

Benthic Foraminifera of the Fangario Formation (Cagliari, Sardinia)

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ABSTRACT — *A rich benthic foraminiferal fauna from Middle Miocene of Sardinia has been described. The fossiliferous layers belong of the Fangario Formation which has the type area near Cagliari. 97 species are classified; 24 of them are discussed and figured. Some paleobathymetric conclusions are inferred.*

RIASSUNTO — [I Foraminiferi bentici della Formazione di Fangario (Cagliari, Sardegna)] — *E' stata studiata la ricca associazione a foraminiferi bentici delle Argille di Fangario, campionata nei pressi di Cagliari, località tipica per la formazione. E' stato possibile determinare 97 specie, numerose delle quali presentano notevole interesse stratigrafico. Tra queste, 24 sono state figurate e corredate di brevi note. La presenza di taxa di rilievo paleoecologico ha fornito buone indicazioni inerenti la paleobattimetria della formazione: le Argille di Fangario dovevano depositarsi in condizioni epibatiali, con profondità compresa tra i 500 e i 1300 metri.*

INTRODUCTION

Benthic foraminiferal fauna examined in the present paper are obtained from the classical Miocene formation well known in literature as the Argille di Fangario. This unit, widely spread in Sardinia, represents the oldest levels of Miocene deposits outcropping near Cagliari, its type area (Gandolfi & Porcu, 1967; Cherchi, 1974). It is represented by a sequence of grey marly clays and marls, containing a very rich and well preserved planktonic and benthic microfauna. Besides the type area, samples of the same formation were collected from a nearby quarry (Cava N. Sestu) in order to obtain further information.

Foraminifera from the Fangario sediments were described, or listed, by Fornasini (1887), Degli Innocenti (1929), Comaschi Caria (1959) and Pecorini & Cherchi (1969). Aim of this short note is to update the taxonomy of the identified foraminifera according to the recent systematics, and to complement it with illustration of the most important taxa, previously almost totally missing.

Washed residues yielded exclusively foraminifera; the percentage of planktonic specimens to benthic ones is about 80. Benthic foraminifera are abundant and diverse 97 species were classified, mostly belonging to the genera: *Bolivina*, *Cibicidoides*, *Gyroidinoides*, *Heterolepa*, *Lenticulina*, *Nodosaria*, *Stilostomella* and *Uvigerina*.

The following species were identified:

Amphycorina semicostata (Costa)
Anomalinoides alazanensis (Nuttall)
Astacolus crepidulus (Fichtel & Möll)
Bolivina budensis (Hantken)
Bolivina hebes Macfadyen
Bolivina pseudoplicata Heron-Allen & Earland
Bolivina punctata d'Orbigny
Bolivina reticulata Hantken
Brizalina arta (Macfadyen)
Bulimina alazanensis Cushman
Bulimina buchiana d'Orbigny
Bulimina lappa Cushman & Parker
Cancris auriculus (Fichtel & Möll)
Cassidulina cruysi Marks
Cassidulina laevigata d'Orbigny

Chrysalogonium longicostatum Cushman & Jarvis
Cibicides lobatulus (Walker & Jacob)
Cibicidoides aknerianus (d'Orbigny)
Cibicidoides pachyderma (Rzehak)
Cibicidoides ungerianus (d'Orbigny)
Cribrorobulina serpens (Seguenza) emend. Selli
Cyclamina cancellata Brady
Cylindroclavulina rudis (Costa)
Dentalina leguminiformis (Batsch)
Ehrenbergina gibbera Galloway & Heminway
Ellipsoglandulina vasarhelyii (Hantken)
Elphidium ortenbursense (Egger)
Florilus scaphum (Fichtel & Möll)
Fursenkoina schreibersiana (Czjzek)
Gyroidina soldanii (d'Orbigny)
Gyroidinoides altiformis (Stewart & Stewart)
Globobulimina pyrula (d'Orbigny)
Globocassidulina subglobosa (Brady)
Guttulina communis (d'Orbigny)
Hanzawaia boueana (d'Orbigny)
Heterolepa dutemplei (d'Orbigny)
Lenticulina calcar (Linné)
Lenticulina cultrata (de Montfort)
Lenticulina helena (Karrer)
Lenticulina inornata (d'Orbigny)
Lenticulina peregrina (Schwager)
Lenticulina spinulosa (Costa)
Lenticulina vortex (Fichtel & Möll)
Martinottiella communis (d'Orbigny)
Martinottiella perparva (Cushman)
Melonis pompilioides (Fichtel & Möll)
Melonis padanum (Perconig)
Melonis soldanii (d'Orbigny)
Marginulina tenuis Bornemann
Marginulina hirsuta d'Orbigny
Marginulinopsis asperuliformis (Nuttall)
Marginulinopsis pedum (d'Orbigny)
Neoeponides haidingeri (d'Orbigny)
Nodosaria acuminata Hantken
Nodosaria ovicula d'Orbigny
Nodosaria pentecostata Costa
Nodosaria raphanistrum (Linné)
Oridorsalis umbonatus (Reuss)
Pandaglandulina dinapolii Loeblich & Tappan
Planularia venezuelana Hedberg
Planulina ariminensis d'Orbigny
Plectofrondicularia semicostata (Neugeboren)
Plectofrondicularia inaequalis (Costa)
Plectofrondicularia rariocosta (Karrer)
Praeglobobulimina pupoides (d'Orbigny)
Pullenia bulloides (d'Orbigny)
Pullenia quadriloba Reuss
Rectobolivina zsigmondyi (Hantken)
Rectuvigerina royoii Bermúdez & Fuenmayor
Reophax sp.
Rosalina globularis d'Orbigny
Sigmolinita tenuis (Czjzek)
Sigmolopsis schlumbergeri (A. Silvestri)
Stilostomella emaciata (Reuss)
Stilostomella gr. nuttalli (Cushman & Jarvis)
Stilostomella pyrula (d'Orbigny)
Stilostomella verneuili (d'Orbigny)
Stilostomella vertebralis (Batsch)
Saracenaria latifrons (Brady)
Siphonina reticulata (Czjzek)
Sphaeroidina bulloides d'Orbigny
Spiroplectammina carinata (d'Orbigny)

Spiroplectammina wrighti (A. Silvestri)
Textularia abbreviata d'Orbigny
Textularia aciculata d'Orbigny
Textularia sagittula Defrance
Textularia soldanii Fornasini
Uvigerina barbatula Macfadyen
Uvigerina gallowayi Cushman
Uvigerina longistriata Perconig
Uvigerina multicostata Le Roy
Uvigerina peregrina Cushman
Uvigerina pygmaea Papp & Turnovsky
Uvigerina rutila Cushman & Tood
Uvigerina schwageri Brady
Vaginulina legumen (Linné)
Valvulinera complanata (d'Orbigny)

All the species figured in the plates are from the type area of the Fangario Formation. They were selected for their stratigraphic significance or abundance. The specimens are deposited in the collection of the Institute of Geology and Paleontology of the University of Bologna.

PALEOBATHYMETRIC REMARKS

Some of the benthic foraminifera from the Fangario Formation appear useful as paleobathymetric indicators. In particular the following groups were considered: bolivinids, *Bulmina buchiana*, costate uvigerinids, *Gyroidinoides altiformis*, miliolids.

Bolivinids. Bolivinids possessing sinuate sutures become more abundant with increasing depth (Boltovskoy & Wright, 1976), with common occurrence in the Mediterranean below 200 meters (Wright, 1978b). In the Fangario faunal assemblage the species with sinuate sutures (i.e. *B. budensis*, *B. hebes*, *B. pseudoplicata*, *B. reticulata*) dominate.

Bulmina buchiana. In the Gulf of Gascogne *B. buchiana* represents a typical epibathyal species (Pujos-Lamy, 1973).

Costate uvigerinids. The relatively abundant uvigerinids from the Fangario Fm. belong only to the costate species. In the Gulf of Mexico (Pflum & Frerichs, 1976) they have a limited bathymetric range and are mostly confined to the upper epibathyal zone.

Gyroidinoides altiformis. Pflum & Frerichs (1976) described a cline of Boomgaart's subspecies: *G. altiformis acuta* and *G. altiformis cushmani*. The latter, well represented in the Fangario microfauna, has an upper depth limit at the top of the bathyal zone. In the Mediterranean *G. altiformis* is abundant below 600 meters (Bandy & Chierici, 1966).

Miliolids. *Sigmoilinita tenuis* and *Sigmoilopsis schlumbergeri*, both very rare, represent the miliolid fauna of Fangario; they are typical epibathyal species.

In conclusion, the Fangario benthic assemblage suggests a water depth of between 500 and 1300 meters, lower epibathyal zone *sensu* Wright, 1978b. (Cfr. Sestu Section in Iaccarino, D'Onofrio & Murru, 1985).

SYSTEMATIC REMARKS

ANOMALINOIDES ALAZANENSIS (Nuttall)

Pl. 1, figs. 1a-c

1932 *Anomalina alazanensis* NUTTALL, p. 31, pl. 8, figs. 5-7.

It is a very frequent element of the Fangario assemblage. In overall morphology the species resembles *Anomalinoides helycinus* (Costa), but it may be distinguished by its evolute umbilical side, depressed sutures, rounded and regularly perforate periphery.

BRIZALINA ARTA (Macfadyen)

Pl. 1, fig. 2

1930 *Bolivina arta* MACFADYEN, p. 58, pl. 4, fig. 21.

This easily recognizable species occurs frequently in the Fangario fauna; it corresponds exactly to the type figures.

BOLIVINA BUDENSIS (Hantken)

Pl. 1, fig. 3

1875 *Textilaria budensis* HANTKEN, p. 67, pl. 15, fig. 1.

Fangario sediments contain a few specimens of this species. It exhibits smooth test with slightly sinuate sutures. Frequently recorded in Oligocene strata, in the Po Valley it ranges up into the early Miocene (AGIP, 1982).

BOLIVINA HEBES Macfadyen

Pl. 1, fig. 5

1930 *Bolivina hebes* MACFADYEN, p. 59, pl. 2, fig. 5 a-c.

Rare specimens are found. This species, described from the Miocene of Egypt, has a typical roughly perforated test with sutures generally indistinct.

BOLIVINA PUNCTATA d'Orbigny

Pl. 1, fig. 4

1839 *Bolivina punctata* d'ORBIGNY, p. 63, pl. 8, figs. 10-12.

Specimens of this distinctly perforated species rarely occur. It differs from the poorly figured type of d'Orbigny in the biserial arrangement of the last formed chambers, which slightly tends to the *Coryphostoma* type of arrangement.

BOLIVINA RETICULATA Hantken

Pl. 1, fig. 6

1875 *Bolivina reticulata* HANTKEN, p. 65, pl. 15, fig. 6.

A few specimens occur in the Fangario assemblage. They generally exhibit a pronounced reticulation which masks the sutures. Other species similar to this taxon such as *Bolivina dertonensis* Gianotti, *B. fastigia* Cushman, and *B. leonardii* Accordi & Selmi (all of them possessing plications) lack of a true reticulation.

BULIMINA ALAZANENSIS Cushman

Pl. 1, fig. 9

1927 *Bulimina alazanensis* CUSHMAN, p. 161, pl. 25, fig. 4.

Only one specimen of this typical costate buliminid has been recovered.

BULIMINA BUCHIANA d'Orbigny

Pl. 1, fig. 7

1846 *Bulimina buchiana* d'ORBIGNY, p. 186, pl. 11, figs. 15-18.

This species represents the most frequent buliminid of the Fangario fauna. It has a wall ornamented with strong, short costae. Marks (1951) considered *B. buchiana* along with *B. inflata* and *B. costata* as junior synonyms of *B. striata*. The examined species differs from *B. striata* in having the lower edges typically rounded; from *B. inflata* in having, the latter, short costae ending with spines. Finally, *B. costata* differs from the identified taxon because of its continuous costae lacking spines.

CASSIDULINA CRUYSI Marks

Pl. 1, figs. 11 a-b

1951 *Cassidulina cruyssi* MARKS, p. 68, pl. 8, figs. 3-4.

Rare specimens occur in the Fangario material, corresponding well to Marks figured types described from the Miocene of the Vienna basin. The species is easily distinguished from *Cassidulina laevigata* d'Orbigny by its subrounded axial periphery. *C. cruyssi* is not recorded in post Miocene sediments.

CIBICIDOIDES AKNERIANUS (d'Orbigny)

Pl. 1, figs. 12 a-c

1846 *Rotalina akneriana* d'ORBIGNY, p. 156, pl. 8, figs. 13-15.

Sparse specimens of the species are recorded. They are easily recognizable, besides the general morphology, by their rounded axial peripheral margin, the deep umbilicus, and the distinctly perforated wall.

EHRENBERGINA GIBBERA Galloway & Heminway

Pl. 1, figs. 14 a-b

1941 *Ehrenbergina serrata* Reuss var. *gibbera* GALLOWAY & HEMINWAY, p. 427, pl. 32, fig. 5.

This species is uncommon in the Fangario assemblage and is the only recorded *Ehrenbergina*. It possesses strong spines in the earlier part of the test; all the specimens are very close to the type figures.

ELLIPSOGLANDULINA VASARHELYII (Hantken)

Pl. 1, fig. 13

1868 *Nodosaria (Dentalina) vasarhelyii* HANTKEN, p. 89, pl. 2, fig. 35.

This species is found sporadically but with specimens identical to the figured types. *Daucina multicostata* Galloway & Morrey is its junior synonym. It has some stratigraphic value, being recorded by some authors only as far as the middle Miocene.

GYROIDINOIDES ALTIFORMIS Stewart & Stewart

Pl. 1, fig. 15 a-c

1930 *Gyroidina soldanii* d'Orbigny var. *altiformis* STEWART & STEWART, p. 67, pl. 9, figs. 2 a-c.

This distinctive species is extremely abundant in the Fangario sediments, with typical specimens lacking morphological variations. The test is plano-convex, with 8 to 10 chambers in the final whorl. The two subspecies *G. acuta* and *G. cushmani* (Boomgaard, 1949; *vide* Ellis & Messina) may represent ecological morphovariants of the same taxon (see Pflum & Freichs, 1976, and the discussion on *G. altiformis* cline). The Fangario specimens are very close to the *G. cushmani* morphotype, exhibiting wide umbilicus and inner umbilical margin thickened by shell material. *Gyroidina miocenica* Tedeschi & Zanmatti, described from the Miocene of the Po Valley, may be a junior synonym of *G. altiformis*.

HETEROLEPA DUTEMPLEI (d'Orbigny)

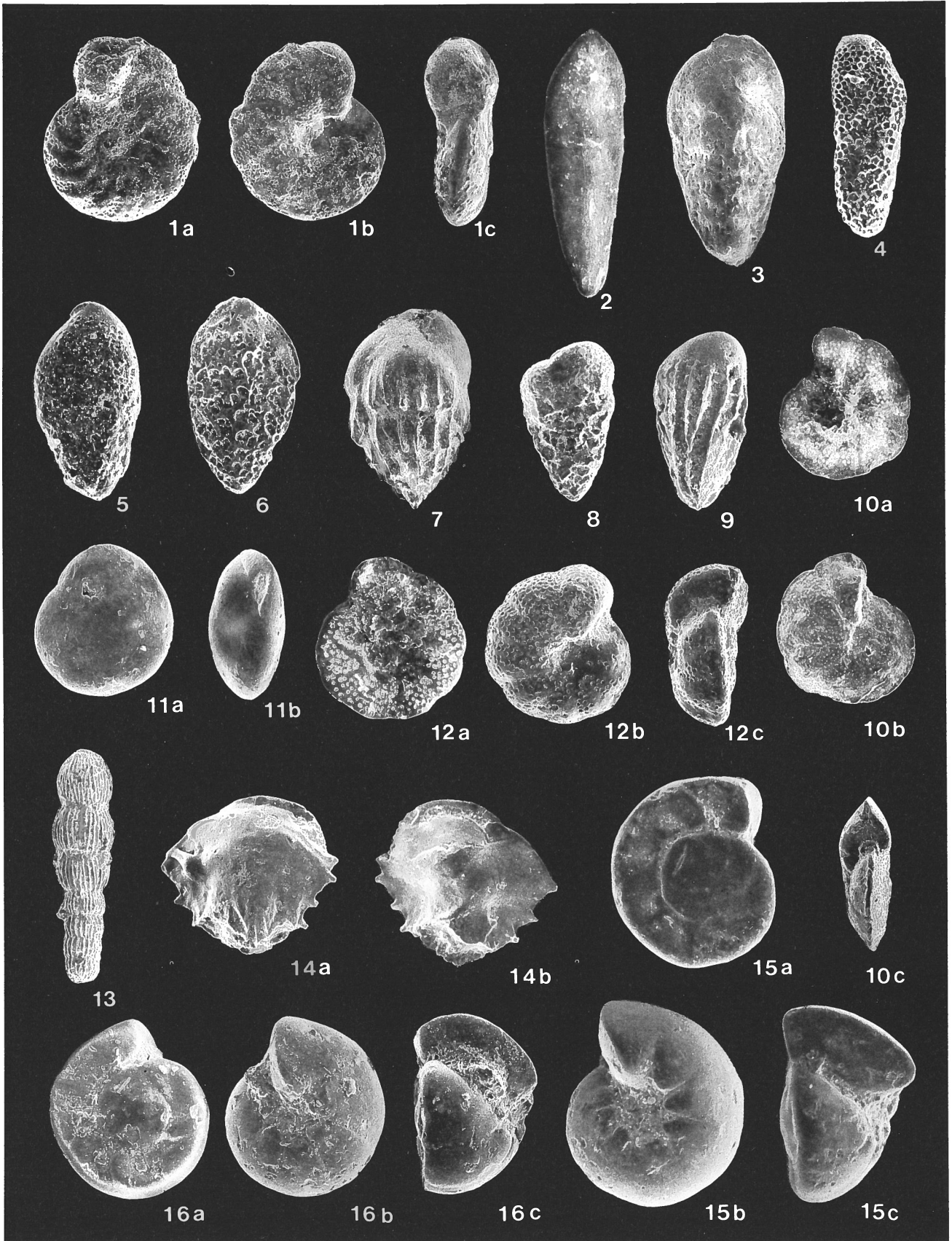
Pl. 2, figs. 1 a-c, 2

1846 *Rotalina dutemplei* d'ORBIGNY, p. 157, pl. 8, figs. 19-21.

In the Fangario sediments the species occurs abundantly, with a large variation concerning size and umbilical convexity. It has a distinctly perforate wall, with generally 8 chambers in the last whorl, the number of which varying according to the size; the sutures are limbate dorsally, slightly depressed ventrally. The convexity degree may vary from specimen to spe-

EXPLANATION OF PLATE 1

- Figs. 1 a-c - *Anomalinoides alazanensis* (Nuttall) x 80
 Fig. 2 - *Brizalina arta* (Macfadyen) x 120
 Fig. 3 - *Bolivina budensis* (Hantken) x 200
 Fig. 4 - *Bolivina punctata* d'Orbigny x 200
 Fig. 5 - *Bolivina hebes* Macfadyen x 200
 Fig. 6 - *Bolivina reticulata* Hantken x 200
 Fig. 7 - *Bulimina bucbiana* d'Orbigny x 100
 Fig. 8 - *Bolivina pseudoplicata* Heron-Allen & Earland x 200
 Fig. 9 - *Bulimina alazanensis* Cushman x 200
 Figs. 10 a-c - *Cibicidoides ungerianus* (d'Orbigny) x 80
 Figs. 11 a-b - *Cassidulina cruysi* Marks x 120
 Figs. 12 a-c - *Cibicidoides aknerianus* (d'Orbigny) x 120
 Fig. 13 - *Ellipsoglandulina vasarhelyii* (Hantken) x 80
 Figs. 14 a-b - *Ehrenbergina gibbera* Galloway & Heminway x 150
 Figs. 15 a-c - *Gyroidinoides altiformis* (Stewart & Stewart) x 120
 Figs. 16 a-c - *Gyroidina soldanii* (d'Orbigny) x 100



cimen: some specimens are identical to the figured type, whereas others are more flat as in *Cibicides dutemplei* figured by Batjes (1958). The taxonomy of this species is unclear. Some authors have considered *Heterolepa simplex* Franzénau as a junior synonym of *H. dutemplei* (Franzenau, 1885; Loeblich & Tappan, 1964), whereas others have kept the two species separate (Sztrákos, 1979).

MARGINULINOPSIS ASPERULIFORMIS (Nuttall)

Pl. 2, fig. 4

1930 *Cristellaria asperuliformis* NUTTALL, p. 282, pl. 23, figs. 9-10.

The species is recorded with very rare specimens, well corresponding to the type figures.

MARGINULINOPSIS PEDUM (d'Orbigny)

Pl. 2, fig. 3

1846 *Marginulina pedum* d'ORBIGNY, p. 68, pl. 3, figs. 13-14.

Described originally from the Miocene of the Vienna basin, this species occurs rarely in the Fangario assemblage; it strictly corresponds to topotype specimens figured by Marks (1951). *Cristellaria checchia-rispolii* Degli Innocenti, whose type is from Fangario, represents a junior synonym of *M. pedum*.

NEOEPONIDES HAIDINGERI (d'Orbigny)

Pl. 2, figs. 13 a-c

1846 *Rotalina haidingeri* d'ORBIGNY, p. 154, pl. 8, figs. 7-9.

The species frequently occurs in the Fangario sediments, with well developed specimens. It may have been identified as *Neoeponides schreibersii* (d'Orbigny) by various authors. Both species were described from the Miocene of the Vienna basin, *N. haidingeri* exhibits less chambers in the final whorl (no more than 5-6). Regarding the presence, in the umbilical area, of radially arranged shell material lobes, described by d'Orbigny for the *N. schreibersii* type, Fangario fauna includes specimens either with or without lobes; therefore, this characteristic should not be considered for separating the two species.

PLECTOFRONDICULARIA SEMICOSTATA (Neugeboren)

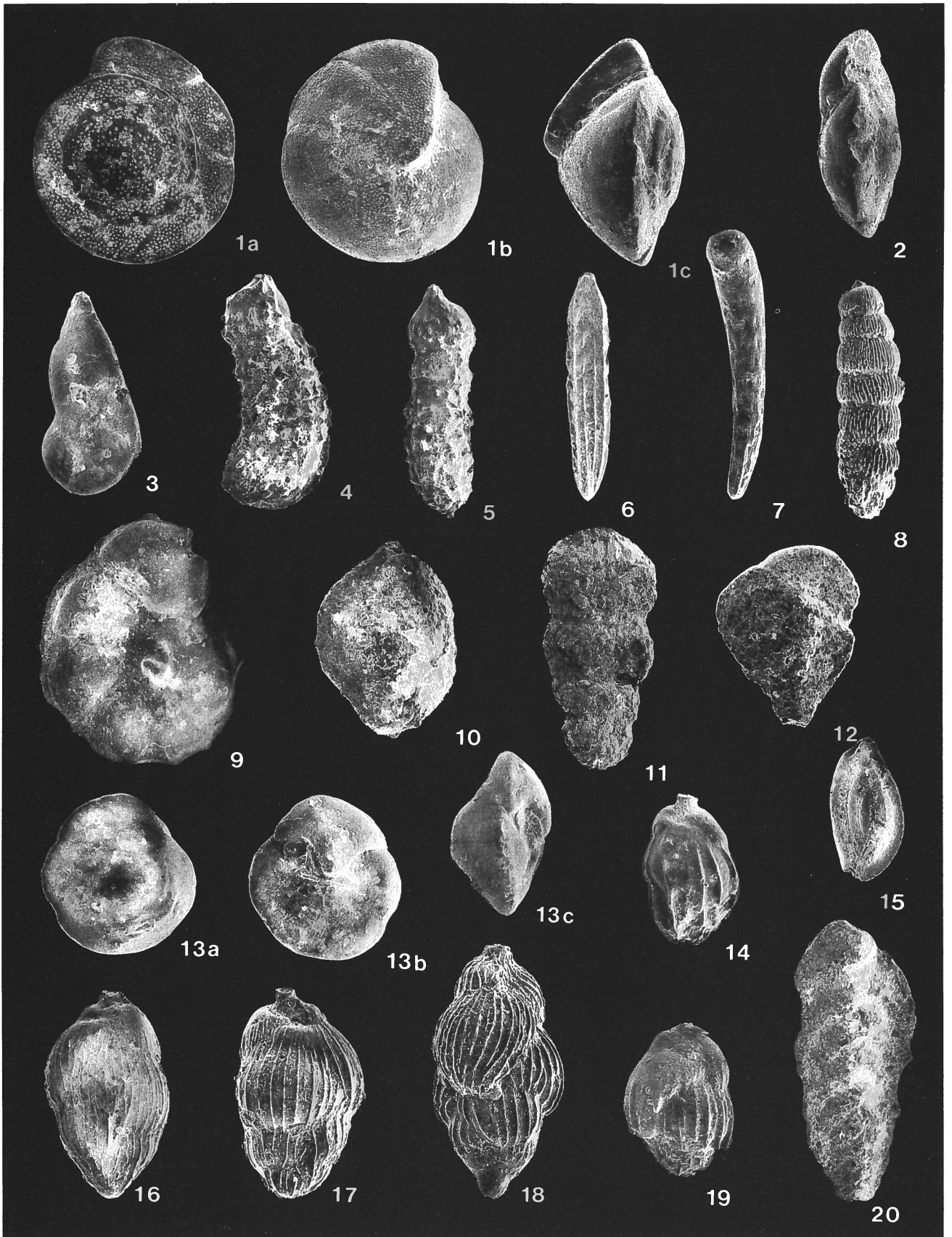
Pl. 2, fig. 6

1850 *Frondicularia semicostata* NEUGEBOREN, p. 123, pl. 3, fig. 9.

Fangario sediments contain a few specimens of this rarely recorded species. It may be distinguished from *P. digitalis* (Neugeboren), a closely related species, in having the strongly developed costae, which ornamented the test, restricted to the lower half of the test.

EXPLANATION OF PLATE 2

- Figs. 1 a-c - *Heterolepa dutemplei* (d'Orbigny) x 60
 Fig. 2 - *Heterolepa dutemplei* (d'Orbigny) x 60
 Fig. 3 - *Marginulinopsis pedum* (d'Orbigny) x 80
 Fig. 4 - *Marginulinopsis asperuliformis* (Nuttall) x 80
 Fig. 5 - *Marginulina hirsuta* d'Orbigny x 60
 Fig. 6 - *Plectofrondicularia semicostata* (Neugeboren) x 100
 Fig. 7 - *Rectobolivina zsigmondyi* (Hantken) x 100
 Fig. 8 - *Rectuvigerina royoi* Bermudez & Fuenmayer x 150
 Fig. 9 - *Lenticulina helena* (Karrer) x 45
 Fig. 10 - *Sigmoilopsis schlumbergeri* (A. Silvestri) x 80
 Fig. 11 - *Reophax* sp. x 40
 Fig. 12 - *Textularia aciculata* d'Orbigny x 100
 Figs. 13 a-c - *Neoeponides haidingeri* (d'Orbigny) x 80
 Fig. 14 - *Uvigerina schwageri* Brady x 80
 Fig. 15 - *Sigmoilinita tenuis* (Czjzek) x 80
 Fig. 16 - *Neoeponides haidingeri* (d'Orbigny) x 80
 Fig. 17 - *Uvigerina multicostata* Le Roy x 100
 Fig. 18 - *Uvigerina pygmaea* Papp & Turnovsky x 100
 Fig. 19 - *Uvigerina barbatula* Macfadyen x 150
 Fig. 20 - *Spiroplectammina carinata* (d'Orbigny) x 50



RECTUVIGERINA ROYOI Bermudez & Fuenmayer

Pl. 2, fig. 8

1963 *Rectuvigerina royo* BERMUDEZ & FUENMAYER, pp. 144-145, pl. 18, fig. 9.

Specimens attributed to this taxon are rare. The ornamentation consists of numerous, delicate costae. It is very closely related to *Rectuvigerina siphogenerinoides* (Lipparini), a species with a different stratigraphic range, but it differs from the latter by having more overlapping chambers, a reduced universal stage, and less depressed sutures.

RECTOBOLIVINA ZSIGMONDYI (Hantken)

Pl. 2, fig. 7

1868 *Nodosaria (Dentalina) zsigmondyi* HANTKEN, p. 87, pl. 1, fig. 12.

A very rare, but characteristic species. The test is distinctly perforated and slightly ornamented in early biserial chambers with thin, longitudinal costae. Specimens lacking ornamentation are described from Hungarian Oligocene (Sztrákos, 1979). The species, in the Po Valley, is recorded only in Miocene sediments (AGIP, 1982).

UVIGERINA BARBATULA Macfadyen

Pl. 2, fig. 19

1930 *Uvigerina barbatula* MACFADYEN, p. 92, pl. 3, fig. 26.

The species is a rare element among the uvigerinids. The ornamentation of the chambers, with the exception of the smooth last one, consists of strong, continuous costae, ending with spinose projections. *Uvigerina macrocarinata* Papp & Turnovsky may have been described as *U. barbatula* by some authors. It is a useful stratigraphic index for the lower and middle Miocene.

UVIGERINA GALLOWAYI Cushman

1929 *Uvigerina gallowayi* CUSHMAN, p. 94, pl. 13, figs. 33-34.

Only rare specimens, of the uvigerinid population correspond with this species. It is ornamented, with the exception of the last chamber, by a few, strong costae ending with downward pointing spines. This species is a typical uvigerinid of Oligocene and early Miocene age.

UVIGERINA LONGISTRIATA Perconig

Pl. 2, fig. 16

1955 *Uvigerina longistriata* PERCONIG, p. 182, pl. 2, figs. 1-4.

It is a frequently occurring species. The chambers are ornamented, with the exception of the last formed one which has a smooth surface in the upper part, by numerous, thin costae. It differs from *Uvigerina pygmooides* in its more compact general morphology and in the different ornamentation of the test. It may be distinguished from *Uvigerina multicostata* because the costae do not break off abruptly at the sutures.

UVIGERINA MULTICOSTATA Le Roy

Pl. 2, fig. 17

1939 *Uvigerina multicostata* LE ROY, p. 251, pl. 2, figs. 4-5, pl. 7, figs. 3-5.

This species occurs frequently. The test, about twice as long as it is broad, is ornamented by thin but well defined costae, breaking off at the sutures, with the exception of the last chamber, or part of it, which is smooth. Wright (1978a) figures a specimen, identified as *Uvigerina rutila*, corresponding well to the here examined taxon; the two closely related species may be separated only because the chambers overlap more in *U. rutila*.

UVIGERINA PYGMOIDES Papp & Turnovsky

Pl. 2, fig. 18

1953 *Uvigerina pygmooides* PAPP & TURNOVSKY, p. 131, pl. 5, fig. C (4).

It is frequent uvigerinid in the Fangario microfauna. The species, originally described from the Miocene of the Vienna basin, is represented by well developed specimens corresponding exactly to the type figures. The test is elongated, fusiform, ornamented by a number of strong costae, totally lacking or very indistinct in the lower part of the test. Specimens figured by d'Orbigny (1846) from the Vienna basin and identified as *Uvigerina pygmaea* correspond, according to Papp & Turnovsky (1953), with *U. pygmooides*. The identified species, recorded from early and middle Miocene of the Carpathians (Cicha *et al.*, 1983) and the Vienna basin (type locality) seems to exhibit a useful stratigraphic range.

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