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LATEST PLEISTOCENE-HOLOCENE PALEOCLIMATIC RECORD AND SEA LEVEL CHANGES IN THE CENTRAL ADRIATIC SEA: FORAMINIFERAL EVIDENCE FROM CORE A 85-10

R. Coccioni - M. Bellagamba - R. Di Leo - D. Savelli - M. Tramontana
Istituto di Geologia, Università di Urbino

ABSTRACT - *Latest Pleistocene-Holocene paleoclimatic record and sea level changes in the central Adriatic Sea: foraminiferal evidence from core A 85-10* - Il Quaternario, **5**(2), 1992, p.147-162 - A quantitative study was carried out on the planktonic and benthonic Foraminifera from Core A 85-10 recovered in the Meso-Adriatic Depression (Central Adriatic Sea). Sediments are uppermost Pleistocene to Holocene in age, probably spanning over the last 18,000 years. A paleoclimatic curve was constructed based on the relative abundance of warm and cold species of planktonic Foraminifera documenting the climatic evolution of the sediments. On the basis of the change in composition of the planktonic foraminiferal assemblages three main biostratigraphic intervals were recognized and interpreted as: last glacial, deglacial and Holocene. Variations in the benthonic foraminiferal assemblages allow to reconstruct sea level changes connected with the Flandrian transgression. The acquired data also suggest that some benthonic foraminiferal species could have survived in a shallower environment than that currently known in the Adriatic Sea.

RIASSUNTO - *Documentazione paleoclimatica e variazioni del livello marino durante il Pleistocene sommitale-Olocene nel mare Adriatico centrale: evidenza dai Foraminiferi della Carota A 85-10* - Il Quaternario, **5**(2), 1992, p.147-162 - E' stato effettuato uno studio quantitativo sui Foraminiferi planctonici e bentonici provenienti dalla Carota A 85-10 recuperata nella Depressione Meso-Adriatica (mare Adriatico centrale). I sedimenti hanno un'età compresa tra il Pleistocene sommitale e l'Olocene e sono probabilmente riferibili agli ultimi 18.000 anni. E' stata costruita una curva paleoclimatica sulla base dell'abbondanza relativa delle specie calde e fredde dei Foraminiferi planctonici; essa documenta l'evoluzione climatica registrata nei sedimenti. Sulla base delle variazioni nella composizione delle associazioni a Foraminiferi planctonici sono stati riconosciuti tre principali intervalli biostratigrafici. Essi sono stati interpretati nel modo seguente: ultimo glaciale, deglaciale e Olocene. Le variazioni delle associazioni a Foraminiferi bentonici hanno consentito di ricostruire le oscillazioni del livello marino connesse con la trasgressione Flandriana. I dati ottenuti indicano inoltre che alcune specie di Foraminiferi bentonici sono sopravvissute in ambienti meno profondi di quelli nei quali vivono attualmente nel mare Adriatico.

Key-words: Foraminifera, Pleistocene, Holocene, climate, sea level, Central Adriatic Sea
Parole chiave: Foraminiferi, Pleistocene, Olocene, clima, livello del mare, Adriatico centrale

1. INTRODUCTION

During the investigations carried out in the Central Adriatic Sea by the Istituto di Geologia of Urbino University since 1984, high resolution 3.5 KHz and microseismic uniboom profiles have been recorded and many sediment cores have been collected. The present study deals with the changes in composition of the planktonic and benthonic foraminiferal assemblages recorded in the gravity core A 85-10 collected on the south-eastern side of the Meso-Adriatic Depression (Fig. 1). Purpose of this paper is to contribute to the knowledge of the latest Pleistocene-Holocene paleoenvironmental and palaeoceanographic evolution of this area.

2. PHYSIOGRAPHIC AND GEOLOGIC SETTING

The Meso-Adriatic Depression is the main physiographic feature of the Central Adriatic Sea. It extends off Pescara for about 125 km in NE-SW direction reaching a maximum depth of about -270 metres (Fig. 1). The whole Meso-Adriatic Depression shows a marked asymmetry, with steeper slopes on the north-western side. The depression consists of two main basins separated by the north-western termination of a SE-NW trending submarine relief (Pelagosa Ridge according to Savelli *et al.*, 1990) that extends more than 150 km southeastwards as far as the Pelagosa Island. The northeastern, deepest basin area is 8 to 30 km wide, narrowing from SW to NE in correspondence with a minor NW-SE oriented structural high, previously described by Van Straaten (1965). The south-western basin unit reaches the depth of –256 m and shows an irregular shape, with maximum widths of about 45 km. The south- eastern side of this latter basin unit extends south-eastwards in a broad valley parallel to the Pelagosa Ridge (Fig. 1).

The north-western side of the Meso-Adriatic Depression is interpreted (Ciabatti *et al.*, 1986) as the synglacial prodelta slope of the Po River during the last glacio-eustatic lowstand sea level. It consists of progradational units probably correlatable with the continental depositional units of flood plain-backswamp environment already recognized on the north-central Adriatic shelf off Ancona (*cf.* Ferretti *et al.*, 1986; Savelli *et al.*, 1987). These south-eastwards prograding units, built by sediments coming from the Po Plain, lie on more ancient Pleistocene clinoforms prograding north-westward, fed by southern sources (Ciabatti *et al.*, 1986; Colantoni *et al.*, 1991). Off the Gargano Promontory, the quaternary sedimentation terminates with four sigmoid clinoforms prograding seawards and interpreted as interglacial mud drapes (Savelli *et al.*, 1990). The Meso-Adriatic Depression, generally interpreted (*cf.* Ciabatti *et al.*, 1986) as a "relict"

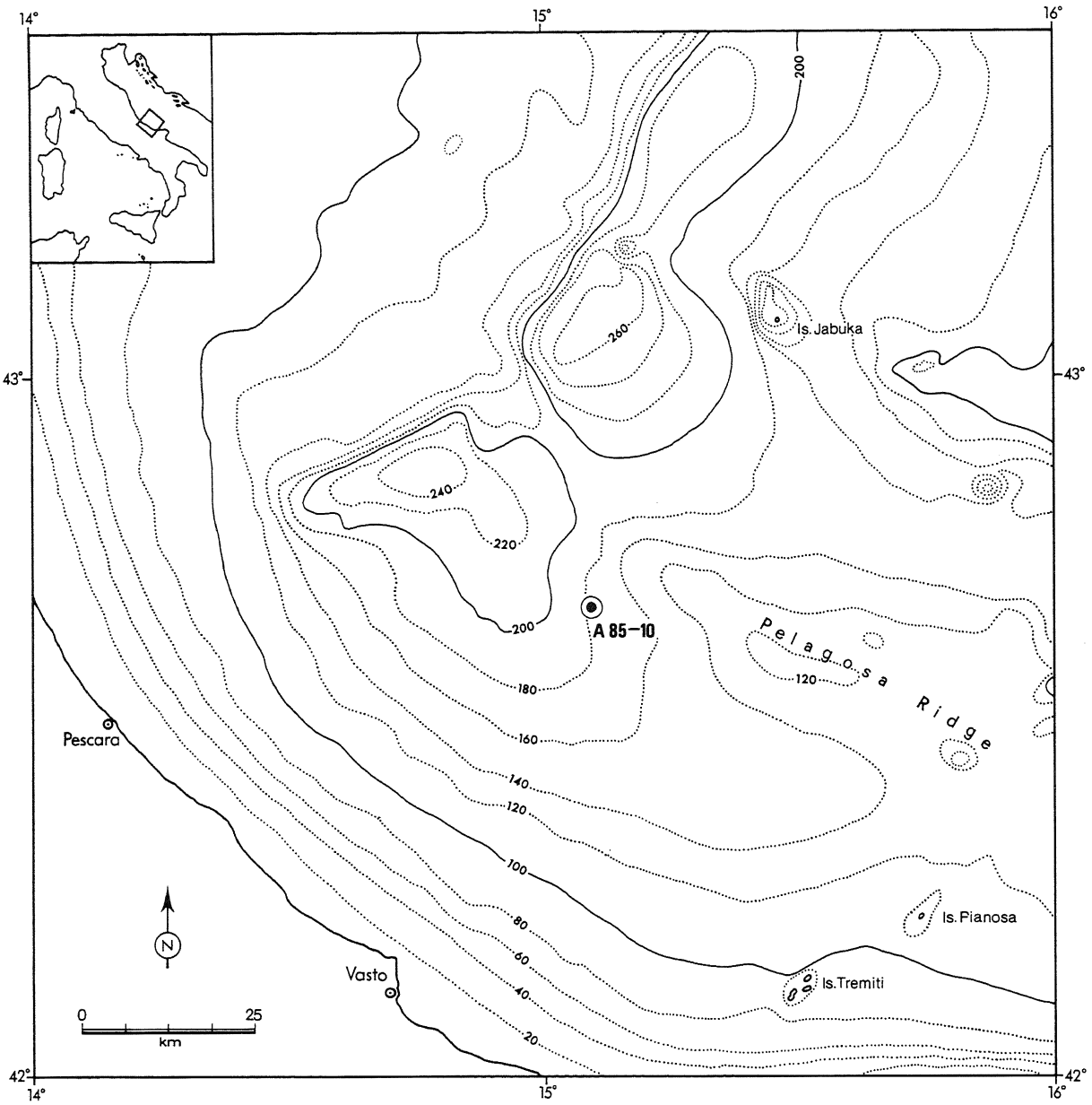

Fig. 1 - Bathymetric location map of the Core A 85-10.
Ubicazione della carota A 85-10 sulla carta batimetrica .

of the Apennine foredeep almost completely filled by the prograding clinoforms, shows some evidence of recent tectonic deformation (Colantoni *et al.*, 1991).

3. CORE DESCRIPTION

Gravity core A85-10 (420 cm of recovery) has been collected on the south-eastern side of the Meso-Adriatic Depression (lat: 42°39.17'N; long: 15°05.60'E) at a depth of -176 m. The core consists of more or less dark greyish mud and silty- sandy muds with subordinated thin and often discontinuous sandy intercalations (Fig. 2). At the top of the core there are 19.5 cm of brownish oxidized mud. Organogenic fragments (Pelecypods, Gasteropods, and Anellids) are diffused in the whole core: they are sometimes concentrated in burrows with dimensions between 1 and 10 mm. The mud is generally bioturbated, plastic and homogeneous. Sands, from very fine to medium, sometimes constitute very thin layers with no evident sedimentary structures: more frequently sands are concentrated in small lenses. They show a high percentage of bioclasts (Pelecypods, Gasteropods, and Anellids) and are often characterized by frequent blackish (volcanic?) clasts. The only significant macroscopic change in the core is the colour variation between the brownish top-mud and the underlying grey muds and the silty-sandy ones.

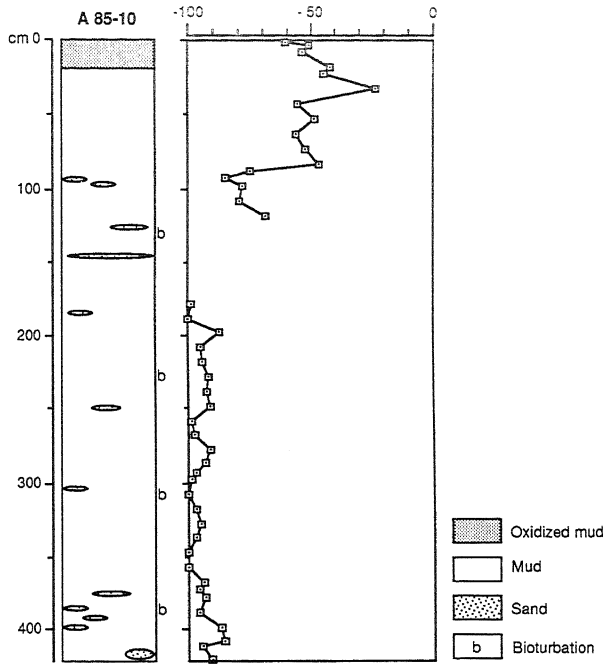

Fig. 2 - Lithologic log and planktonic foraminiferal paleoclimatic curve of Core A 85-10.

Colonna litologica della carota A 85-10 e curva paleoclimatica ottenuta dai foraminiferi planctonici.

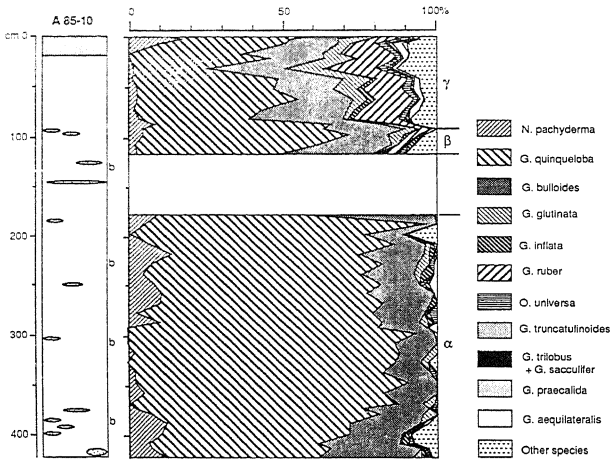

Fig. 3 - Cumulative curve of planktonic foraminifera throughout Core A 85-10. Lithology as in Fig. 2.

Curva cumulativa relativa all'abbondanza percentuale dei foraminiferi planctonici lungo la carota A 85-10. Per la litologia si veda la Fig. 2.

4. MATERIALS AND METHODS

Fifty samples of 2 cm^3 were taken mainly at 10 cm intervals, and subordinately at 6 cm intervals. Samples were disaggregated in water, washed through a 63 μm sieve, and then dried. Washed residues contain from less 1 up to 70% of biogenic components which mainly consists of foraminifera and subordinately of Ostracoda and fragments of Pelecypods, Gasteropods, and Anellids. In all the samples the benthonic foraminifera are more numerous than the planktonic foraminifera. Preservation of the foraminifera ranges from excellent to good.

For faunal analysis benthonic and planktonic foraminifera were picked up from the fraction larger than 63μ, identified and counted. At least 200 to 300 benthonic and planktonic foraminiferal specimens were counted in each sample. Samples containing rare individuals (interval from 118 to 178 cm) were excluded from analysis. The generic classification used in this study follows that of Loeblich & Tappan (1988). Species identification was made using a wide range of literature. Figures 6 to 11 show photographs obtained using a scanning electron microscope of almost all the taxa identified. All the material used in this study is stored in the collection of the Geological Institute, University of Urbino.

5. RESULTS AND DISCUSSION

5.1 Planktonic foraminifera

In total 18 species were recognized belonging to 7 genera (see species list). A cumulative curve was constructed that shows the percentage variations of the identified species throughout the core (Fig. 3). *Globigerina quinqueloba* and *Globigerina bulloides* occur in all the samples, and the former is always the most abundant species. *G. bulloides* shows an inverse relation of abundance with *G. quinqueloba*. The latter is also present with morphotypes (= *G. quinqueloba* mf. A) having 5 1/2 to 6 chambers, instead of 5, in the last whorl and lacking the flaplike extension of the final chamber, as already observed (Asioli, personal communication, February 1991) in other cores from the Meso-adriatic Depression. *Globigerinoides ruber* is present in three varieties: *alba*, *rosea*, and *cyclostoma*. *Globigerinita glutinata* is found with both bullate and non bullate-forms.

5.1.1 Environmental indicators

According to climatic significance previously established by several Authors (Parker, 1958; Todd, 1958; Blanc-Vernet, 1969; Tolderlund, 1969; Bé & Tolderlund, 1971; Vergnaud-Grazzini, 1973; Blanc-Vernet *et al.*, 1975;Vergnaud-Grazzini, 1976; Bé, 1977; Cita *et al.*, 1977; Thunell, 1978; Blanc-Vernet *et al.*, 1979) we have recognized:

Warm-water species: *Globigerinoides* gr. *ruber* (including *G. gomitulus*, *G. elongatus*, and *G. ruber* s.s.), and *Orbulina universa* are continuously present from

118 cm to the top of the core, except for the absence of *O. universa* at 93 cm, with each species showing variable percentages. The values range from 3.6 to 21% for *G.* gr. *ruber* (the highest value being found at 33 cm) and from 0.2 to 3.9% for *O. universa.* In the remaining portion of the core these species are sporadically found. *Globigerinoides sacculifer* together with *Globigerinoides trilobus* occurs in almost all the samples from 108 cm to the top of the core. They are also found at 218 cm and at 248 cm. Maximum value is at 8 cm (2.2%). *Globigerinoides tenellus* is sporadically present from 83 cm to the top of the core, with percentages not higher than 2.1%.

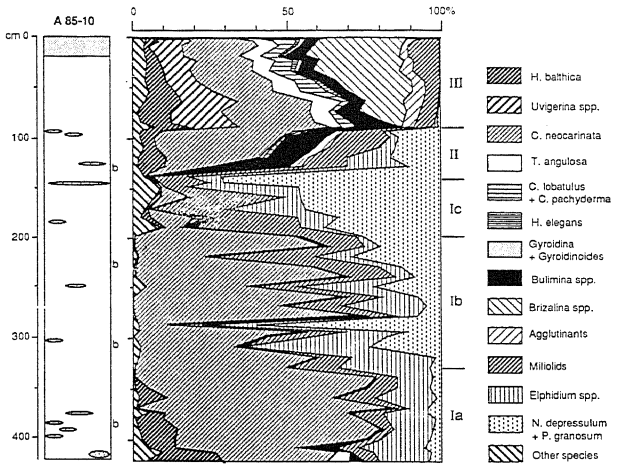

Fig. 4 - Cumulative curve of benthonic foraminifera throughout Core A 85-10. Lithology as in Fig. 2.

Curva cumulativa relativa all'abbondanza percentuale dei foraminiferi bentonici lungo la carota A 85-10. Per la litologia si veda la Fig. 2.

Cold-water species: *Neogloboquadrina pachyderma* occurs in all samples, except for 293, 298, 308 and 328 cm. The maximum value is found at 3 cm (17.4%). *G. quinqueloba* is usually common in almost all the samples; however, the percentages fluctuate remarkably (23.8 to 92.9%) reaching the maximum value at 298 cm. *G. bulloides* is contained in all samples with percentages ranging from 4.2 to 40.2%. The maximum value is found at 178 cm.

Temperate-warm water species: In this group we include *Globigerina praecalida*, *Globigerina rubescens*, *Globigerinella aequilateralis*, *Globorotalia inflata*, *Globorotalia truncatulinoides*, *Globigerinoides quadrilobatus*, and *Globigerinoides ruber cyclostoma* which all together mainly occur from 118 cm to the top of the core.

5.1.2 Climatic curve

For each sample, the algebraic sum of warm-water species percentages (positive values) and cold-water species percentages (negative values) gives the climatic curve (Fig. 2). It is characterized by constantly negative values, therefore cold or at least temperate. In particular, the most marked effects of the cold climate are found from the bottom of the core up to 178 cm. In fact, in this interval values are more or less constantly negative (up to about -100%) with very limited oscillations. Unfortunately, the scarcity of planktonic foraminifera did not allow the reconstruction of the climate curve for the interval 178÷118 cm. Starting from 118 cm the values of the climatic curve are less negative than those found in the preceding interval. This fact proves the change to generally more temperate conditions. Warmer conditions are recorded from 83 cm to the top, with the minimum relative (-23.3%) reached at 33 cm from the core top.

Our climatic curve correlates well with the upper part of that taken from the study of planktonic foraminifera from the core KET 8218 coming from the southern Adriatic Sea (see Blanc-Vernet, 1988, Fig. 3).

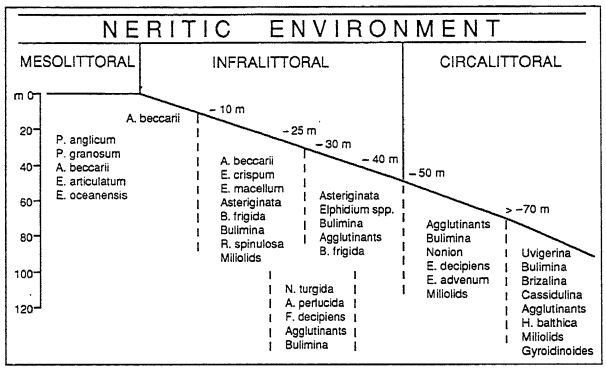

Fig. 5 - Simplified environmental sketch of the present-day distribution pattern of benthonic foraminifera from 0 to 120 m depth in the Adriatic Sea (redrawn from Asioli & Borsetti, 1989).

Schema semplificato del modello di distribuzione attuale dei foraminiferi bentonici nel mare Adriatico relativo all'intervallo batimetrico 0-120 m (da Asioli & Borsetti, 1989).

5.1.3 Paleoclimatic interpretation

From bottom to top of the Core A85-10 three climatic intervals (termed α, β, and γ) can be identified (Fig. 3). Interval α (from the bottom of the core up to 178 cm) is characterized by assemblages mainly consisting of cold-water species. Warm-water species (*G. ruber*, *O. universa*, *G. praecalida*) are sporadically present and with low percentages. Interval β (from 118 up to 93 cm) differs from the underlying interval because of its slight increase in abundance of warm-water species. Interval γ (from 93 cm up to the top of the core) is characterized by the remarkable increase in abundance of warm-water species. Moreover, at the base of this interval *G. truncatulinoides* occurs (88÷73 cm). In the Adriatic Sea, as in the Western Mediterranean, this species is found in only two levels of the deglacial and Holocene whereas it is absent in the glacial contrary to what occurs in the Eastern Mediterranean (Asioli *et al.*, 1988). The presence of *G. truncatulinoides*, which becomes extinct in the Eastern Mediterraean 10,000 years B.P. (Buckley *et al.*, 1982; Thunell & Williams, 1982; Znaïdi-Rivault, 1982; Glacon *et al.*, 1983; Blanc-Vernet *et al.*, 1984)

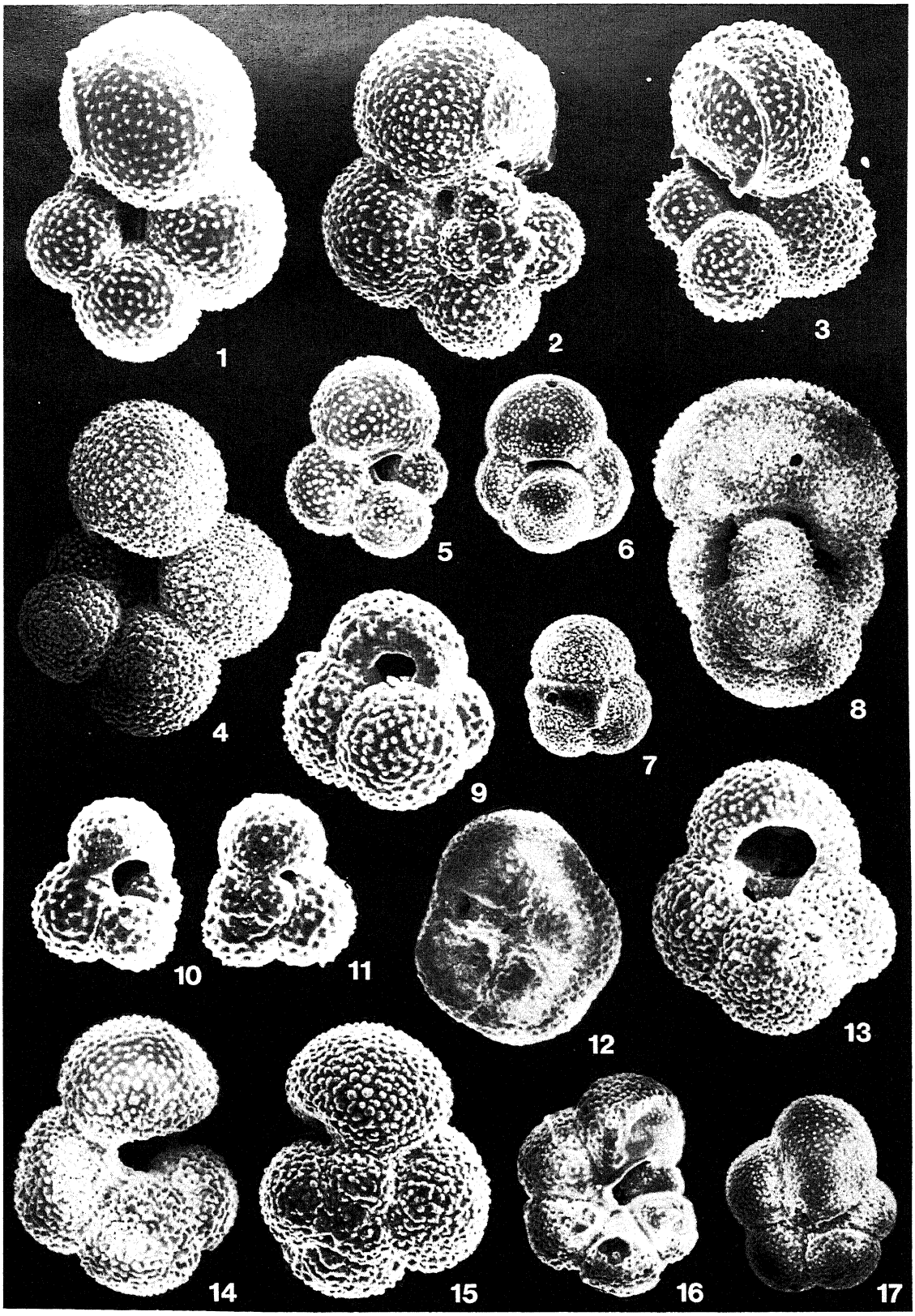

Fig. 6 - 1-2) *Globigerina praecalida* Blow, cm 18, x118; 3) *Globigerina praecalida* Blow, cm 3, x118; 4) *Globigerina praecalida* Blow, cm 33, x98; 5) *Globigerina bulloides* d'Orbigny, cm 388, x118; 6) *Globigerinita glutinata* (Egger), cm 1, x118; 7) *Globigerinita glutinata* (Egger) mf. with bulla , cm 143, x118; 8) *Globigerinella aequilateralis* (Brady), cm 3, x78; 9) *Globigerina rubescens* Hofker, cm 388, x118; 10-11) *Globigerinoides tenellus* Parker, cm 33, x118; 12) *Neogloboquadrina pachyderma* (Ehrenberg), cm 407, x118; 13) *Globigerina bulloides* d'Orbigny, cm 73, x118; 14-15) *Globigerina bulloides* d'Orbigny, cm 33, x118; 16) *Globigerina quinqueloba* Natland mf. A, cm 388, x118;17) *Globigerina quinqueloba* Natland, cm 378, x118.

proves a limited flow of "Atlantic" type water in the Adriatic Sea.

With reference to the climatic curve intervals α, β, and γ could be referred to the "last glacial", "deglacial", and Holocene respectively. Therefore, these intervals could respectively correspond to intervals C-B-A (or at least part of them) of the Cores IN 68-10 from the South Adriatic Through and of the cores IN 68-21 and AD 85-30 from the Meso Adriatic Depression (see Asioli *et al.*, 1988, Fig. 2).

6. BENTHONIC FORAMINIFERA

Seventy-seven taxa belonging to 48 genera were recognized (see species list). The percentages of all species, plotted against the core depth, are reported in Fig. 4.

The percentages of each species fluctuate, sometimes considerably, throughout the core. *Cassidulina neocarinata*, which is associated with *Globocassidulina subglobosa* in Fig. 4, is one of the most abundant species and occurs in all samples with percentages ranging from 0.8% to 84.2%. *Hyalinea balthica* is present in most samples with percentages ranging from 0.1% to 24.5%. *Uvigerina* spp. (*i.e.*, *U. dirupta*, *U. mediterranea*, *U. peregrina*, and *U.* sp.) are continuously distributed from 118 cm to the top of the core with percentages ranging from 0.2% to 19.9%. In the upper portion of the core the percentages are higher. On the contrary, these forms occasionally occur with very low percentages below 118 cm. *Trifarina angulosa* and *Cibicidoides pachyderma*, the latter associated with *Cibicides lobatulus* in Fig. 4, occur in all the samples above 128 cm and also at 178 cm. The percentages range from 0.7% to 9.6% for *T. angulosa* and from 0.7% to 10.4% for *C. pachyderma* together with *C. lobatulus*. *Trifarina angulosa* is also present from 407 cm (0.2%) to 420 cm (7.4 %). *Hoeglundina elegans* is found from 83 cm to the top of the core and also at 178 cm in very low percentages (0.1% to 3.3%). *Gyroidinoides umbonatus* together with *Gyroidinoides altiformis* and *Gyroidina soldanii* (see Fig. 4), occurs from 53 cm to the top of the core and also from 83 cm to 88 cm with percentages not exceeding 2.1%. *Bulimina* spp. (*i.e.*, B. etnea, *B. inflata*, and *B. marginata*) are continuously present from 138 cm to the top with percentages ranging from 1.6% to 23.9%. These forms are sporadically found from the bottom of the core to 188 cm where they occur with percentages ranging from 0.2% to 9.5%. *Brizalina* spp. (*i.e.*, *B. catanensis* and *B. spathulata*) occur in all samples from 88 cm to the top with percentages ranging from 1.7% to 30.6%.

They are also present, but sporadically, from 138 to 407 cm in very low percentages (0.2% to 1.3%). *Elphidium* spp. (*i.e.*, *E. advenum*, *E. crispum*, and *E. macellum*) are found from the bottom to 53 cm with percentages ranging from 0.1% to 41%. *Nonion depressulum* and *Protelphidium granosum*, which are associated in Fig. 4, occur in all samples except for 43 cm. The percentages range from 0.1% up to 70.8%. Miliolids, which are represented by several species belonging to the genera *Quinqueloculina*, *Pyrgo*, *Triloculina*, *Sigmoilinita*, *Sigmoilopsis*, and *Spiroloculina*, are present in all the samples, except for 308 cm, with percentages ranging from 3.6% to 34.7%. Agglutinated forms (*i.e.*, *Bigenerina nodosaria*, *Glabratella* sp., *Pseudoclavulina crustata*, *Spiroplectammina wrighti*, and *Textularia sagittula*) occur continuously from 128 cm to the top of the core with percentages ranging from 2% to 6.2%.

They are also found, but sporadically, from the bottom to 198 cm with very low percentages (0.1% to 1.8%). "Other species", which include all the species non mentioned above (see species list), are present in all samples with percentages ranging from 0.1% to 9.6%.

6.1 Palaeobathymetric interpretation

On the basis of the present-day distribution pattern of benthonic foraminifera in the Adriatic Sea (see Fig. 5) which is derived from existing exhaustive literature (Cita & Chierici, 1962; Cita & Premoli Silva, 1967; Iaccarino, 1967; D'Onofrio, 1969; D'Onofrio, 1972; D'Onofrio *et al.*, 1973; Fregni, 1978, 1980; Fregni & Borsetti, 1980; Parisi *et al.*, 1982; Albani & Barbero, 1982; Curzi *et al.*, 1984; Jorissen, 1987, 1988; Asioli *et al.*, 1988; Asioli & Borsetti, 1989; Colantoni *et al.*, 1989; Hohenegger *et al.*, 1989) three strongly differentiated intervals (I, II, and III) can be identified in Core A85-10. Moreover, in the former interval three subintervals (Ia, Ib, and Ic) can be discriminated (Fig. 4):

Interval I, Subinterval Ia (cm 420÷328): the assemblages mainly consist of *C. neocarinata* together with *G. subglobosa*, *H. balthica*, Miliolids, *Elphidium* spp., and *N. depressulum* together with *P. granosum*; furthermore, *T. angulosa*, *Bulimina* spp., *Brizalina* spp., and agglutinated forms also occur occasionally . This interval could represent a deep infralittoral-low circalittoral environment (depth of 40÷50 m). The presence of *H. balthica* and *T. angulosa*, which presently live in the Adriatic Sea at a depth of at least 100 m (Jorissen, 1988), could be correlated, also according to Asioli & Borsetti (1989), with the variations of certain parameters (*e.g.*, turbidity, temperature of waters, nutrients, pH, Eh, dissolved oxygen, depth light, substratum, trophic structures, productivity, symbiosis), which permit these forms to survive in a shallower environment than that currently known.

Interval I, Subinterval Ib (cm 328÷198): the microfaunas mainly consist of *C. neocarinata* together with *G. subglobosa*, Miliolids, *Elphidium* spp., and *N. depressulum* together with. *P. granosum*. The two latter species are found with higher percentages than those found in the underlying interval. *H. balthica* and agglu-

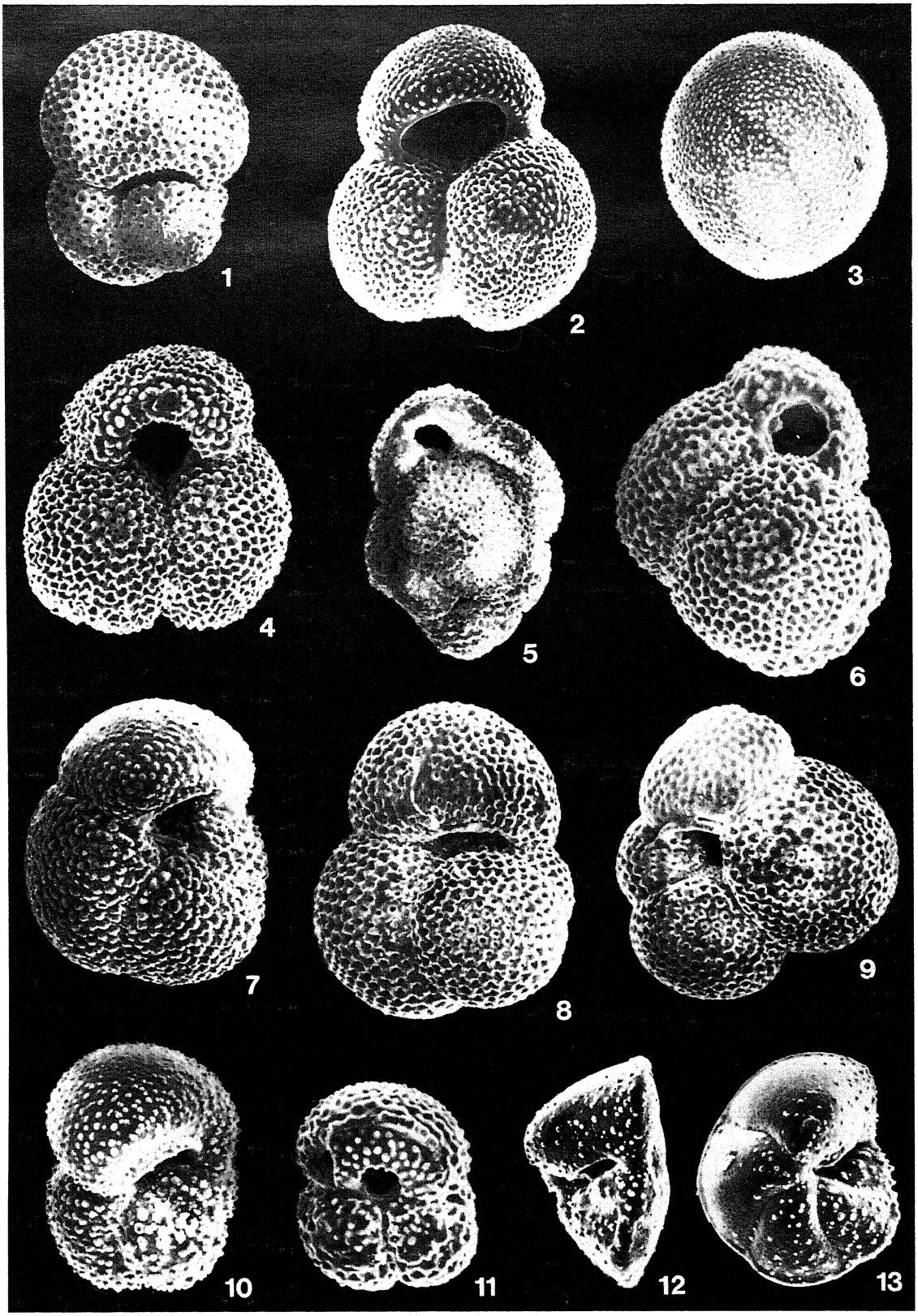

Fig. 7 - 1: *Globigerinoides trilobus* (Reuss), cm 33, x78; 2) *Globigerinoides ruber* (d'Orbigny), cm 23, x78; 3) *Orbulina universa* d'Orbigny, cm 3, x78; 4) *Globigerinoides ruber* (d'Orbigny), cm 73, x78; 5) *Globigerinoides elongatus* (d'Orbigny), cm 33, x78; 6) *Globigerinoides gomitulus* (Seguenza), cm 73, x78; 7) *Globorotalia inflata* (d'Orbigny), cm 43, x78; 8) *Globigerinoides quadrilobatus* (d'Orbigny), cm 43, x78; 9) *Globigerinoides sacculifer* (Brady), cm 43, x78; 10) *Globorotalia oscitans* Todd, cm 407, x118; 11) *Globigerinoides ruber* (d'Orbigny) *cyclostoma* , cm 3, x118; 12-13) *Globorotalia truncatulinoides* (d'Orbigny), cm 88, x118.

tinated forms appear with very low percentages in some scattered levels. These species indicate a deep infralittoral environment (depth of 40 m). However, a rapid and temporary change of the assemblages occur at 293 cm. In fact, *N. depressulum* together with *P. granosum* remarkably increase in abundance whereas *C. neocarinata*, *Elphidium* spp., and Miliolids markedly decrease. This change could be probably related to variations in some environmental parameters (*e.g.*, nutrients and oxygen content).

Interval, Subinterval Ic (cm 198÷138): Miliolids, *Elphidium* spp., and *N. depressulum* together with *P. granosum* predominate. In particular, the two latter forms remarkably increase in abundance upwards. *C. neocarinata* together with *G. subglobosa* decrease in abundance compared with the underlying interval whereas "other species" increase in abundance. *H. balthica* occurs in most samples with low percentages. *Bulimina* spp., *T. angulosa*, *C. lobatulus* together with *C. pachyderma*, *H. elegans*, and agglutinated forms characterize, with very low percentages, the lower portion of the interval. As in the preceding interval these assemblages are compatible with a deep infralittoral environment (depth of 40 m). However, the presence of *H. elegans* which is presently living at a depth more than 300 m (Jorissen, 1988) is difficult to explain. Also in this case we must suppose that the variations in certain factors (see above) can permit certain species to live even at a depth inferior to that known.

Interval II (cm 138÷88): The associations mainly consist of *H. balthica*, *C. neocarinata* together with *G. subglobosa*, *Bulimina* spp., agglutinated forms, Miliolids, *Elphidium* spp., and *N. depressulum* together with *P. granosum*. However, the latter two forms decrease in abundance compared with those recognized in the underlying interval. "Other species", *C. lobatulus* together with *C. pachyderma*, *T. angulosa*, and *Uvigerina* spp. occur with very low percentages. The latter forms increase in abundance on the top of the interval where, on the contrary *Elphidium* spp. decrease. The microfaunas of this interval clearly indicate a deeper environment (circalittoral, depth of 50÷70 m) compared with the underlying interval.

Interval III (cm 88÷0): *H. balthica*, *Uvigerina* spp., *C. neocarinata* together with *G. subglobosa*, *T. angulosa*, *C. lobatulus* together with *C. pachyderma*, *Bulimina* spp., *Brizalina* spp., agglutinated forms, and Miliolids dominate. Compared with the preceding interval *Uvigerina* spp., *T. angulosa* and *C. lobatulus* together *G. pachyderma* increase in abundance. *H. elegans*, and *Gyrodinoides umbonatus* together with *Gyroidina altiformis* and *Gyroidina soldanii* occur in very low percentages. The assemblages of this interval indicate an environment still deeper (depth more than 70 m) compared with the underlying interval. Specimens of taxa living in shallower water, such as *Elphidium* spp., *N. depressulum* together with *P. granosum* are interpreted as displaced. The presence of *H. elegans* also in this interval could prove the hypothesis that this form could survive in a shallower environment than that currently known in the Adriatic Sea.

7. CONCLUSIONS

The quantitative study of the foraminiferal assemblages from core A85-10 allowed the reconstruction of the climatic evolution and the sea level changes in the Meso Adriatic Depression during the latest Pleistocene-Holocene.

The planktonic foraminiferal assemblages permitted to construct a paleoclimatic curve and to identify three intervals according to the subdivisions previously recognized by Asioli & Borsetti (1988) in the Adriatic sea. From bottom to top they are as follows: last glacial (cm 420÷178), deglacial (cm 118÷88), and Holocene (cm 88÷0). The base of the latter interval is characterized by the presence of *G. truncatulinoides* which could testify the presence of limited flow of "Atlantic" type water in the Adriatic Sea. Unfortunately, due to the rarity of planktonic foraminifera in the interval cm 178÷118 it was impossible to define the same interval.

The study of the benthonic foraminiferal assemblages allowed to recognize some sea level changes. In the lower to the middle portion of the core we can recognize, from bottom to top, the passage from a deep infralittoral-low circalittoral environment to an infralittoral environment and then to a deep infralittoral environment. Finally, a strong sea level rise occurs which produces an immediate change from a deep infralittoral environment to a circalittoral environment. This sea level rise is the expression of the Flandrian transgression. The advancing Flandrian transgression (from South to North) could have reworked and redistributed a part of the sediments. On the basis of this reconstruction, some species seem to have survived in a shallower environment than that currently know in the Adriatic Sea, as already recognized by some previous Authors.

APPENDIX

Species list

The foraminiferal taxa identified in the Core A 85-10 are listed below in alphabetical order.

Planktonic foraminifera:

Globigerina bulloides d'Orbigny, 1826
Globigerina praecalida Blow, 1979
Globigerina quinqueloba Natland, 1938
Globigerina rubescens Hofker, 1956
Globigerinella aequilateralis (Brady) = *Globigerina aequilateralis* Brady, 1879

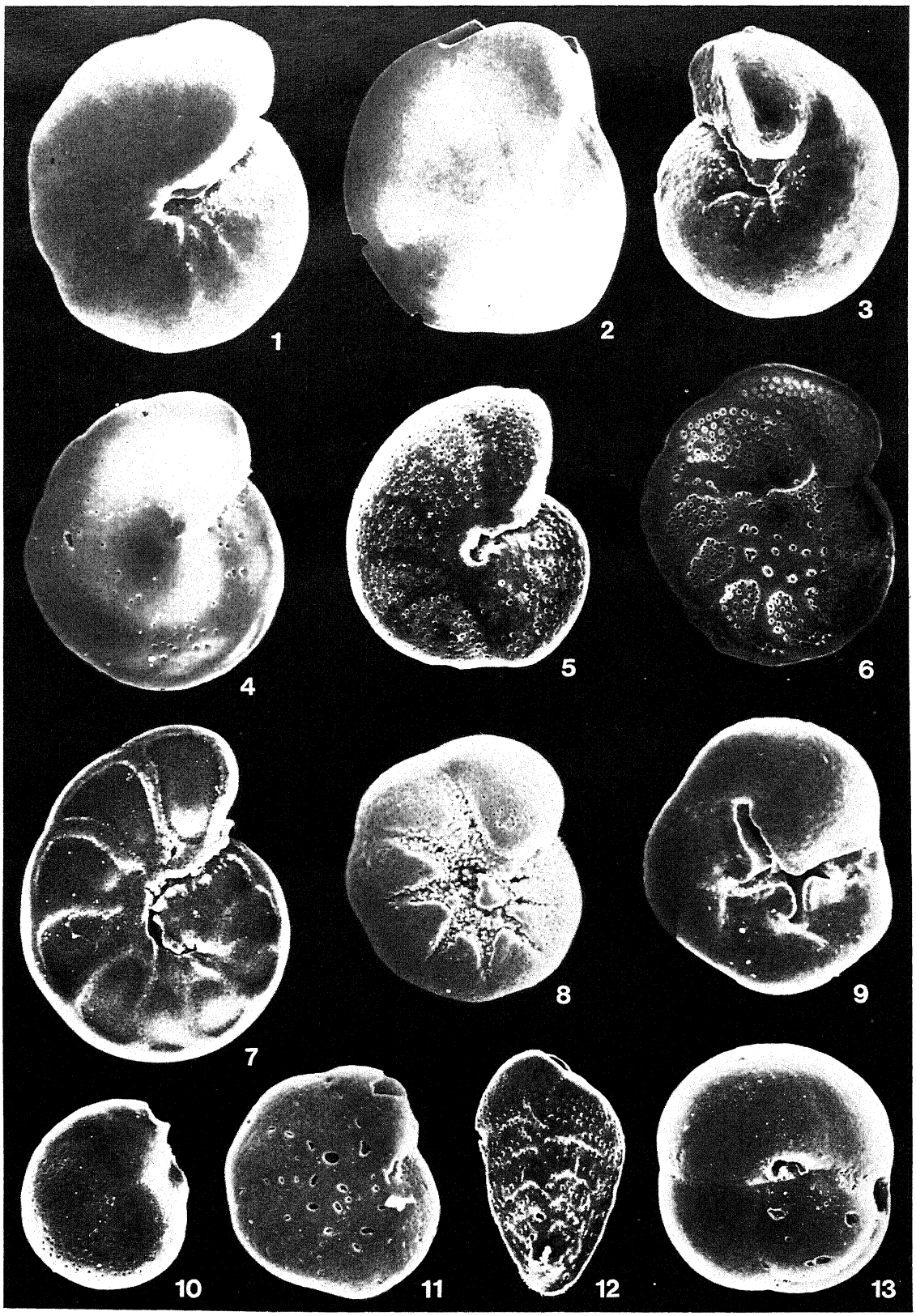

Fig. 8 - 1) *Gyroidina soldanii* (d'Orbigny), cm 23, x114; 2) *Hoeglundina elegans* (d'Orbigny), cm 23, x57; 3) *Gyroidinoides altiformis* (R.E.&K.C. Steward), cm 33, x114; 4) *Cibicidoides pachyderma* (Rzehak), cm 33, x57; 5) *Nonion barleeanum* (Williamson), cm 23, x114; 6) *Planulina ariminensis* d'Orbigny, cm 23, x57; 7) *Hyalinea balthica* (Schroeter), cm 88, x95; 8) *Protelphidium granosum* (d'Orbigny), cm 208, x76; 9) *Rosalina globularis* d'Orbigny, cm 420, x95; 10) *Globocassidulina subglobosa* (Brady), cm 23, x114; 11) *Cribroelphidium decipiens* (Costa), cm 378, x114; 12) *Bulimina inflata* Seguenza, cm 98, x114; 13) *Sphaeroidina bulloides* d'Orbigny, cm 88, x114.

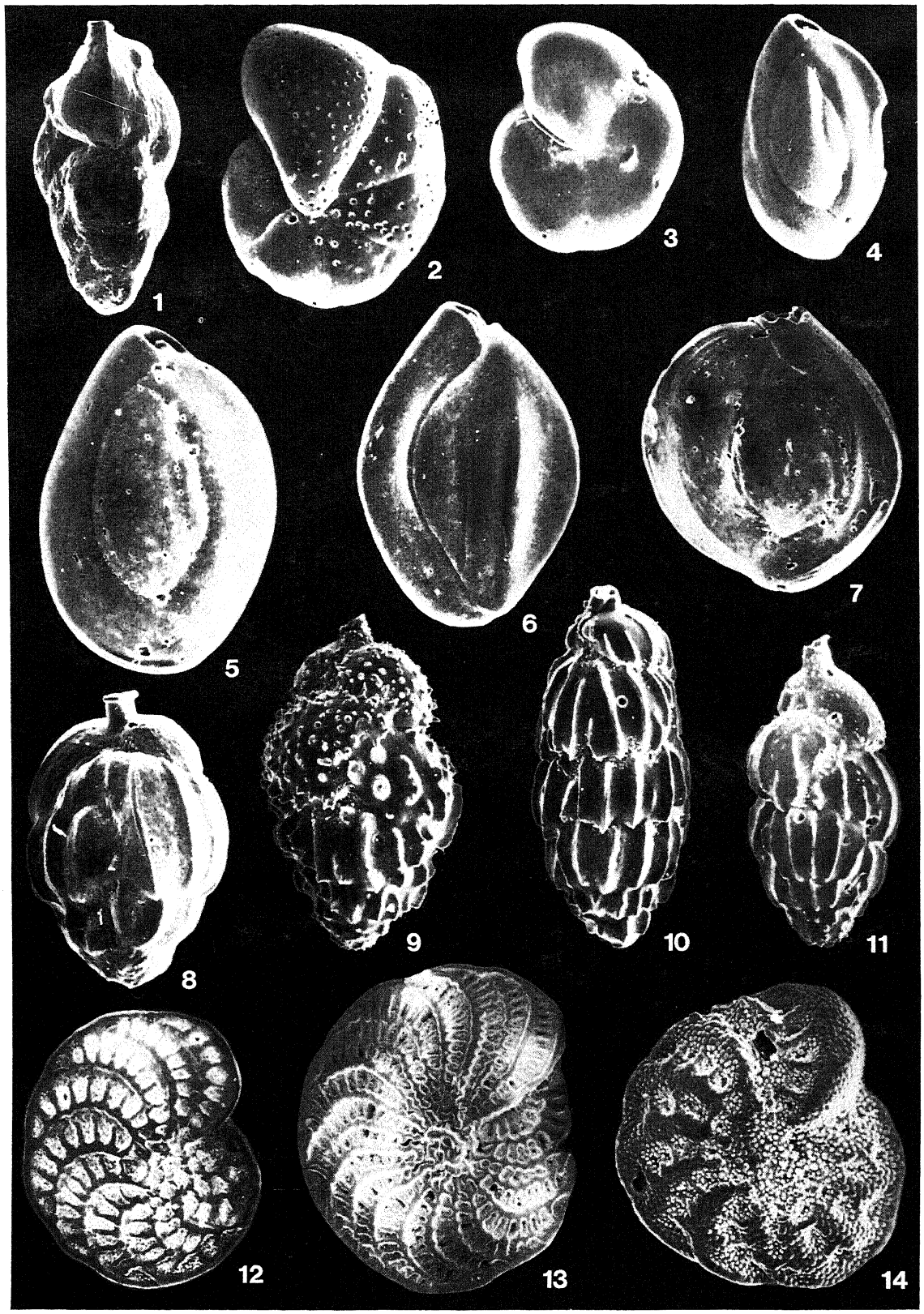

Fig. 9 - 1) *Trifarina angulosa* (Williamson), cm 23, x76; 2) *Cibicides lobatulus* (Walker & Jacob), cm 3, x76; 3) *Gyroidinoides umbonatus* (Silvestri), cm 23, x114; 4) *Quinqueloculina oblonga* (Montagu), cm 43, x114; 5) *Quinqueloculina seminulum* (Linnè), cm 23, x76; 6) *Quinqueloculina padana* Perconig, cm 88, x114; 7) *Quinqueloculina bicornis* (Walker & Jacob), cm 43, x76; 8) *Uvigerina mediterranea* Hofker, cm 23, x95; 9) *Uvigerina dirupta* Todd, cm 88, x95; 10) *Uvigerina peregrina* Cushman, cm 88, x76; 11) *Uvigerina* sp., cm 53, x76; 12) *Elphidium macellum* (Fichtel & Moll), cm 218, x57; 13) *Elphidium crispum* (Linnè), cm 378, x28; 14) *Elphidium advenum* (Cushman), cm 208, x95.

Globigerinita glutinata (Egger) = *Globigerina glutinata* Egger, 1895
Globigerinoides elongatus (d'Orbigny) = *Globigerina elongata* d'Orbigny, 1826
Globigerinoides gomitulus (Sequenza) = *Globigerina gomitulus* Seguenza, 1880
Globigerinoides quadrilobatus (d'Orbigny) = *Globigerina quadrilobata* d'Orbigny, 1846
Globigerinoides ruber (d'Orbigny) = *Globigerina rubra* d'Orbigny, 1839
Globigerinoides sacculifer (Brady) = *Globigerina sacculifera* Brady, 1877
Globigerinoides tenellus Parker, 1858
Globigerinoides trilobus (Reuss) = *Globigerina triloba* Reuss, 1850
Globorotalia inflata (d'Orbigny) = *Globigerina inflata* d'Orbigny, 1839
Globorotalia oscitans Todd, 1958
Globorotalia truncatulinoides (d'Orbigny) = *Rotalia truncatulinoides* d'Orbigny, 1839
Neogloboquadrina pachyderma (Ehrenberg) = *Aristospira pachyderma* Ehrenberg, 1861
Orbulina universa d'Orbigny, 1839

Benthonic foraminifera:

Amphicoryna scalaris (Batsch) = *Nautilus scalaris* Batsch, 1791
Asterigerinata planorbis (d'Orbigny) = *Asterigerina planorbis* d'Orbigny, 1846
Bigenerina nodosaria d'Orbigny, 1826
Brizalina catanensis (Seguenza) = *Bolivina catanensis* Seguenza, 1862
Brizalina spathulata (Williamson) = *Textularia variabilis* Williamson var. *spathulata* Williamsom, 1858
Bulimina etnea Seguenza, 1862
Bulimina inflata Seguenza, 1862
Bulimina marginata d'Orbigny, 1826
Cassidulina neocarinata Thalmann, 1950
Cibicides lobatulus (Walker & Jacob) = *Nautilus lobatulus* Walker & Jacob, 1798
Cibicidoides pachyderma (Rzehak) = *Truncatulina pachyderma* Rzehak, 1886
Cornuspira foliacea (Philippi) = *Orbis foliaceus* Philippi, 1844
Cornuspira involvens (Reuss) = *Operculina involvens* Reuss, 1850
Cribroelphidium decipiens (Costa) = *Polystomella decipiens* Costa, 1856
Dentalina aciculata (d'Orbigny) = *Nodosaria aciculata* d'Orbigny, 1826
Dentalina leguminiformis (Batsch) = *Nautilus leguminiformis* Batsch, 1791
Discanomalina coronata (Parker & Jones) = *Anomalina corona ta* Parker & Jones, 1857
Elphidium advenum (Cushman) = *Polystomella advena* Cushman, 1922
Elphidium crispum (Linnè) = *Nautilus crispus* Linnè, 1758
Elphidium macellum (Fichtel & Moll) = *Nautilus macellus* Fichtel & Moll, 1798
Epistominella lecalvezi (Lys & Bourdon) = *Pseudoparrella lecalvezi* Lys & Bourdon, 1958)
Fissurina apiculata (Reuss) = *Oolina apiculata* Reuss, 1851
Fissurina longirostris Seguenza, 1862
Fissurina marginata (Walker & Jacob) = *Serpula marginata* Walker & Jacob, 1798)
Fissurina orbignyana Seguenza, 1862
Fissurina piriformis (Buchner) = *Lagena piriformis* Buchner, 1940
Fissurina quadricostulata (Reuss) = *Lagena quadricostulata* Reuss, 1870
Fissurina staphyllearia Schwager, 1866
Glabratella sp.
Globocassidulina subglobosa (Brady) = *Cassidulina subglobosa* Brady, 1881
Gyroidina soldanii (d'Orbigny) = *Rotalia soldanii* d'Orbigny, 1866
Gyroidinoides altiformis (R.E. & K.C.Steward) = *Gyroidina soldanii* d'Orbigny var. *altiformis* R.E. & K.C.Steward, 1930
Gyroidinoides umbonatus (Silvestri) = *Rotalia soldanii* d'Orbigny var. *umbonata* Silvestri, 1898
Hanzawaia boueana (d'Orbigny) = *Truncatulina boueana* d'Orbigny, 1846
Hoeglundina elegans (d'Orbigny) = *Rotalia elegans* d'Orbigny, 1826
Hyalinea balthica (Schroeter) = *Nautilus balthicus* Schroeter, 1783
Lagena apiopleura Loeblich & Tappan, 1953
Lagena clavata (d'Orbigny) = *Oolina clavata* d'Orbigny, 1846
Lenticulina cultrata (de Montfort) = *Robulus cultratus* de Montfort, 1808
Lenticulina inornata (d'Orbigny) = *Robulina inornata* d'Orbigny, 1846
Lenticulina peregrina (Schwager) = *Cristellaria peregrina* Schwager, 1866
Nonion barleeanum (Williamson) = *Nonionina barleeana* Williamson, 1858
Nonion depressulum (Walker & Jacob) = *Nautilus depressulus* Walker & Jacob, 1798
Nonionella turgida (Williamson) = *Rotalina turgida* Williamson, 1858
Oolina hexagona (Williamsom) = *Entosolenia squamosa* (Montagu) var. *hexagona* Williamsom, 1848
Oolina squamosa (Montagu) = *Vermiculum squamosum* Montagu, 1803
Patellina corrugata Williamson, 1858
Planulina ariminensis d'Orbigny, 1826
Planulina wüllerstorfi (Schwager) = *Anomalina wüllerstorfi* Schwager, 1866
Praeglobobulimina pupoides (d'Orbigny) = *Bulimina pupoides* d'Orbigny, 1846
Protelphidium granosum (d'Orbigny) = *Nonionina granosa* d'Orbigny, 1846
Pseudoclavulina crustata Cushman, 1936
Pullenia quadriloba Reuss, 1867
Pullenia quinqueloba (Reuss) = *Nonionina quinqueloba* Reuss, 1851
Pyrgo bulloides (d'Orbigny) = *Biloculina bulloides* d'Orbigny, 1826
Pyrgo depressa (d'Orbigny) = *Biloculina depressa* d'Orbigny, 1826
Pyrgo oblonga (d'Orbigny) = *Biloculina oblonga* d'Orbigny, 1839
Quinqueloculina bicornis (Walker & Jacob) = *Serpula bicornis* Walker & Jacob, 1798
Quinqueloculina oblonga (Montagu) = *Vermiculum oblonga* Montagu, 1803
Quinqueloculina padana Perconig, 1954
Quinqueloculina seminulum (Linnè) = *Serpula seminulum* Linnè, 1758
Rosalina globularis d'Orbigny, 1826
Sigmoilinita tenuis (Czjzek) = *Quinqueloculina tenuis* Czjzek, 1848
Sigmoilopsis celata (Costa) = *Spiroloculina celata* Costa, 1855
Sigmoilopsis schlumbergeri (Silvestri) = *Sigmoilina schlumbergeri* Silvestri, 1904
Sphaeroidina bulloides d'Orbigny, 1826
Spiroloculina excavata d'Orbigny, 1846
Spiroplectammina wrighti (Silvestri) = *Spiroplecta wrighti* Silvestri, 1903
Stainforthia complanata (Egger) = *Virgulina schreibersiana* Czjzek var. *complanata* Egger, 1893
Stilostomella pyrula (d'Orbigny) = *Nodosaria pyrula* d'Orbigny, 1826
Textularia sagittula Defrance, 1824
Trifarina angulosa (Williamson) = *Uvigerina angulosa* Williamson, 1858
Triloculina gibba d'Orbigny, 1826
Uvigerina dirupta Todd, 1948
Uvigerina mediterranea Hofker, 1932
Uvigerina peregrina Cushman, 1923
Uvigerina sp.

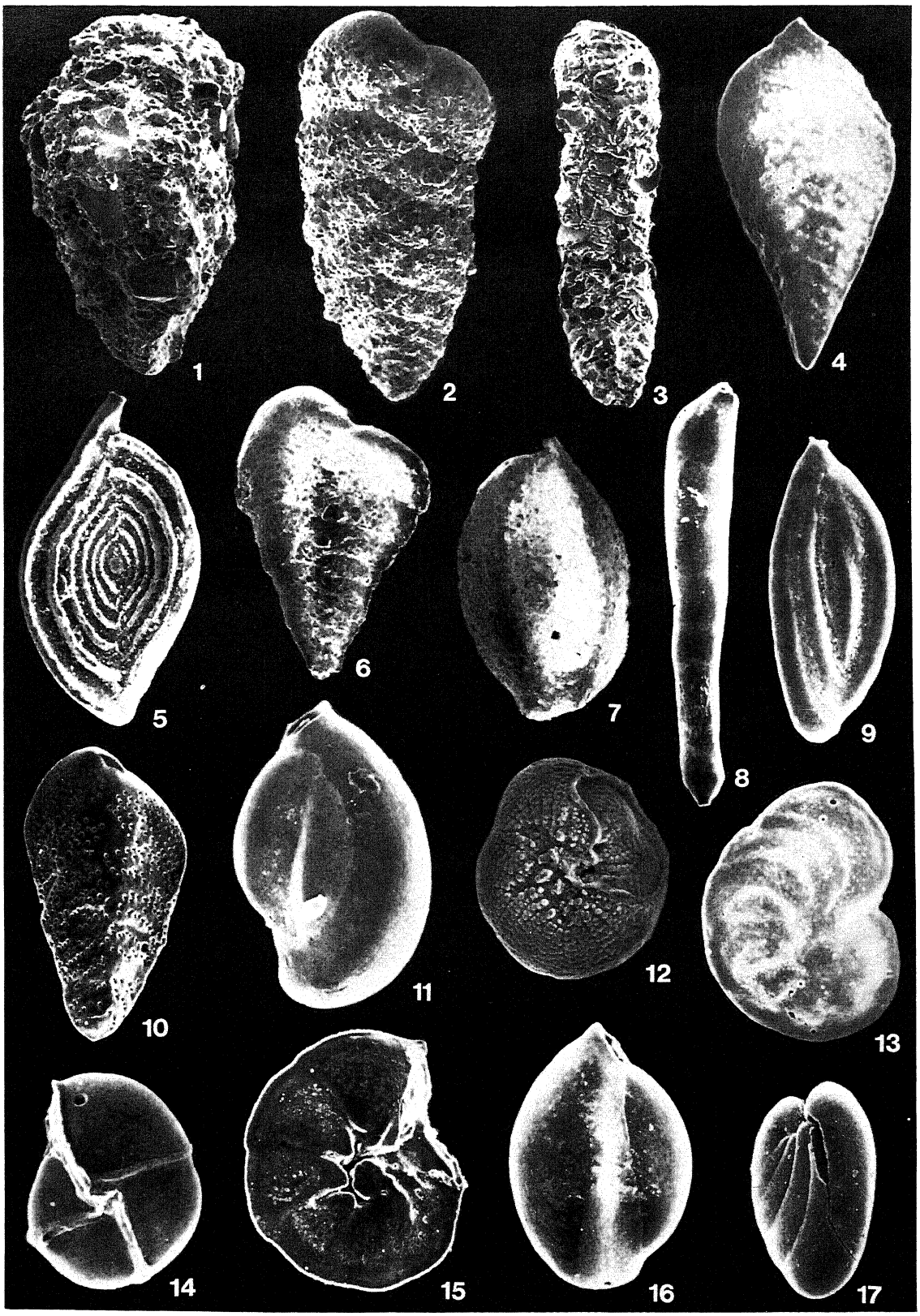

Fig. 10 - 1) *Pseudoclavulina crustata* Cushman, cm23, x32; 2) *Textularia sagittula* Defrance, cm 23, x57; 3) *Bigenerina nodosaria* d'Orbigny, cm 23, x38; 4) *Brizalina spathulata* (Williamson), cm 3, x114; 5) *Spiroloculina excavata* d'Orbigny, cm 88, x76; 6) *Spiroplectammina wrighti* (Silvestri), cm 63, x76; 7)*Sigmoilopsis celata* (Costa), cm 23, x57; 8) *Dentalina leguminiformis* (Batsch), cm 88, x57; 9) *Sigmoilinita tenuis* (Czjzek), cm 33, x114; 10) *Brizalina catanensis* (Seguenza), cm 23, x114; 11) *Triloculina gibba* d'Orbigny, cm 8, x114; 12) *Glabratella* sp., cm 208, x114; 13) *Hanzawaia boueana* (d'Orbigny), cm 53, x95; 14) *Pullenia quadriloba* Reuss, cm 88, x114; 15) *Epistominella lecalvezi* (Lys & Bourdon), cm 53, x114; 17) *Nonionella turgida* Williamson, cm 33, x95.

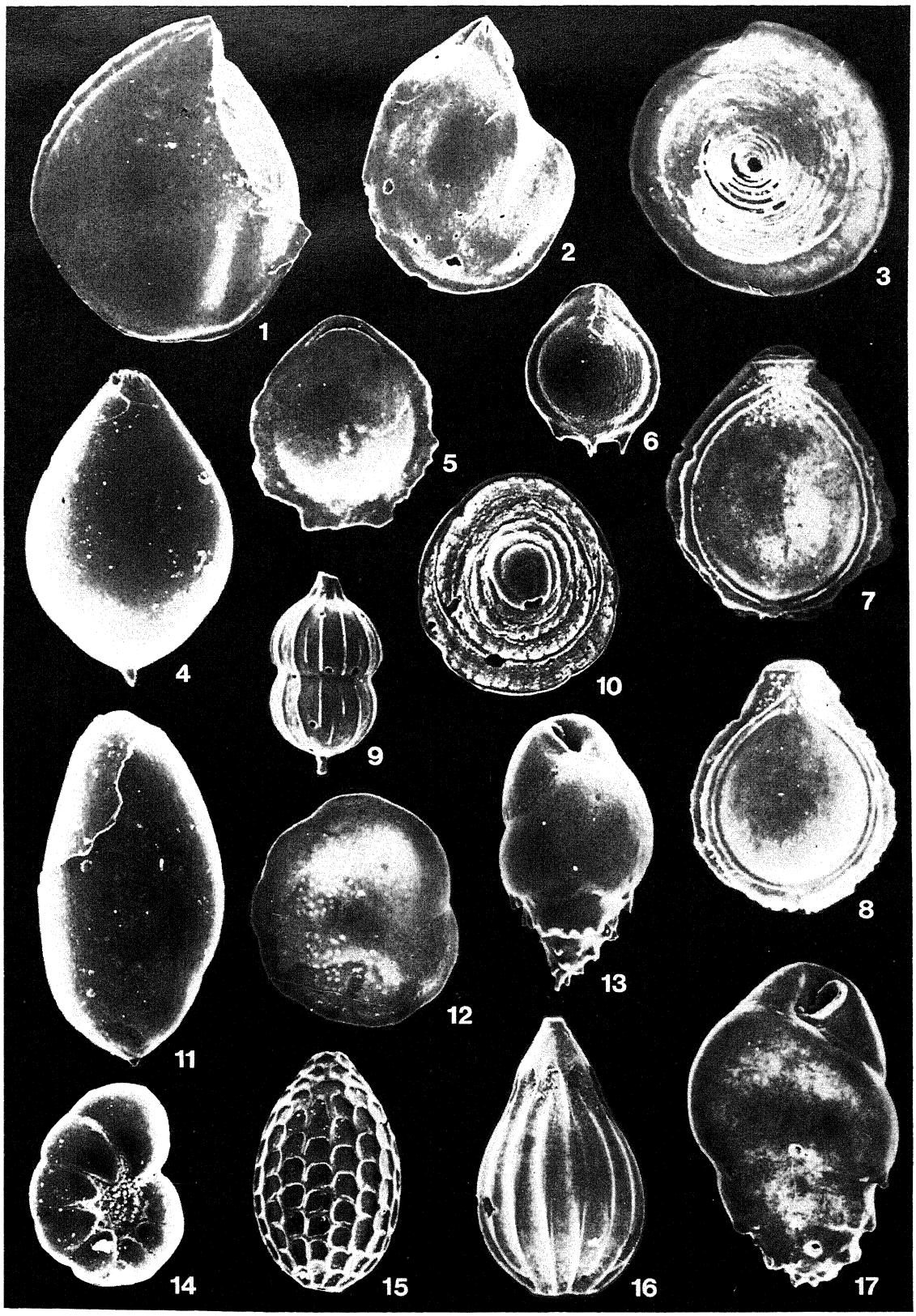

Fig. 11 - 1) *Lenticulina peregrina* (Schwager), cm 53, x114; 2) *Lenticulina inornata* (d'Orbigny), cm 23, x114; 3) *Cornuspira involvens* (Reuss), cm 3, x76; 4) *Fissurina apiculata* (Reuss), cm 318, x95; 5) *Fissurina marginata* (Walker & Jacob), cm 83, x114; 6) *Fissurina staphyllearia* Schwager, cm 208, x114; 7) *Fissurina quadricostulata* (Reuss), cm 83, x114; 8) *Fissurina orbignyana* Seguenza, cm 88, x114; 9) *Amphicoryna scalaris* (Batsch), cm 33, x114; 10) *Patellina corrugata* Williamson, cm 208, x114; 11) *Praeglobobulimina pupoides* (d'Orbigny), cm 53, x57; 12) *Cassidulina neocarinata* Thalmann, cm 398, x95; 13) *Bulimina marginata* d'Orbigny, cm 23, x114; 14) *Nonion depressulum* (Walker & Jacob), cm 208, x114; 15) *Oolina squamosa* (Montagu), cm 308, x114; 16) *Lagena apiopleura* Loeblich & Tappan, cm 88, x114; 17) *Bulimina etnea* Seguenza, cm 88, x114.

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