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Neorotalia omanensis and *Operculina musawaensis* from the Sultanate of Oman

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ABSTRACT: Two new species of larger benthic foraminifera, *Neorotalia omanensis* n. sp. and *Operculina musawaensis* n. sp. are described and illustrated from the eastern Oman Mountains. *N. omanensis* n. sp. occurs in the Musawa Formation in association with the planktonic foraminifera *Morozovella edgari* and *Truncarotaloides topilensis* indicating an early to middle Eocene age (P10-P13). *Operculina musawaensis* n. sp. occurs in the Abat Formation in association with the planktonic foraminifera *Acarinina esnaensis* and *A. soldadensis* indicating an early Eocene age (P6). This is the first known record showing the presence of genus *Neorotalia* in the Middle East. Representatives of the larger foraminiferal genus *Linderina* sp. are also described and illustrated from the Musawa Formation and compared with the published *Linderina* species in the surrounding countries.

Keywords: *Neorotalia omanensis*; *Operculina musawaensis*; Abat Formation; Musawa Formation; Oman.

نوعين جديدين من نيوروتاليا عمانينسس وابركيولينا موساواينس من سلطنة عمان مع ملاحظات على تصنيف الندرينا

عبدالرزاق صديق الصايغ

ملخص: تم في هذا البحث وصفى نوعين جديدين من المثقبات كبيرة الحجم وهي نيوروتاليا عمانينسس و ابركيولينا موساواينسس حيث تم وصف وتوضيح النوعين من المنطقة الشرقية لجبال عمان. تتواجد مثقبات النيوروتاليا في تكوين موساوا مترافقة مع مثقبات طافية مثل مورزوفيلا ادجاري و ترنكوروتالويدس توبلينسيس مما يدل على عمر يتبع عصر الأيوسين الأوسط ذات النطق الحيوية (P10 – P13). تتواجد ابركيولينا موساواينسس تكوين الأبات مترافقة مع مثقبات هائمة مثل أكارنينا إسنااِنسس و سولدادنسيس مما يدل على عمر الأيوسين المبكر (P6). وهو لأول مرة سجلت وجود جنس نيوروتاليا في منطقة الشرق الأوسط. وكذلك تم وصف مثقبات كبيرة الحجم من تكوين موصاوى و مقارنتها مع أنواع الندرينا المنشورة في الدول المجاورة.

مفتاح الكلمات : نيوروتاليا عمانينسس وابركيولينا موساواينس ، متكون ابات، متكون مصاوى ، عمان.

1. Introduction

The genus *Neorotalia* sp. is poorly known from Arabia. The only published record from the northern Oman Mountains is *Linderina rajasthanensis* (Singh, 1953), found by White (1989) in Wadi Rusayl. White (1989) synonymized all four of Singh's (1953) species (*rajasthanensis*, *bikanerensis*, *kolayatensis*, *kirtharensis*) under one name (*rajasthanensis*) stating that test size, and shape (globular to discoidal with central boss, depending on the amount of lateral thickening) are insignificant as the means of discriminating species. The geographic distribution of the recorded species is very broad, including southern Europe (England to Romania), the Middle East, the Indian Sub-continent, Indonesia, Australia, Western Pacific and the Caribbean, possibly reflecting the presence of different genera with similar features (Ferrandex-Canadell and Serr-Kiel, 1999). In this paper the author reports two new species of large foraminifera in the Abat and Musawa Formations in the eastern part of the northern Oman Mountains.

2. Geological Setting

The section studied is located in the Jabal Ja'alan area of the Sharqiyah region, in the foothills of the eastern Oman Mountains, north Oman (Figure 1). The samples studied were collected from the Abat and Musawa Formations outcropping along the southern side of Wadi Musawa (Figure 1). Here a 1220 m thick mixed clastic-carbonate succession of Tertiary age rests unconformably on an older granitic basement. The Tertiary strata comprise, from bottom to top, the Abat, Musawa and Tahwah Formations (Figure 2). The samples yielding the new taxa described herein were collected from unit D of the Abat Formation and Unit H of the Musawa Formation (Figure 2). The Abat Formation comprises interbedded marine limestone (mudstone to packstone) and shale. The Musawa Formation contains three fluvial units, each of which is ferruginous towards its base and contains coal towards its top. The fluvial units are overlain by marine limestone and shale. The Abat Formation is Late Palaeocene to Early Eocene and the Musawa Formation is Early to Late Eocene based on planktonic foraminiferal assemblages. Previous work in the area was mainly focused on geological mapping (Villey *et al*., 1986; Filbrandt *et al*., 1990; Roger *et al*., 1991). Although Villey *et al*. (1986) include micropalaeontological data, these data are limited to faunal lists and broad age assignments and do not include illustrations and descriptions of the taxa recorded.

Figure 1. Location map of the study area (modified after Montenat *et al*., 1977).

3. Lithostratigraphy

This section describes the lithostratigraphic units containing the microfossils reported in the present study.

1. Abat Formation

Type-Locality: Wadi Musawa - Latitude 22^0 19' N and Longitude 58^0 23' E

This unit unconformably overlies Maastrichtian sandstone turbidite and marl of the Fayah Formation, and is conformably overlain by sandstone of the Musawa Formation within which it interdigitates in its upper part. The lower part of the Abat Formation consists of thinly interbedded shale and mudstone overlain by planktonic foraminifera-bearing wackestone with interbeds of mudstone and calcarenite. These beds pass upwards (across a 9 m unexposed section) into resedimented wackestone and packstone comprising six depositional cycles. The middle part of the Abat

Formation is characterized by thinly bedded wackestone overlain by shale and followed by an upper unit of limestone and dolomite capped by a palaeosol horizon.

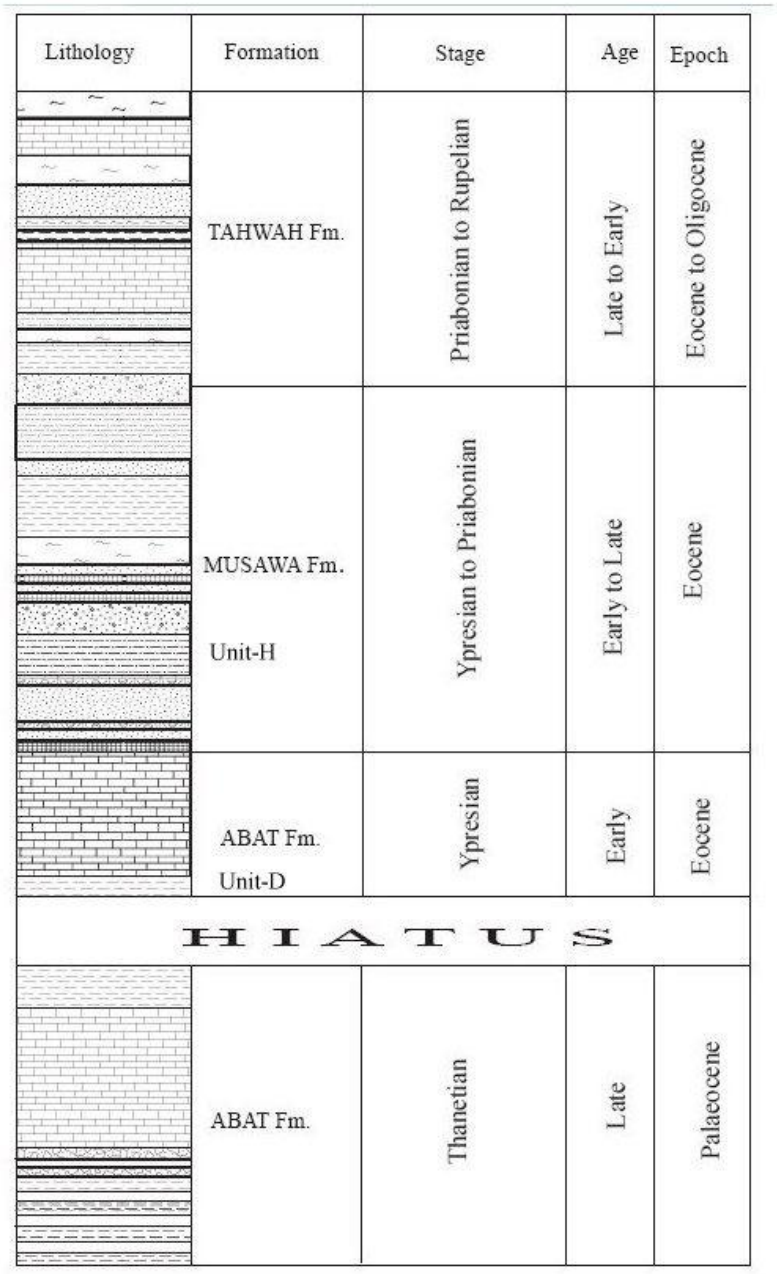

Figure 2. Lithostratigraphic column of the Wadi Musawa Section.

Planktonic foraminifera, including *Morozovella* sp. and *Subbotina* sp., are common in the mudstone and shale of the lower part of the formation. Larger foraminifera, including *Discocyclina* sp., *Daviesina* sp., *Miscellanea* sp., *Nummulite*s sp. and *Assilina* sp. together with small rotaliids, textulariids, calcareous red algae, echinoids and corals are common in the limestone of the upper part of the Abat Formation (Figure 3). The larger foraminifera commonly appear to have been penecontemporaneously redeposited and become progressively more abraded up section. Reworked Cretaceous radiolaria and charophytes also occur within this interval.

The Abat Formation has been dated as Late Palaeocene to Early Eocene (Thanetian to Ypresian) on the basis of its planktonic foraminifera, and comprises a thick sequence of open-marine basinal sediments. Common deep-marine planktonic-foraminiferal shale and mudstone form the lower part of the Abat Formation which shoals upwards into high-energy middle to outer shelf limestone. The latter is dominated by larger and smaller benthonic foraminifera with subordinate dasycladacean algae, calcareous red algae, echinoid plates and corals. The specimens of *Operculina musawaensis* n. sp. described herein were collected from the lower part of Unit D of the Abat Formation (Figure 2).

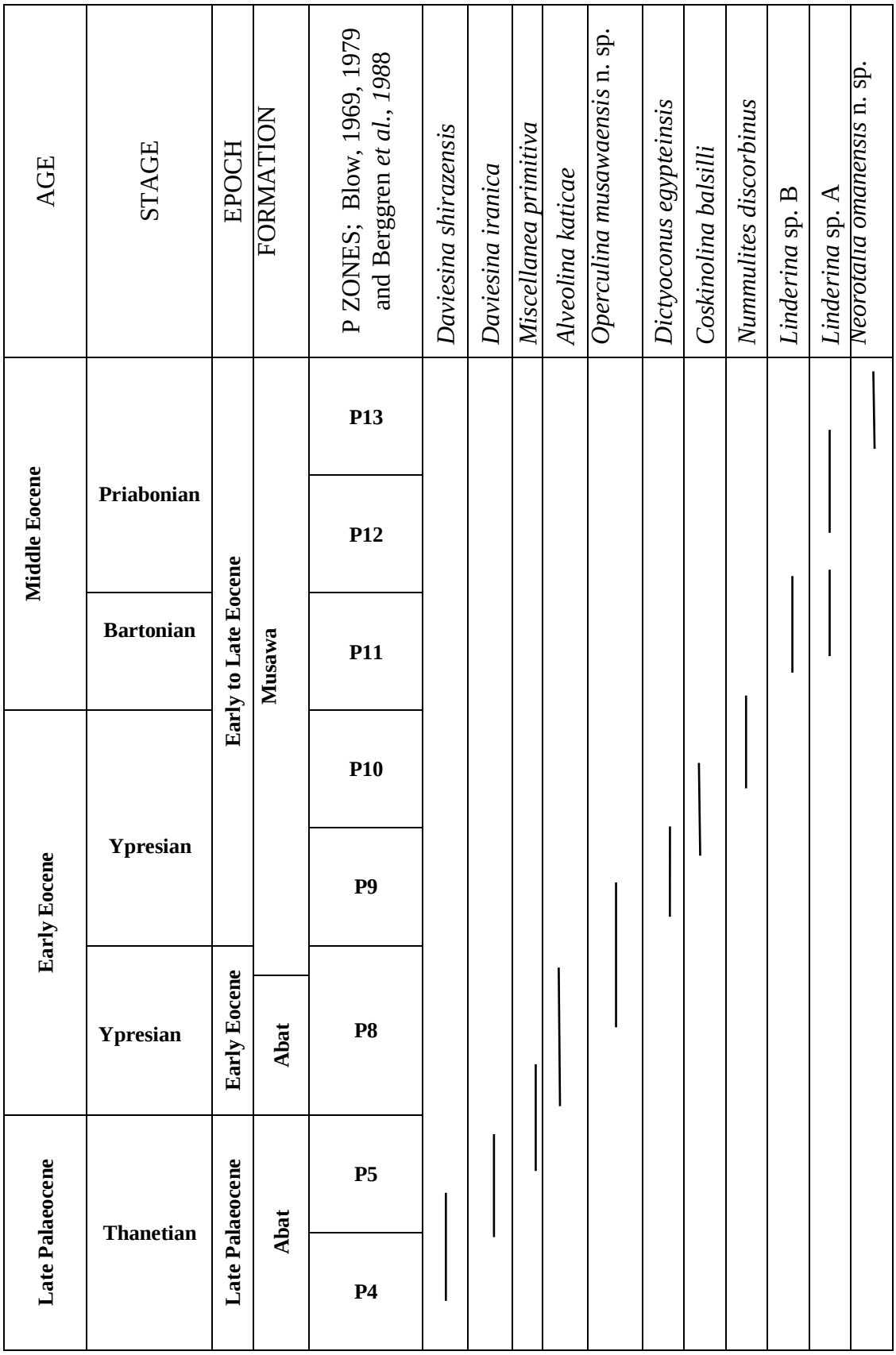

Figure 3. Distribution chart of the key taxa of benthonic foraminifera.

UNIT D

Description: This unit begins with packstone and mudstone separated by a very thin (7 cm thick) distinctive silicified mudstone from an overlying a 24 m thick massive larger foraminiferal limestone (wackestone-packstone). The basal part of Unit D comprises bioturbated limestone (packstone) overlain by mudstone rich in planktonic foraminifera (*Acarinina* sp. and *Morozovella* sp.) and larger foraminifera including *Alveolina* sp., *Nummulites* sp., *Discocyclina* sp. and *Operculina musawaensis* n. sp. This passes upwards into shale containing *Nummulites* and small rotaliids. The unit becomes more indurated up-section and rich in larger foraminifera, ostracods, corals, bivalves, gastropods and oysters. Lithoclasts and foraminifera are less abundant in the uppermost part of the unit, where clasts of grey chert are common, together with rare silicified burrows. Bivalves (often disarticulated) are also common in the uppermost part of the unit.

The characteristic microfossils in the Abat Formation include larger foraminifera (*Alveolina* sp., *Nummulites honogoensis, N. globulus*, *Discocyclina* sp., *Assilina* ex. gr. *exponens*, *Somalina* sp., *Actinocyclina* sp., *Operculina musawaensis n*. sp., *Ranikothalia* sp.) together with planktonic foraminifera (*Acarinina esnaensis, A. soldadoensis* and *Morozovella aragonensis*) which occur in the basal part of this unit. Other fossil fragments present include gastropods, and rare brachiopods, with smaller rotaliids, miliolids and textulariids. Rare dasycladacean algae occur in the middle to upper part of this unit, together with ostracods (*Bairdia* sp., *Cytherella* sp., *Phalococythere* sp. and *Xestoleberis* sp.).

***Age*:** An Early Eocene age is indicated by the presence of *Morozovella marginodentata*, *M. aragonensis*, *Acarinina esnaensis*, and *A. soldadoensis* along with associated larger foraminifera, including *Nummulites* cf. *globulus*. Although *Somalina* is typically considered to be Middle Eocene in age, White (1989) found *Somalina hottingeri* in late *Early* – Eocene rocks from the northern Oman Mountains. This unit corresponds to the *Morozovella aragonensis* Zone (P8) of Blow (1969) and Berggren and Miller (1988).

***Thickness*:** 33 m.

***Environment*:** The unit shows a gradual change from deep marine basinal facies rich in planktonic foraminifera in its lower part into shallow marine mid-outer shelf limestone with *Nummulites* sp., *Assilina* sp. and *Discocyclina* sp., and rare dasycladacean green algae (fragments) in its upper part. The Abat Formation is capped by non-fossiliferous shale of probable fluvial origin and palaeosols. Ostracods (*Bairdia* sp., *Cytherella* sp., *Phalcocythere* sp. and *Xestoleberis* sp.) suggest a shallow marine environment.

2. Musawa Formation

Type-Locality: Wadi Musawa - Latitude $22^0$19' N and Longitude $58^0$23' E

The Early to Late Eocene (Ypresian to upper Bartonian) Musawa Formation comprises a regressive siliciclastic package at its base and a transgressive interval at its top. It contains fluvial sandstones, palaeosoland coal and shale, together with marine mudstone bearing planktonic foraminifera and re-deposited larger foraminifera and radiolaria. Reworked radiolaria and charophytes tend to occur together, especially in the fluviatile, coal-bearing beds. The middle part of the Musawa Formation represents an outer shelf environment.

The lower part of the Musawa Formation is characterised by deep, open marine planktonic foraminifera including *Morozovella* sp.. Its middle part is dominated by planktonic foraminifera (*M. edgari, Globigerinatheka* sp., *Truncorotaloides* sp. and *Turborotalia blowcentralis*).

The upper part of the Musawa Formation represents a shallow marine, outer shelf environment with common in-situ larger foraminifera including *Nummulites* sp., *Operculina* sp., *Discocyclina* sp., *Dictyoconus* sp., *Coskinolina* sp, and *Neorotalia omanensis* n. sp. Bivalves and gastropods, including *Bicorbula* sp., lucinids and naticids (N. Morris, 1998), are indicative of an intertidal to tidal-flat environment. The uppermost part of the formation consists of inner-shelf facies with miliolids and molluscs. It becomes more estuarine-dominated towards its top as indicated by the presence of coal seams and the presence of ostracods such as *Neocyprideis* sp., *Bythocypris* sp., *Hornibrookella* sp. and *Paracosta* sp. *Neorotalia omanensis* n. sp. and *Linderina* sp. specimens were collected from Unit H of the Musawa Formation.

UNIT H

Description: This unit consists of 75 m of marl overlain by 2-3 m of nodular grey limestone and marl. A three meter thick hummocky-cross-stratified limestone caps this unit. The marl layers contain abundant conical-shaped solitary corals and larger foraminifera, including *Alveolina* sp., *Discocyclina dispansa*, *Nummulites* sp., *Neorotalia omanensis* n. sp., miliolids and ostracods. The hummocky-cross-stratified limestone contains *Bicorbula* sp., lucinids and naticids.

Planktonic foraminifera. including *Morozovella* sp, *Truncorotaloides libyaensis*, and *Globigerina* sp., *occur* in the middle of the unit. The larger foraminifera include *Nummulites maculatus*, *Nummulites* cf. *schaubi*, *Discocyclina dispansa*, *Assilina* sp., *Alveolina* sp., *Neorotalia omanensis* n. sp., *Operculina* sp., *Linderina* sp., *Nonionella* sp., *Pararotalia* sp. and miliolids and rare ostracods. Burrows and macrofossils, including gastropods (i.e. *Natica* sp.), oysters and corals occur throughout.

***Age*:** Middle Eocene (upper Lutetian) age is indicated by the presence of the planktonic foraminifera: *Truncorotaloides libyaensis, Truncorotaloides topilensis, Morozovella bolivariana, Globigerinatheka barri, Globigerinatheka curryi* and *Globigerinatheka* sp.. Benthonic foraminifera (*Nummulites schaubi* and *N. maculates)* were recorded by Racey (1995) from the Middle Eocene (lower and middle Lutetian) of the northern Oman Mountains. The unit ranges within the

Truncorotaloides topilensis Zone to the *Truncorotaloides libyaensis/Morozovella bolivariana* Zone, representing the local expression of the standard zones, the *Globigerinatheka subconglobata subconglobata* Zone to the *Orbulinoides beckmanni* Zone (P13), of Blow (1969) and Berggren and Miller (1988).

***Thickness*:** 81 m

***Environment*:** This is an outer shelf environment which was deeper at the base of the unit. It is indicated by abundant and diverse planktonic foraminifera. The topmost part of the unit is characterized by a low-intertidal to sub-tidal molluscan assemblage (N. Morris, Personal commun. 1998).

TAXONOMIC NOTES

SYSTEMATIC PALAEONTOLOGY

Order Foraminiferida (Eichwald, 1830)

Suborder Rotaliina, (Delage and Hérouard, 1896)

Superfamily Rotaliacea (Ehrenberg, 1839)

Family ROTALIIDAE (Ehrenberg, 1839)

Type species: *Neorotalia mexicana* Nuttall, 1928

Description: Test low trochospiral. The umbilicus is filled with a simple plug and the wall is finely pillared dorsally and ventrally. In equatorial section the chambers are high and narrow and the intercameral septa are strongly doubled peripherally only.

Neorotalia omanensis Al-Sayigh n. sp.

Plate 1, Figures 1-8

Material: Twenty three specimens found in samples WME 148 and WME 184 (Unit H), from the Musawa Formation, Wadi Musawa Section, SE Oman. Latitude 22° 19' 11" N and Longitude 58° 23' 10" E.

Type- specimens: Holotype Plate 1 , Figures1-3, sample WME 184.

Paratypes Plate 2 , Figures 4-6, sample WME 148.

Depository: Earth Sciences Department, College of Science, Sultan Qaboos University, Muscat, Sultanate of Oman ARS – N1, ARS – N2 and ARS-N3 2005.

Etymology: After Sultanate of Oman Country.

Diagnosis: A distinctive large (2.3 mm diameter) planoconvex species of *Neorotalia* with 9-13 chambers in the last whorl. Surface coarse and pustulate, umbilical region characterised by a rosette pattern of plugs.

Description: Test trochoid, rounded planoconvex. Periphery lobate to subcircular. There are 3-3.5 whorls with 9-13 triangular chambers in the last whorl in the equatorial section. Umbilical side strongly convex with large pillars on the umbilical shoulder surrounded by fine pustules. Spiral side flat to slightly convex with pustules coarser towards centre. Aperture is extraumbilical-umbilical.

Dimensions: Holotype Diameter 2.3 mm. thickness 1.3 mm

Paratypes Diameter 2.2 mm. thickness 1.1 mm

Neorotalia omanensis n. sp. specimens are slightly different from *Neorotalia aticantina,* as described by Colom (1954), which is biconvex and smaller in size (0.5 to 0.7 mm in diameter and 0.4 to 0.6 mm thick). The Omani species have fine pustules at the periphery coarsening towards the centre on both sides, and a greater number of whorls than *Neorotalia aticantina* (Colom,1954) and *Neorotalia mexicana* (Nuttall, 1952). The *N. omanensis* shows a greater number of chambers in the last whorl than *N. aticantina* (Colom, 1954) and has an equal number of chambers in the last whorl to *N. mexicana* (Nuttall, 1952). The genus *Neorotalia* shows some similarities with *Daviesina*, although *Daviesina* is restricted to the Palaeocene and has a circular to subcircular, slightly trochospiral test with large pillars on umbilical shoulders.

Geographic distribution and stratigraphic range: The genus *Neorotalia* is previously unknown from the Middle East, having been reported from the Oligocene of southern Mexico (Nuttall, 1952) and the Ypresian/Lutetian boundary in Spain (Colom, 1954).

Local range and faunal associations: The Musawa Formation containing *Truncorotaloides topilensis*, *Morozovella edgari* and *Globigerinatheka euganea*, indicates a lower to middle Lutetian age. This species ranges from the *Morozovella edgari*/*Truncorotaloides topilensis* Zone (P10) to the *Truncorotaloides libyaensis/Morozovella bolivariana* Zone (P13), which is equivalent to the *Hantkenina nuttalli* Zone (P10) and to the *Orbulinoides beckmanni* Zone (P13) of Blow (1969) and Berggren and Miller (1988) respectively.

Genus Operculina (*d'Orbigny* 1826)

Type species *Lenticulites complanatus* (Defrance, 1822)

Description

Planispirally coiled, evolute with flat to flattened lenticular to compressed test; loosely coiled with rapidly opening spire, comprising few whorls and subdivided by numerous high chambers. Wall calcareous, perforate with smooth or pustulose surface.

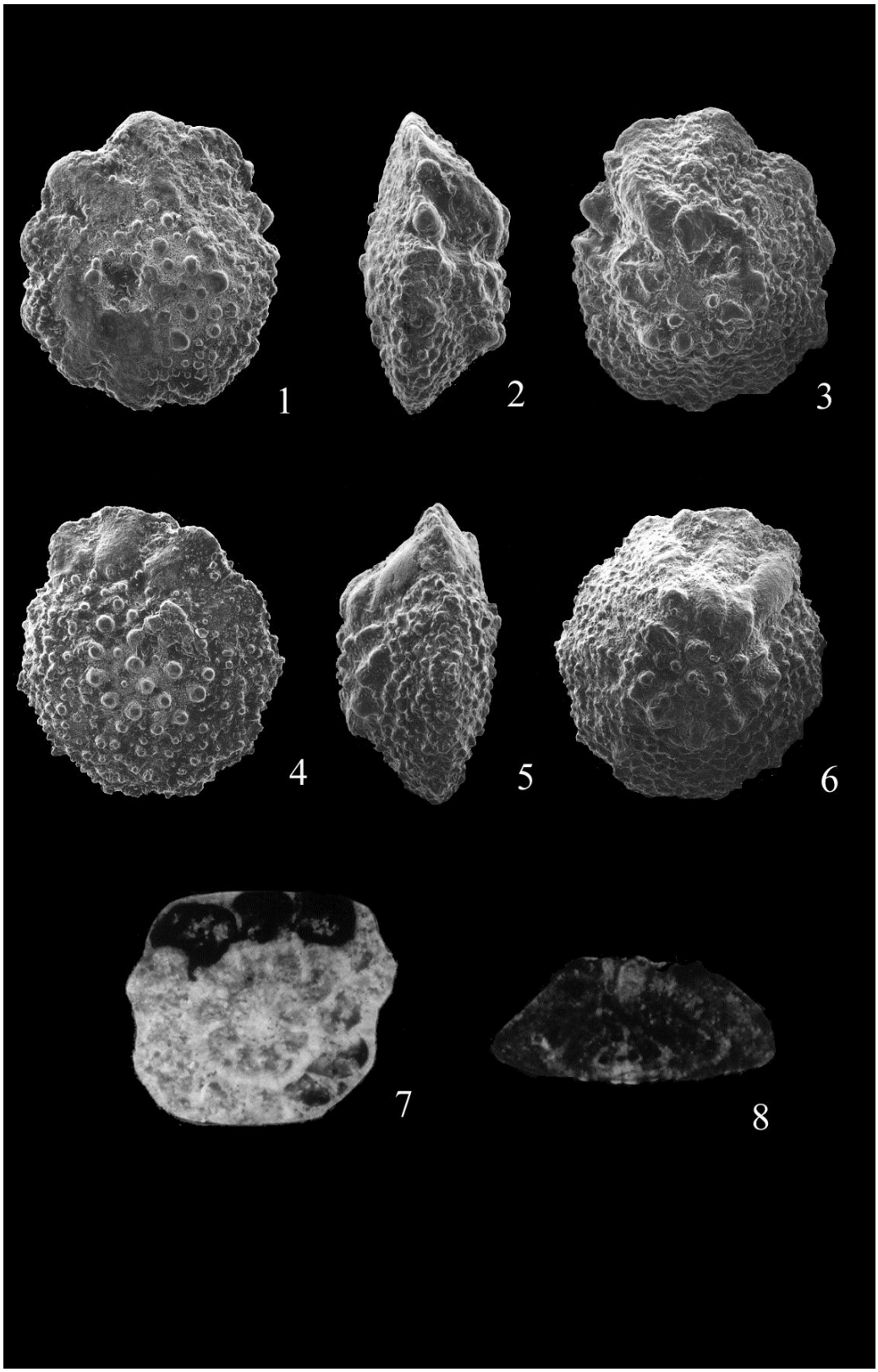

Plate 1:

Figures 1-6 *Neorotalia omanensis* n. sp. From samples WME 148 and WME 184, Wadi Musawa section, Jabal Ja'alan area, SE Oman. Middle Eocene. in spiral, edge and umbilical view, respectively, x65. Figures 1-3 Holotype Figures 4-6 Paratype.

Figures 7-8 *Neorotalia omanensis* n. sp. paratypes from sample WME148, Wadi Musawa section, Jabal Ja'alan area, SE Oman. Middle Eocene. Equatorial and axial sections, x50 and x55 respectively.

Operculina musawaensis *Al-Sayigh* *n. sp.*
Plate 2, Figures 5-8

***Material*:** 12 specimens of A-forms from sample WM35, Abat Formation (Unit D), Wadi Musawa. GRID REFERENCE Lat. 22^0 19' N and Long. 58^0 23' E.
***Type species*:** Holotype: Plate 2. Figure 4
Paratypes: Plate 2. Figures 6-8
Depository: Earth Sciences Department, College of Science, Sultan Qaboos University, Muscat, Sultanate of Oman. ARS – O1, ARS – O2 and ARS - O3. 2005.
Etymology: After Wadi Musawa, SE Oman Mountains, Sultanate of Oman Country.
Diagnosis: A small heavily pustular species with a distinctive large polar pustule, relatively few chambers per whorl and a markedly tight spire (4 whorls in a radius of about 1 mm).
***Description*:**
A-form. Test discoidal, flat with polar region thickened by secondary lamellation. Marginal cord is well-developed with septal sutures radial and recurved towards the periphery. Chambers are 1.5-2 times higher than wide with twenty four arcuate chambers in the last whorl. The spire is tight and opens uniformly. The proloculus has an internal diameter of 0.035-0.043mm.

Dimensions

	Maximum	Minimum	Average
Diameter (mm)	1.7	1.6	1.65
Height (mm)	0.22	0.17	0.19
D/T	7.7	16	8.68

Whorl #	1	2	3	4
Radius (mm)	0.15-0.17	0.24-0.35	0.56-0.64	1.01
Chambers Number	7-8	11-16	17-19	22-25

A-form (Paratype)
B-Form
Not found
Remarks: This species is similar to *Operculina campi,* described by Graham (1950) from the Miocene Meganos Formation of California, but differs in possessing more whorls (6-7 whorls in *O. campi*) and has a flatter, more compressed test. *O. campi* is known only from the Miocene. *O. musawaensis* also differs from *O. jiwani*, described by Racey (1995) from the late Palaeocene of Oman, in that *O. jiwani* has a larger test diameter (1.26-2.37 mm) and a larger proloculus (0.063-0.094 mm).
Geographical distribution and stratigraphic range: Previously unknown.
Local range and faunal associations: Found in Wadi Musawa in the Abat Formation in association with *Acarinina esnaensis* and *A. soldadoensis* within the *Acarinina soldadoensis* Zone (P6) indicating an Early Eocene age. Other associated larger foraminifera are *Alveolina* sp., *Nummulites honogoensis, N. globulus*, *Discocyclina* sp., *Assilina* ex. gr. *exponens*, *Somalina* sp., *Actinocyclina* sp., *Operculina musawaensis* n. sp. Associated planktonic foraminifera are *Morozovella aragonensis* and *Subbotina quadrata.*
Family: **LINDERINIDAE Loeblich and Tappan, 1964**
Genus *Linderina* Schlumberger, 1893
Type species: *Linderina brugesi* Schlumberger, 1893
Generic description of *Linderina*

Test large up to 3.5 mm in diameter, discoidal, centrally thickened. Periphery rounded, peripheral outline lobate, wall calcareous and test surface covered with small pustules. Early chambers of microspheric test form an irregular cluster, rather than a distinct spire. Megalospheric test with bilocular embryo followed by a nepionic ring of seven to eight small chambers with a concentric series of small arched chambers in a single equatorial layer. Younger chambers are progressively larger and alternating in position. Early stage is covered by numerous layers of calcite resulting in an inflated central region traversed by fine pores connecting the chambers to the exterior. Apertures and intercameral openings occur at the base of the chamber against the chambers of the previous whorl.

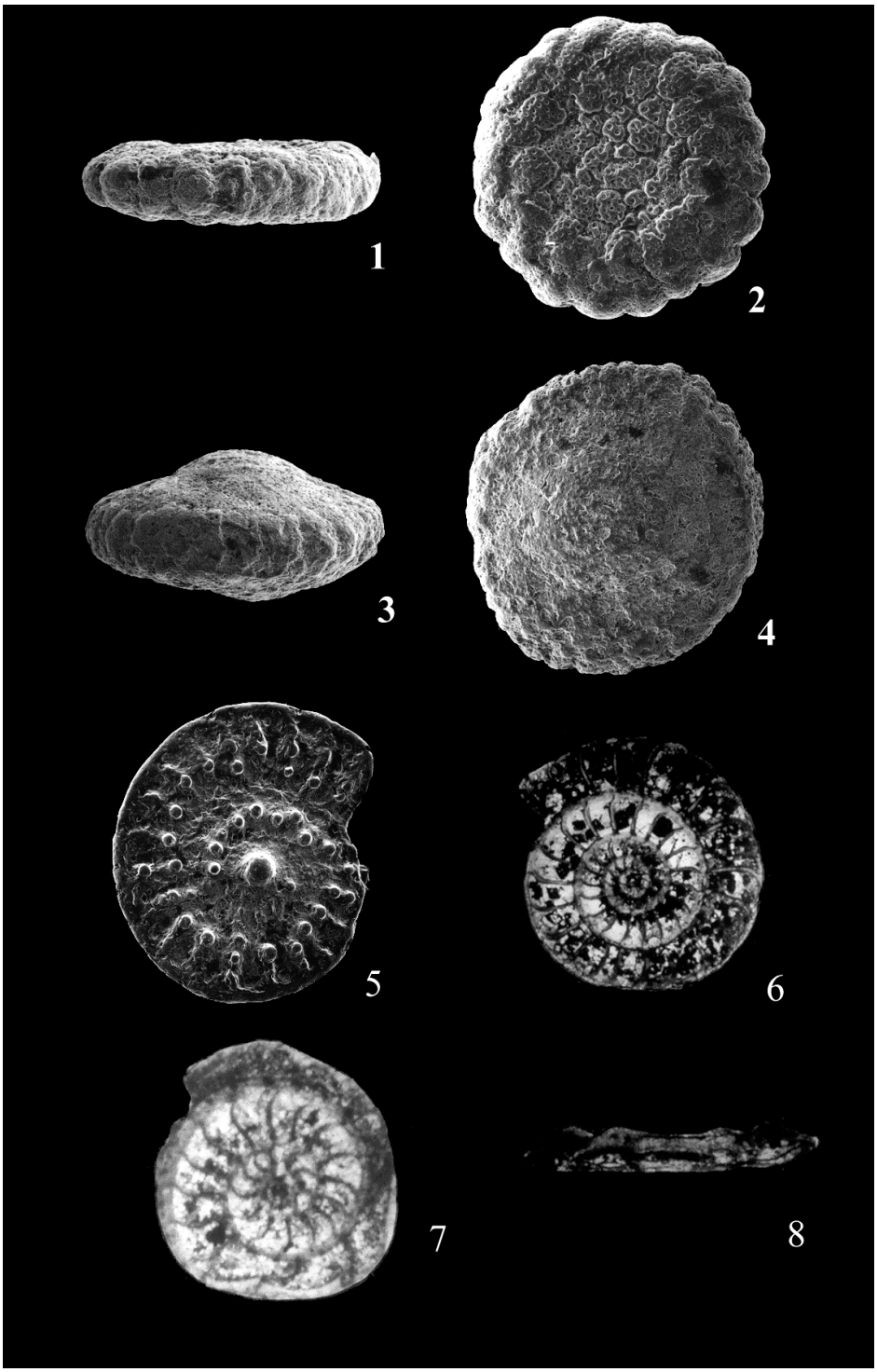

Plate 2:

Figures 1-2 *Linderina* sp. A. From sample WME 184, Wadi Musawa section, Jabal Ja'alan area, SE Oman. Middle Eocene. Edge and side view, respectively, x50.

Figures 3-4 *Linderina* sp B. From sample WME 148, Wadi Musawa section, Jabal Ja'alan area, SE Oman. Middle Eocene. Edge and side view, respectively, x20.

Figures 5-8 *Operculina musawaensis* n. sp. Holotype (A-form). From sample WM 35 Wadi Musawa section, Jabal Ja'alan area, SE Oman. early Eocene. Side view, x30.

Figures 7-8 *Operculina musawaensis* n. sp. paratypes A-forms from sample WM 35, Wadi Musawa section, Jabal Ja'alan area, SE Oman. early Eocene. equatorial oblique and axial section, respectively, all x30.

Plate 3:

Figures 1-4 *Linderina* sp. A

Figure 5 *Linderina* sp. B

4. Discussion

Illustrations in the Ellis and Messina Catalogue (1940) and observations during this study suggest that the globular forms with umbonal lamellar thickening (e.g. Plate 2, Figures 3-4; Plate 3. Figure 5) are all megalospheric, whereas the discoidal forms (without or with very little umbonal lamellar thickening e.g. Plate 2, Figures 1-2, Plate 3, Figures 1-4) appear to be microspheric.

Of the sixteen published species, four are now assigned to other genera: *Linderina douivillei* (Silvestri, 1948) to *Orbitoides* (Neumann, 1958); *L. visserae* (Hofker, 1958) to *Hellenocyclina* (MacGillavry, 1963); *L. ovata* (Halkyard,

1919) to *Droogerinella* (Popescu and Brotea, 1994) and *L. chapmani* (Halkyard, 1919) to *Halkyardia* (Neumann, 1958). Of the remaining potentially valid species *L. rajasthanensis* (Singh, 1953), *L. kirtharensis* (Singh, 1953), *L. kolayatensis* (Singh, 1953), *L. bikanerensis* (Singh, 1953), *L. paronai*, Osimo, *L. floridensis* (Colom,1954), and *L. bihilensis* (Silvestri, 1948) are known only from megalospheric forms and pustules. *L. nuttalli* is known only from a microspheric form. Two species, *L. brugesi* (Schlumberger, 1893) and *L. buranensis* (Nuttal and Brighton,1930) are known from megalospheric and microspheric forms. All records appear to be from the Middle Eocene to the lower part of the Upper Eocene (Bartonian).

Freudenthal (1969) further reduced these ten species to four: *L. buranensis* (within which he synonmised *L. bihilensis* and *L. nuttalli), L. rajasthanensis* (within which he synonymised *L. bikanerensis, L. koyaltensis* and *L. kirtharensis*), *L. paranoi* and *L. floridensis.* Freudenthal (1969) also mentioned that *L. floridensis* may be a synonym of *L. paranoi.*

This study refers to the globular form as sp. A and the discoidal form as sp. B.

Linderina sp. A
Plate 2, Figures 1-2, Plate 3, Figures 1-4

Material: Fourteen specimens from WME 181 and WME 183 from the Wadi Musawa section.
Description: Test small, biconvex, globular, stout with rounded periphery. Central pillars are absent. The protoconch is circular in outline and the deuteroconch is crescentic. Chambers in axial section are narrower at the center and increase gradually in thickness from the centre towards the periphery. Wall finely perforated. The proloculus size varies between 0.04 and 0.07 mm in diameter.

Dimensions

	Maximum	Minimum	Average
Diameter (mm)	1.40	1.02	1.21
Height (mm)	0.81	0.49	0.65
D/T ratio	1.73	2.08	2.28

Remarks: This species differs from *Linderina bikanerensis* Singh (1953) in having a larger and more globular test and circular protoconch, and can thus be distinguished externally and internally.
Geographic distribution and stratigraphic range: Previously known from the Middle East under a variety of names. The genus *Linderina* is also known from the upper chocolate clay of Sulieman Range, Pakistan (Adams, 1970) and from Rajistan, India (Singh, 1953) and Meghalaya (Nagapa, 1956).
Local range and faunal associations: *Linderina* sp. A is found at Wadi Musawa in association with *Globigerinatheka barri* in strata of presumed Middle Eocene age, within *Truncorotaloides topilensis* Zone P11 and *Globigerinatheka barri* Zone, which is equivalent to *Globigerinatheka subconglobata subconglobata* and *Morozovella lehneri* Zones (P11-P12) of Blow (1969) and Berggren and Miller (1988). The associated fauna includes: the planktonic foraminifera *Truncorotaloides libyaensis*, *Morozovella bolivariana, Globigerinatheka barri, Globigerinatheka curryi*, *Globigerinatheka* sp. benthonic foraminifera *Nummulites schaubi* and *N. maculatus* were recorded by Racey (1995).

Linderina sp. B.
Plate 2, Figures 3-4, Plate 3, Figure 5

Material: Twenty five specimens from sample WME 182.
Description: Test large, discoidal with rim encircling the central area and with a slightly wavy periphery. Equatorial chambers arcuate, large and arranged overlapping alternately, increasing in size towards the center varying in size from 0.09 mm to 0.12 mm across. In axial section the test is thick at the centre and narrows towards the margins. Pillars are fine, radial over most of the test. Protoconch is about 0.11 mm in axial section, and 0.08 mm in equatorial section.

Dimensions

	Maximum	Minimum	Average
Diameter (mm)	2.2	1.5	1.85
Height (mm)	0.33	0.29	0.31
D/T ratio	6.66	5.17	5.97

Remarks: This species is characterized by its discoidal test, wavy test periphery and distinctive equatorial chambers.
Geographic distribution and stratigraphic range: Previously known from the Middle East.
Local range and faunal associations: *Linderina* sp. B is found in Wadi Musawa in association with *Truncorotaloides topilensis* and *Morozovella* sp., indicating a Middle Eocene age within the *Truncorotaloides topilensis* Zone (P11), equivalent to the *Globigerinatheka subconglobata subconglobata* Zone (P11) of Blow (1969) and of Berggren and

Miller (1988). Associated larger foraminifera include *Alveolina* sp., *Discocyclina dispansa, Nummulites* and *Neorotalia omanensis* n. sp.

5. Conclusions

Two new larger foraminiferal species, *Operculina musawaensis* n. sp., and *Neorotalia omanensis* n. sp., are described and illustrated. The presence of *Neorotalia* sp. represents the first record in the Middle East. Two forms of *Linderina* sp. are also described and illustrated. It is concluded that of the sixteen published species, four (*L. douvillei, L. visserae, L. ovata* and *L.chapmani*) are referable to other genera and one (*L. baldaci*) is insufficiently described/illustrated to permit even a generic assignment. Of the remaining species, two are known from both megalospheric and microspheric specimens (*L. brugesi* and *L. buranensis*), one is only known from a microspheric form (*L. nuttalli*) and the remainder are only known from megalospheric forms (*L. bikinarensis, L. floridensis, L. glaesseneri, L. kirtharensis, L. kolayatensis, L. parona*i, and *L. rajahstanensis*). Of these, L. kolyatensis, *L. bikanerensis L. kirtharensis* and *L. rajahstanensis* are synonymous (with *L. rajahstanensis* having priority) and the status of *L. glaessneri* remains problematic. Closer examination of the Oman materials and published descriptions indicate that globular forms with umbonal lamellar thickening are megalospheric and discoidal forms without or with very little umbonal lamellar thickening are probably microspheric. Because test size and shape (both dependent to a certain degree on the amount of lamellar thickening) are not species specific, many of the *Linderina* species could be grouped under a single species. Alternatively, the smaller globular forms may be juveniles.

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