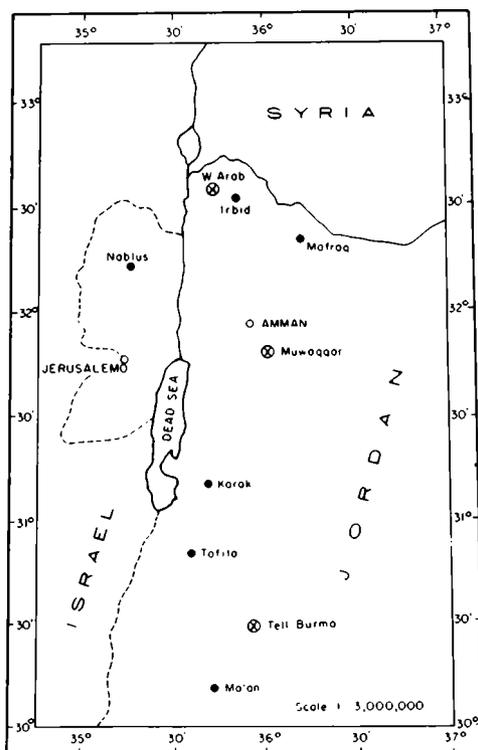


LATE MESOZOIC AND EARLY CAINOZOIC BENTHIC FORAMINIFERA FROM JORDAN

by A. I. FUTYAN

ABSTRACT. Foraminiferal faunas from the Late Mesozoic–Early Cainozoic succession in three widely separated surface sections in Jordan are studied in detail. The benthic and planktic foraminifera have been used to interpret the stratigraphy. The Mesozoic–Cainozoic boundary is marked by distinct lithological and microfaunal changes; there is also a hiatus between the Middle and Late Paleocene. Thirteen new species and one subspecies are described and illustrated.

RESEARCH into the biostratigraphy of the Late Cretaceous (Maastrichtian) and Early Cainozoic (Paleocene and Early Eocene) succession in East Jordan, has resulted in the description and illustration of thirteen species and one subspecies of foraminiferid considered new. The material studied was collected from three surface sections in northern, central, and southern Jordan; at Wadi Arab, Muwaqqar, and Tell Burma respectively (text-fig. 1). The sections and the relative sample



TEXT-FIG. 1. Location map.

positions are indicated in text-fig. 2. The planktic foraminiferal generic names used are those of Bolli (1957), El-Naggar (1966), and Loeblich and Tappan (1957). New names introduced by Loeblich and Tappan (1964) are regarded here as of sub-generic importance and not used.

BIOSTRATIGRAPHY

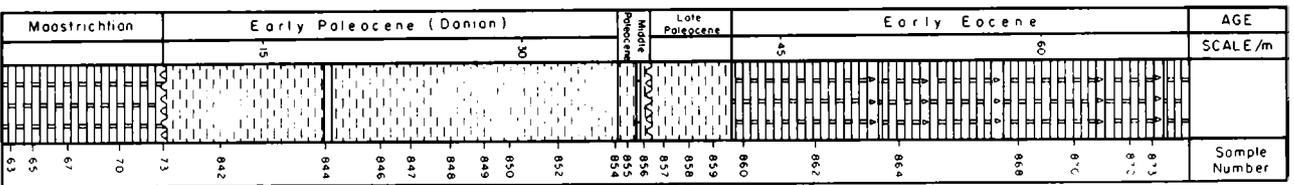
This study is based on samples from three previously undescribed widely separated, stratigraphic surface sections of Late Cretaceous–Early Cainozoic age in Jordan. Two hundred and twenty-seven species and subspecies of benthic and planktic foraminifera were recorded and used to establish the stratigraphy. The Cretaceous–Paleocene boundary is an unconformity in all three sections and is marked by a distinct lithological and microfaunal break.

In the Tell Burma section early Middle Paleocene is overlain unconformably by the Late Paleocene. In the Muwaqqar section 4 m of Late Paleocene marls rest directly on Late Maastrichtian chalks and marls while at Wadi Arab Late Paleocene shales overlie Early Paleocene marls. Several benthic species, including *Neoflabellina rugosa leptodisca* (Wedekind), *Praebulimina carseyae* (Plummer), *Spiroplectammina knebeli* LeRoy, *Vaginulina cretacea* Plummer, and the planktics *Globotruncana gansseri* Bolli, and *G. lugeoni* Bolli, disappear above sample 68 in Tell Burma, 141 in Wadi Arab, and 3 in the Muwaqqar section (text-fig. 2). Several other species such as *Gavelinopsis baylissi* sp. nov., *Hopkinsina arabina* sp. nov., and *Vaginulinopsis directa* (Cushman) first appear in the samples above accompanied by a sudden abundance of *Globotruncana esnehensis* Nakkady and *G. stuartiformis* Pessagno. This characteristic fauna enables two subzones to be established. These represent the Middle and Late Maastrichtian in the three sections. Both the Middle Maastrichtian benthic and planktic assemblages include species which occur in the Middle Maastrichtian Cr3c Zone in the Netherlands and Belgium and the Middle Maastrichtian *G. gansseri* Zone in Egypt (El-Naggar 1966) and Trinidad (Bolli 1959, 1966). The appearance of several new species in the sequence overlying the Middle Maastrichtian, their very short ranges, and the relative abundance of *G. esnehensis* Nakkady, which characterizes the Late Maastrichtian in Egypt (El-Naggar 1966), indicates that this part of the section at all three localities is of Late Maastrichtian age. The interval comprising samples 842–847 at Tell Burma is considered to be Middle Danian on the following evidence:

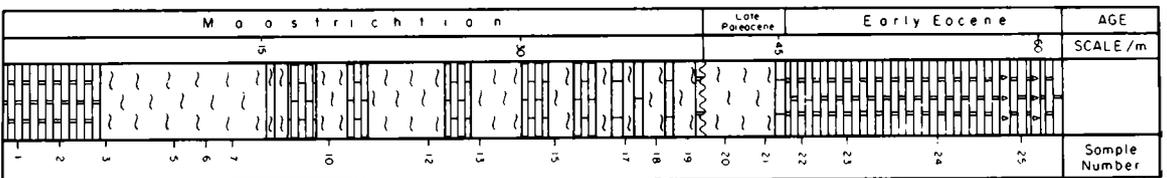
1. Certain species described by Pozaryska (1965) from the Middle Danian, Bryozoan limestone of Stevns Klint and from zones II and III of Wind, Danske Kalk of Denmark (Hofker 1966), are present, these include the benthics *Allomorphina paleocenica* Cushman, *Anomalinoidea acuta* (Plummer), *A. danicus* Brotzen, *Guttulina problema* d'Orbigny, *Karrerella fallax* Rzehak, and *Lenticulina spissocostata* (Cushman) and the two planktic species *Globigerina trilocolinoides* Plummer and *Globorotalia pseudobulloides* (Plummer).

2. *Globigerina daubjergensis* Brönnimann and *Globorotalia compressa* (Plummer) which, according to Troelsen (1957), occur abundantly in the highest type Danian, are very rare or absent at Tell Burma.

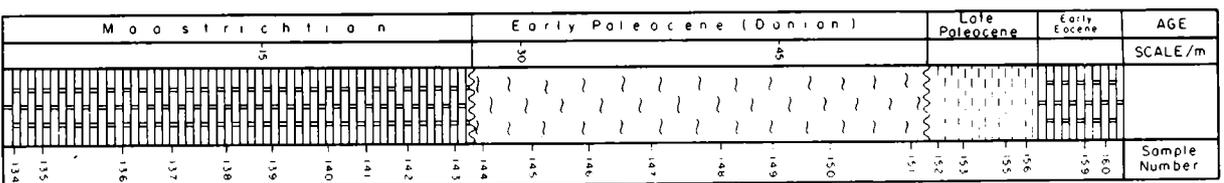
TELL BURMA



MUWAQQAR



WADI ARAB



TEXT-FIG. 2. Lithological logs and sample locations.

3. Type Danian foraminifera include species such as *Alabamina midwayensis* Brotzen, *Chiloguembelina morsei* Kline, *Loxostomoides applinae* (Plummer), and *Pulsiphonina prima* (Plummer) which occur in the upper part of the Danian sequence, Hofker (1966), Pozaryska (1965). They do not appear in the Tell Burma section below sample 848.

At Tell Burma the interval from sample 848 to 854 and from 144 to 151 in the Wadi Arab section are considered Late Danian in age because several species characteristic of the Late Danian elsewhere, are abundant. These are *Gavelinella limbata* Olsson, *Globigerina daubjergensis* Brönnimann, *Globorotalia compressa* (Plummer), and *Globigerina trinidadensis* Bolli.

At Tell Burma the Late Danian is overlain by strata containing acute-margined globorotalids, in particular *Globorotalia angulata* (White) and *G. uncinata* Bolli. These planktics are accompanied by the following benthics *Chilostomella czjzeki* Reuss, *Gyroidinoides girardana* (Reuss), *G. globosa* (Hagenow), *Lenticulina alabamensis* (Cushman), *L. punctata* (Rzehak), *Martinottiella alabamensis* (Cushman), *Nodosaria robinsoni* sp. nov., and *Siphogenerinoides*. A correlation can be made based on this fauna between this part of the section and the Middle Paleocene *Globorotalia uncinata* Zone of Bolli (1957, 1959, 1966), the Egyptian *G. uncinata* Subzone of El-Naggar (1966), and the lower part of the *Globigerina* and keeled *Globorotalia* Zone of Reiss (1955), Israel.

The Late Paleocene is present in the three sections studied and shows a pronounced faunal change from the underlying Danian or Middle Paleocene. The following diagnostic planktic species were recorded: *Globigerina velascoensis* Cushman, *Globorotalia acuta* Toulmin, *G. aequa* Cushman and Renz, *G. velascoensis* (Cushman), *Alabamina floscellus* (Schwager), *Bulimina serratospina* Finlay, *Clavulina parisiensis* d'Orbigny, *Eouvigerina zealandica* (Finlay), *Pseudonodosaria laevigata* (d'Orbigny), and *Reussella pseudocacumenata* Olsson. These species indicate that the sections can be correlated with the Late Paleocene, *Globorotalia velascoensis* Zone of Bolli (1957, 1959, 1966) and the *G. acuta/G. aequa* Zone of Berggren (1963, 1965), Bolli and Cita (1960), El-Naggar (1966), and Olsson (1960).

The Paleocene in the sections is quite distinct both lithologically and faunally from the overlying Early Eocene. Most of the Paleocene species become extinct before the Early Eocene. The Paleocene-Early Eocene boundary has been drawn at the top of the *G. velascoensis* Zone (*G. acuta* Subzone/*G. aequa*) Berggren (1965), Bolli (1957, 1959, 1966), Bolli and Cita (1960), El-Naggar (1966), and Loeblich and Tappan (1957). This is supported by:

1. The complete extinction of certain genera such as *Neoflabellina*, which is known from the Late Cretaceous and Paleocene only.
2. The first appearance of several species known to characterize the Eocene in several parts of the world, e.g. *Clavulinoides triquetra* (Reuss), *Hanzawaia cushmani* (Nuttall), *Lenticulina incisus* (Lys), and *Rectobolivina nuttalli* (Cushman and Siegfus).
3. The first appearance of several Early Eocene planktic species recorded from North America, Europe, and the Middle East, such as *Globigerina soldadoensis* Brönnimann, *Globorotalia formosa gracilis* Bolli, *G. rex* Martin, and *G. wilcoxensis* Cushman and Ponton.

TABLE 1. Stratigraphical distribution of selected benthic foraminiferal species in the Maastrichtian-Early Eocene strata in East Jordan.

Benthic Foraminifera	Maastrichtian		Paleocene		Eocene	
	Middle	Late	Early	Middle	Late	Early
<i>Spiroplectammina knebeli</i> LeRoy		x x x x				
<i>Vaginulina cretacea</i> Plummer	x x x x x					
<i>Neoflabellina leptodisca</i> (Wedekind)		x x x				
<i>Vaginulina silicula</i> Plummer	x x x x x x					
<i>Neoflabellina reticulata deltoidea</i> (Marsson)	x x x x x x x x					
<i>Siphogenerinoides oveyi</i> Nakkady						
<i>Reussella aegyptiaca</i> Nakkady	x x x x x x x x x x					
<i>Bolivina incrassata</i> Reuss	x x x x x x x x x x					
<i>Gyroidinoides tellburmaensis</i> sp. nov.		x x x x x x x x x x				
<i>Hopkinsina arabina</i> sp. nov.			x x x x x x			
<i>Gavelinopsis baylissi</i> sp. nov.			x x x x x			
<i>Alabama wilcoxensis limbata</i> (Plummer)						
<i>Cibicidoides felix</i> (Martin)						
<i>Angulogavelinella bandata</i> sp. nov.						
<i>Clavulina barnardi</i> sp. nov.				x x x x		
<i>Marginulinopsis eoacaenicus</i> (Franke)				x x x x x		
<i>Fronicularia midwayensis</i> Cushman				x x x x		
<i>Valvulinera duwi</i> (Nakkady)				x x x x x		
<i>Marginulina jordanensis</i> sp. nov.						
<i>Gavelinella limbata</i> Olsson						
<i>Fronicularia nakkadyi</i> sp. nov.						
<i>Loxostomoides applinae</i> (Plummer)						
<i>Pulsiphonia prima</i> (Plummer)						
<i>Martinottiella alabamensis</i> (Cushman)						
<i>Nodosaria robinsoni</i> sp. nov.						
<i>Siphogenerinoides elnaggari</i> sp. nov.						
<i>Quadriformina esnehensis</i> (Nakkady)						
<i>Clavulina parisiensis</i> d'Orbigny						
<i>Vaginulinopsis wadiarabensis</i> sp. nov.						
<i>Fronicularia pickeringi</i> sp. nov.						
<i>Palmula woodi</i> Nakkady						
<i>Eouvigerina zealandica</i> (Finlay)						
<i>Gaudryina soldadoensis tellburmaensis</i> subsp. nov.						
<i>Lenticulina incisus</i> Lys.						
<i>Eouvigerina iranica</i> (Thomas)						
<i>Reussella truncanella</i> (Finlay)						
<i>Rectobolivina nuttalli</i> (Cushman and Siegfus)						
<i>Bulimina leroyi</i> sp. nov.						
<i>Valvulinaria pseudotumeyensis</i> sp. nov.						
<i>Hanzawaia cushmani</i> (Nuttall)						
<i>Clavulinoides cf. depressa</i> (Cushman and Ellisor)						
<i>Clavulinoides triquetra</i> (Reuss)						

SYSTEMATIC PALAEONTOLOGY

Genus GAUDRYINA d'Orbigny in de Sagra 1839
Gaudryina soldadoensis tellburmaensis subsp. nov.

Plate 81, figs. 1, 2

Holotype. BMNH. P49102.*Type locality and horizon*. Tell Burma, southern Jordan, Early Eocene, sample 862.*Dimensions of holotype in mm*. Length 1.1; maximum width 0.45; thickness 0.25.*Derivation of name*. After the type locality.*Material*. Sixteen specimens from four samples. This subspecies appears in the Late Paleocene of the Tell Burma section and ranges to the Early Eocene.

Diagnosis. Test triserial with pyramidal initial portion followed by inflated chambers semicircular in cross-section separated by deeply depressed sutures. Inflated chambers slightly indented.

Description. Test elongate with a pyramidal, triserial early portion forming about one-third of test. This is followed by the biserial portion which comprises semicircular chambers in cross-section. Chambers of triserial portion are indistinct while the biserial portion has six to eight clearly defined inflated chambers. Sutures indistinct in triserial portion; deeply depressed forming marked indentations throughout biserial portion. Wall very finely arenaceous, smooth with calcite cement. Aperture rounded with a thickened margin near the inner edge of the last-formed chamber, showing tendency to become terminal.

Remarks. Subspecies differs from the nominate species in having inflated biserial chambers and in being triangular in cross-section in the triserial and circular in the biserial parts. As in the nominate species, aperture rounded with thickened margin near the inner edge of last-formed chamber, showing tendency to become terminal; in this respect the subspecies approaches the genus *Bermudezina*. *Gaudryina laevigata* Franke var. *saadi* Haque (1956) from the Early Eocene of West Pakistan is similar in shape, but the biserial portion is rounded quadrangular in cross-section.

Genus CLAVULINA d'Orbigny, 1826

Clavulina barnardi sp. nov.

Plate 81, figs. 3, 4

Holotype. BMNH. P49101.

Type locality and horizon. Tell Burma, southern Jordan, Danian, sample 852.

Dimensions of holotype in mm. Length 1.0; width 0.17.

Derivation of name. After Professor T. Barnard, University College, London.

Material. Forty-two specimens from six samples. *Clavulina barnardi* sp. nov., is a good Danian index fossil in the Tell Burma and Wadi Arab sections.

Diagnosis. A slender *Clavulina* with sharply pyramidal, triserial portion followed by slightly irregular flask-shaped, inflated, uniserial chambers. Sutures deeply excavated.

EXPLANATION OF PLATE 81

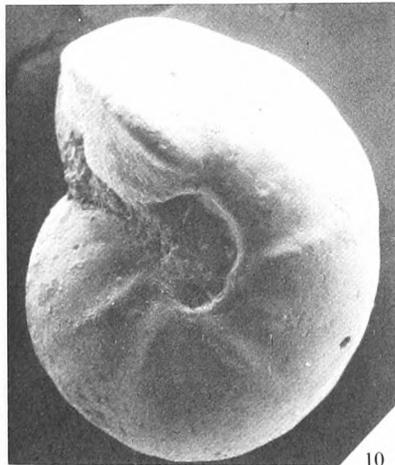
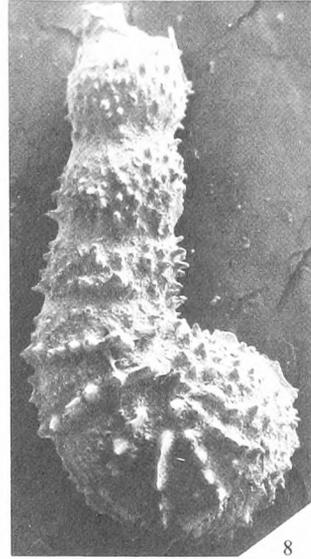
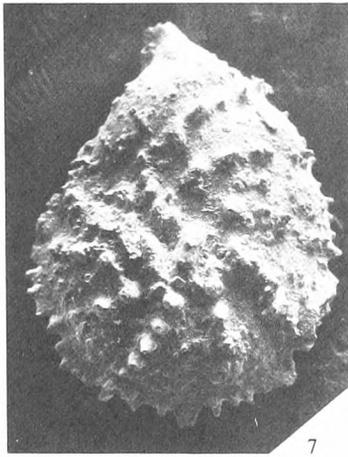
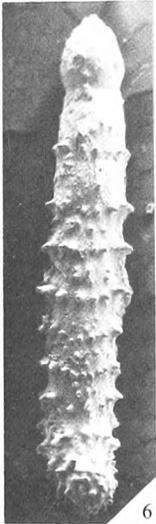
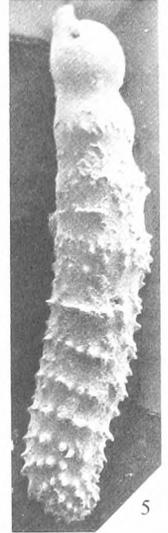
Figs. 1, 2. *Gaudryina soldadoensis tellburmaensis* subsp. nov. 1, 2, holotype, sample 862, Tell Burma section; 1, frontal view, $\times 63$; 2, side view, $\times 65$.

Figs. 3, 4. *Clavulina barnardi* sp. nov. 3, holotype, sample 852, Tell Burma section, $\times 65$; 4, paratype, sample 852, Tell Burma section, $\times 60$.

Figs. 5, 6. *Marginulina jordanensis* sp. nov. 5, holotype, sample 849, Tell Burma section, frontal view, $\times 36$; 6, paratype, sample 849, Tell Burma section, side view, $\times 36$.

Figs. 7-9. *Vaginulinopsis wadiarabensis* sp. nov. 8, 9, holotype, sample 156, Wadi Arab section; 8, frontal view, $\times 38$; 9, side view, $\times 38$; 7, paratype, sample 858, Tell Burma section, frontal view, $\times 43$.

Figs. 10-12. *Gyroidinoides tellburmaensis* sp. nov. 10-12, holotype, sample 65, Tell Burma section, $\times 100$; 10, umbilical view; 11, side view; 12, spiral view.



FUTYAN, Foraminifera from Jordan

Description. Test elongate, early portion triserial and sharply pyramidal with acute apical end comprising about one-fifth to one-half of entire test. The uniserial portion consists of three to eight flask-shaped inflated chambers, with subacute to rounded profiles in longitudinal section. The sutures are indistinct in triserial portion, deeply excavated in uniserial portion. Wall finely arenaceous with calcite cement and with rough surface. Aperture rounded terminal at end of tubular neck. Microspheric generation has slender test, smaller, initial, triserial portion and larger number of uniserial chambers than megalospheric generation.

Remarks. The test varies widely in both size of the initial triserial portion which may comprise one-fifth to one-half of the test and number of uniserial chambers which may be three to eight.

This species is similar to *Pseudoclavulina globulifera* Ten Dam and Sigal (1950), but differs in having a triserial, sharply pyramidal early portion and uniserial chambers with slightly angular or rounded outlines in profile.

Genus VAGINULINOPSIS Silvestri, 1904
Vaginulinopsis wadiarabensis sp. nov.

Plate 81, figs. 7-9

Holotype. BMNH. P49111.

Type locality and horizon. Wadi Arab, near Irbid, northern Jordan, Late Paleocene, sample 156.

Dimensions of holotype in mm. Length 1.85; maximum width 1.0; thickness 0.25.

Derivation of name. After the type locality.

Material. Thirty-five specimens from three samples. This species is restricted to the Late Paleocene at Tell Burma and Wadi Arab.

Diagnosis. Test with large, planispirally coiled, proximal portion having flanged spinose periphery, heavily ornamented surface, and raised sutures with low sharp spines; followed by uniserial portion with inflated chambers, depressed sutures, and surface in part covered by short spines. Final chambers elongate globular, sutures broadly depressed. Aperture terminal with neck.

Description. Compressed, elongate test, early portion consisting of ten or eleven chambers in about two planispiral whorls. Later portion uniserial, comprises one to four inflated chambers. Periphery of planispiral proximal portion flanged with short spinose projections, uniserial chambers are broadly rounded. Chambers indistinct in coiled part obscured by heavy ornament, but distinct and inflated in uniserial portion. Sutures of proximal part limbate, raised and composed of sharply pointed projections, coalescing irregularly near umbo. Sutures broadly depressed in uniserial portion. Surface of chambers covered with short spines. Aperture terminal radiate with short neck.

Remarks. The number of chambers in the uniserial portion of this species vary from one to four. It is heavily ornamented and characterized by a large, coiled initial portion, spinose sutures, periphery, and surface. It resembles *Vaginulinopsis tuberculata* Plummer (1927), which also occurs in the material examined, but has a larger,

coiled initial portion, a stouter test, a flanged, spinose periphery and surface, and one to two inflated uniserial chambers. *V. tuberculata*, also has four to six laterally compressed chambers which are longer than high. *V. verruculosa* Martin (1943) from the Lodo Formation, California, has less closely coiled chambers and different ornamentation.

Genus MARGINULINA d'Orbigny, 1826

Marginulina jordanensis sp. nov.

Plate 81, figs. 5, 6

Holotype. BMNH. P49108.

Type locality and horizon. Tell Burma, southern Jordan, Late Danian, sample 849.

Dimensions of holotype in mm. Length 1.9; width 0.4; thickness 0.16.

Derivation of name. After Jordan.

Material. Twenty-three specimens from three samples. Species confined to the Late Danian of the Tell Burma and Wadi Arab sections.

Diagnosis. A *Marginulina* with two or three chambers forming part of an initial whorl, followed by ten to thirteen slightly inflated chambers arranged rectilinearly. Sutures distinct, raised, marked by spinose tubercles. Last two chambers more inflated than preceding ones and separated by deeply depressed sutures.

Description. Test elongate, slightly compressed laterally, slightly curved, and with concave dorsal and convex ventral margins. Periphery broadly rounded. Test has ten to thirteen chambers, initial two or three form part of a whorl followed by linear succession of slightly inflated chambers broader than high. Sutures raised and marked by spinose tubercles. Last two chambers more inflated than preceding ones and separated by deeply depressed smooth sutures. Chamber wall covered by sparse random coarse tubercles. Aperture terminal, dorsal, rounded, radiate with distinct neck.

Remarks. This species resembles *M. wetherelli* Jones, 1854, a form described from the Eocene, London Clay. *M. wetherelli* is more compressed, with larger initial coiled portion and less-inflated chambers. It also lacks the last two inflated chambers with depressed sutures. *M. jordanensis* sp. nov. does not vary significantly.

Genus NODOSARIA Lamark, 1812

Nodosaria robinsoni sp. nov.

Plate 82, figs. 5, 6

Holotype. BMNH. P49109.

Type locality and horizon. Tell Burma, southern Jordan, Middle Paleocene sample 856.

Dimensions of holotype in mm. Length 0.8; width 0.3.

Derivation of name. After Dr. E. Robinson, University College, London.

Material. Nineteen specimens from two samples. Several well-preserved specimens occur in the Middle Paleocene sample 856 from Tell Burma. The species seems to be confined to the Middle Paleocene.

Diagnosis. Nodosariid with uniserial, inflated chambers covered by twenty-two to twenty-four closely spaced, fine, longitudinal ribs, which become obsolete on the upper half of the last chamber.

Description. Test elongate, cylindrical or slightly tapering, with three or four strongly inflated, almost globular, chambers. Sutures indistinct and deeply depressed. Ornament consists of twenty-two to twenty-four fine, distinct, very closely spaced ribs extending throughout most of the test becoming obsolete on upper half of last chamber. Aperture terminal, radiate.

Remarks. This species shows slight variation in chamber number ranging from three to five. *Nodosaria robinsoni* sp. nov. differs from *N. limbata* d'Orbigny in having fine, distinct, longitudinal ribs. *N. (Dentalina) capitata* Boll var. *striatissima* Andreae, 1884 is similar, but larger, with more chambers and an initial spine. Specimens referred by Hillebrandt (1962) to *N. limbata* d'Orbigny, 1840 and by Pozaryska (1965) to *Marginulina* sp., are similar and may belong to this species. These were recorded from the Austrian and Polish Paleocene respectively.

Genus FRONDICULARIA DeFrance in d'Orbigny 1826

Frondicularia pickeringi sp. nov.

Plate 82, fig. 2

Holotype. BMNH. P49104.

Type locality and horizon. Tell Burma, southern Jordan, Late Paleocene, sample 858.

Dimensions of holotype in mm. Length 1.5; maximum width 1.1; thickness 0.1.

Derivation of name. After Dr. T. Pickering, former Mining Advisor to N.R.A. Jordan.

Material. Thirty specimens from three samples. Species confined to the Late Paleocene at Tell Burma.

Diagnosis. A *Frondicularia* with large, thin, much compressed test distinctly rhomboidal in outline, periphery truncate in upper half of test, irregular with thin, serrated, transparent keel in lower half. Initial portion ornamented by two to five fine ribs which in some specimens extend towards the aperture.

Description. Test free, large, elongate, longer than broad, thin, compressed. Distinctly rhomboidal in outline, with greatest width towards middle of test. Periphery truncate

EXPLANATION OF PLATE 82

Fig. 1. *Frondicularia nakkadyi* sp. nov., holotype, sample 858, Tell Burma section, $\times 30$.

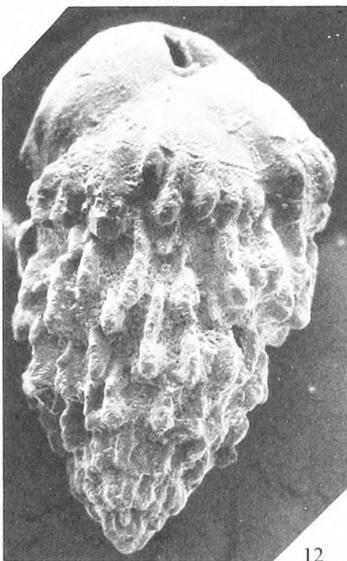
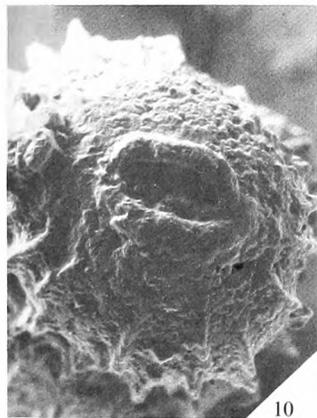
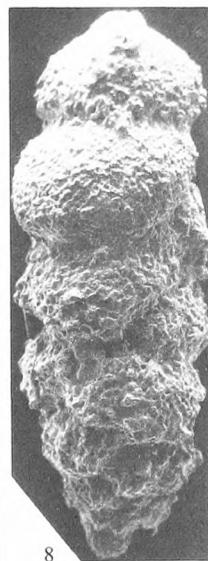
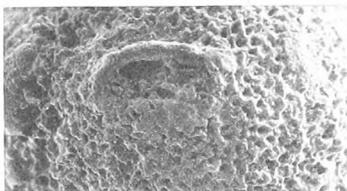
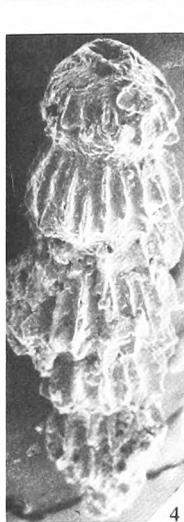
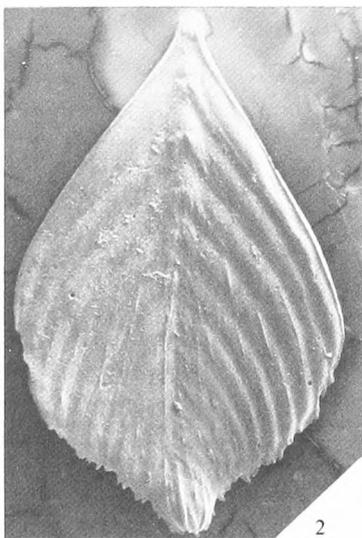
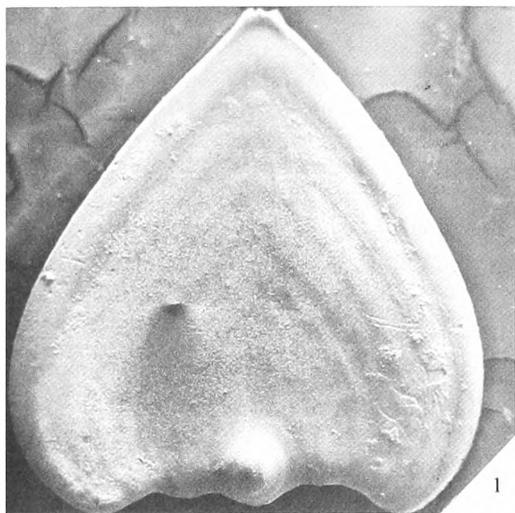
Fig. 2. *Frondicularia pickeringi* sp. nov., holotype, sample 858, Tell Burma section, $\times 45$.

Figs. 3, 4, 10. *Siphogenerinoides elnaggari* sp. nov. 4, 10, holotype, Tell Burma section, sample 857; 4, frontal view, $\times 140$; 10, apertural view, $\times 225$. 3, paratype, Tell Burma section, sample 856, $\times 150$.

Figs. 5, 6. *Nodosaria robinsoni* sp. nov. 5, holotype, Tell Burma section, sample 856, $\times 87$; 6, paratype, Tell Burma section, sample 856, $\times 82$.

Figs. 7-9. *Hopkinsina arabina* sp. nov. 7, 8, holotype, Muwaqqar section, sample 13; 7, apertural view, $\times 230$; 8, frontal view, $\times 125$; 9, paratype, sample 5, Muwaqqar section, $\times 134$.

Figs. 11, 12. *Bulimina leroyi* sp. nov. 11, holotype, Tell Burma section, sample 864, $\times 132$; 12, paratype, Muwaqqar section, sample 23, $\times 143$.



FUTYAN, Foraminifera from Jordan

in distal part of test, but slightly irregular with thin, serrated, transparent keel and occasional short spines in proximal part. In adult forms there are ten to twelve very narrow, chevron-shaped chambers. Final chamber embraces more than half of test. Initial chambers slightly inflated, gently curved, and ornamented by two to five fine, longitudinal ribs which in some specimens extend towards the aperture. Sutures limbate, hyaline, slightly depressed terminating distally in slightly raised beads which mark the position of successive apertures. Aperture terminal, protruding, and radiate. In some specimens initial portion of test may develop obliquely from the long axis of test, giving rise to a curved initial portion with two to three chambers arranged in part of the whorl.

Remarks. The long fine ribs extending from the initial portion across the test surface are absent in some specimens. The rhomboidal outline, prominent, slightly inflated, ribbed proximal portion, marked consecutive apertures, and serrated margin of proximal half of periphery distinguish this species from other similar forms. *F. pitmani* McLean, 1952 from the Paleocene, Vincentown Formation, New Jersey is similar but has a different outline and long spines near the proloculus. It has a rounded periphery and more inflated initial portion. *Flabellina gahannamensis* Ansary, 1955, from the Late Eocene of Egypt is similar in shape, but has a clearly coiled initial portion with numerous coarse, closely spaced ribs extending right across the surface of the test.

Frondicularia nakkadyi sp. nov.

Plate 82, fig. 1

Holotype. BMNH. P49105.

Type locality and horizon. Tell Burma, southern Jordan, Late Paleocene, sample 858.

Dimensions of holotype in mm. Length 2.3; maximum width 2.4; thickness 0.12.

Derivation of name. After Professor S. E. Nakkady, Assuit University, Egypt.

Material. Seventeen specimens from four samples. The species first appears in the Late Danian at Tell Burma sample 850 continuing as a rare form to the top Palaeocene.

Diagnosis. Test free, large, thin, flat with rounded, triangular outline, periphery truncate, proximal part lobate, surface smooth, chambers strongly embracing, sutures limbate, flush, proloculus slightly inflated.

Description. Test free, large, thin, flat, compressed, very slightly broader than long with greatest breadth near proximal part. Periphery truncate and curved in distal part, truncate and lobate in proximal part. Chambers narrow, ten to thirteen strongly embracing. Sutures distinct, limbate flush or slightly depressed. Proloculus large, globular, surface in proximal part smooth or with two to three faint longitudinal ribs, confined to the initial part of test. Remainder of surface smooth, aperture terminal, radiate.

Remarks. This species is very variable in outline. The broad, proximal part can be straight, undulating or lobed. The area of the proloculus in the megalospheric form is inflated. In some specimens the second and third chambers are broadly curved

and embrace the proloculus. The microspheric form has a very small proloculus followed by two to three small, curved chambers. This species differs from *Fron-dicularia wanneri* Nakkady, 1950, because the central raised ridge which extends from the proloculus to the aperture is absent. *F. palegredensis* Weiss, 1955 from the Peruvian Paleocene is similar in shape, but lacks the broad, lobate proximal peripheral outline of *F. nakkadyi* sp. nov. *F. palegredensis* also has prominent costae over the proloculus, some of which extend along the median line.

Genus SIPHOGENERINOIDES Cushman, 1927

Siphogenerinoides elnaggari sp. nov.

Plate 82, figs. 3, 4, 10

Holotype. BMNH. P49110.

Type locality and horizon. Tell Burma, southern Jordan, Late Paleocene, sample 857.

Dimensions of holotype in mm. Length 0.46; width 0.19.

Derivation of name. After Dr. Z. R. El-Naggar, Kuwait University.

Material. Thirteen specimens from three samples. Recorded from the Middle and Late Paleocene at Tell Burma.

Diagnosis. Initial part triserial, becoming biserial and followed by uniserial, inflated chambers, clearly defined by deeply incised sutures. Chambers ornamented with numerous, plate-like, thin costae, occasionally ending proximally in slightly spinose projections.

Description. Test free, elongate cylindrical except for blunt, slightly tapering proximal part. Chambers in early part of test irregularly triserial in microspheric and biserial in megalospheric generation. Three to five obliquely arranged chambers in distal part inflated and becoming nodosarian. Sutures distinct, deeply incised. Ornament consists of fourteen to sixteen thin, plate-like, longitudinal costae over the whole surface, interrupted by incised sutures and ending proximally in slightly spinose projections. Aperture terminal, elliptical, and bounded by slightly raised rim, connected to preceding apertures by straight tooth plate.

Remarks. This species has probably evolved from *Siphogenerinoides brevispinosa* Cushman, 1939, which appears lower in the sequence, by development of longitudinal costae instead of closely spaced, short spines. In shape and ornament it closely resembles *Siphogenerina mayi* Cushman and Parker, 1931 from the Miocene, Temblor Formation of California. It differs, however, in the shape of the aperture and its internal structure. *Siphogenerinoides elnaggari* sp. nov. does not vary significantly.

Genus HOPKINSINA Howe and Wallace, 1932

Hopkinsina arabina sp. nov.

Plate 82, figs. 7-9

Holotype. BMNH. P49107.

Type locality and horizon. Muwaqqar, near Amman, Maastrichtian, sample 13.

Dimensions of holotype in mm. Length 0.55; maximum width 0.3.

Material. Thirty-five specimens from seven samples. Recorded from the Late Maastrichtian of the three sections.

Diagnosis. Triserial early portion forming one-half of test followed by irregularly triserial chambers which become uniserial. Maximum width at approximately half the length. Sutures deeply depressed, surface of chambers covered by prominent nodes. Chambers compact in proximal portion, inflated, subglobular in distal portion.

Description. Test free, elongate, with greatest width at approximately half the length. Early part triserial, comprising about half the test, followed by irregularly, triserial chambers which become uniserial. Initial part subacute and chambers compact, later becoming distinctly inflated and subglobular. Sutures deeply depressed; wall coarsely perforate, covered with prominent nodes spaced about three times their diameter apart. Aperture terminal, elliptical, bounded by low but distinct rim.

Remarks. The species varies mainly in the distal part of the test which is irregularly triserial, biserial, or becomes uniserial. *Uvigerina elongata* Brotzen, 1936, is similar in shape to *Hopkinsina arabina* sp. nov., but has smaller nodes confined to the initial part of the test and compressed rather than inflated chambers. *U. hispida* Schwager, 1866 has coarse spines, thickly distributed over the entire test and a distinctly protruding neck.

Genus BULIMINA d'Orbigny, 1826

Bulimina leroyi sp. nov.

Plate 82, figs. 11, 12

Holotype. BMNH. P49099.

Type locality and horizon. Tell Burma, southern Jordan, Early Eocene, sample 864.

Dimensions of holotype in mm. Length 0.5; width 0.4.

Derivation of name. After Professor L. LeRoy.

Material. Forty-five specimens from seven samples. Common in the Tell Burma Early Eocene but rare in the Muwaqqar Early Eocene.

Diagnosis. Test elongate, slightly tapering, greatest width at distal end, covered by coarse, closely spaced, plate-like, longitudinal costae. Upper part of last whorl smooth and finely perforate. Chambers roughly rectangular in shape, two to two and one-half times broader than long.

Description. Test elongate, slightly tapering, longer than broad, greatest width at distal end. Chambers distinct, slightly inflated, two to two and one-half times broader than long, roughly rectangular in shape, arranged triserially. Sutures distinctly depressed. Wall, except for the distal part of the last chamber which is smooth and finely perforate, covered by coarse, closely spaced plate-like, longitudinal costae, which are partly interrupted across depressed sutures. Costae more prominent on surface of chambers than across sutures. Aperture long, narrow, terminal on last-formed chamber. Microspheric generation slender with nearly parallel sides, megalospheric form generally stouter with more tapering test.

Remarks. *Bulimina microcostata* Cushman and Parker, 1936, is similar in shape, but has finer costae and these cover only the lower third of the test. *B. instabilis* Cushman and Parker 1936 is more inflated with irregularly branching costae. *B. leroyi* sp. nov. differs from similar Late Cainozoic forms, such as *B. inflata* Seguenza, 1862 and *B. striata* d'Orbigny, 1843, in having a more elongate, slender test.

Genus VALVULINERIA Cushman, 1926
Valvulineria pseudotumeyensis sp. nov.

Plate 83, figs. 4-6

Holotype. BMNH. P49112.

Type locality and horizon. Tell Burma, southern Jordan, Early Eocene, sample 864.

Dimensions of holotype in mm. Diameter 0.65; thickness 0.25.

Derivation of name. Similar to *Valvulineria tumeyensis*.

Material. Forty-five specimens from four samples. Holotype from the Tell Burma section, where it first appeared in sample 864, 6 m above the Paleocene-Early Eocene boundary. It is common in the Early Eocene at Muwaqqar and Wadi Arab.

Diagnosis. Test free, about equally biconvex, trochospiral, with coarsely perforate wall and raised limbate sutures on spiral and umbilical surfaces. Sutures thickened and strongly elevated towards pole on spiral side but less pronounced on umbilical side.

Description. Test free, biconvex, trochospiral with almost circular outline. Periphery rounded and nonlobulate but broken by raised sutures. Chambers slightly inflated, nine or ten in last whorl increasing gradually in size as added arranged in about two and one-half whorls all visible on spiral side; only those of last whorl seen on umbilical side. Umbilicus surrounded by thickened imperforate shell material. Last chamber has wide imperforate apertural face visible on umbilical side. Sutures thickened and strongly elevated; those on spiral side of last whorl continue on to the umbilical side, where they coalesce around the umbilicus. Sutures curved on spiral surface, straight and radiate on umbilical side, becoming much thicker towards pole on spiral side and umbilicus on umbilical side. Wall coarsely perforate. Aperture arched, umbilical-extraumbilical, opening into umbilical cavity, with narrow lip.

Remarks. Sutures between last two chambers in some specimens are limbate and flush with surface. Spiral suture on spiral side occasionally thickened and irregular, concealing previous whorls. This species is similar in size and morphology to *V. tumeyensis* Cushman and Simonson, 1944, reported from the Late Eocene-Oligocene, Tumey Formation, California. It differs, however, in having thick, strongly raised sutures on both sides of the test and an umbilicus bounded by thickened shell material. *Eponides elevatus* (*Truncatulina elevata* Plummer, 1926) is also similar in shape, but much smaller (half the diameter), has a subconical test and an angular periphery.

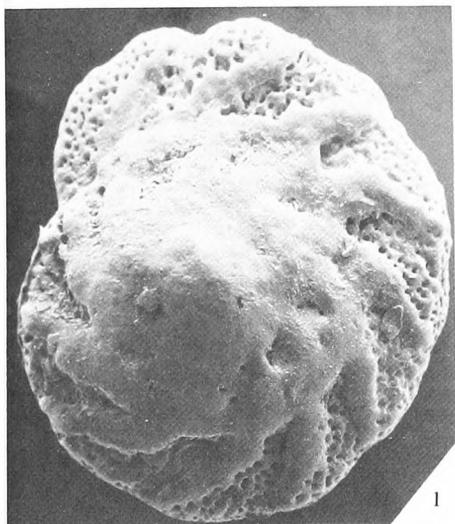
Genus *GYROIDINOIDES* Brotzen, 1942*Gyroidinoides tellburmaensis* sp. nov.

Plate 81, figs. 10-12

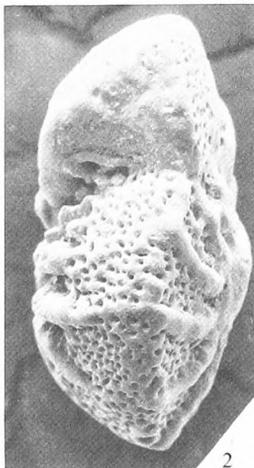
Holotype. BMNH. P49106.*Type locality and horizon*. Tell Burma, southern Jordan, Maastrichtian, sample 65.*Dimensions of holotype in mm*. Diameter 0.6; thickness 0.25.*Derivation of name*. After the type locality.*Material*. Fifty specimens from eight samples. Found in the Maastrichtian of all three sections.*Diagnosis*. Test free, planoconvex, trochospiral, flat spiral side, strongly convex, umbilical side, deep, open umbilicus, angular periphery and limbate, slightly raised sutures.*Description*. Test free, planoconvex, with flattened or very slightly concave spiral side. Umbilical side strongly convex with moderately large, deep, open umbilicus and high, flattened, apertural face aligned at right angles to previous whorl. Three to three and one-half visible whorls on spiral side. Periphery sharply angular, slightly raised above flat surface of spiral side particularly on last two to three chambers. Nine to ten chambers visible in last whorl. Sutures limbate, oblique, slightly curved on spiral side, straight, radiate on umbilical side, also slightly raised on spiral side especially on early whorls, but flush on umbilical side. In some specimens sutures slightly depressed between last two chambers on both sides. Wall is smooth, very finely perforate. Aperture, a long, narrow slit at base of broad, flattened, apertural face, extending from periphery to umbilicus and with thin apertural flap which widens towards the umbilicus.*Remarks*. This species, when compared with *Gyroidinoides subangulata* (Plummer) 1926 from the Paleocene Midway Formation in the U.S. Gulf Coast area is much larger, has a more acute periphery, more whorls, wider umbilicus and limbate sutures on the spiral side. *G. girardana* (Reuss) 1851 which also occurs in the material studied does not have an angular periphery, raised limbate sutures on the spiral side, but has more inflated chambers. *G. tellburmaensis* sp. nov., does not vary significantly.

EXPLANATION OF PLATE 83

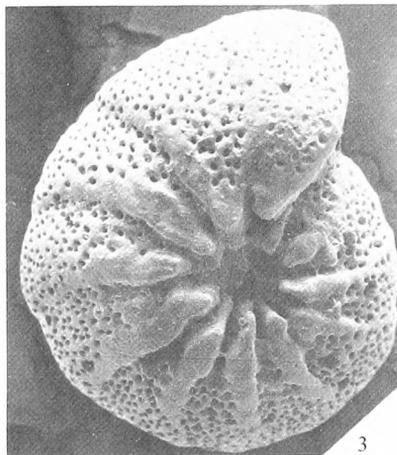
Figs. 1-3. *Angulogavelinella bandata* sp. nov. 1, holotype, sample 846, Tell Burma section, spiral view, $\times 140$. 2, 3, paratype, sample 847, Tell Burma section; 2, side view, $\times 120$; 3, umbilical view, $\times 120$.Figs. 4-6. *Valvulineria pseudotumeyensis* sp. nov. 4, 5, holotype, sample 864, Tell Burma section; 4, spiral view, $\times 90$; 5, side view, $\times 90$. 6, paratype, sample 23, Muwaqqar section, umbilical view, $\times 92$.Figs. 7-9. *Gavelinopsis baylissi* sp. nov. 7, 9, holotype, sample 17, Muwaqqar section; 7, spiral view, $\times 118$; 9, umbilical view, $\times 120$. 8, paratype, sample 17, Muwaqqar section, side view, $\times 73$.



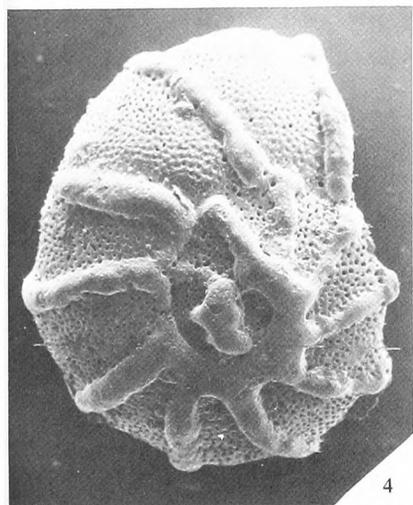
1



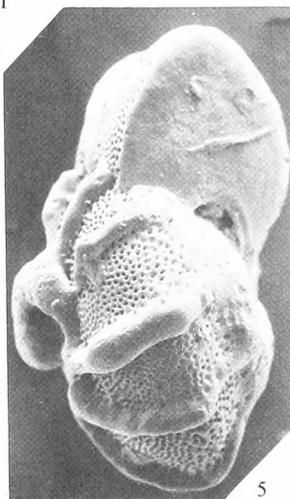
2



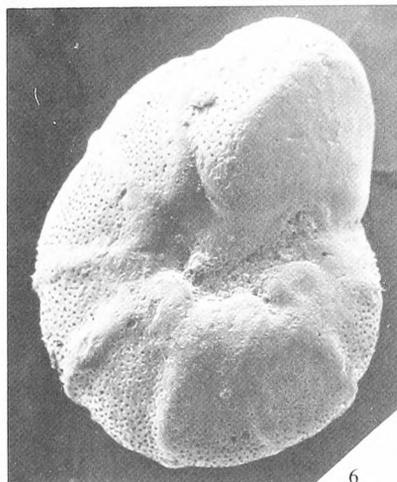
3



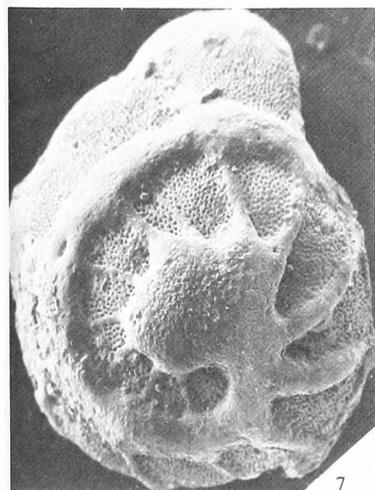
4



5



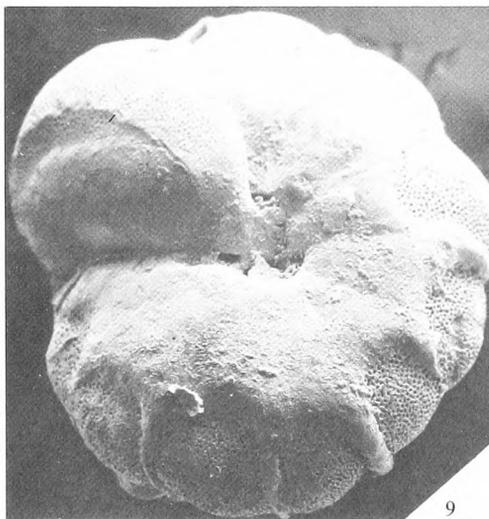
6



7



8



9

Genus *ANGULOGAVELINELLA* Hofker, 1957
Angulogavelinella bandata sp. nov.

Plate 83, figs. 1-3

Holotype. BMNH. P49098.

Type locality and horizon. Tell Burma, southern Jordan, Middle Danian, sample 846.

Dimensions of holotype in mm. Diameter 0.5; thickness 0.20.

Derivation of name. Based on the type of sutures on the dorsal side.

Material. Thirty-two specimens from three samples. Species found only in the Middle Danian at Tell Burma.

Diagnosis. Test free, unequally biconvex, trochospiral with coarsely perforate wall on both sides; surface of initial whorls raised, covered by thick, milky-white shell material on spiral side. Limbate, raised sutures composed of broad bands of shell material present on both sides of test.

Description. Test free, unequally biconvex, with trochospiral surface of initial whorls raised and last half whorl on spiral side flattened. Umbilical side strongly convex with subacute periphery. Eleven or twelve chambers present in last whorl. Chambers arranged in three to three and one-half whorls partly visible on spiral side. Umbilical side involute with only chambers of last whorl visible. Early whorls on spiral side in most specimens, covered by milky-white shell material. Spiral suture indistinct. Sutures are strongly limbate, broad, raised, and strongly recurved on spiral side composed of bands of milky-white shell material. On umbilical side sutures straight and radiate from an irregular, small umbilical depression. Wall, apart from sutures, coarsely perforate on both sides. Aperture an oblique, elongate slit at base of last chamber midway between periphery and umbilicus. It extends across part of the apertural face and is bounded by a raised rim.

Remarks. Sutures between the last two or three chambers depressed in some specimens, and periphery slightly lobulate. In some specimens sutures are very broad, covering more than two-thirds of the spiral side. *Angulogavelinella bandata* sp. nov. differs from *Pseudovalvulinaria avnimelechi* Reiss, 1952, by having strongly limbate, broad, raised sutures on the spiral side and an open umbilicus.

Genus *GAVELINOPSIS* Hofker, 1951
Gavelinopsis baylissi sp. nov.

Plate 83, figs. 7-9

Holotype. BMNH. P49103.

Type locality and horizon. Muwaqqar, near Amman, Late Maastrichtian, sample 17.

Dimensions of holotype in mm. Diameter 0.55; thickness 0.22.

Derivation of name. After Dr. D. D. Bayliss to acknowledge his contribution to micropalaeontology in Jordan.

Material. Forty-five specimens from nine samples. Confined to the Late Maastrichtian at Muwaqqar and Wadi Arab.

Diagnosis. Test free, spiroconvex, with high spiral side and slightly convex umbilical side. Spiral and radial sutures prominent, limbate, and raised. Area around umbilicus and first whorl on spiral side covered by imperforate shell material. Wall smooth and finely perforate.

Description. Test free, spiroconvex with very high spiral side. Umbilical side slightly convex. Chambers arranged in high trochospire of about two and one-half whorls all visible on spiral side, inflated chambers nine or ten in last whorl. Only chambers of last whorl visible on umbilical side, but the nine chambers are covered by a thin sheet of imperforate shell material extending from the umbilicus towards the periphery. Umbilicus small but distinct. Spiral suture prominent, limbate, and raised, radial sutures slightly recurved, prominent limbate, and raised on both sides of test, except between last three chambers where they are depressed. The first whorl on spiral side covered by imperforate shell material. Wall smooth, finely perforate, monolamellid, and radial. Aperture, slit extending from near the periphery to the umbilicus at base of broad apertural face.

Remarks. This species varies in the convexity of the umbilical side which is occasionally flattened or slightly convex, as well as in the thickness and extent of thickened imperforate shell material which covers from one-half to two-thirds of the umbilical side and one-fifth to one-third of the spiral side. Koch in 1967 described *Gavelinopsis(?) proelevata* from the Early Maastrichtian of Jordan and figured a paratype specimen (pl. 60, fig. 6) which closely resembles this species, but differs from the holotype of *G.(?) proelevata* Koch in having a very high spiral side and lacking an umbilical boss. However, *G.(?) proelevata* Koch differs from *G. baylissi* sp. nov., in having a more compressed, biconvex test, it has no shell material covering the chambers on the umbilical side and it possesses an umbilical boss. *Valvulineria pseudotumeyensis* sp. nov., is similar in shape, but has a low spiral biconvex test, a more involute spiral side, and an arched aperture with narrow lip opening into the umbilicus.

Acknowledgements. I thank Professor T. Barnard, University College, London, for supervising the work, and D. D. Bayliss for providing samples and for help with the manuscript. I also wish to thank D. J. Batten and D. J. Evans for valuable suggestions. Robertson Research International Limited provided research facilities and contributed towards the cost of publication.

REFERENCES

- ANDREAE, A. 1884. Beitrage zur Kenntniss des Elsässer Tertiars, Theil II, Die Oligocän-Schichten. *Geol. Spezialkarte Elsass-Loth., Abhandl.* 2, 3, 1-239.
- ANSARY, S. E. 1955. Report on the foraminiferal fauna from the Upper Eocene of Egypt. *Publ. Inst. Des. Egypt.* 5, 1-160.
- BERGGREN, W. A. 1963. Problems of Paleocene stratigraphic correlation. First Saharan symposium, Tripoli. *Rev. Inst. France. Petrol.* 134-143.
- 1965. Some problems of Paleocene-Lower Eocene planktonic foraminiferal correlations. *Micro-paleontology*, 11, 278-300.
- BOLLI, H. M. 1957. The genera *Globigerina* and *Globorotalia* in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad. *Bull. U.S. Natl Mus.* 215, 61-80.
- 1959. Planktonic foraminifera from the Cretaceous of Trinidad. *Bull. Amer. Paleont.* 39, 257-277.
- 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. *Asoc. Venezolana Geol. Min. Petr. Bol. Inform.* 9, 3-32.

- BOLLI, H. M. and CITA, M. B. 1960. Upper Cretaceous and Lower Tertiary planktonic foraminifera from the Paderno d'Adda section, Northern Italy. *21st Int. Geol. Congr. Copenhagen*, **5**, 150-161.
- BROTZEN, F. 1936. Foraminiferen aus dem schwedischen, unter Senon von Eriksdal in Schonen. *Sver. Geol. Unders. Arsb.* **30**, 1-206.
- 1948. The Swedish Paleocene and its foraminiferal fauna. *Ibid.* **42**, 3-140.
- CUSHMAN, J. A. 1939. New American Cretaceous foraminifera. *Contr. Cushman Lab. Foramin. Res. Sharon, Mass.*, **15**, 4, 89-93.
- and PARKER, F. L. 1931. Miocene foraminifera from the Temblor of the east side of the San Joaquin Valley, California. *Ibid.* **7**, 1-16.
- 1936. Some American Eocene Buliminas. *Ibid.* **12**, 2, 39-45, pls. 7-8.
- 1947. *Bulimina* and related foraminiferal genera. *Prof. Pap. U.S. geol. Surv.* **210D**, 1-176.
- 1951. Paleocene Foraminifera of the Gulf Coastal region and adjacent areas. *Ibid.* **232D**, 1-75.
- and SIMONSON, R. R. 1944. Foraminifera from the Tumey Formation. Fresno County, California. *J. Paleont.* **18**, 1-30.
- DAM, A. TEN and SIGAL, J. 1950. Some new species of foraminifera from the Dano-montian of Algeria. *Contr. Cushman, Fdn Foramin. Res.* **1**, 31-37.
- D'ORBIGNY, A. 1840. Memoire sur les foraminiferes de la craie blanche du bassin de Paris. *Mem. Soc. Geol. France*, ser. 4, **1**, 1-51, pls. 1-4.
- EL-NAGGAR, Z. R. 1966. Stratigraphy and planktonic foraminifera of the Upper Cretaceous-Lower Tertiary succession in the Esna-Idfu region, Nile Valley, Egypt, U.A.R. *Bull. Brit. Mus. (N.H.), Geol. suppl.* **2**, 1-290.
- HAQUE, A. F. M. 1956. The foraminifera of the Ranikot and the Laki of The Nammal Gorge Salt Range. *Paleont. Pakistanica, Mem. geol. Surv. Pakistan*, **1**, 1-300.
- HILLEBRANDT, A. VON. 1962. Das Paleozän und seine Foraminiferen-fauna im Becken von Reichenhal und Salzburg. *Bayer Akad. Wiss., Math. Nat. Kl. Abh.* **108**, 1-182.
- HOFKER, J. 1966. Maastrichtian, Danian and Paleocene Foraminifera. *Palaeontographica suppl.* **10**, 1-376.
- JONES, T. R. 1854. In: MORRIS, J. *A catalogue of British fossils*. London, the author, **2**, 1-372.
- KOCH, W. VON. 1967. Zur Micropalaeontologie und Biostratigraphie der Oberkreide und des Alttertiar von Jordanien I. Oberkreide *Geol. Jb.* **85**, 627-668.
- LOEBLICH, A. R. and TAPPAN, H. 1957. Planktonic foraminifera of Paleocene and Early Eocene ages from the Gulf and Atlantic coastal plains. *Bull. U.S. Natl Mus.* **215**, 173-198.
- 1964. Sarcodina—chiefly 'Thecamoebians' and Foraminiferida—*Treatise on Invertebrate Paleontology*, Part C, Protista 2. Univ. Kansas Press. xxxi + 900 pp.
- MARTIN, L. T. 1943. Eocene foraminifera from the type Lodo formation Fresno County, California. *Stanford Univ. Publ. Geol. Sci.* **3**, 93-125.
- MCLEAN, J. D. 1952. New and interesting species of foraminifera from the Vincentown formation. Part 1. New species. *Acad. Nat. Sci. Philadelphia, Not. Nat.* **242**, 1-18.
- NAKKADY, S. E. 1950. A new foraminifera fauna from the Esna Shales and Upper Cretaceous Chalk of Egypt. *J. Paleont.* **24**, 675-692.
- OLSSON, R. K. 1960. Foraminifera of the Latest Cretaceous and Earliest Tertiary age in the New Jersey coastal plain. *Ibid.* **34**, 1-56.
- PLUMMER, H. J. 1927. Foraminifera of the Midway formation of Texas. *Bull. Univ. Texas*, **2644**, 9-198.
- POZARYSKA, K. 1965. Foraminifera and biostratigraphy of the Danian and Montian in Poland. *Palaeont. Polonica*, **14**, 1-156.
- REISS, Z. 1952. Two new species of foraminifera from Israel. *Bull. Res. Council Israel*, **2**, 269-270.
- 1955. Micropaleontology and the Upper Cretaceous-Lower Tertiary boundary in Israel. *Ibid.* **5B**, 105-120.
- REUSS, A. E. 1851. Über die fossilen Foraminiferen und Entomostraceen der Septarienthone der Umgegend von Berlin. *Deutsch. Geol. Ges. Zeitschr.* **3**, 49-91, taf. 3-7.
- SCHWAGER, C. 1866. Fossile Foraminiferen von Kar Nikobar. *Novara Exped. 1857-1859, Wien, Österreich, Geol. Theil*, **2**, **2**, 187-268, pls. 4-7.
- SEGUENZA, G. 1862. Prime ricerche intorno ai rizopodi fossili delle argille Pleistoceniche dei dintorni di Catania. *Accad. Gioenia Sci. Nat. Catania, Atti*, **2**, **18**, 84-126, tav 1-2.

- THALMANN, H. E. 1959. New names for foraminiferal homonyms; IV. *Contr., Cushman Found. Foram. Res. Ithaca, N.Y.*, **10**, 4, 130-131.
- TROELSEN, J. C. 1957. Some planktonic foraminifera of the type Danian and their stratigraphic importance. *Bull. U.S. Natl Mus.* **215**, 125-131.
- WEISS, L. 1955. Foraminifera from the Paleocene Pale Greda formation of Peru. *J. Paleont.* **29**, 1-21, pls. 1-6.

ABDURAHMAN I. FUTYAN

Robertson Research International Ltd.

Ty'n-y-Coed

Llanrhos

Llandudno, LL30 1SA

Original manuscript submitted 9 August 1974

Final manuscript submitted 6 October 1975