recognize with certainty the Sicilian, by the occurrence of *Globorotalia truncatulinoides excelsa*. The features of the sediments of the two areas are indicative of two environments characterized by different depths. In most of the study area, in fact, they are made up of alternations of sandstones and conglomerates which depict different submarine shore environments (lower shoreface, upper shoreface and foreshore), characterizing, throughout the general regressive trend, minor sea-level fluctuations. Palaeontologic features reflect these environmental changes: it is a question of shallow environments characterized by associations prevalently made up of benthic Foraminifera and lacking in stratigraphically meaningful forms. The Sicilian sediments found in the vicinity of Porto S. Giorgio, however, are made up of pelites with a rich association, both benthic and planktic. In particular the benthic forms are indicative of a relatively deep environment (epibathyal) and among the planktic ones well-developed individuals of *Globorotalia truncatulinoides excelsa* give evidence for a depositional environment below 100 m depth. The existence of two depositional environments, characterized by different depths, should be related to the reactivation of the previous Emilian faults, in the easternmost part of the study area.

RIASSUNTO - [Ambienti deposizionali e associazioni microfaunistiche nel Siciliano del bacino periadriatico marchigiano (Italia centrale)]- *E' stata condotta una dettagliata analisi stratigrafico-sedimentologica dei sedimenti di chiusura del ciclo marino plio-pleistocenico nelle Marche meridionali. L'individuazione, nella maggior parte dell'area esaminata, di una superficie di discontinuità nella parte alta della successione marina plio-pleistocenica, correlabile con la regressione emiliana di Ruggieri 1980, ha permesso di riferire i sedimenti in questione al Siciliano. Soltanto in una piccola parte dell'area esaminata, nei pressi di Porto S. Giorgio, è stato possibile riconoscere sicuramente il Siciliano per la presenza di *Globorotalia truncatulinoides excelsa*.*

Le caratteristiche dei sedimenti delle due aree denotano l'esistenza, durante il Siciliano, di due ambienti caratterizzati da diversa profondità. Nella maggior parte dell'area esaminata, infatti, essi sono costituiti da alternanze di sabbie e conglomerati che rappresentano diversi ambienti di spiaggia sottomarina (lower shoreface, upper shoreface e foreshore). Essi testimoniano, nel generale trend regressivo, oscillazioni secondarie del livello marino. Le caratteristiche paleontologiche rispecchiano queste variazioni ambientali: si tratta sempre di ambienti poco profondi caratterizzati da associazioni prevalentemente costituite da Foraminiferi bentonici e prive di forme stratigraficamente significative.

*I sedimenti siciliani rinvenuti nei pressi di Porto S. Giorgio sono costituiti, invece, da peliti che contengono una ricca associazione sia bentonica che planctonica. In particolare i bentonici sono indicativi di un ambiente abbastanza profondo (epibatiale); anche i planctonici, presentando individui ben sviluppati di *Globorotalia truncatulinoides excelsa*, testimoniano un ambiente deposizionale superiore ai 100 metri.*

L'esistenza dei due ambienti deposizionali, caratterizzati da diversa profondità, va messa in relazione alla ripresa delle precedenti faglie emiliane, nella parte più orientale dell'area esaminata.

INTRODUCTION

Studies carried out up to now on the Marche-Abruzzi Plio-Pleistocene marine cycle sediments have allowed a precise chronostratigraphic setting of the base of the cycle to be made. However,

greater difficulty has been encountered in defining the shallow facies of the sediments that closed the cycle. In the uppermost portion of the marine succession, the presence of the Emilian has been

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documented with certainty, whereas for some time there have been doubts as to the presence of the Sicilian. In fact, as has been observed in the area investigated (southern Marche-northern Abruzzi), *Globorotalia truncatulinoides excelsa*, whose appearance is known to mark the Emilian / Sicilian boundary, is usually missing in the Foraminifera associations.

On the basis of accurate sedimentological and stratigraphic investigations, Cantalamessa *et al.* (1986) recognized the Sicilian in the upper part of the succession, finding an unconformity surface. This unconformity, which can be correlated to the Emilian regression (Ruggieri, 1980), has allowed the Emilian sediments (Q_m) to be separated from the Sicilian (Q_{m1}), even in the absence of stratigraphically significant paleontological elements.

The absence of *Globorotalia truncatulinoides excelsa* could be attributed to an ecological exclusion in a sedimentary environment characterized by modest depth (Cantalamessa *et al.*, 1995). This species has recently been found in a limited outcrop of clayey sediments in the neighborhood of Porto S. Giorgio (southern Marche) where the rich benthic association indicates a deeper environment (epibathyal) than that of the sandy-conglomerate sediments of the Q_{m1} sequence, of which they are probably heteropic. The existence of two depositional environments characterized by differing depths in the Porto S. Giorgio Sicilian is connected to the reactivation of the preceding Emilian faults in the easternmost part of the area (Cantalamessa *et al.*, 1990).

The aim of the present work is to present the results of a detailed and essentially stratigraphic-sedimentary study of the successions related to the various depositional environments found in the Sicilian of the above-mentioned area.

GEOLOGICAL SETTING OF THE PORTO S. GIORGIO AREA

Lying to the east of the S. Elpidio a Mare - Fermo - Lapedona alignment, the area is part of the southeastern sector of the *Outer Marche Basin*, filled in by terrigenous sediments of the Plio-Pleistocene marine cycle (P_2 - Q_{m1} , Cantalamessa *et al.*, 1986). In the innermost part, these sediments are transgressive and unconformably overlie the turbiditic deposits of the *Formazione della Laga*; in the easternmost part of the area, however, they unconformably overlie the Lower Pliocene deposits.

In general, the Plio-Pleistocene sequence begins with transgressive deposits followed by a

powerful clayey succession ca 2300 m thick, in which bodies and/or coarse- and fine-grained clastic horizons are intercalated at various stratigraphic heights. The sequence closes with sands and conglomerates in facies from littoral to continental.

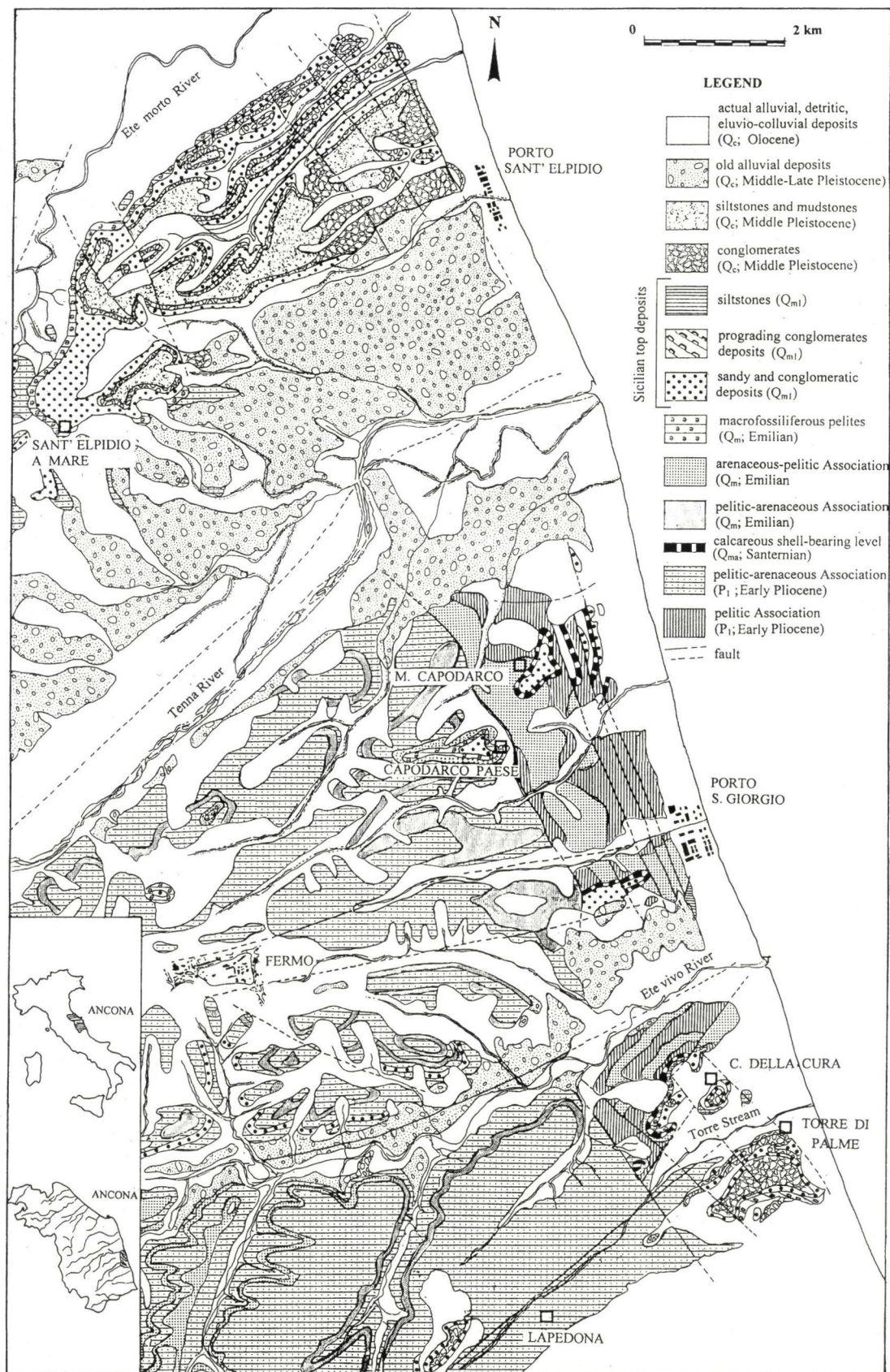
The geological characteristics of the Porto S. Giorgio area have been illustrated in detail by Cantalamessa *et al.* (1990), who recognized the presence of two different Lower Pleistocene lithostratigraphic successions (Text-fig. 1). One deals with the more depressed area (basin) and occupies the majority of the area; the other, the ridge area (the M. Capodarco - C. della Cura ridge), is more limited and crops out in the easternmost sector between the River Tenna and the Fosso della Torre. The latter rests unconformably on the Early Pliocene deposits arranged in an eastward-verging asymmetrical anticline, draped by a thin discontinuous pelite veil containing microfauna of varying age.

Sicilian deposits can also be observed in a limited outcrop immediately to the south of the town of Porto S. Giorgio. They are separated from the M. Capodarco - C. della Cura succession by an Apenninic direct fault.

Particularly, the stratigraphy of the study area is schematically presented in Text-fig. 2, where column A refers to the ridge succession (M. Capodarco - C. della Cura) while columns B, C, and D refer to the basin area (Capodarco paese; S. Elpidio a Mare; Torre di Palme); column E regards the outcrop immediately to the south of Porto S. Giorgio.

In column A (the ridge area), above the pelite and pelitic-arenaceous sediments of the upper part of Early Pliocene (P_1), a thin discontinuous pelite veil can be found with a microfauna content represented by Middle-Late Pliocene - Earliest Pleistocene forms (*Globorotalia bononiensis*, *G. aemiliana*, *G. crassaformis*, *G. inflata*, *Globigerina* aff. *calida*, *G. calabra*, *Bulimina marginata*, *Orthomorphina stainforthi*) associated with Early Pliocene ones such as *Globorotalia puncticulata* (Pl. 1, figs. 1a-16a). This association, characterized by fossils of varying age, may be related to very scant or no sedimentation at the point of a structural high. In such conditions, in fact, the remains of organisms, not covered with a sufficient sedimentary amount, passed through repeated mixings *in situ*, with the forms of the uppermost part of the Early Pliocene underlying sediments.

In clear unconformity, a calcareous shell-bearing level (Q_{ma}) of modest thickness follows. It indicates a shallow high-energy marine environ-



Text-fig. 1 - Geological sketch of the Porto S. Giorgio area.

environment which oscillates from the circum-littoral to the epibathyal and which was set up in this external part of the ridge owing to longitudinal direct faults that dislocated the structure and caused the lowering of the calcareous shell-bearing level.

Locally, the marine succession is closed with mainly sandy and sandy-pebbly deposits ca. 20-30 m thick (Q_{ml}) which are usually blandly unconformable with the underlying sediments. The paleontological and sedimentological characteristics of these sediments closing the Plio-Pleistocene cycle are related to the Sicilian (Q_{ml}) and indicate a shallow sedimentary environment.

In columns B, C, and D (the basin area), the succession base is made up of pelite deposits in which are intercalated at varying heights sandy and sandy-clayey bodies, graded in medium-thick layers with plane-parallel and crossed lamination. The previously mentioned pelites contain a microfauna association made up mainly of benthic Foraminifera with *Hyalinea balthica* being the most representative form, which means these sediments can be attributed to the Emilian; the rather scarce plankton forms are represented by *Globorotalia inflata*, *Globigerina calabra*, *G. aff. calida* and *G. bulloides*.

In continuity, there follow the macrofossiliferous pelites which display the same microfauna characteristics as are found in the same unit in the western part of the M. Capodarco - C. della Cura structure; above, sands and conglomerates, coeval with the upper terms of the ridge succession, with thickness ranging from 20 to 80 m, are found.

Both in the basin area and in that of the ridge, coarse-grained continental deposits with evident basal unconformity are found above the Q_{ml} sequence.

Column E refers to a modest outcrop observable in the southeastern part of the M. Capodarco - C. della Cura structure immediately south of Porto S. Giorgio. This outcrop is made up of predominantly clayey-silty sediments, separated from the ridge succession by an Apenninic direct fault, whose stratigraphic relationships with respect to the surrounding units are not clear.

The micropaleontological analysis carried out on these sediments revealed that their deposition occurred in an epibathyal environment during the Sicilian (Q_{ml}).

SICILIAN FACIES ASSOCIATIONS AND DEPOSITIONAL ENVIRONMENTS

The Sicilian succession in the study area displays considerable uniformity from the standpoint of facies associations; their thickness varies in the various zones and they may be repeated several times in time.

In particular, three distinct facies associations have been recognized, variously superimposed and juxtaposed, which reflect the same number of underwater beach deposition environments and, in their general regressive trend, characterize secondary oscillations of the sea level.

The macrofossiliferous pelites give way, by means of a more or less marked unconformity, to deposits of the Q_{ml} sequence, represented here by beach environment sands and conglomerates ca 80 m thick. These will now be briefly described:

FACIES A ASSOCIATION

This association is characterized by yellowish sands in thick and very thick layers, weakly cemented in fine and extremely fine grain-size. The most typical internal structure is the hummocky cross-bedded stratification with its irregularly wavy lamination in fusiform batches separated by erosive surfaces, which are also slightly hummocky cross-bedded. Fragments of bioclasts and small flat pebbles are frequently observed distributed along the laminae. The structure has a wavelength of about 5-6 m with no precise orientation. Graded layers, and those with plane-parallel lamination where slight unconformity can be seen, are rare. The small-scale symmetrical ripple or mega-ripple-type drag structures are often limited to the upper part of the storm layer; this suggests that the wavy movement reworked the material emplaced by the event itself. In some outcrops, very flat and wide erosive depressions can be observed; these are filled in by material, more coarse-grained than the base form, with low-angle lamination from flat to oblique characterized by pebble alignment. Bioturbation is almost always present and often completely homogenizes the sediment by canceling all the sedimentary drag structures. Numerous tunnels, both horizontal and vertical, have been dug by burrowing organisms such as *Callianassa*. A common feature of the majority of the layers of this lithofacies is the presence of small pelite inclusions, sometimes arranged into effective layers, predominantly represented by intraformational clay fragments. On the whole, this association of facies is arranged in layers of variable thickness and lateral continuity and con-

nected with stratification surfaces which are ill-defined and irregular, owing to their erosive contact and in places to the almost complete bioturbation of the layers.

The sedimentary features described for this association correspond essentially to a lower shoreface environment and are the result of sedimentation occurring inside a zone situated between the base level of an ordinary wave movement and that of a storm one. In fact, it is presumed that the marine processes active during sedimentation are attributable to a sea normally characterized by a microtidal regime with periodic high-energy events, especially in the winter period (Massari *et al.*, 1988)

FACIES B ASSOCIATION

This lithofacies is generally made up of units of limited thickness, of not more than 5 m, and consists on the whole of alternations of medium-fine sand and relatively coarse-grained gravel.

The base of this lithofacies is more sandy and characterized more or less by the same structures seen previously, i.e. symmetric or asymmetric ripples and megaripples and the related concave cross-bedding. The paleocurrent measurements mainly indicate a N-S or slightly oblique transport along the shore. Bioturbation is almost always present but often limited to the upper part of the sandy layers, which indicates long periods of stasis without sedimentation. The gravelly layers are always characterized by clear surface erosion with respect to the underlying sandy layers, which slope slightly eastward. The clasts are essentially calcareous and display two dominant modes, one of particle size and one of morphometrics, isodiametric coarse-grained pebbles in a matrix of small pebbles of variable or predominantly flat shape; this indicates mixtures

of different gravel populations during a storm event, in connection with drastic erosion of the shoreline profile and the seaward transporting of large volumes of coarse-grained sediments, and with massive deposition at the foot of the submerged beach. The 10- to 30 cm-thick gravelly layers sometimes display positive grading and a clast-supported structure.

This context makes it possible for the different particle sizes to mix. The lamination present in the sandy layers sloping toward the ground seems to indicate a shoreward migration during periods of stasis in the bar system along the coast; at times these bars managed to become amalgamated with the submerged beach profile.

The sedimentary features of this lithofacies correspond essentially to an upper shoreface environment.

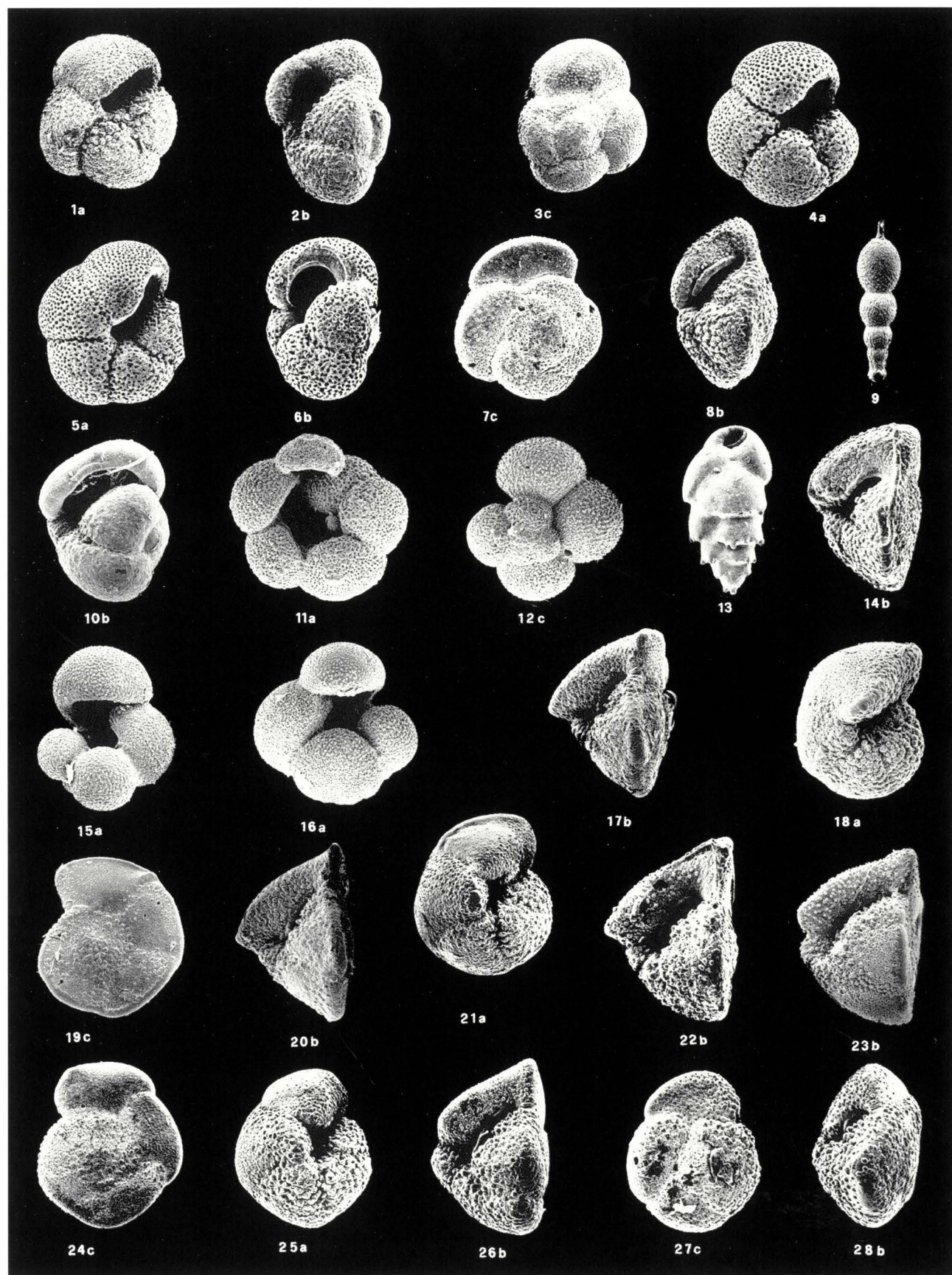
FACIES C ASSOCIATION

This lithofacies also displays at all times a limited thickness, never more than 2 m. It is made up of thin and very regular stratification, parallel or cross-bedded at a low angle of 8° to 10°, and predominantly slopes towards the sea. There is evident parallelism between the basal erosive surfaces and the depositional laminae. The layers show very well selected sediments, sometimes unimodal and sometimes bimodal, made up of very coarse-grained sands and/or predominantly fine-grained gravels. Where imbrication is visible, it is always clearly identifiable and immersing towards the sea.

The microfauna association, too, reflects the same variations in depth. In fact, it goes alternately from a benthic Foraminifera microfauna made up mostly of *Bolivina*, *Bulimina*, *Cassidulina*, *Valvulineria* and *Quinqueloculina*, to one mainly represented by *Ammonia*, *Elphidium* and *Florilus*.

EXPLANATION OF PLATE 1

Fig. 1a - *Globorotalia puncticulata* (Deshayes) (x 35). Fig. 2b - *Globorotalia puncticulata* (Deshayes) (x 50). Fig. 3c - *Globorotalia puncticulata* (Deshayes) (x 40). Fig. 4a - *Globorotalia puncticulata* (Deshayes) (x 50). Fig. 5a - *Globorotalia bononiensis* Dondi (x 50). Fig. 6b - *Globorotalia bononiensis* Dondi (x 65). Fig. 7c - *Globorotalia crassaformis* (Galloway & Wissler) (x 45). Fig. 8b - *Globorotalia aemiliana* Colalongo & Sartoni (x 45). Fig. 9 - *Orthomorphina stainforthi* Perconig (x 30). Fig. 10b - *Globorotalia inflata* (d'Orbigny) (x 50). Fig. 11a - *Gobigerina umbilicata* Orr & Zaitzeff (x 50). Fig. 12c - *Globigerina calabra* Colalongo & Sartoni (x 30). Fig. 13 - *Bulimina marginata* d'Orbigny (x 35). Fig. 14b - *Globorotalia crassaformis* (Galloway & Wissler) (x 50). Fig. 15a - *Globigerina* aff. *calida calida* Parker (x 20). Fig. 16a - *Globigerina calabra* Colalongo & Sartoni (x 30). Fig. 17b - *Globorotalia truncatulinoides excelsa* Ruggieri, Sprovieri & Unti (x 50). Fig. 18a - *Globorotalia truncatulinoides excelsa* Ruggieri, Sprovieri & Unti (x 50). Fig. 19c - *Globorotalia truncatulinoides excelsa* Ruggieri, Sprovieri & Unti (x 40). Fig. 20b - *Globorotalia truncatulinoides excelsa* Ruggieri, Sprovieri & Unti (x 60). Fig. 21a - *Globorotalia truncatulinoides truncatulinoides* (d'Orbigny) (x 50). Fig. 22b - *Globorotalia truncatulinoides excelsa* Ruggieri, Sprovieri & Unti (x 50). Fig. 23b - *Globorotalia truncatulinoides truncatulinoides* (d'Orbigny) (x 50). Fig. 24c - *Globorotalia truncatulinoides truncatulinoides* (d'Orbigny) (x 45). Fig. 25a - *Globorotalia truncatulinoides pachyteca* Blow (x 50). Fig. 26b - *Globorotalia truncatulinoides truncatulinoides* (d'Orbigny) (x 50). Fig. 27c - *Globorotalia truncatulinoides pachyteca* Blow (x 70). Fig. 28b - *Globorotalia truncatulinoides pachyteca* Blow (x 50).
(a, face umbilical; b, profiles; c, face spiral).



In the southern area in the sandy Sicilian succession, and more precisely above the first sandy level of lower shoreface, an approx. 10-m-thick clinostratigraphic gravelly body is intercalated. This is the deposition of a gravel beach in a typical progradation sequence genetically linked to a fan delta system.

The Sicilian sediments which are present to the east of the M. Capodarco - C. della Cura structure immediately south of the town of Porto S. Giorgio display considerably different characteristics. The outcrop is of reduced size and is made up mainly of greyish-blue silty clays intercalated with medium-thin layers of marls and limestone marls with an overall thickness of ca. 12 m. The lower part of the section is formed of massive bluish silty clays with scant bioturbation and fragments of Bivalvia. Instead, the upper part is intensely bioturbated and characterized by alternations of yellowish sandy layers and of thin marly-limestone ones.

The micropaleontological analysis revealed a well-preserved Foraminifera microfauna with a clearly defined prevalence of the planktonic fraction with respect to the benthic one; however, the latter is always highly diversified.

The microfauna association is the following: *Anomalinoides ornatus*, *Bigennerina nodosaria*, *Bolivina subspinescens*, *B. albatrossi*, *Bulimina basispinosa*, *B. marginata*, *B. sublimbata*, *Cassidulina neocarinata*, *Cibicides lobatulus*, *Cibicidoides kullenbergi*, *C. pseudoungerianus*, *C. robertsonianus*, *Dentalina leguminiformis*, *Eggerella bradyi*, *Fissurina marginata*, *F. orbignyana*, *F. staphyllearia*, *Globocassidulina oblonga*, *G. subglobosa*, *Gyroidina soldanii*, *Gyroidinoides neosoldanii*, *Hanzawaia boueana*, *Heterolepa floridana*, *Hoeglundina elegans*, *Karrieriella bradyi*, *Lagena* cf. *apiopleura*, *L. semistriata*, *Lenticulina calcar*, *L. cultrata*, *L. rotulata*, *L. stellata*, *Marginulina cherensis*, *M. costata*, *Martinottiella communis*, *Melonis padanum*, *M. soldanii*, *Oridorsalis umbonatus*, *O. umbonatus stellatus*, *Pandaglandulina dinapolii*, *Pyrgo bul-*

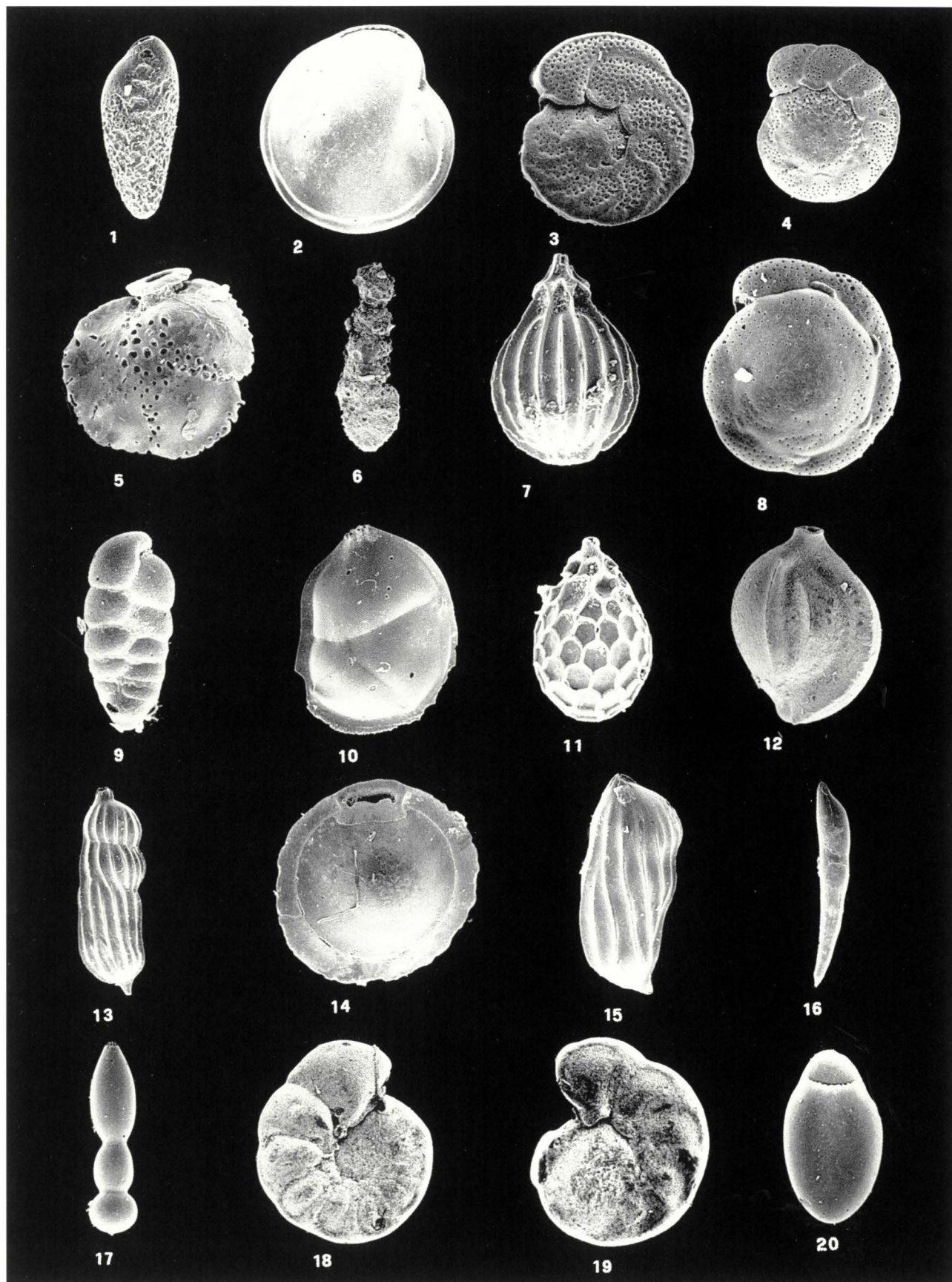
loides, *P. depressa*, *Planulina ariminensis*, *Praeglobobulimina ovata*, *Pullenia bulloides*, *P. quinqueloba*, *Quinqueloculina bicarinata*, *Sigmoilopsis celata*, *S. schlumbergeri*, *Siphonina reticulata*, *Sphaeroidina bulloides*, *Spiroloculina canaliculata*, *Stilostomella monilis*, *S. pyrula*, *Trifarina angulosa*, *Triloculina gibba*, *Uvigerina peregrina*, *Uvigerina pygmaea*, *Globigerina* gr. *bulloides*, *G. calabra*, *G. aff. calida calida*, *G. falconensis*, *G. quadrilatera*, *G. quinqueloba*, *G. rubescens*, *G. umbilicata*, *Globigerinoides helacinus*, *G. immaturus*, *G. ruber*, *G. sacculifer*, *G. tenellus*, *G. inflata*, *G. oscitans*, *G. gr. scitula*, *G. tosaensis*, *G. tosaensis tenuithecata*, *G. truncatulinoides*, *G. truncatulinoides pachythea*, *G. truncatulinoides excelsa*, *Hastigerina siphonifera*, *Neoglobobulimina humerosa*, *N. pachyderma*, *Orbulina universa* and *O. bilobata*.

In this association, the most significant form from the stratigraphic standpoint is *Globorotalia truncatulinoides excelsa*, the presence of which allows the sediments in question to be ascribed with certainty to the Sicilian. With regard to the depth of the sedimentation environment, this may be deduced on the basis of certain considerations. First of all, the rich Foraminifera association is predominantly formed by planktonic forms, the most common of which are *G. gr. truncatulinoides*, *G. gr. tosaensis* and *G. gr. inflata*. In particular, *Globorotalia truncatulinoides excelsa*, which is known to have a highly evolved morphology, requires depths of over 100 m in order to complete its life cycle (Bé, 1977).

In their study of modern planktonic Foraminifera, Hemleben et al. (1989) demonstrated considerably greater depths for *G. gr. truncatulinoides*. The benthic Foraminifera are also well represented and display a high degree of diversification (Pl. 2). Among these, the most significant forms are: *Bolivina albatrossi*, *Cibicidoides kullenbergi*, *Oridorsalis umbonatus*, *Planulina ariminensis* and *Nodosariidae*. From what has been said above, it can be hypothesized that the clays in question were deposited in an epibathyal environment.

EXPLANATION OF PLATE 2

Fig. 1 - *Bolivina albatrossi* Cushman (x 75). Fig. 2 - *Hoeglundina elegans* (d'Orbigny) (x 55). Fig. 3 - *Planulina ariminensis* d'Orbigny (x 50). Fig. 4 - *Cibicidoides* sp. (x 35). Fig. 5 - *Siphonina reticulata* (Czjzek) (x 90). Fig. 6 - *Bigennerina nodosaria* d'Orbigny (x 20). Fig. 7 - *Lagena* sp. (x 75). Fig. 8 - *Cibicidoides* sp. (x 75). Fig. 9 - *Karrieriella bradyi* (Cushman) (x 40). Fig. 10 - *Lenticulina peregrina* (Schwager) (x 55). Fig. 11 - *Oolina* sp. (x 150). Fig. 12 - *Triloculina gibba* d'Orbigny (x 30). Fig. 13 - *Marginulina costata* (Batsch) (x 30). Fig. 14 - *Pyrgo depressa* (d'Orbigny) (x 35). Fig. 15 - *Marginulina cherensis* Tedeschi & Zanmatti (x 35). Fig. 16 - *Dentalina leguminiformis* (Batsch) (x 20). Fig. 17 - *Stilostomella consobrina* (d'Orbigny) (x 20). Figs. 18-19 - *Hyaline balthica* (Schroeter) (x 50). Fig. 20 - *Chilostomella* sp. (x 65).

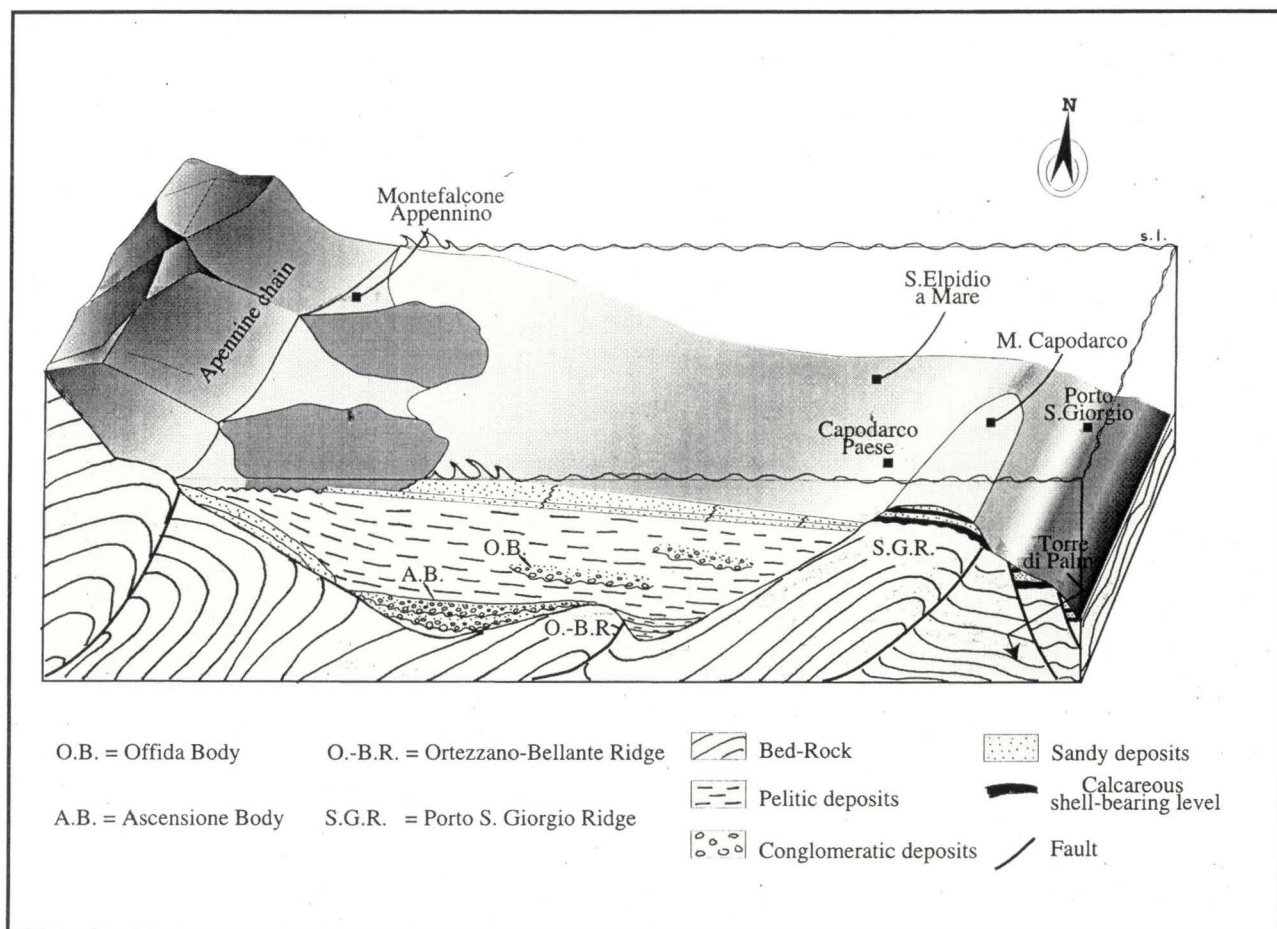


CONCLUSIONS

The Apennine tectonogenesis reaches its point of highest development in the upper part of Early Pliocene (in the *Globorotalia puncticulata* Zone) when it gives rise to the uplifting and emergence of the chain in the innermost area and, in the outermost part, reveals minor longitudinal ridges. These describe the peri-Adriatic Basin in several sectors, e.g. the Ortezzano - Bellante ridge and the shoreface ridges of which that of Porto San Giorgio is one. Further compressional phases, which take place from Middle Pliocene to Early Pleistocene, probably connected with reactivation of Early Pliocene thrusts condition the sedimentation in the basin. In fact, in the inner areas this is more continuous, displays considerably greater thicknesses and begins with sandy beach deposits (e.g. Montefalcone) followed by a powerful clay succession with transgressive-regressive trend. At varying stratigraphic heights in this powerful pelite succession, coarse-grained clastite bodies are

found such as the Ascensione and Offida ones. However, the more upraised external areas show a lesser rate of sedimentation, the absence of turbidites and the presence of gaps in the sedimentation more or less extensive in time (Text-fig. 3).

In particular, in the same period of time on the M. Capodarco - C. della Cura ridge study area, in addition to the pelite and pelitic-arenaceous sediments of the upper part of Early Pliocene, there is scant or no sedimentation (mixed fauna pelites). There follows unconformably a calcareous shell-bearing level, probably attributable to basal Pleistocene, whose sedimentological and paleontological characteristics indicate an environment with high energy but shallow depth. Pelitic hemipelagic sedimentation continues in the remaining area of the basin, and thus the two previously described types of succession (basin and ridge) originate. During the Emilian, the morphological differences between the two areas become progressively less marked as a result of a gradual and generalized filling. In fact, in the upper part of the



Text-fig. 3 - Sicilian paleogeographic situation of the periadriatic Marche basin. In section, it is possible to follow the tectono-sedimentary evolution of the area from Early Pliocene, at the top, to Sicilian.

Emilian the ridge area is also affected by macrofossiliferous clay sedimentation. At the same time, the external front of the Porto S. Giorgio ridge undergoes a series of longitudinal fault dislocations; by determining a lowering of the calcareous shell-bearing level, these create environments that become little by little deeper eastwards, as is witnessed by the sedimentological and paleontological characteristics of the macrofossiliferous clays. Finally, during the Sicilian in the easternmost part of the area, the previous Emilian direct faults are reactivated; this causes the setting up of an (offshore) environment deeper than that in the remainder of the area and characterized by sandy and conglomerate facies.

This last-mentioned sandy-conglomerate succession is found in most of the area, represented by various submarine beach environments with bases characterized by an erosive phase of regional dimension (Ruggieri, 1980): with a sudden leap in facies, the macrofossiliferous clays of the offshore environment give way to lower shoreface sandy sediments. From the standpoint of facies associations, this shoreface displays considerable uniformity, while the thicknesses vary from ca 20 m up to a maximum of 80 m. As can be seen from Text-fig. 2, the S. Elpidio a mare and Torre di Palme successions, north and south of the ridge respectively, show greater thickness. This situation can be correlated to the reactivation of the transversal tectonic lines, which now act as direct faults. In particular, three distinct facies associations, variously superimposed and juxtaposed, can be recognized, reflecting the same number of submarine beach deposition environments: lower shoreface, upper shoreface and foreshore. The paleontological characteristics confirm these environmental variations. In the general regressive trend, these facies characterize secondary oscillations of the sea level.

The sedimentation is closed with continental environment deposits having evident basal unconformity.

The pelites in the southeastern portion of the ridge area prove considerably different, from both the paleontological and the sedimentological standpoints. In particular, it can be hypothesized, from an analysis both of the benthic and of the

plankton microfauna associations, that their deposition took place in an epibathyal environment. From this point of view, the most significant benthic forms are *Bolivina albatrossi*, *Cibicidoides kullenbergi*, *Oridorsalis umbonatus*, *Planulina ariminensis* and *Nodosariidae*. Within the plankton, the *Globorotalia truncatulinoides* group is important; according to some Authors (Bé, 1977; Hemleben *et al.*, 1989) this needs depths of at least 100 m to be able to complete its life cycle.

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