PRJ, Vol. 8 (January 1996); P. 25–48, 3 FIGS, 9 PLATES

Foraminiferal Study of the Miocene From Well D2-NC41, Northwestern Offshore, Libya

Ahmed K. Abusrewil*

دراسة منخربات عصر الميوسين من البئر D2-NC41، شمال غربي الجرف القاري، ليبيا

أحمد أبو سريويل

من خلال المحتوى الأحاتي للمنخربات لعدد 20 عينة فتاتية من المقطع تحت السطح للبئر D2-NC41 بمنطقة الجرف القاري لشمال غربي ليبيا والتي تغطي تكوينات المايا (جزء)، تبتة، مرسى زواغة، وجزء من السبابيل العائدة لعصور المايوسين الأوسط وحتى أسفل البلايوسين السفلي، قد تم التعرف على عدد 38 نوع من المنخربات الطافية و 85 نوع من المنخربات القاعية.

المنخربات الطافية في الجزء السفلي من المقطع تدل على النطاق ن8 للعالم بلو (1969، 1979) والدالة على عمر اللأنغيان (نطاق البري أوربيولينا كلوميروسا كلوميروسا). أما الأنطقة الحياتية ن8—ن18 والدالة على عمر السيرافاليان — أسفل البلايوسين السفلي فانه لم يكن بالإمكان تحديدهما بدقة نظراً لندرة المنخربات الطافية في هذا الجزء من المقطع.

الجزء السفلي من المقطع نسبياً غني بالمنخربات الطافية «25 نوع» وهذا يشير إلى بيئة ترسيبية ذات مياه عميقة، وباتجاه إلى أعلى المقطع نلاحظ نقص أو غياب المنخربات الطافية، وزيادة أو بداية ظهور بعض أنواع المنخربات القاعية مثل الالفيديوم والبينوروبليس، البوريليس ميلو وكوينكويلوكولينا تشير إلى أن تكاوين المايا العلوي (سيرافاليان)، وتبتة (تورتونيان) ومرسى زواغة (ميسينيان) كلها قد ترسبت تحت بيئة ترسيبية ضحلة، أما تكوين سبابيل (بلايوسين) فقد إبتدأ الترسيب عند بيئة بحرية أكثر عمقاً وهذا مشار إليه بواسطة ظهور منخربات طافية جديدة.

Abstract. *Analysis of the foraminiferal contents of twenty cutting samples from the subsurface section of well D2-NC41, offshore NW Libya, covering the Middle Miocene-lowermost Pliocene Al Mayah (part) Tubtah, Marsa Zouaghah, and Sbabil (part) Formations, has resulted in the recognition of 38 planktonic and 85 benthonic foraminiferal species.*

Planktonic Foraminifera at the lower part of the section indicate Zone N8 of Blow (1969, 1979) of Langhian age (=Praeorbulina glomerosa glomerosa Zone). Zones N9-N18 indicating Serravallian – lowermost Lower Pliocene are not precisely determined due to the lack of planktonic Foraminifera.

The lower part of the section is relatively rich in planktonic Foraminifera (25 species) indicating deep water paleoenvironment. Upward the section a noticeable decrease and/or absence of planktonic Foraminifera, and the increase and/or first appearance of benthonic foraminiferal species Elphidium spp., *Peneroplis* spp., *Borelis melo, and Quinqueloculina* spp. *would indicate continuous shallowing during the deposition of the upper Al Mayah Formation (Serravallian), the Tubtah Formation (Tortonian), and the Marsa Zouaghah Formation (Messinian). The Sbabil Formation (Pliocene) deposition commenced with more deep marine environment indicated by the new appearance of planktonic Foraminifera.*

INTRODUCTION

This study is part of a large micropalaeontological project of the Oligiocene–Pliocene of the Tarabulus Basin, Pelagian Platform, offshore northwestern Libya which is being carried out by the Petroleum Research Centre, Tripoli, to re-evaluate its foraminiferal contents, biostratigraphy, palaeoecology, stratigraphy and correlation with neighbouring areas.

* Petroleum Research Centre, P.O. Box 6431, Tripoli, G.S.P.L.A.J.

More than 50 exploratory wells have been drilled in this area. Many other biostratigraphical investigations have been published (Van Hinte *et al.*, 1980; Hammuda *et al.*, 1985; Eliagoubi, 1986, Hammuda *et al.*, 1991). On onshore areas of NW Libya Salem and Spreng (1980), and Sherif (1991) published more detailed studies on Miocene biostratigraphy of Al Khums Formation.

Well D2-NC41 which is situated in the centre of the Tarabulus Basin, (Fig. 1) was drilled in 1977. It penetrated a sedimentary sequence of 12377 ft (3772.5m) ranging in age from Cenomanian to Pliocene. The sea bed was encountered at 545 ft (166 m) and the first recovery at 805 ft (245 m) within the Sbabil Formation.

Twenty cutting samples were processed using standard micropalaeontological techniques. The Foraminifera were picked and partly identified at the Geology Department, Glasgow University, United Kingdom. The benthonic Foraminifera were photographed using scanning-electron microscope and 9 plates were prepared. The planktonic Foraminifera and other additional benthonic Foraminifera from the same samples were indentified at the Petroleum Research Centre, Tripoli, Libya. The nomenclature of Foraminifera is mainly based on those by Loeblich and Tappan (1964, 1988).

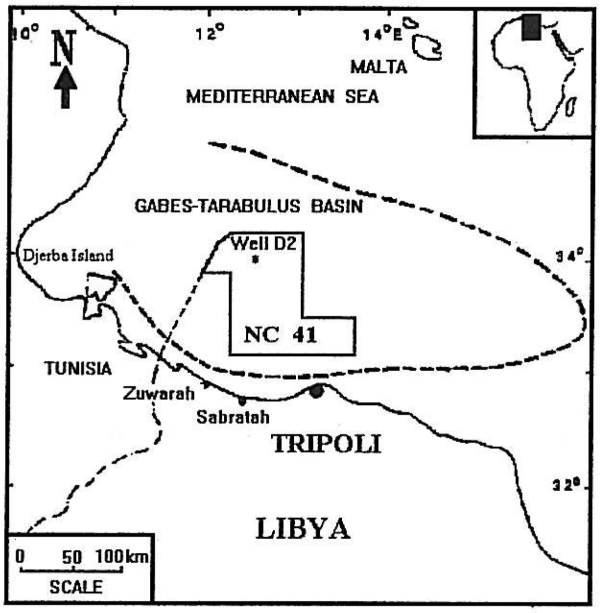

Fig. 1. Location map of the study area.

STRATIGRAPHY

The studied sequence in well D2-NC41 consists of four rock units, these are in ascending order:

Al Mayah Formation

Al Mayah Formation in well D2-NC41 consists of 2945 ft (depth 4990 ft–2045 ft) sequence of silty and sandy clays and shales with levels of sand. Originally the name "Mahmoud Formation" was given to the lower 1378 ft and the name "Beglia Formation" to the 1567 ft by Costa and Fandi (1977), however, the whole sequence is attributed to Al Mayah Formation (Hammuda *et al.*, 1985, pp. 25–32, 129–133).

Tubtah Formation

The Tubtah Formation in well D2-NC41 consists of 815 ft (depth 2045 ft–1230 ft) sequence of limestone (wackestone/packestone), grey green clay with levels of wackestone, and limestone (wackestone, locally boundstone), sometimes oolitic. Originally, Costa and Fandi (1977) considered this interval to belong to the upper part of the "Beglia Formation".

Marsa Zouaghah Formation

The Marsa Zouaghah Formation in well D2-NC41 consists of 360 ft (depth 870 ft–1230 ft) sequence of crystalline gypsum with levels of white, fossiliferous, slighty dolomitic limestone (wackestone/packestone). Costa and Fandi (1977) considered this interval as the "Saouaf Formation" which is unconformably overlain by "Raf Raf Formation" (=Sbabil Formation of Hammuda *et al.*, 1985).

Sbabil Formation

Only the lower 65 ft (depth 870 ft–805 ft) of this formation had been recovered from this well, however, the sea bed is at 545 ft giving possible thickness of 325 ft. The Sbabil Formation at this location consists of a sequence of mudstone and wackestone with interbeds of clay beds unconformably overlying the Marsa Zouaghah Formation.

BIOSTRATIGRAPHY

Planktonic Foraminifera

Thirty four planktonic forminiferal species have been identified (Fig. 2), they are: *Globigerina* cf. *apertura* CUSHMAN, *G. brazieri* JENKINS, *G. connecta* JENKINS, *G. eximia* TODD, *G.* cf. *falconensis* BLOW, *G.* cf. *globularis* ROEMER, *G. venezuelana* HEDBERG; *Globigerinita glutinata* (EGGER), *Gt. uvula* (EHRENBERG); *Globigerinoides apertasuturalis* JENKINS, *Gn. bisphericus* TODD, *Gn.* cf. *bollii* BLOW, *Gn. bullatus* CHANG, *Gn. dinapolii* OGNIBEN, *Gn. extremus* BOLLI, *Gn. immaturus* LEROY, *Gn. muratai* ASSANO, *Gn. obliquus* BOLLI, *Gn. quadrilobatus* (D'ORBIGNY), *Gn. parawoodi* KELLER, *Gn. sacculifer* (BRADY), *Gn. subsacculifer* CITA, PRIMOLI SILVA and ROSSI, *Gn. trilobus* (REUSS); *Globigerinopsoides algeriana* CITA and MAZZOLA; *Globoquadrina dehiscens* (CUSHMAN, PARR and

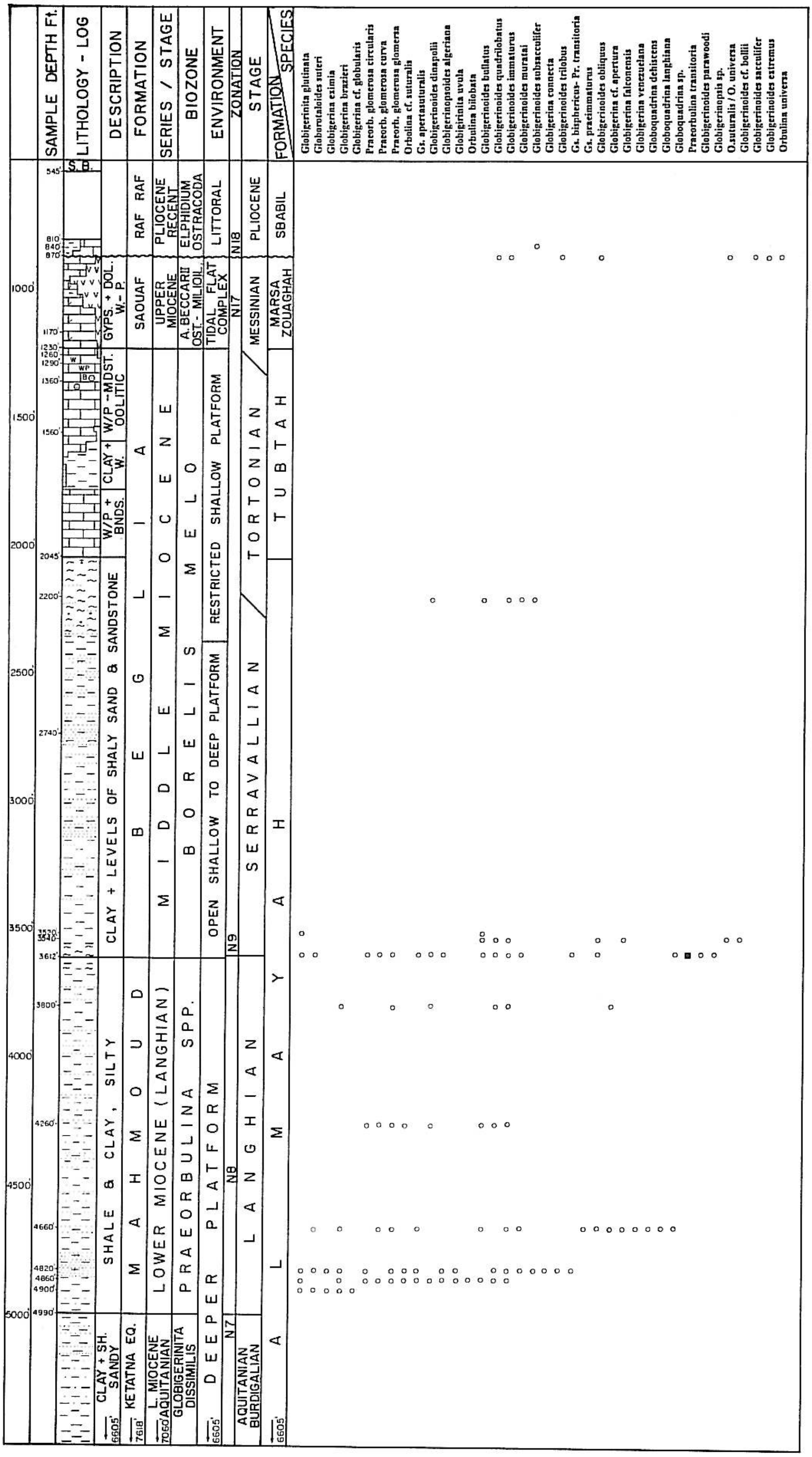

Fig. 2. Distribution of planktonic Foraminifera in the Miocene-Lowermost Pliocene of well D2-NC41, offshore, NW Libya.

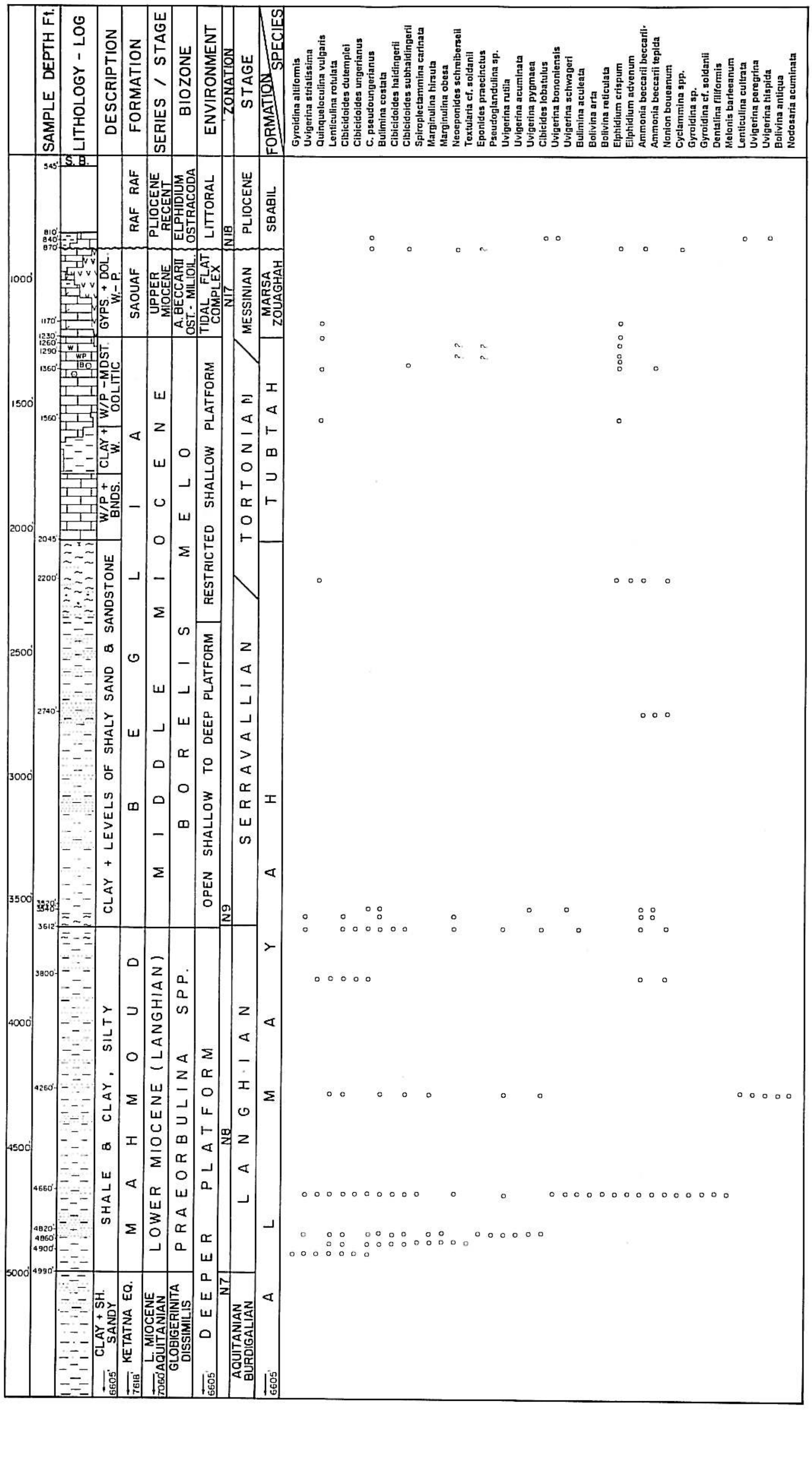

Fig. 3. Distribution of benthonic Foraminifera in the Miocene-Lowermost Pliocene of well D2-NC41, offshore, NW Libya.

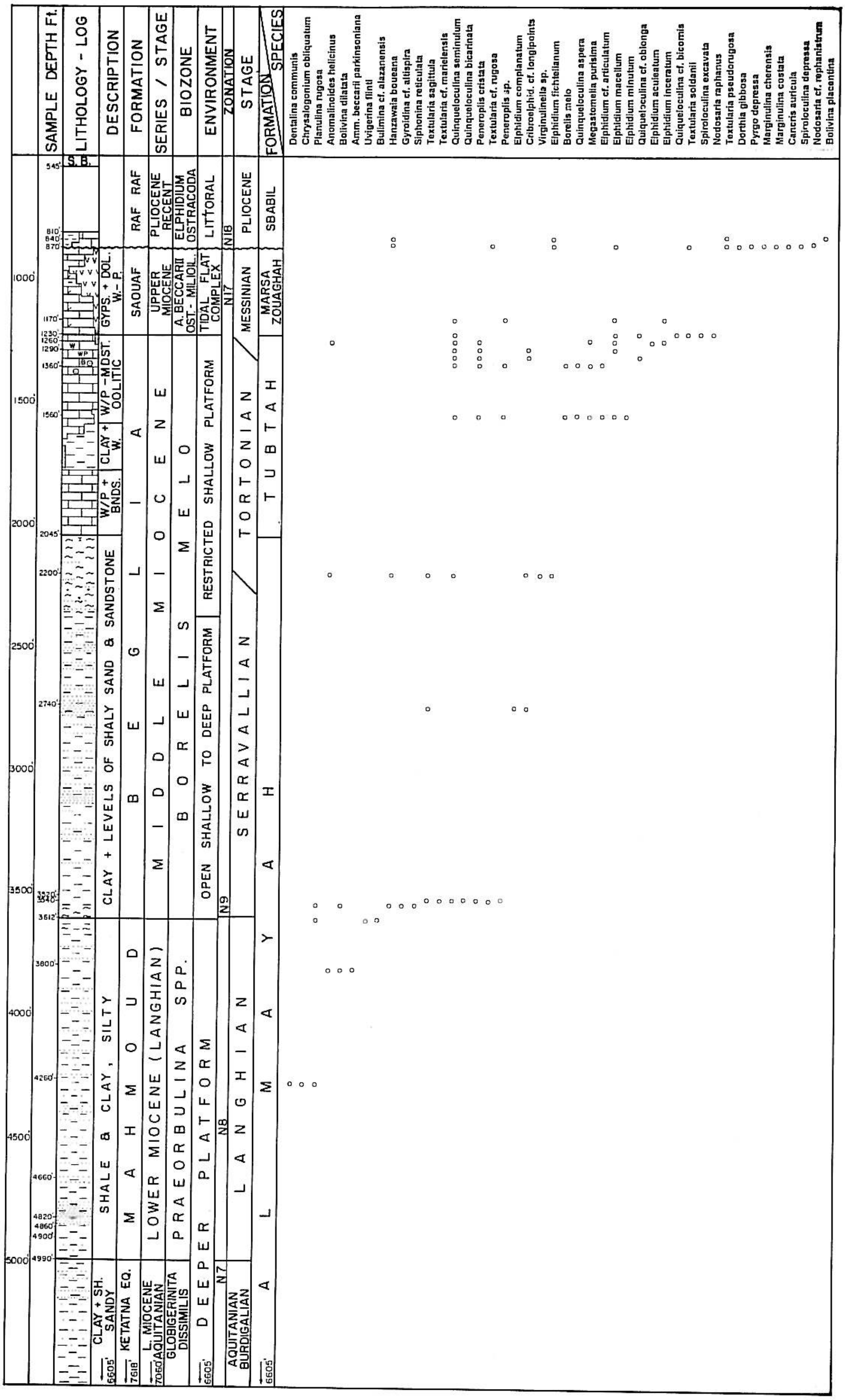

Fig. 3. Continuation.

COLLINS), *Gq. langhiana* CITA and GELATI; *Globorotaloides suteri* BOLLI; *Orbulina bilobata* (D'ORBIGNY), *O.* cf. *suturalis* BRONNIMANN, *O. universa* D'ORBIGNY; *Praeorbulina glomerosa circularis* (BLOW), *Pr. glomerosa curva* (BLOW), Pr. *glomerosa glomerosa* (BLOW) and *Pr. tranistoria* (BLOW).

Benthonic Foraminifera

Eighty five benthonic foraminiferal species have been identified (Fig. 3). They are: *A. Anomalinoides helicinus* (COSTA); *Ammonia beccarii beccarii* (LINNE'), *A. beccarii parkinsoniana* (D'ORBIGNY), *A. beccarrii tepida* (CUSHMAN); *Bolivina* cf. *antiqua* D'ORBIGNY, *B. arta* MACFADYEN, *B. dilatata* REUSS, *B. placentina* ZANMATTI, *B. reticulata* VON HANTKEN; *Borelis melo* (FICHTEL *and* MOLL); *Bulimina aculetata* D'ORBIGNY, *B.* cf. *alazanensis* CUSHMAN, *B. costata* D'ORBIGNY; *Cancris auricula* (FICHTEL and MOLL); *Chrysalogonium obliquatum* (BATSCH); *Cibicides lobatulus* (WALKER and JACOB); *Cibicidoides dutemplei* (D'ORBIGNY), *C. haidingerii* (BRADY), *C. pseudoungerianus* (CUSHMAN), *C. subhaidingerii* (PARR), *C. ungerianus* (D'ORBIGNY); *Cribroelphidium* cf. *longipointis* (SHCHEDRINA); *Cyclammina* sp.; *Dentalina communis* (D'ORBIGNY), *D. filiformis* (D'ORBIGNY); *Dorothia gibbosa* (D'ORBIGNY); *Elphidium aculeatum* (D'ORBIGNY), *E.* advenum (CUSHMAN), *E.* cf. *articulatum* (D'ORBIGNY), *E. complanatum* (D'ORBIGNY), *E. crispum* (LINNE'), *E. fichtelianum* (D'ORBIGNY), *E. incertum* (WILLIAMSON), *E. macellum* (FICHTEL and MOLL), *E. minutum* (REUSS); *Eponides praecinctus* KARRER; *Gyroidina altiformis* (CUSHMAN), *G. altispira* CUSHMAN and STAINFORTH, *G.* cf. *soldanii* (D'ORBIGNY), *G.* sp.; *Hanzawaia boueana* (D'ORBIGNY); *Lenticulina cultrata* (D'E'MONTFORT), *L. rotulata* (LAMARCK); *Marginulina cherensis* TEDESCHI and ZANMATTI, *M. costa* (BATSCH), *M. hirsuta* D'ORBIGNY, *M. obesa* CUSHMAN; *Megastomella purisima* (BRAMLETTE); *Meloniis barleeanum* (WILLIAMSON); *Neoeponides schreiberseii* (D'ORBIGNY), *Nodosaria acuminata* HANTKEN, *N.* cf. *raphanistrum* (LINNE'), *N. raphanus* (LINNE'); *Nonion boueanum* (D'ORBIGNY); *Peneroplis carinata* SILVESTRI, *P. cristata* SILVESTRI, *P.* sp., *Planulina rugosa* (PHLEGER and PARKER); *Pseudoglandulina sp.*; *Pyrgo depress* (D'ORBIGNY); *Quinqueloculina aspera* D'ORBIGNY, *Q. bicarinata* D'ORBIGNY, *Q.* cf. *bicornis* (WALKER and JACOB), *Q. oblonga* (MONTAGU), *Q. seminulum* (LINNE'), *Q. vulgaris* D'ORBIGNY; *Siphonina reticulata* (CZJEK); *Spiroloculina depressa* D'ORBIGNY, *S. excavata* D'ORBIGNY; *Textularia* cf. *marielensis* LALICKER and BERMUDEZ, *T. pseudorugosa* LACROIX, *T.* cf. *rugosa* COSTA, *T. sagittula* DEFRANCE, *T.* cf. *soldanii* FORNASINI, *T. soldanii* FORNASINI; *Uvigerina acuminata* HOSIUS, *U. bononiensis* FORNASINI, *U. flinti* CUSHMAN, *U. hispida* SCHWAGER, *U. peregrina* CUSHMAN, *U. pygmaea* D'ORBIGNY, *U. rutila* CUSHMAN and TODD, *U. schwageri* BRADY, *U. striatissima* PERCONIG; and *Virginulinella sp.*

AGE DETERMINATION AND ZONATION

Planktonic Foraminifera

Miocene

1. Aquitanian: In the Mediterranean area the Early Miocene boundary is taken at the base of the Aquitanian at the first appearance of *Globoqadrina dehiscens* (Iaccarino, 1985). The *Globoquadrina dehiscens dehiscens* Subzone (=Zone N4 and lower part of Zone N5 of Blow 1969, 1979) of the *Globoquadrina dehiscens dehiscens – Catapsydrax dissimilis* Zone was correlated with the Aquitanian stage (Iaccarino, *op. cit.*, p. 285), the upper boundary was taken at the first appearance of *Globigerinoides altiaperturus* which is in coincidence with the interval from the first appearance of *Globiquadrina dehiscens dehiscens* to the first appearance of *Globigerinoides altiaperturus*. In well D2/NC41 the Aquitanian has not been encountered in the studied samples.

2. Burdigalian: Iaccarino (1985, pp. 285–286) followed Demmarcq *et al.* (1974, *fide* Iaccarino, *op. cit.*) in their proposal of the second stratotype of the Burdigalian, they recognized Zones N5 (part), N6, and N7 of Blow (1969, 1979) to which Iaccarino (*op. cit.*, p. 285) correlated the *Globigerinoides altiaperturus – Catapsydrax dissimilis* Subzone of the *Globoquadrina dehiscens dehiscens* Zone and the *Globigerinoides-trilobus* Zone coinciding with the Burdigalian stage. The lower boundary of the Burdigalian was taken at the first occurrence of *Globigerinoides altiaperturus* and the upper boundary at the lower boundary of the Langhian coincident with the first occurrence of *Praerorbulina* spp. and *Globoquadrina langhiana* corresponding to the base of Zone N8 of Blow (1969, 1979). In well D2/NC41 the Burdigalian has not been encountered in the studied samples. However, Costa and Fandi (1977) drawn the base of the Langhian 90 ft below sample 4900 (i.e. at depth 4990 ft in well D2/NC41).

3. Langhian: Iaccarino (1985), Berggren and Miller (1989), and Miller and Katz (1987, part) considered the first appearance of *Praerorbulina glomerosa* marking the lower boundary of Zone N8 of Blow (1969, 1979) equivalent to the base of the *Praeorbulina glomerosa* Zone. Iaccarino (1985, p. 286) drawn the upper boundary of the *Praerorbulina glomerosa* Zone (=Zone N8) within the Langhian at the first appearance of *Orbulina saturalis* marking the lower boundary of the *Orbulina suturalis* Subzone of the *O. suturalis – Globorotalia peripheroronda* Zone corresponding to the base of Zone N9. The upper boundary of the Langhian corresponds to the first appearance of *Orbulina universa* marking the lower boundary of the *Orbulina universa* Subzone of the *O. suturalis-Grt. peripheroronda* Zone, an event which is in coincidence with the last appearance of *Praeorbulina glomerosa* and thus identify the Langhian–Serravallian boundary (Iaccarino, *op. cit.*, p. 286, however, text-figure 4, p. 298 shows shorter range of *Pr. glomerosa*). Berggren and Miller (1989, p. 310) also considered the first appearance of *Orbulina saturalis* limiting the upper boudary of Zone N8 in the Lower Miocene.

However, studies by Blow (1969, 1979), Stainforth *et al.* (1975), Kennett and Srinivasan (1983), Bolli and Saunders (1985), Jenkins (1985), Belanger and Berggren (1986) and McLaughlin (1989) considered the *Praeorbulina glomerosa* Zone (=Zone N8 of Blow 1969, 1979) within the late Lower Miocene and the upper boundary of the Zone limiting the lower Middle Miocene boundary corresponding to the first appearance of *Orbulina suturalis*. Blow (1969, 1979) considered the Langhian equivalent to his Zones N9 – lower N15 corresponding to the whole Middle Miocene. Thus, based on the correlation with Iaccarino (1985), Miller and Katz (1987), and Berggren and Miller (1989) the Langhian is equivalent to Zones N8 and lower N9 of Blow (1969, 1979) and equivalent Zones corresponding to the interval from the first appearance of *Praeorbulina* spp. to the first appearance of *Orbulina universa* including the planktonic foraminiferal zones, the *Praeorbulina glomerosa* Zone and *Orbulina suturalis* Zone. In Well D2/NC41 this stage (i.e. the Langhian) is represented by 1390 ft (depth 3600–4990 ft) sequence in the lower part of the studied Al Mayah Formation in accordance with the total range of *Praeorbulina* spp. The first appearance of *Orbulina* spp. close to *O. universa* marking the top of the *Praeorbulina glomerosa* Zone (=Zone N8).

4. Serravallian: The first appearance of *Orbulina universa* marks the lower boundary of the Serravallian within the Middle Miocene of the Mediterranean area (Agip Mineraria, 1957, 1980; and Iaccarino, 1985). Similarly, the first appearance of *Orbulina* spp. was taken as the Middle Miocene lower boundary by Stainforth *et al.* (1975) and Kennett and Srinivasan (1983). Blow (1969, 1979) considered the Langhian representing the Middle Miocene and drawn its upper boundary (i.e. the Middle/Upper Miocene boundary) approximately at the middle of his Zone N15, slightly below the *Canadiana* Datum and the *Globorotalia acostaensis* Datum. Similarly Agip Mineraria (1957, 1980); Van Hinte *et al.* (1980), Belanger and Berggren (1986), and Berggren and Miller (1989) drawn the Middle Miocene upper boundary slightly below the first occurrence of *Neogloboquandrina acostaensis* which appeared very early in the Late Miocene limiting the lower boundary of Zone N16. Iaccarino (1985, pp. 285, 290, text-figures 1–4) also considered the upper boundary of the Middle Miocene corresponding to the upper boundary of the Serravallian slightly below the lower boundary of the *Globorotalia acostaensis* Zone within the uppermost Zone N15 (=*Globorotalia menardii* Zone) corresponding to the Middle/Upper Miocene boundary in the Mediterranean area. Stainforth *et al.* (1975), Kennett and Srinivasan (1983), Bolli and Saunders (1985), Miller and Katz (1987) and Mclaughlin (1989) took the upper boundary of the Middle Miocene with the first appearance of *Globorotalia acostaensis*, corresponding to the upper boundary of the *Globorotalia menardii* Zone (Stainforth *et al.*, 1975; Bolli and Saunders, 1985). In well D2/NC41 the lower boundary of the Serravallian is taken at the last appearance of *Praeorbulina* spp. This boundary is taken as the lower boundary of Zone N9 in accordance with Agip Mineraria (1957, 1980), Stainforth *et al.*, (1975), Kennett and Srinivasan (1983) and Iaccarino (1985). The upper boundary of the Serravallian is not exactly determined due to the lack of planktonic Foraminifera from the upper part of Al Mayah Formation in this well.

5. Tortonian: The lower boundary of the Tortonian (i.e. the Serravallian/Tortonian boundary) was drawn at the first occurrence of *Sphaeroidinellopsis seminulina*, *Globigerinoides sacculifer*, and *Globigerinita glutinata* slightly above the first occurrence of *Globorotalia menardii* and below the first occurrence of *Globorotalia acostaensis* (Agip Mineraria, 1957, 1980). Van Hinte *et al.* (1980, p. 214) placed the Tortonian lower boundary within the "*Globorotalia menardii*" Zone slighty below the first occurrence of sinistrally coiled *Globorotalia acostaensis*. Iaccarino (1985) following Cita and Blow (1969) (*Fide* Iaccarino, *op. cit.*) considered the lower boundary of the type Tortonian falls within the uppermost part of Zone N15 slightly below the first occurrence of *Globorotalia acostaensis*. Blow (1969) considered the Middle Miocene (lower part of Zone N15)/Late Miocene (upper part of Zone N15) boundary corresponding to the Langhian/Tortonian–Messinian boundary at the Middle of Zone N15 (*Globorotalia (Turborotalia) continuosa* Zone). Belanger and Berggren (1986, pp. 326–329) and Berggren and Miller (1989, pp. 310, 312) also considered the Middle Miocene/Late Miocene boundary slightly below the first occurrence of *Neogloboquadrina acostaensis*. Studies by Stainforth *et al.* (1975), Kennett and Srinivasan (1983), Bolli and Saunders (1985), and McLaughlin (1989) took the first appearance of *Globorotalia acostaensis* corresponding to the lower boundary of Zone N16 (=*Globorotalia acostaensis* Zone) in coincidence with Middle/Upper Miocene boundary. Based on the lack of planktonic Foraminifera above the base of the Serravallian in well D2/NC41, the exact boundary of the Tortonian is not determined, however, in accordance with previous studies, it is possible that the lower boundary could be drawn within the *Borelis melo* Zone (Costa and Fandi, 1977; Hammuda *et al.*, 1991). The upper boundary of the Tortonian is taken at the first appearance of *Globorotalia conomiozea* at the lower limit of Zone N17 (*Globorotalia conomiozea* Zone) (Van Hinte *et al.*, 1980; Iaccarino, 1985). Bolli and Saunders (1985) and McLaughlin (1989) placed the upper boundary of the Tortonian corresponding to the first appearance of *Globorotalia humerosa*, *Globigerinoides obliquus extremus*, *Turborotalia humerosa*, and *Sphaeroidinellopsis seminulina*. Agip Mineraria (1957, 1980) placed the upper boundary of the Tortonian at the first introduction of saline deposits, lacking in most sections the normal foraminiferal fauna of the Messinian. Similar procedure was adopted in well D2/NC41 by Costa and Fandi (1977) and the present work. However, further studies may prove that the top of the Tortonian (i.e. the Tortonian/Messinian boundary) may be below the present interpretation.

6. Messinian: The first occurrence of *Globorotalia conomiozea* was taken to limit the lower boundary of the Messinian in the Mediterranean area by Van Hinte *et al.* (1980, pp. 214–216), and Iaccarino (1985, p. 285, 293–299). The same criteria for limiting the lower boundary of the Messinian was also used by Kennett and Srinivasan (1983, p. 9, Temperate Zonation), Jenkins (1985, p. 266, 268), and Belanger and Berggren (1986, pp. 326–329), the later authors correlated the uppermost late Miocene with Zone N17 (the *Globorotalia conomiozea* Zone) above the *Neogloboquadrina acostaensis* Zone. Agip Mineraria (1957, 1980) considered the Messinain corresponding to the *Globorotalia humerosa* Zone in coincidence with the last appearance of most planktonic Foraminifera in the Mediterranean area in response to the Messinian Salinity. Bolli and Saunders (1985, pp. 159, 167—176) and McLaughlin (1989) considered the uppermost Miocene (Zone N17 = *Globorotalia humerosa* Zone) start at the first occurrence of *Globorotalia humerosa*. Blow (1969, p. 250–252, 289, 1979, pp. 52–56, 91) considered the Messinian corresponding to Zone N17 (*Globorotalia (G.) tumida plesiotumida* Zone) in coincidence with the first evolutionary appearance of *Globorotalia (G.) tumida plesiotumida*. Kennett and Srinivasan (1983, p. 8) considered Zone N18 representing the uppermost Miocene corresponding to the first appearance of *Globorotalia tumida tumida* in the tropical zonation. While Berggren and Miller (1989, pp. 310, 312) considered Zone N17 corresponding to the late Upper Miocene. The upper boundary of the Messinian in the Mediterranean area (i.e. the Miocene/Pliocene boundary) is taken at the first open marine conditions after the late Miocene salinity crisis in the area corresponding to the first appearance of *Sphaeroidinellopsis* spp., *Orobulina* spp., and other planktonic foraminiferal species (Agip Mineraria 1957, 1980) and to the first appearance of *Sphaeroidinellopsis*, *Globorotalia humerosa*, *Globigerinoides elongatus and Globigerinoides ruber* (Iaccarino, 1985, pp. 285, 287, 290). The first appearance of *Globorotalia margaritae* was taken as the upper boundary of the Miocene corresponding to the lower limit of the *Globorotalia margaritae* Zone (Stainforth *et al.*, 1975, p. 15, 88, 90–96). Van Hinte *et al.* (1980, pp. 214–216), Bolli and Saunders (1985, pp. 159, 167–176) and McLaughlin (1989) also considered the first appearance of *Globorotalia margaritae* as the upper boundary of the Miocene. In well D2/NC41 the Messinian is determined in correlation with lithostratigraphic equivalents in the Gabes–Tarabulus Basin (Costa and Fandi 1977; Van Hinte *et al.*, 1980; Hammuda *et al.*, 1991, Kassab *et al.*, 1995).

The Miocene/Pliocene Boundary

The Miocene/Pliocene boundary in the Mediterranean region is taken at the end of the salinity crisis corresponding questionably to the N17–N18 boundary coinciding with appearance of open marine fauna characterized by the first occurrence of *Sphaeroidinellopsis sphaeroides*, *Globorotalia humerosa*, *Globigerinoides elongatus* represented by the *Sphaeroidinellopsis seminulina* Zone below the *Globorotalia margaritae* Zone (Iaccarino, 1985, pp. 285, 287, 294–299). Similarly Agip Mineraria (1957, 1980) took the Miocene/Pliocene boundary slightly below the first appearance of *Globorotalia margaritae* corresponding to appearance of planktonic Foraminifera above the Messinian due to the salinity crisis in the Mediterranean area. Elsewhere, the Miocene/Pliocene boundary is taken at the first appearance of *Globorotalia margaritae* (Stainforth *et al.*, 1975; Bolli and Saunders, 1985; McLaughin, 1989), first appearance of *Globorotalia puncticulata* (Kennet and Srinivasan, 1983, p. 9; Jenkins, 1985; Belanger and Berggren, 1986), first appearance of *Globorotalia tumida* (Berggren and Miller (1989), and the first appearance of *Sphaeroidinella dehiscens* in the tropical areas (Kennett and Srinivasan, 1983, p. 8). In well D2/NC41 the Miocene/Pliocene boundary is taken at the first appearance of planktonic Foraminifera at the Messinian/Zanclean boundary characterized by *Orbulina universa*, *Globigerinoides extremus*, *Gn. sacculifer*, *Gn. trilobus*, *Gn. quadrilobatus*, and *Gn. immaturus*.

Benthonic Foraminifera

Most of the benthonic foraminiferal species recorded in this study from the Miocene to lowermost Pliocene have been recorded elsewhere in the Mediterranean region and other areas ranging throughout the Miocene and some cross the Miocene to the Pliocene–Pleistocene (Agip Mineraria, 1957, 1980, Mediterranean area; Souaya, 1963, 1967, Miocene of Egypt; Eliagoubi, 1972, NE Libya; Mazzola, 1976, Miocene of Sirt Basin, Libya; Hageman, 1979, Pliocene–Pleistocene of Greece; Salem and Spreng, 1980, Sherif 1991, Middle Miocene of NW Libya; Boltovsky, 1980, DSDP, S. Pacific and Indian Ocean; Van der Zwaan, 1982; Late Miocene of the Mediterranean, Van der Zwaan *et al.*, 1986, Miocene–Pleistocene of the Mediterranean; Morkhoven *et al.*, 1986, Miocene–Recent, Borsetti *et al.*, 1986, Miocene–Pleistocene of the Mediterranean; and Brun *et al.*, 1984, Middle–Upper Miocene of Nigeria). However, some of the benthonic foraminiferal species encountered in the studied section of well D2/NC41 have been reported elsewhere in a restricted occurrence. Species that were reported to first occur in strata as old as Middle Miocene (Langhian) and may range to younger strata (Eliagoubi, 1972; Mazzola, 1976; Salem and Spreng, 1980; Van der Zwaan, 1982; Brun *et al.*, 1984; Borsetti *et al.*, 1986; and Van der Zwaan *et al.*, 1986) and occur in the Langhian of well D2/NC41 are: *Cibicides lobatulus, Bolivina antiqua, Elphidium advenum, Uvigerina bononiensis, U. rutila, U. schwageri, U. striatissima, Cibicidoides haidingerii, and Eponides praecinctus.* The last five species are restricted to the Langhian in well D2/NC41.

Species reported elsewhere to first occur in the Serravallian and younger strata (Maazola, 1976; Van Hinte *et al.*, 1980; Van der Zwaan, 1982; Borsetti *et al.*, 1986) and first occur in the Serravallian of well D2/NC41 are: *Uvigerina flinti and Elphidium complanatum. Elphidium aculeatum* has been recorded from the Tortonian to Pliocene (Agip Mineraria, 1957, 1980; Hageman, 1979, Pliocene to Pleistocene; Van der Zwaan, 1982, Late Miocene). In well D2/NC41 it is also first observed in the Tortonian. *Textularia pseudorugosa, Sprioloculina depressa*, and *Dorothia gibbosa* made thier first appearance within the Pliocene to Pleistocene of the Mediterranean (Agip Mineraria, 1957, 1980) also first appeared in the lower part of the Pliocene Sbabil Formation of well D2/NC41 (Fig. 3). The nature of the studied material (sandstones, siltstones, silty shales, evaporites and limestones) and the interval of sampling and the crystallization of many species specimens resulted in a not well defined distribution of species, thus out of the 85 benthonic species recorded in this study 25 species are identified from one samply only, and 15 species are recognized in 2 samples only (Fig. 3). Twenty two species are identified from one sample each in the Langhian, two species from the Serravallian, one species from the Tortonian and three species from the Messinian. Most of these species may occur in older and/or younger strata elsewhere in the Mediterranean and other parts of the world. However, some of them have facies controlled stratigraphic intervals (Agip Mineraria, 1957, 1980; Eliagoubi, 1972; Salem and Spreng, 1980, Van Hinte *et al.*, 1980, Van der Zwaan, 1982; Brun *et al.*, 1984; Borsetti *et al.*, 1986; Belanger and Berggren, 1986; Morkhoven *et al.*, 1986; Van der Zwaan *et al.*, 1986; Miller and Katz, 1987; Sherif 1991).

PALAEOECOLOGY

AL MAYAH FORMATION: The lower part of the studied Al Mayah section (depth 4900 ft–4660 ft., 4 samples) consists of silty shales and silty clays. It is relatively rich in planktonic (30 species) and benthonic (36 species) Foraminifera. The increase in percentage of planktonic Foraminifera indicates deep open marine environment (Smith, 1955; Bandy, 1964; and Boltovsky, 1969). Benthonic Foraminifera identified from this interval characterized by

1. *Cibicidoides* spp.: *C. dutemplei*, water depth 100 m–600 m; *C. haidingerii*, W.D. 100–600 m; *C. pseudoungerianus*, W.D. 35 m–1000 m; *C. subhaidingerii*, W.D. 100 m–2000 m; and *C. ungerianus*, 500 m. These species are found in muddy substrate, normal open marine, outer neritic to lower bathyal (W.D. 100 m–2000 m) (Brolsma, 1978; Hageman, 1979; Haynes, 1981, Van der Zwaan, 1982; Morkhoven *et al.*, 1986).
2. *Uvigerina* spp: *U. striatissima*, rich; *U. rutila*, common, *U. acuminata*, *U. pygmaea*, *U. bononiensis*, and *U. schawageri* rare. *Uvigerina* spp. are found most abundant at outer shelf and upper continental slope, outer neritic (100 m)–u. bathyal (1600 ml) (Haynes, 1981). Borsetti *et al.* (1986) found *Uvigerina bononiensis* in the outer neritic and less than 300 meters water depth.
3. *Ammonia* spp. (rare). The rare occurrence of *Ammonia* spp. may indicate water depth of open normal marine environment deeper than middle neritic (more than 90 m) (Hageman, 1979; Walton and Sloan, 1990).

The second interval of Al Mayah Formation (drilling depth 4260 ft–3520 ft., 5 samples) also contains a relatively rich planktonic Foraminifera (24 species) indicating open marine environment (Smith, 1955; Bandy, 1964; Boltovsky, 1969). Forty one benthonic species are identified from this interval characterized by

1. *Ammonia beccarii beccarii* (rich). Shallow, warm, normal marine, inner-middle neritic (Hageman, 1979).
2. *Bolivina spp.: B. dilatata and B. antiqua.* Outer neritic to middle bathyal (100 m–1000 m) muddy substrate, normal open marine (Brolsma, 1978, Van Hinte *et al.*, 1980; Haynes, 1981; Van der Zwaan, 1982, Brun *et al.*, 1984; Sherif, 1991).
3. Bulimina spp.: *B. costata* and *B. acuteata.* Open

normal marine, water depth 100 m–3000 m, outer neritic–abyssal, prefered depths 100 m, 400 m, 600 m, 800 m (Brolsma, 1978, Van Hinte *et al.*, 1980; Van der Zwaan 1982; Morkhoven *et al.*, 1986).

4. *Cibicidoides* spp.: *C. dutemplei* (W.D. 100 m–600 m); *C. pseudoungerianus* (W.D. 35 m–1000 m); *C. ungerianus* (W.D. to 500 m). *C. subhaidingerii* (W.D. 100 m–2000 m), *and C. haidingerii* (W.D. 100–600 m) (Hageman, 1979; Van der Zwaan, 1982; Morkhoven *et al.*, 1986).

5. *Lenticulina rotulata: Lenticulina* spp. prefer outer neritic – upper bathyal (100 m–400 m), also found at 100 m–1000 m (Brolsma, 1978).

6. *Peneroplis* spp. (rare): Inner to middle neritic (W.D. 0-152 meters) (Souaya, 1963).

7. *Quinqueloculina seminulina* (rare): Restricted shallow to shallow open marine, inner to middle neritic (25 m–35 m) (Haynes, 1981).

8. *Uvigerina* spp.: *U. striatissima, U. rutila, U. hispida, U. peregrina, U. pygmaea,* and *U. schwageri. Uvigerina* species are found most abundant at water depth 100 m–600 m (Haynes, 1981). *Uvigerina hispida* inhibits upper bathyal to lower bathyal, 200–2000 m, (Morkhoven *et al.*, 1986). Brun *et al.* (1984) estimated 500 m water depth. *Uvigerina peregrina* inhibits normal marine of wide water depth range, 100 m–1600 m (Brolsma, 1978; Sejrup *et al.*, 1981; Haynes, 1981; Van der Zwaan, 1982; Belanger and Berggren, 1986; Cassell and Sen Gupta, 1989), however, Brolsma (1978), Sejrup *et al.* (1981), and Cassell and Sen Gupta (1989) referred to 100 m–600 m water depth preference for *U. peregrina.*

9. *Nonion boueanum*: The rare occurrence of *Florilus boueanum* would indicate water depths less than upper bathyal (Van Hinte *et al.*, 1980). Hageman (1979) refers to open normal marine environment. Sherif (1991) quoted open shallow marine.

The uppermost Al Mayah Foramtion consists of 1475 ft. (drilling depth 3520 ft.–2045 ft.) of clays, shaly sands and sandstones. More shallow environment prevailed during the deposition of this part of Al Maya Formation indicated by the low diversity of both planktonic (5) and benthonic (13) species. The increase in *Ammonia*, *Textularia* and *Elphidium* would indicate inner to middle neritic (Souaya, 1963; Hageman, 1979; Haynes, 1981; Van der Zwaan, 1982; Sherif, 1991). The presence of panktonic Foraminifera in low diversity would indicate open marine connections (Smith, 1955; Bandy, 1964; Boltovsky, 1969).

TUBTAH FORMATION AND LOWERMOST MARSA ZOUAGHAH FORMATION: Drilling depth interval 2045 ft.–1170 ft. This interval consists of limestones (wackestone, packestone) with interbeds of clay and is oolitic in the upper part of the Tubtah Formation. It is relatively rich in *Borelis melo*, *Elphidium* spp., *Peneroplis*, and *Quinqueloclina* spp. and very poor in planktonic Foraminifera.

1. *Elphidium aculealtum* prefers sandy, vegetated substrate of normal salinity (Hageman, 1979).

2. *E. macellum* is found in innershelf, 0–5 m (Sherif, 1991), *E. crispum* inhibits open normal marine inner neritic to middle neritic (0–90 m) environment (Souaya, 1963; Eliagoubi, 1972; and Sherif, 1991).

3. *Quinqueloculina seminulum* may flourish in open shallow marine with vegetated substrate, it is slightly tolerant to hyposaline, water depth 25–35 meters, inner neritic (Hageman, 1979; Haynes, 1981).

4. *Peneroplis* spp.: Vegetated carbonate substrate, inner to middle neritic (0–152 m), rich from 0–18 m (Souaya, 1963).

5. *Borelis melo*: Large milolids inhibit shallow, warm, clear hypersaline environments (Haynes 1981; Walton and Sloan, 1990). *Borelis melo* inhibits shallow, warm, clear, marine waters of the inner neritic, 0–33 m on sandy and oolites substrate (Haynes, 1981; Sherif, 1991). This interval reflects shallow, warm, normal marine vegetated inner neritic platform with slight restrictions upward.

MARSA ZOUAGHAH FORMATION: Drilling depth interval 1170 ft–870 ft. This part of the Marsa Zouaghah Formation consists of wackestone-packestones, gypsum and dolomitic wackestone–packestone. No Foraminifera have been found. The presence of evaporites is interpreted as Sabkha deposits (0–10 m) in the Messinian of well NC35A, offshore NW Libya (Van Hinte *et al.*, 1980).

SBABIL FORMATION: Drilling depth interval 870 ft.–840 ft. The Sbabil Formation, at this locality, is made of clay, wackestone, and mudstone–sequence. Twenty one benthonic species and nine planktonic species are identified. The benthonic assemblage is characterized by:

1. *Elphidium* spp. (*E. fichtelianum*, vegetated substrate, Hageman, 1979; *E. crispum*, inner neritic – upper bathyal, Souaya, 1963; *E. macellum*. inner shelf, Sherif, 1991).

2. Miliolids: *Spiroloculina depressa, and Pyrgo depressa.* Smal miliolids inhibit warm, clear, shallow marine waters (Haynes, 1981) and shallow, warm clear, shallow marine waters (Haynes, 1981) and shallow, warm clear, hypersaline waters (Walton and Sloan, 1990).

3. *Bolivina antiqua:* Brun *et al.* (1984) refer to waters deeper than 150 m and abundant in bathyal depths.

4. Nodosarids: *Nodosaria* cf. *rephanus* inhibits outer neritic – middle bathyal, 100 m–1000 m (Haynes, 1981).

5. *Uvigerina peregrina*: Hageman (1979) referred to open marine waters of 0–1600 m depth. Van Hinte *et al.* (1980) concluded a water depth of 610 m for a benthonic association contains *Uvigerina peregrina* in

the Sbabil Formation of well NC35A, offshore, NW Libya.

6. *Cibicidoides pseudoungerianus* has been found at water depth range 0–1800 m (Brolsma, 1978).

7. *Cibicidoides subhaidingerii* water depth range 100–2000 m (Morkhoven, 1986).

Thus, it is possible that this faunal association of planktonic and benthonic Foraminifera indicates open normal marine middle neritic to upper bathyal (100 m – less than 600 m water depth).

CONCLUSIONS

Twenty samples from well D2-NC41, offshore, NW, Libya, drilling depth interval 4900 ft–840 ft have been studied for their foraminiferal contents in aim to re-evaluate the biostratigraphy and palaeoecology of the studied section. This resulted in:

1. Eighty five benthonic and 38 planktonic foraminiferal species are recognized.
2. Based on the planktonic foraminiferal species the N8 Zone of Blow (1969, 1979) (=*Praeorbulina glomerosa glomerosa* Zone), the boundary of Zones N8/N9, and Zone N17/N18 are determined.
3. The lack of planktonic Foraminifera in some parts of the section did not permit precise zonation for those parts.
4. Four rock units are encountered, Al Mayah, Tubtaha, Marsa Zouaghah, and Sbabil Formations. Based on their foraminiferal contents and/or stratigraphic position, these rock units are considered of Middle Miocene to lowermost Pliocene as follows:
   (a) Al Mayah Formation (part): Langhian – Serravallian (Middle Miocene).
   (b) Tubtah Formation: Tortonian (low Upper Miocene).
   (c) Marsa Zouaghah Formation: Messinian (high Upper Miocene)
   (d) Sbabil Formation: Lower Pliocene

The boundary between the Serravallian and Tortonian is not determined.

5. The Langhian part of Al Mayah Formation was deposited in normal open marine, muddy to fine substrate platform with water depth that may range between outer neritic to upper bathyal (100 m–600 m). A decrease in depth is noticed upward the section towards the top of Al Mayah Formation to probably lesser than outer neritic open marine platform.
6. The Tubtah Formation and the lower part of the Marsa Zouaghah Formation contain benthonic Foraminifera indicative of deposition under warm, clear, shallow, normal marine environment in a vegetated inner neritic platform (less than 100 m W.D.) with slight restrictions upward.
7. The remaining interval of the Marsa Zouaghah Formation (upper 300 ft) yielded no Foraminifera, the presence of evaporites suggests Sabkha deposits (0–10 m) in accordance with the Messinian salinity crisis.
8. The lowermost Sbabil Formation foraminiferal fauna indicates open marine middle neritic to upper bathyal (100 m – less than 600 m W.D.).

ACKNOWLEDGEMENTS

The author wishes to thank the management of the Petroleum Research Centre, Tripoli, Libya, for awarding the grant to carry out this research in the United Kingdom and permission to publish this work, Prof. M. Keen and Staff members of the Geology Department, Glasgow University, U.K., for various help during his stay in U.K., Mr. Peter for the scanning electron microscopy, Mr. Douglas for photography. Thanks are also extended to my colleagues and staff members of the Geology Department, Exploration Management at P.R.C. for their encouragement and support, for Mrs. Laila El-Aradi, for typing the manuscript.

Major part of this research has been carried out at P.R.C., Tripoli, under the supervision of Dr. I.I. M. Kassab to whom I am deeply indebted.

Plate 1

1. *Bolivina reticulata* (VON HANTKEN), × 100, S. 4660
2. *Bolivina arta* (MACFADYEN) × 87, S. 4660
3. *Bolivina* cf. *antiqua* (D'ORBIGNY), × 110, 9. 840
4. *Bolivina dilatata* (REUSS), × 175, S. 3540
5. *Bolivina dilatata* (REUSS), × 140, S. 3540
6. *Virgulinella* sp., × 130, S. 2200
7. *Virgulinella* sp., × 140, S. 2200
8. *Virgulinella sp.*, × 125, S. 2200
9. *Textularia* cf. *soldanii* (FORNASINI), × 40, S. 4860
10. *Textularia sagittula* (DEFRANCE), × 82, S. 2200
11. *Textularia sagittula* (DEFRANCE), × 93, S. 2200
12. *Textularia soldanii* (FORNASINI), × 24, S. 870
13. *Textularia soldanii* (FORNASINI), × 18, S. 870
14. *Textularia soldanii* (FORNASINI), × 25, S. 1230
15. *Textularia pseudorugosa* (LACROIX), × 53, S. 840
16. *Textularia* cf. *rugosa* (COSTA), × 145, S. 3520
17. *Cyclammina* sp., × 40, S. 4660
18. *Spiroplectammina carinata* (D'ORBIGNY), × 66, S. 4660
19. *Spiroplectammina carinata* (D'ORBIGNY), × 54, S. 4860

Plate 2

1. *Elphidium crispum* (LINNE'), × 52, S. 1170
2. *Elphidium crispum* (LINNE'), × 60, S. 1260
3. *Elphidium crispum* (LINNE'), × 70, S. 1230
4. *Cribroelphidium* cf. *longipoints* (SHCHEDRINA), × 78, S. 1350
5. *Elphidium complanatum* (D'ORBIGNY), × 120, S. 2740
6. *Ephidium advenum* (CUSHMAN), × 112, S. 4660
7. *Cribroelphidium* cf. *longipoints* (SHCHEDRINA), × 56, S. 1290
8. *Peneroplis* sp., × 100, S. 3520
9. *Gyroidina* sp., × 190, S. 4660
10. *Cancris auricula* (FICHTEL and MOLL), × 122, S. 870
11. *Peneroplis carinata* (SILVESTRI), × 70, S. 1350
12. Peneroplis cristata (SILVESTRI), × 73, S. 3520

Plate 3

1. *Spiroloculina depressa* (D'ORBIGNY), × 25, S. 876
2. *Spiroloculina excavata* (D'ORBIGNY), × 62, S. 1230
3. *Quinqueloculina* cf. *bicornis* (WALKER and JACOB), × 66, S. 1230
4. *Quinqueloculina* cf. *oblonga* (MONTAGU), × 35, S. 1320
5. *Quinqueloculina* cf. *oblonga* (MONTAGU), × 91, S. 1230
6. *Quinqueloculina vulgaris* (D'ORBIGNY), × 67, S. 1230
7. *Quinqueloculina vulgaris* (D'ORBIGNY), × 58, S. 3800
8. *Quinqueloculina aspera* (D'ORBIGNY), × 65, S. 1350
9. *Quinqueloculina aspera* (D'ORBIGNY), × 45, S. 1560
10. *Quinqueloculina bicarinata* (D'ORBIGNY), × 95, S. 3520
11. *Borelis melo* (FICHTEL and MOLL), × 78, S. 1560
12. *Borelis melo* (FICHTEL and MOLL), × 71, S. 1560
13. *Borelis melo* (FICHTEL and MOLL), × 65, S. 1560
14. *Borelis melo* (FICHTEL and MOLL), × 57, S. 1560
15. *Borelis melo* (FICHTEL and MOLL), × 68, S. 1350

Plate 4

1. *Nonion boueanum* (D'ORBIGNY), × 119, S. 3600
2. *Nonion boueanum* (D'ORBIGNY), × 192, S. 4660
3. *Nonion boueanum* (D'ORBIGNY), × 158, S. 4660
4. *Nonion boueanum* (D'ORBIGNY), × 106, S. 2200
5. *Nonion boueanum* (D'ORBIGNY), × 100, S. 2200
6. *Nonion boueanum* (D'ORBIGNY), × 123, S. 3800
7. *Lenticulina cultrata* (DE MONTFORT), × 114, S. 4260
8. *Marginulina obesa* (CUSHMAN), × 38, S. 4860
9. *Lenticulina rotulata* (LAMARCK), 122, S. 4820
10. *Lenticulina rotulata* (LAMARCK), × 77, S. 4660
11. *Lenticulina cultrata* (DE MONTFORT), × 130, S. 4260
12. *? Dentalina filiformis* (D'ORBIGNY), × 55, S. 4660
13. *Dentalina communis* (D'ORBIGNY), × 41, S. 4260
14. *Lenticulina rotulata* (LAMARCK), × 104, S. 4260
15. *Marginulina obesa* (CUSHMAN), × 36, S. 4820
16. *Nodosaria* cf. *raphanistrum* (LINNE'), × 95, S. 840
17. *Chrysalogonium obliquatum* (BATSCH), × 20, S. 4260
18. *Nodosaria raphanus* (LINNE') × 26, S. 1230
19. *Marginulina hirsuta* (D'ORBIGNY), × 50, S. 4820

Plate 5

1. *Cibicidoides subhaidingerii* (PARR), × 91, S. 3600
2. *Cibicidoides subhaidingerii* (PARR), × 104, S. 3600
3. *Cibicidoides subhaidingerii* (PARR), × 112, S. 3540
4. *Cibicidoides subhaidingerii* (PARR), × 132, S. 3600
5. *Cibicidoides subhaidingerii* (PARR), × 95, S. 3600
6. *Cibicidoides subhaidingerii* (PARR), × 141, S. 3600
7. *Cibicidoides subhaidingerii* (PARR), × 125, S. 4660
8. *Hanzawaia boueana* (D'ORBIGNY), × 210, S. 840
9. *Cibicidoides pseudoungerianus* (CUSHMAN), × 163, S. 840
10. *Megastomella purisima* (BRAMLETTE), × 64, S. 1260
11. *Megastomella purisima* (BRAMLETTE), × 33, S. 1560
12. *Megastomella purisima* (BRAMLETTE), × 40, S. 1350
13. *Cibicidoides dutemplei* (D'ORBIGNY), × 90, S. 3540

Plate 6

1. *Cibicidoides dutemplei* (D'ORBIGNY), × 142, S. 4260
2. *Cibicidoides dutemplei* (D'ORBIGNY), × 84, S. 4860
3. *Cibicidoides dutemplei* (D'ORBIGNY), × 135, S. 3600
4. *Cibicidoides dutemplei* (D'ORBIGNY), × 105, S. 4820
5. *Cibicidoides dutemplei* (D'ORBIGNY), × 142, S. 4860
6. *Cibicidoides dutemplei* (D'ORBIGNY), × 142, S. 4660
7. *Cibicidoides dutemplei* (D'ORBIGNY), × 142, S. 3600
8. *Planulina rugosa* (PHLEGER and PARKER), × 186, S. 3540
9. *Planulina rugosa* (PHLEGER and PARKER), × 108, S. 4260
10. *Planulina rugosa* (PHLEGER and PARKER), × 110, S. 4260
11. *Cibicides lobatulus* (WALKER and JACOB), × 137, S. 4820
12. *Cibicidoides ungerianus* (D'ORBIGNY), × 80, S. 3600
13. *Cibicidoides ungerianus* (D'ORBIGNY), × 137, S. 3600

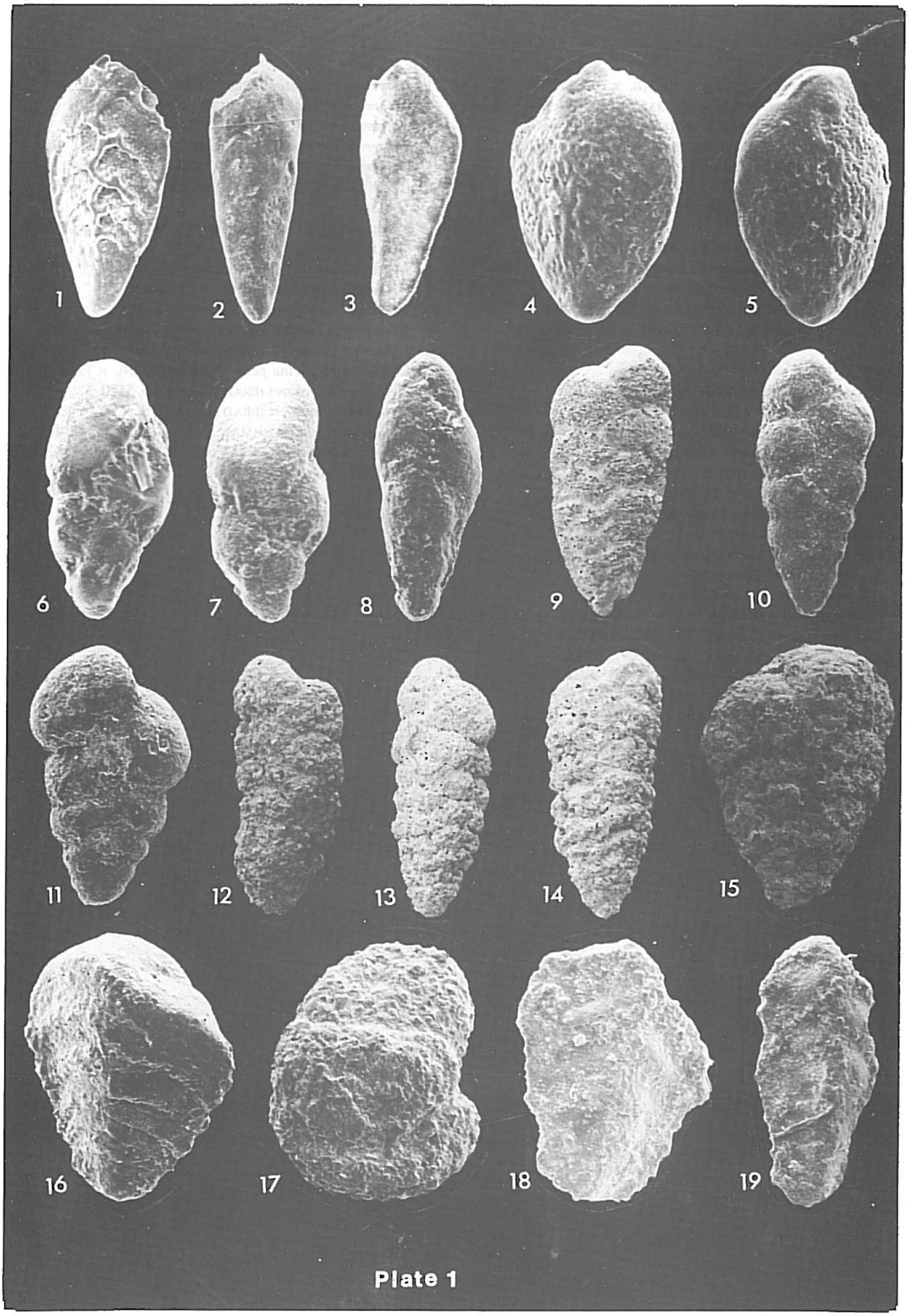

Plate 1

Plate 7

1. *Ammonia beccarii tepida* (CUSHMAN), ×202, S. 2740
2. *Ammonia beccarii tepida* (CUSHMAN), ×195, S. 3540
3. *Ammonia beccarii tepida* (CUSHMAN), ×208, S. 4660
4. *Ammonia beccarii tepida* (CUSHMAN), ×181, S. 4660
5. *Ammonia beccarii tepida* (CUSHMAN), ×75, S. 4260
6. *Ammonia beccarii tepida* (CUSHMAN), ×65, S. 1350
7. *Ammonia beccarii parkinsoniana* (D'ORBIGNY), ×166, S. 3800
8. *Ammonia beccarii tepida* (CUSHMAN), ×142, S. 3520
9. *Ammonia beccarii beccarii* (LINNE), ×56, S. 3800
10. *Gyroidina altiformis* (CUSHMAN), ×184, S. 4900
11. *Gyroidina* cf. *soldanii* (D'ORBIGNY), ×62, S. 4660
12. *Melonis barleeanum* (WILLIAMSON), ×70, S. 4660

Plate 8

1. *Uvigerina acuminata* (HOSIUS), ×82, S. 4820
2. *Uvigerina acuminata* (HOSIUS), ×91, S. 4820
3. *Uvigerina rutila* (CUSHMAN and TODD), ×113, S. 3600
4. *Uvigerina pygmaea* (D'ORBIGNY), ×120, S. 3520
5. *Uvigerina pygmaea* (D'ORBIGNY), ×108, S. 4820
6. *Uvigerina hispida* (SCHWAGER), ×108, S. 4260
7. *Uvigerina bononiensis* (FORNASINI), ×97, S. 840
8. *Bulimina aculeata* (D'ORBIGNY), ×133, S. 3600
9. *Bulimina aculeata* (D'ORBIGNY), ×183, S. 4660
10. *Bulimina costata* (D'ORBIGNY), ×108, S. 4820
11. *Bulimina costata* (D'ORBIGNY), ×88, S. 4660
12. *Bulimina costata* (D'ORBIGNY), ×88, S. 4860
13. *Bulimina costata* (D'ORBIGNY), ×128, S. 4660
14. *Bulimina costata* (D'ORBIGNY), ×100, S. 4260
15. *Bulimina costata* (D'ORBIGNY), ×100, S. 4660
16. *Bulimina costata* (D'ORBIGNY), ×110, S. 3540.
17. *Bulimina costata* (D'ORBIGNY), ×152, S. 3520

Plate 9

1. *Uvigerina striatissima* (PERCONIG), ×91, S. 3600.
2. *Uvigerina striatissima* (PERCONIG), ×91, S. 4660.
3. *Uvigerina striatissima* (PERCONIG), ×76, S. 3540.
4. *Uvigerina striatissima* (PERCONIG), ×99, S. 3600.
5. *Uvigerina bononiensis* (FORNASINI), ×116, S. 4660.
6. Detail of wall surface of specimen illustrated in fig. 2, ×483.
7. More detail of wall surface of the same specimen illustrated in fig. 2, ×950.
8. Apertural view of same specimen, ×200.
9. *Uvigerina flinti* (CUSHMAN), ×83, S. 3600.
10. *Uvigerina flinti* (CUSHMAN), ×97. S. 3600.
11. *Uvigerina schwageri* (BRADY), ×97, S. 4660.
12. *Uvigerina peregrina peregrina* (CUSHMAN), ×95, S. 840.
13. *Uvigerina peregrina peregrina* (CUSHMAN), ×79, S. 840.
14. *Uvigerina schwageri* (BRADY), ×162, S. 3520.
15. *Uvigerina schwageri* (BRADY), ×186, S. 3520.
16. *Uvigerina rutila* (CUSHMAN and TODD), ×108, S. 4660.
17. *Uvigerina rutila* (CUSHMAN and TODD), ×125, S. 4260.

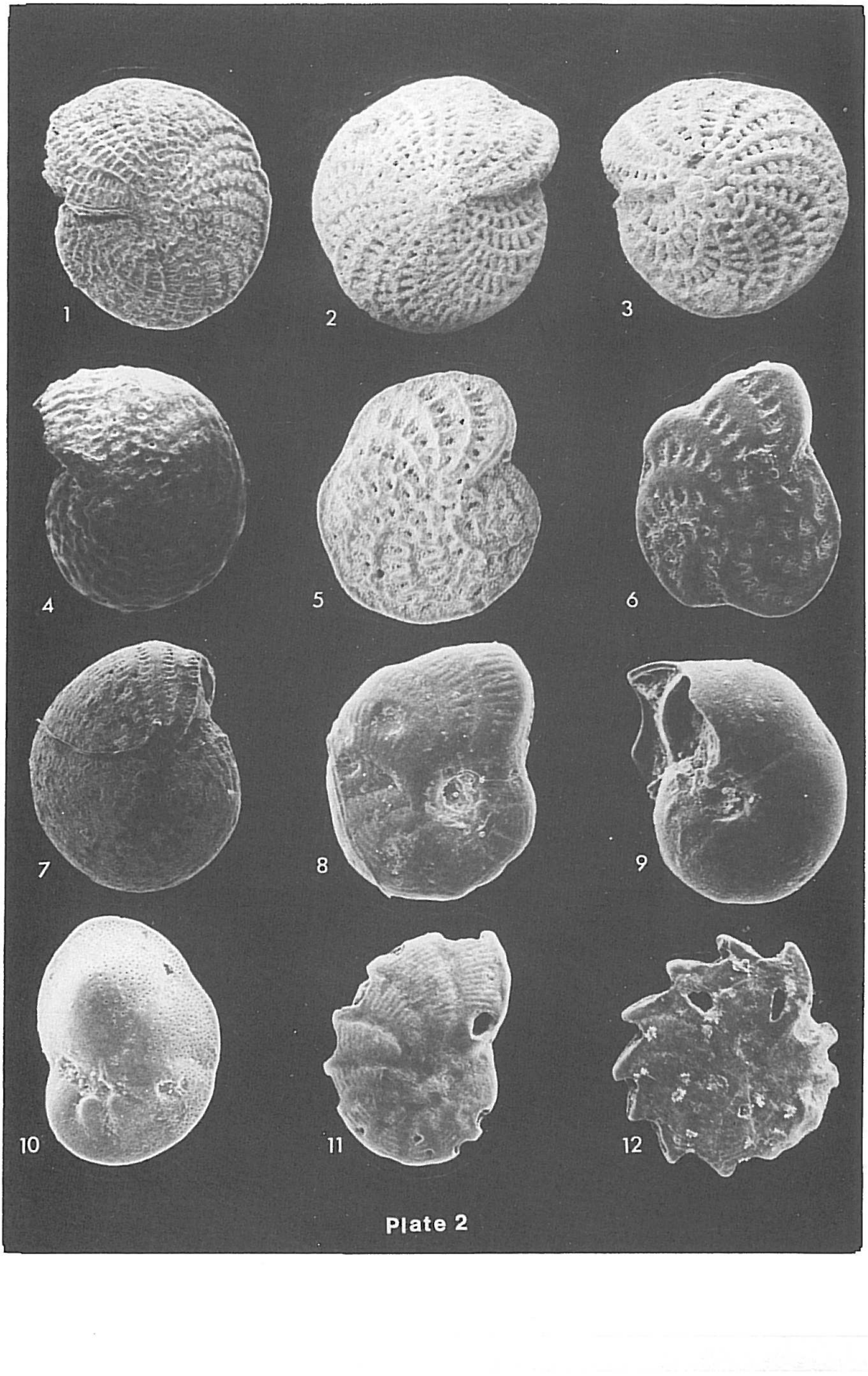

Plate 2

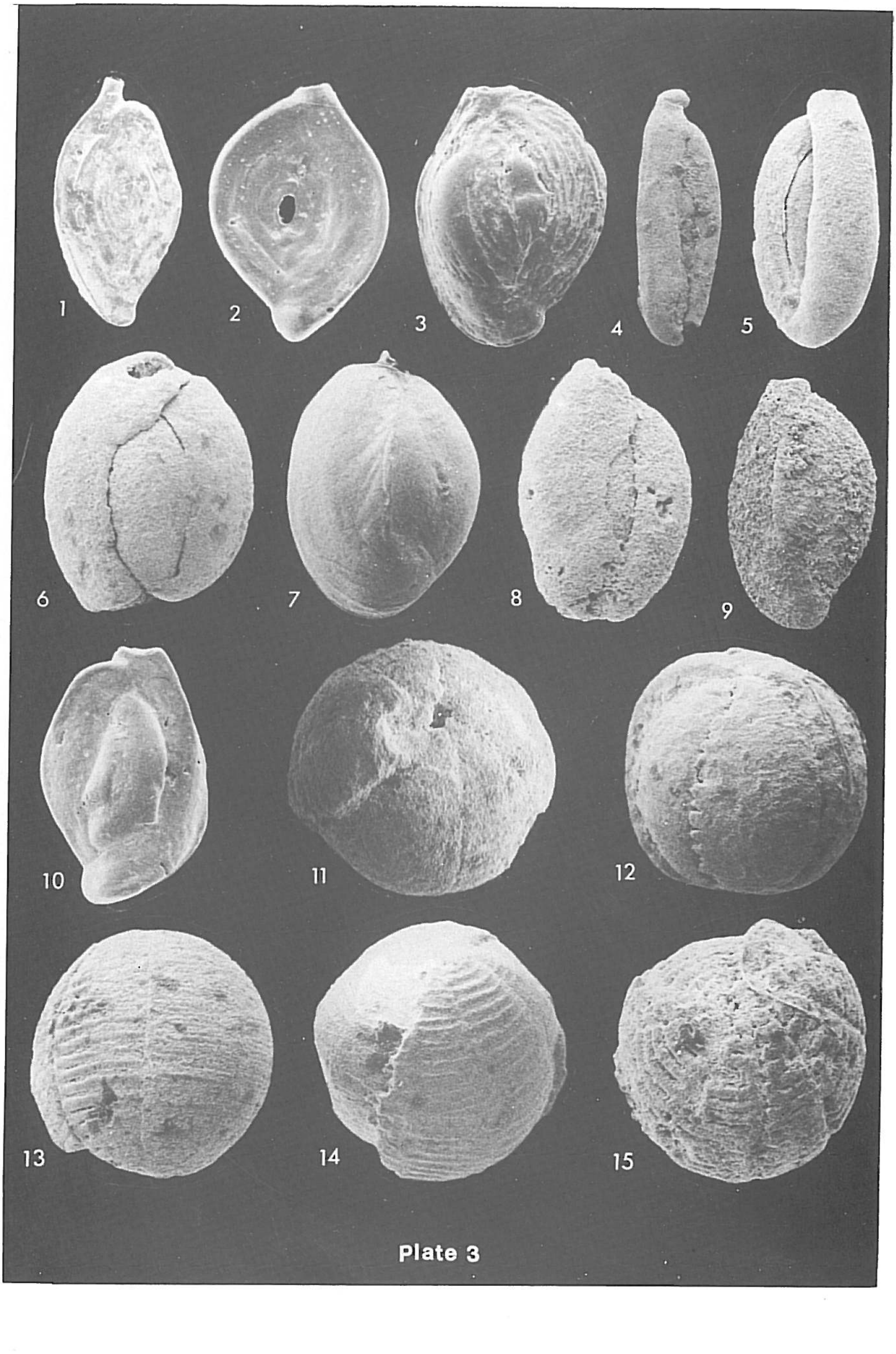

Plate 3

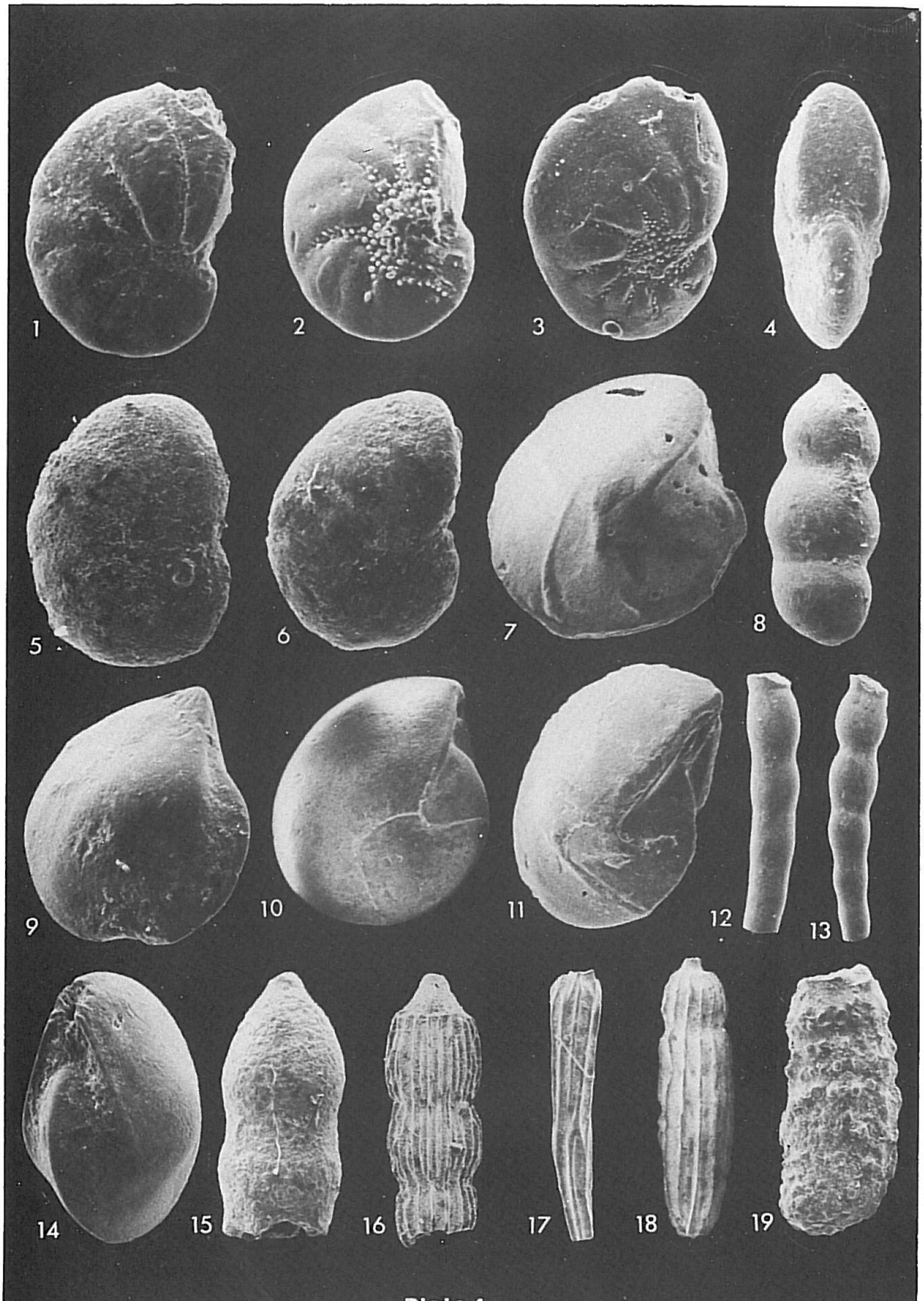

Plate 4

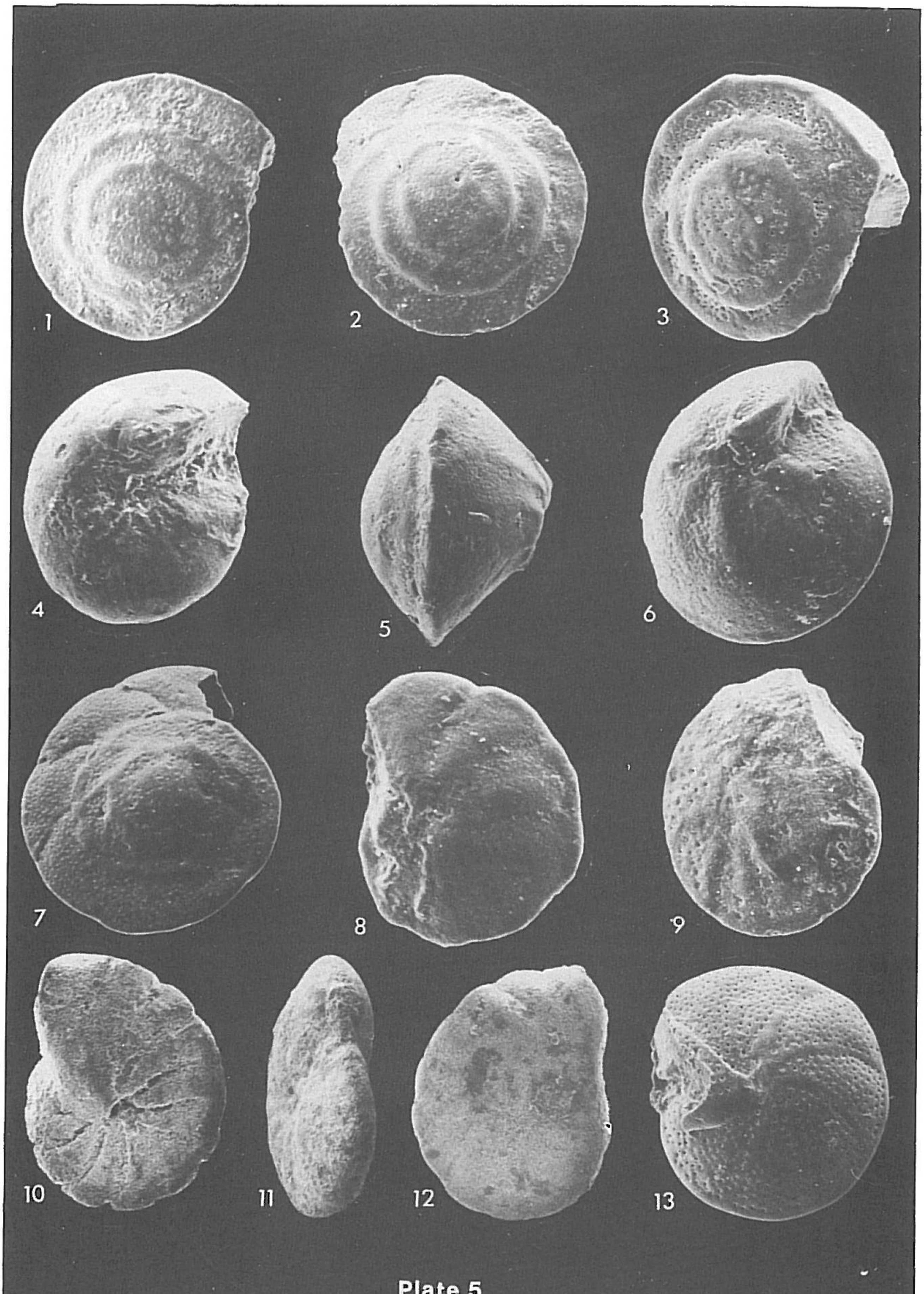

Plate 5

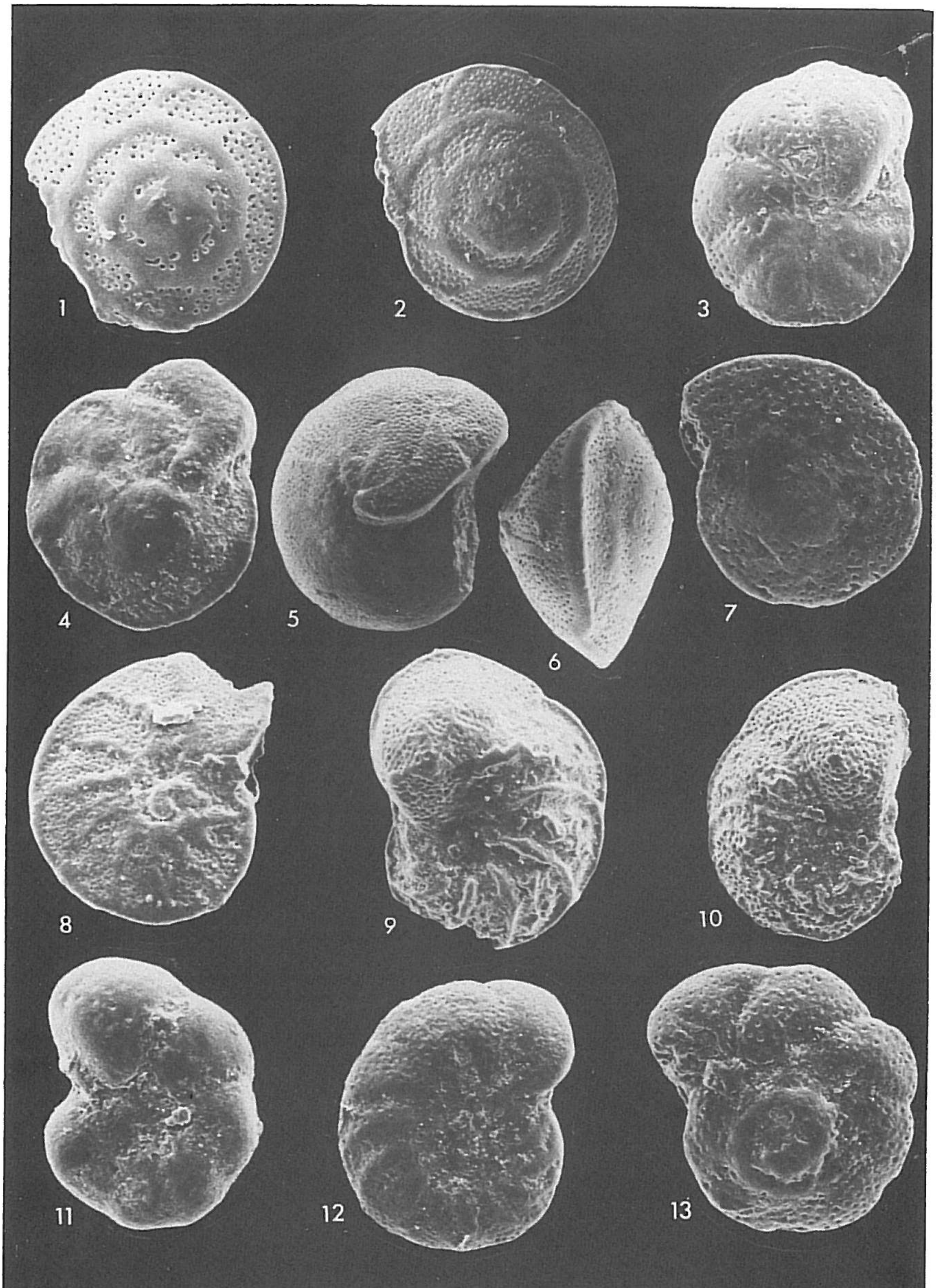

Plate 6

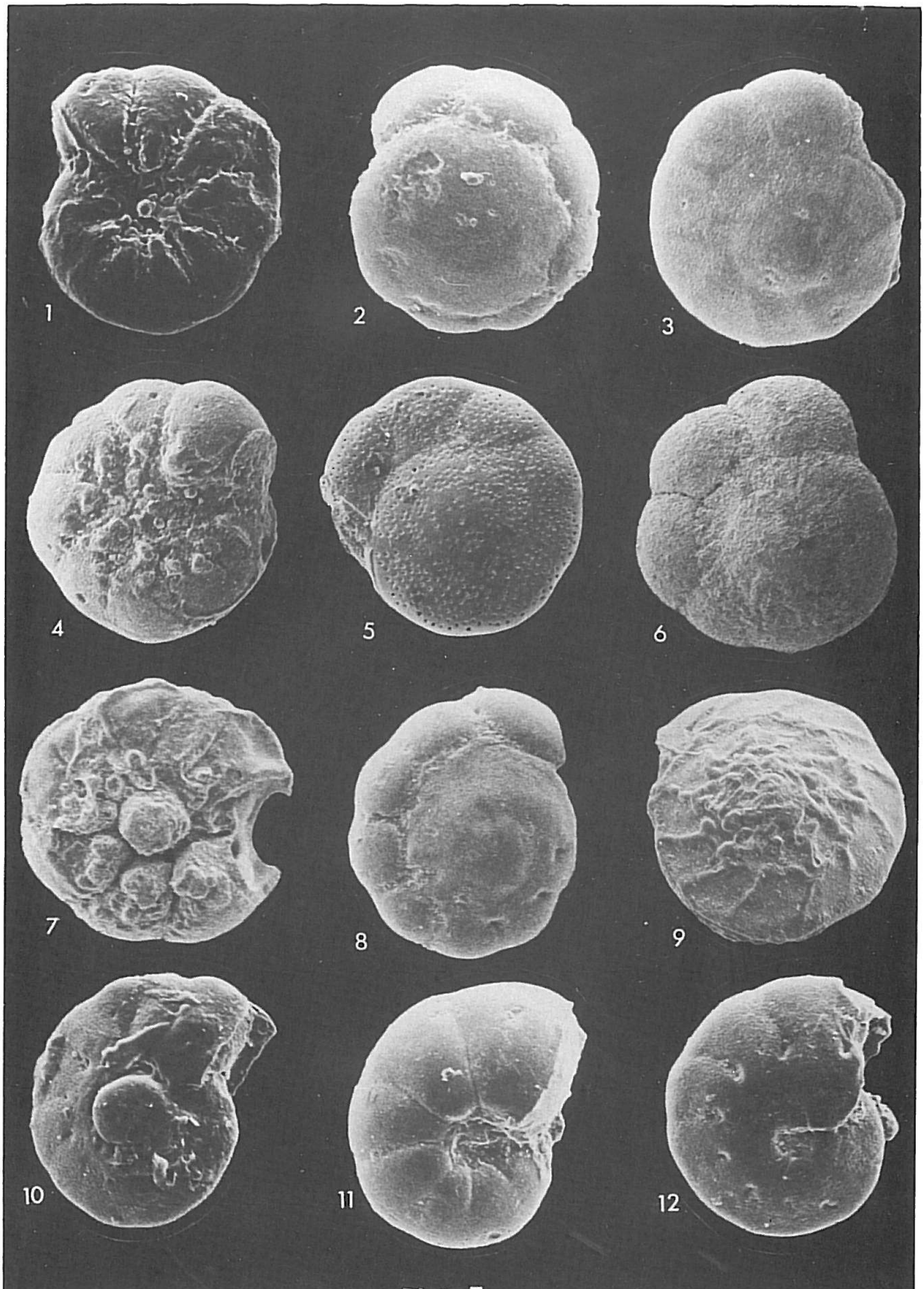

Plate 7

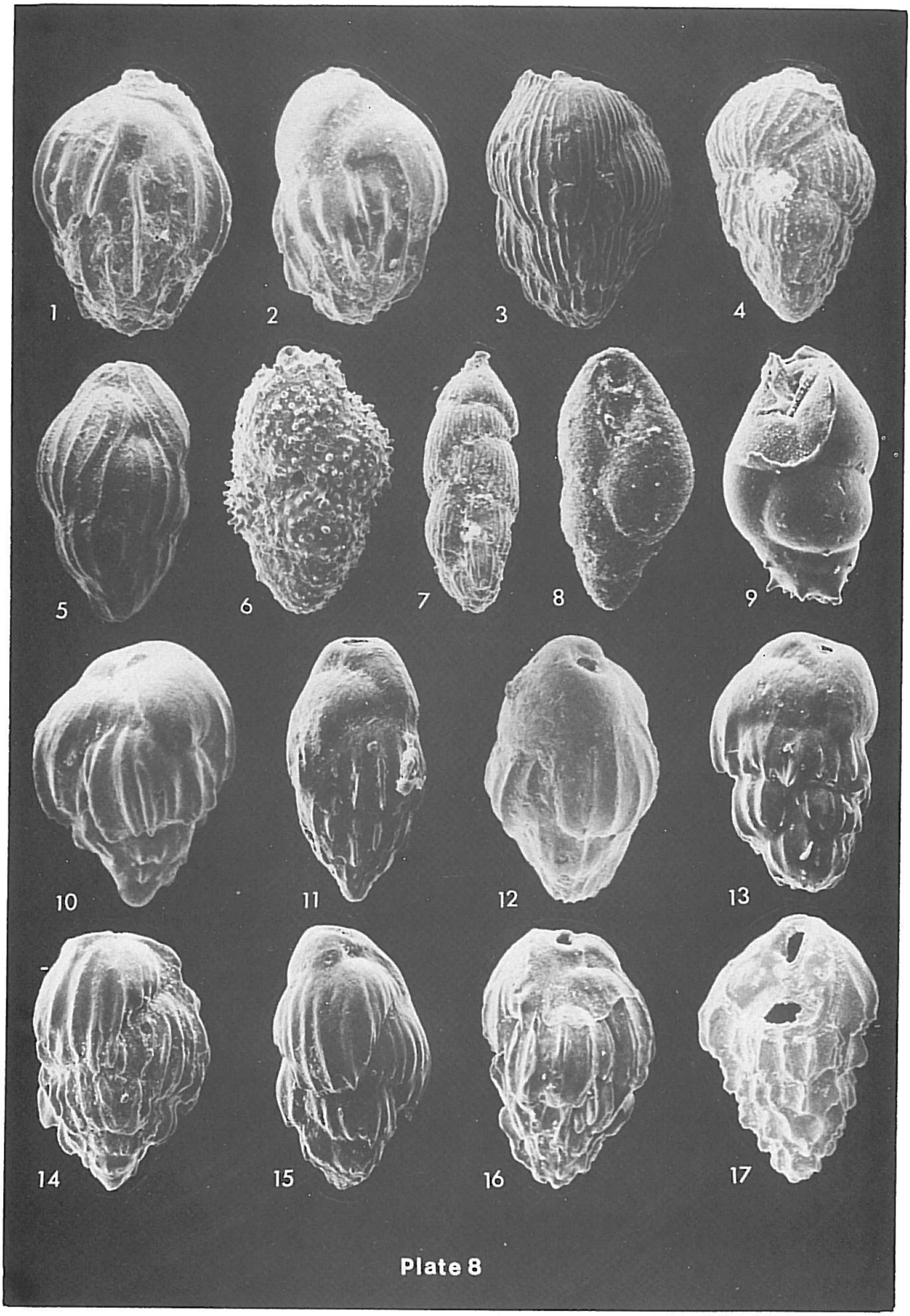

Plate 8

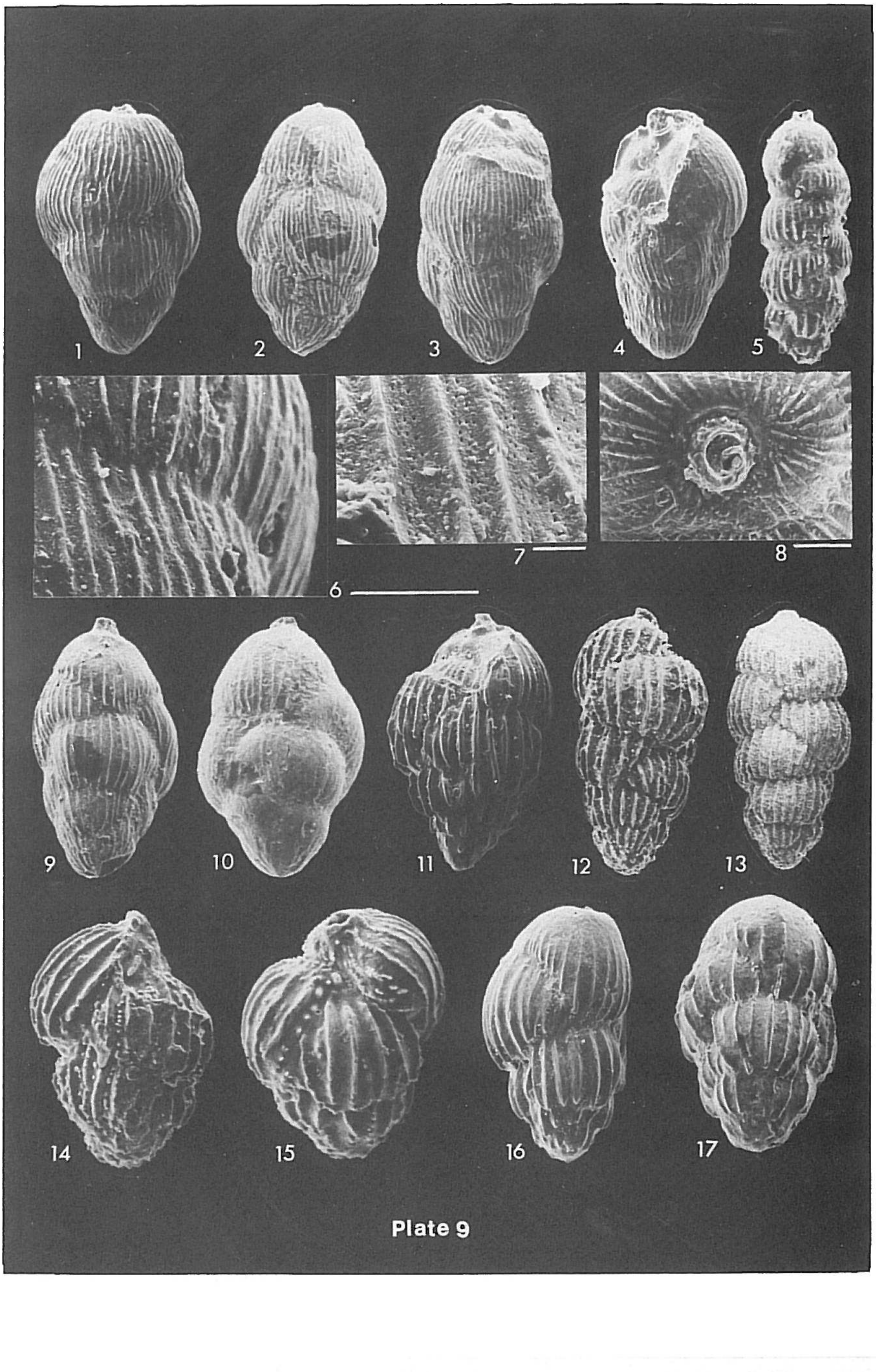

Plate 9

REFERENCES

Agib Mineraria, 1957, Foraminifera Padani (Terziario e Quaternario), Atlante 1 conografico e Distribuzione stratigrafica. *Agib Mineraria*, Milano 1957, 52 pls, 1st. Edition.

Agib Mineraria, 1980, Foraminifera Padani (Terziario e Quaternario), Atlante 1 congrafico e distribuzione stratigrafica. *IBID*, 68 pls, 2nd Edition.

Bandy, O.L., 1964, Cenezoic planktonic foraminiferal zonation. *Micropal.*, **10**, **1**, 1–17, 6 text-figs., 1 table.

Belanger, P.E. and Berggren, W.A., 1986, Neogene benthic Foraminifera of the Hatton – Rockall Basin. *Micropal.* **32**, **4**, 324–356, pls. 1–7, 6 text-figs, 3 append.

Blow, W.H., 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: P. Bronnimann and H.H. Renz (Eds.), *Proceed. 1st. Int. Conf. Plankt. Microfoss.*, Leiden: E.J. Brill, **I**, 199–422, 54 pls., 43 figs.

Blow, W.H., 1979, *The Cainozoic Globigerinida*. Leiden: E.J. Brill, 3 vols. 1413 p., 264 pls., 65 figs.

Bolli, H.M. and Saunders, J.B., 1985, Oligocene to Holocene low latitude planktonic Foraminifera. In: H.M. Bolli, J.B. Saunders and K. Perch-Nielson (Eds.) and K.E. Fancett (Assist.), *Plankton Stratigraphy, Planktonic Foraminifera, Calcareous Nannofossis and Calpionellids.* Cambridge Earth SC. Ser., Cambridge Univ. Press, Cambridge, U.K., **I**, 155–262, 46 figs.

Boltovsky, E., 1969, Living Planktonic Foraminifera at the 90° E miridian from the equator to the antarctic. *Micropal*, **15**, **2**, 237–255, pls. 1–3, 4 text-figures.

Boltovsky, E.,1980, On the benthonic bathyal-zone Foraminifera as stratigraphic guide fossils. *J. Foram. Res.* **101**, **3**, 163–172, pls. 1–4.

Borsetti, A.M., Iaccarino, S., Jorissen, F.J., Poignont, A., Sztrakos, K., Van der Zwann, G.J. and Verhallen, P.J.J., M., 1986, The Neogene development of *Uvigerina* in the Mediterranean. In: Atlantic-European Oligocene-Recent *Uvigerina*, taxonomy, paleoecology and paleobiogeographyy. *Utrecht Micropal.* Bull. **35**, 183–235, 19 pls, 1 figure.

Brolsma, M.J., 1978, Quantitative forminiferal analysis and environmental interpretation of the Pliocene and topmost Miocene on the south coast of Sicily. Int. Geol. Correl. Project No. 1. *Utrecht Micropal. Bull.* **18**, 159, 8 pls., 50 figs.

Brun, L., Chierici, M.A., Meijer, M. and Monteil, L., 1984, Stratigraphic and paleoecological distribution of some diagnostic species of Bolivinitidae (Foraminifera) from the Tertiary of the Gulf of Guinea. *Benthonics '83, 2nd International Symp. Benthic Foraminifera (Pau, Apri 1983)*, 91–104, 5 figs., 2 pls.

Cassell, D.T. and Sen Gupta, B.K., 1989, Foraminiferal stratigraphy and paleoenvironments of the Tertiary Uscari Formation, Limon Basin, Costa Rica. *J. Foram. Res.* **19**, **1**, 52–71, 7 text-figs., 1 table, 8 pls.

Costa, V. and Fandi, A., 1977, N.O.C. composite well log: D_2/NC41. *N.O.C.* Tripoli, Libya, Encl. no. 1.

Eliagoubi, B.A.H., 1972, *Vindobonian (Miocene) Foraminifera from the Faidia Formation, Umm Errzem region, northeastern* Libya. M. Sc. Thesis, University of Idaho Graduate School, April 1972, 107 pp., 2 pls., 9 figs., 3 tables.

Eliagoubi, B.A. H., 1986, Upper Cretaceous – Lower Tertiary planktonic Foraminifera from the northwestern Libyan offshore. *J. Afric. Earth Sc.* **5**, **4**, 423–440, 9 pls., 3 figs., (Pergamon).

Hageman, J., 1979, Benthonic foraminiferal assemblages from Plio-Pleistocene open bay to lagoonal sediments of the western Peloponnesus (Greece). *Utrecht Micropal.* Bull. **20**, 171 pp., 10 pls., 28 figs.

Hammuda, O.S.,, Sbeta, A.M., Mouzughi, A.J. and Eliagoubi, B.A., 1985, *Stratigraphic Nomenclature of the Northwestern Offshore of Libya.* Earth SC. Soc. Libya, Tarabulus, Libya 166 pp.

Hammuda, O.S., Van Hinte, J.E. and Nederbracht, S., 1991, Geohistory analysis mapping in central and southern Tarabulus Basin, northwestern offshore. In: M.J. Salem, O.S. Hammuda and B.A. Eliagoubi (Eds.), *The Geology of Libya.* Amsterdam, Elsevier, **IV**, pp. 1657–1680, 13 figs.

Haynes, J. R., 1981, *Foraminifera.* Macmillan Publishers Ltd. (G.B.). John Wiley and Sons, Ins. New York (Halsted Press), 433 p., 15 plates, 94 text-figs.

Iaccarino, S., 1985, Mediterranean Miocene and Pliocene Planktonic Foraminifera. In: H.M. Bolli, J.B. Saunders, and K. Perch-Nielsen (Eds.) and K.E. Fancett (Assist.) *Plankton Stratigraphy, Planktonic Foraminifera, Calcareous Nannofossils.* Cambridge Earth Sc. Ser. Cambr. Univ. Press, Cambridge, **I**, 283–314, 6 figs.

Jenkins, D.G., 1985, Southern mid-latitude Paleocene to Holocene Planktonic Foraminifera, In: H.M. Bolli, J.B. Saunders and K. Perch-Nielsen (Eds.) and E. Karin (Assist.), *Plankton Stratigraphy, Planktonic Foraminifera, Calcareous Nannofossils and Calpionellids.* Cambridge Earth Sc. Ser. Camb. Univ. Press, Cambridge, **I**, 263–282, 7 tex-figs.

Jongsma, D., Van Hinte, J.E. and Woodside, J.M., 1985, Geologic structure and neotectonics of the North African continental margin south of Sicily. *Marine Petrol. Geol.* **2**, 156–179, figs. 1–17.

Kassab, I.I.M.,Abusrewil, A.K. and Abuhmida, F.E., 1995, Biostratigraphy of the Oligocene-Miocene of subsurface offshore northwestern Libya typified by well H1/NC41. *Unpub. Rep. Pet. Res. Cent.* (N.O.C.), Tripoli, Libya.

Kennett, J.P. and Srinivasan, M.S., 1983, Neogene Planktonic Foraminifera, a Phylogenetic Atlas. Hutchinson Ross Pub. 256 p., 61 pls., 26 text-figures, 1 table.

Loeblich, A.R., Jr., and Tappan, H., 1964, Sarcodina chiefly "Thecamoebians" and Foraminiferida, in R.C. Moore (Ed.) *Treatise on Invertebrate Paleontology, Part C, Portista* **2**, Lawrence: *Geol. Soc. Am. and* Univ. Kan. Press, 900 p., 650 figs.

Loeblich, A.R., Jr., and Tappan, H., 1988, *Foraminiferal genera and their classification.* Van Nostrand Reinhold Pub. New York, U.S.A., **1**, 970 p., **2**, 212 p., 847 plates.

Mazzola, G., 1976, *Atlas of Tertiary Benthonic Microforaminifera from Sirte Basin (Libya).* Agip NAME, Libyan Branch, Tripoli, 18 pls., 1 range chart.

McLaughlin, P.P., Jr., 1989, Neogene planktonic foraminiferal biostratigraphy of the southwestern Dominican Republic. *J. Foram. Res.* **19**, **4**, 294–310, pl. 1–3, 6 figures, 3 tables.

Miller, K.G. and Katz, M.E., 1987, Oligocene to Miocene benthic-foraminiferal and abyssal circulation changes in the North Atlantic. *Micropal.* **33**, **2**, 97–149, pls. 1–13.

Morkhoven, F.P.C.M. van, Berggren, W.A. and Edwards, A.S., 1986, Cenozoic cosmopolitan deep-water benthic Foraminifera. *Bull. Centres Rech. Explor. Prod. Elf-Aquitaine*, **11**, Pau. 4211 p., 126 pls, 8 text-figs.

Salem, M.J. and Spreng, A.C., 1980, Middle Miocene stratigraphy, Al Khums area, northwestern Libya. In: M.J. Salem and M.T. Busrewil (Eds.), *The Geology of Libya*, London, Academic Press, **I**, 97–116, 20 figs.

Sejrup, H.-P., Fiaeran, T., Hold, M., Beck, L., Hagn, J.M., Miljeteig, I., Morvik, I. and Norvik, O., 1981, Benthonic Foraminifera in surface sample from the Norwegian continental margin between 62° N and 62° N. *J. Foram. Res.* **11**, **4**, 277–295, pls. 1–2, 24 text-figs.

Sherif, Kh. A.T., 1991, Biostratigraphy in Al Khums area, northwestern Libya. In: M.J. Salem, O.S. Hammuda, and B.A. Eliagoubi (Eds.), *The Geology of Libya*, Elsevier, **IV** 1421–1456, pls. 1–7, 23 figs.

Smith, F.D., Jr., 1955, Planktonic Foraminifera as indicators of depositional environments. *Micropal.* **1**, **2**, 147–151, 2 text-figures.

Souaya, F.J., 1963, Micropaleontology of four sections south of Qoseir, Egypt. *Micropal.* **9**, **3**, 233–266, pls. 1–8, 3 test-figs.

Souaya, F.J., 1965, Miocene Foraminifera of the Gulf of Suez region, U.A.R. part 1 – Systematics (Astrorhizoidea – Buliminoidea). *Micropal.* 11, no. 3, 301–334, pls. 1–3, 2 text-figs.

Stainforth, R.M., Lamb, J.L., Luterbacher, H., Beard, J.H. and Jeffords, R.M., 1975, Cenozoic planktonic foraminiferal zonation and characteristics of index forms. *Univ. Kansas Paleont. Contributions*, **Article 62**, *Lawrence, Kansas*, pp. 1–425, fig. 1–213, tables 1–9.

Thomas, E.,, 1980, Details of *Uvigerina* development in the Cretan Mio-Pliocene. Int. *Geol. Correl. Project no. 1. Utrecht Micropal. Bull.* **23**, 168 p., 5 pls., 65 figs.

Van der Zwaan, G.J., 1982, Paleoecology of Late Miocene Mediterranean Foraminifera. *Utrecht Micropal. Bull.* **25**, 202 pp., 15 pls., 65 figs.

Van der Zwaan, G.J., Jorissen, F.J., Verhallen, P.J.J.M. and Van Daniels, C.H., 1986, *Uvigerina* from the eastern Atlantic, North Sea Basin, Paratethys and Mediterranean. In: G.J. Van der Zwann, F.J. Jorissen, P.J.J.M. Verhallen and C.H. Van Daniels (Eds.), *Atlantic-European Oligiocene-Recent Uvigerina. Utrecht Micropal. Bull.* **35**, 1986, pp. 7–20, 5 text-figs.

Van Hinte, J.E. Colin, J.P. and Lehmann, R., 1980, Micropaleontologic record of the Messinain Event at Esso Libya Inc. Well B1-NC 35A on the Pelagian Platform. In: M.J. Salem and M.T. Busrewil (Eds), *The Geology of Libya.* London, Academic Press, **I**, 205–243, pls. 1–13, 8 figs.

Walton, W.R. and Sloan, B.J., 1990, The genus *Ammonia* BRUNNICH, 1772, Its geographic distribution and morphologic variability. *J. Foram. Res.* 1990, **20**, **2**, 128–156, pls. 1–4, 7 figs.