EOCENE MARINE SEDIMENTS IN THE SPERRGEBIET, SOUTH WEST AFRICA

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(With 15 figures)

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ABSTRACT

Twelve taxa of calcareous nannofossils and twenty-one of benthic foraminifera have been identified from calcareous marine siltstones near Bogenfels, South West Africa. These taxa establish the sediments as upper Eocene. It is equally correct to assign them either to Martini's NP 19–NP 20 nannofossil zones (37,2–39,5 m.y.B.P.) or to Bukry's *Isthmolithus recurvus* subzone (38–41 m.y.B.P.). The sediments were deposited in a shallow, near-shore environment; the overlying watermass was cool-temperate and had normal marine salinity.

The informal name 'Langental beds' is suggested for the low-lying, fossiliferous rocks in the area, at least some of which are upper Eocene. The informal name 'Buntfeldschuh beds' is suggested for the topographically higher, essentially unfossiliferous units. The Buntfeldschuh beds may be upper Paleocene–lower Eocene.

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INTRODUCTION

Study of the Tertiary Period in southern Africa is severely constrained by the scarcity of outcrops. This is especially true along the western coastal margin of the subcontinent. Scattered outcrops occur in the southern coastal zone between Cape Town and Hondeklip Bay, but between Hondeklip Bay and the

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Kunene River—a distance of more than 1 200 km—the only known marine Tertiary beds are a few small exposures in the Sperrgebiet (Fig. 1). It is therefore imperative to extract as much geological information as possible from these outcrops, since they are the only positive record left of Tertiary marine incursion along this long stretch of coastline.

The main purpose of this paper is to present an account of the microfossils in these rocks, although aspects of the lithology, depositional environment and stratigraphic status are discussed as well.

TERTIARY MARINE DEPOSITS

All the Tertiary deposits occur in the 'Sperrgebiet'. The name means 'the forbidden area', and was applied by the German government a few months after diamonds were discovered (1908) in the northern part of the area. General prospecting was forbidden in the region lying between the coast and the Great Escarpment and extending from the Orange River northwards to latitude 26°S—the area originally defined as the Sperrgebiet (Stocken 1962).

Tertiary marine deposits occur sporadically as small outcrops from Buntfeldschuh in the south to Lüderitz Krater in the north, a distance of about 40 km (Fig. 1). The best-preserved and most-studied outcrops occur at two localities: Buntfeldschuh, and a few kilometres north and north-east of Bogenfels. Smaller outcrops occur at or near Eisenkieselklippenbake, Lüderitz Krater, Advokat Bake and in a few other patches (see Beetz 1926, and the geological map in Kaiser 1926).

BUNTFELDSCHUH

LITHOLOGY

At Buntfeldschuh there is a surf-cut platform at 120–140 m (Martin 1973). About 45 m of marine sediments lie on this platform. The marine unit consists of a sporadically occurring pebble conglomerate at the base, overlain by clayey, mostly fine-grained sandstones. Occasional pebble lenses dominated by chalcedony, agate and jasper cut through the sandstones (Fig. 2). These lenses are known to be diamondiferous; Beetz (1926) reports the finding of gemstones as large as 2,5 cts.

The sandstones are predominantly greyish green (5 GY 7/2), although dusky yellow (5 Y 6/4), dark greyish orange (10 YR 6/6) and very pale orange (10 YR 8/2) colours are also common (colours from the GSA Rock Color Chart). Most units are fine-grained in texture; quartz is the most abundant component grain, with minor, variable amounts of feldspar, rock fragments and opaque minerals. Only a few calcareous layers are present, and in these the $CaCO_3$ occurs as cement. The sandstones are mostly poorly to moderately indurated. Figure 3 shows a thin section cut from a more indurated sample.

Overlying the marine rocks is a thick (over 40 m) sequence of cross-bedded brown aeolian sandstone (Fig. 4). This aeolian sequence is capped by about 1 m

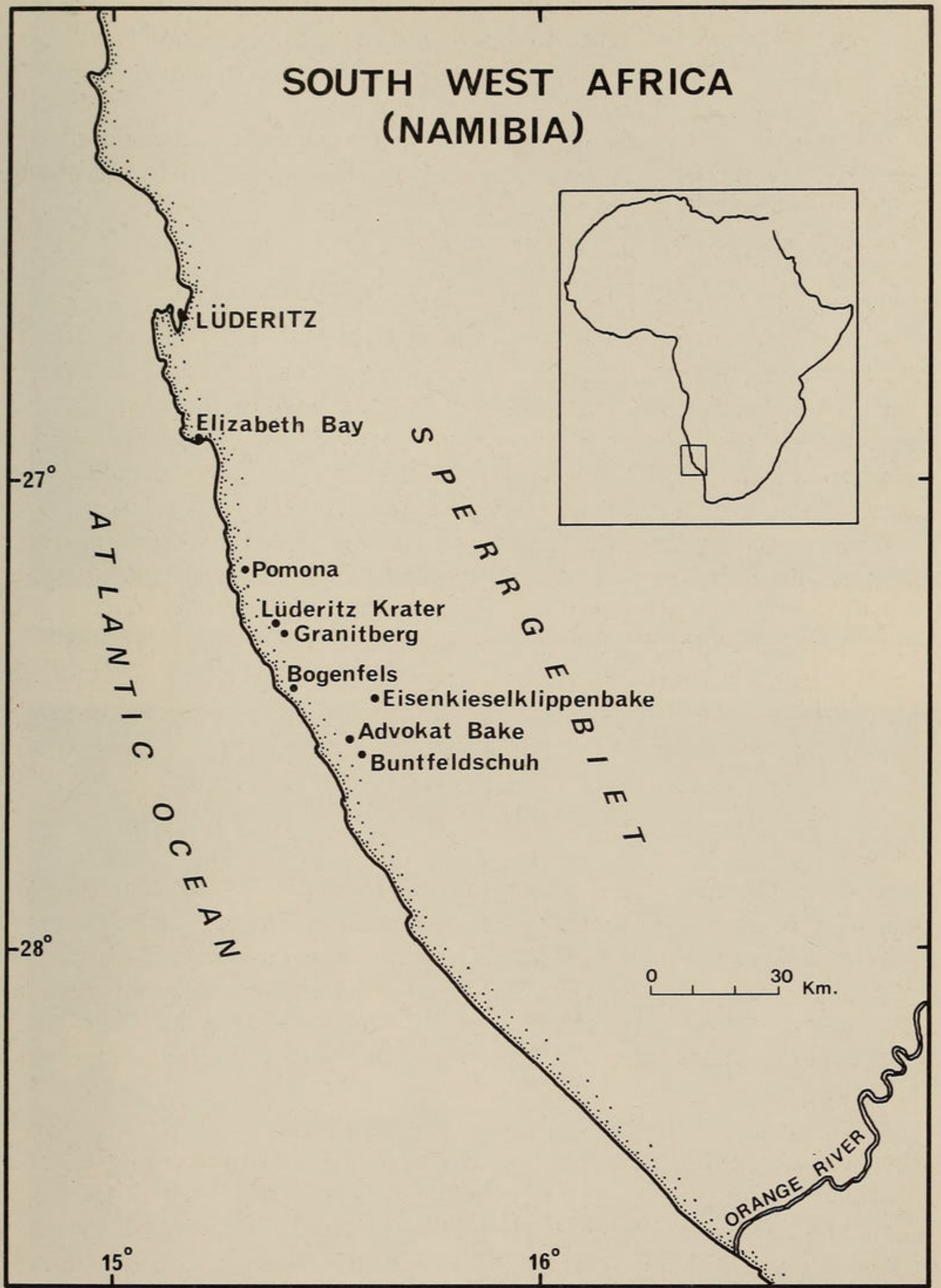

Fig. 1. Map showing the locations of Tertiary marine outcrops mentioned in the text.

Fig. 2. Pebble lens in Buntfeldschuh sandstones. Pebbles are predominantly vein quartz, chalcedony, agate and jasper.

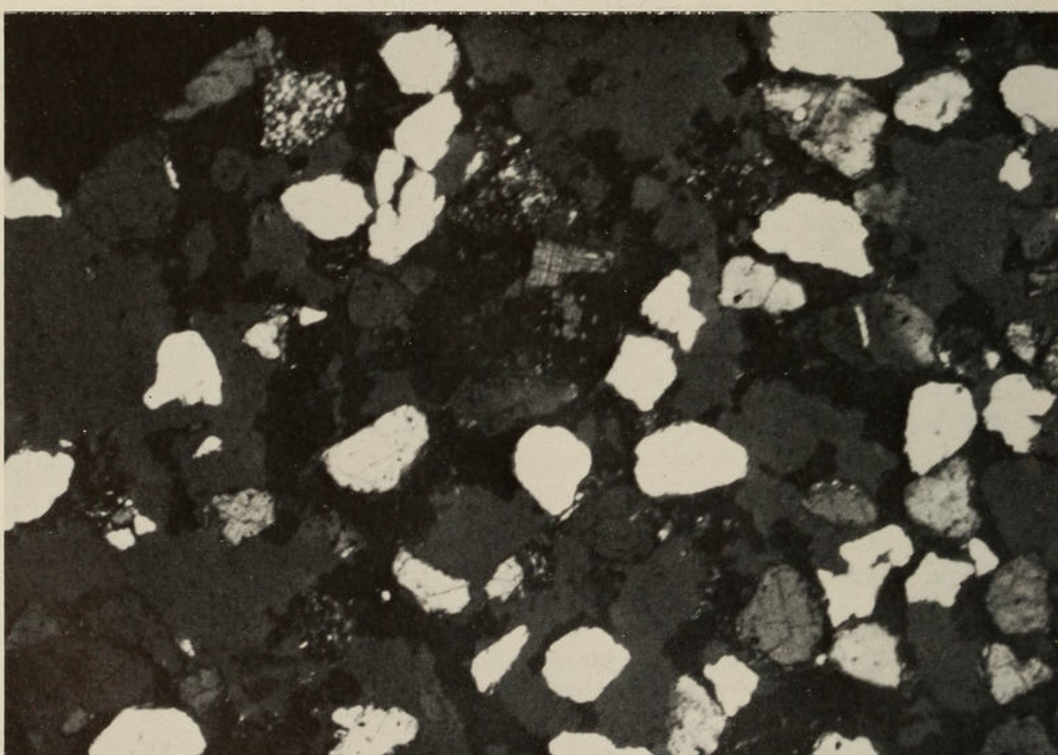

Fig. 3. Photomicrograph of a greywacke sandstone from Buntfeldschuh. Groundmass is comminuted mica and clay; grains are mostly quartz, with some altered feldspar and rock fragments.

Fig. 4. Cross-bedded aeolian sandstones overlying ?upper Paleocene–lower Eocene marine beds at Buntfeldschuh. 'Diagenetic'-ooid-bearing calcrete caps the section.

of calcrete, containing the same unusual diagenetic ooids and intraclasts (Fig. 5) first reported by Siesser (1973) from ?Pliocene–Pleistocene calcretes of the Cape Province.

Further details of the Tertiary section at Buntfeldschuh are given by Beetz (1926). Unpublished work by geologists of Consolidated Diamond Mines, South West Africa suggests that the Buntfeldschuh-escarpment section may be more stratigraphically complex than previously realized. Local faulting and tilting in the section allows recognition of at least two marine members. The lower member overlies a remnant of the Pomona beds (here capped by Tafelberg Quartzite) in a small depression at the northern end of the escarpment (C. G. Stocken pers. comm. 1979).

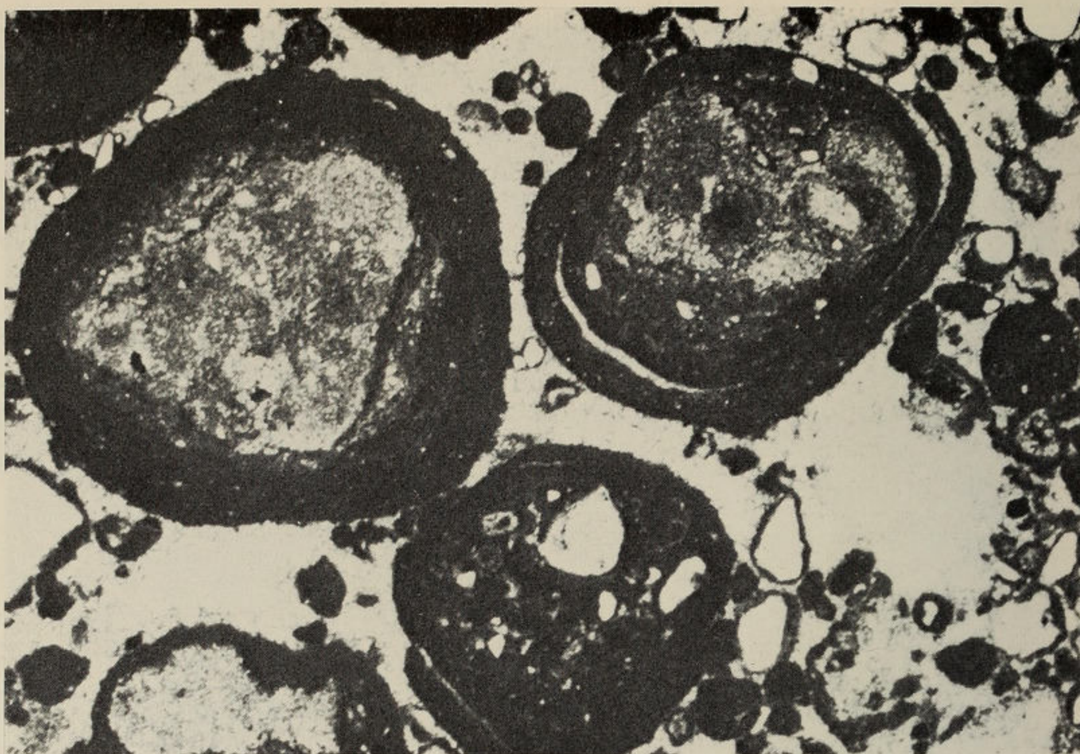

Fig. 5. 'Diagenetic' ooids and intraclasts set in an intergranular fabric of microspar and micrite at Buntfeldschuh (see Fig. 4).

Fig. 6. Burrow in sandstone at Buntfeldschuh.

PALAEONTOLOGY

The only macrofossils found in the marine section were burrows (Fig. 6). Fish teeth have been reported by Böhm (1926) and C. G. Stocken (pers. comm. 1979).

All samples collected were barren of microfossils.

BOGENFELS

Tertiary remnants are preserved 3–5 km north and north-east of Bogenfels village in two depressions on either side of the Langental (Fig. 7). The larger exposures are south and east of the Langental. The smaller, but better-known deposits, are on the northern side of the Langental, adjacent to Wanderfeld IV (Fig. 7). Most attention in the past has focused on the smaller exposure, which will be referred to here as the Wanderfeld IV locality, since it is the most fossiliferous exposure and also overlies the only known marine Cretaceous deposit between the southern Cape Province and the Kunene River. The following lithological and micropalaeontological descriptions of this section refer specifically to the Wanderfeld IV outcrops.

LITHOLOGY

Tertiary outcrops rest on a platform carved into the late Precambrian Bogenfels Formation (mostly dolostone and phyllitic schists in this area), at an elevation of about 70 m. Beetz (1926) gives general characteristics for the Tertiary beds. Klinger (1977) presents a diagrammatic stratigraphic section, and the following description is taken partly from his section, and partly from our own observations.

The marine beds are only about 4 m thick. They consist of a pebble layer at the base, which is overlain by concretionary calcareous sandstones and marly sandstones and siltstones. At least one layer of light-brown (5 YR 5/6) ferruginous calcirudite occurs near the bottom of the section. This layer contains pebbles, but is predominantly composed of neomorphosed mollusc fragments set in micrite and microspar (Fig. 8). The marly sand- and siltstones are mostly pale greenish yellow (10 Y 7/2), poorly consolidated, and calcareous. The calcareous concretionary layers are greyish yellow (5 Y 7/4) to pale greenish yellow (10 Y 7/2) and are moderately well indurated. All layers contain occasional macrofossils and agates. This section is generally much more calcareous than the Buntfeldschuh section.

PALAEONTOLOGY

Klinghardt discovered the first fossils at Bogenfels (Haughton 1930*b*). Reuning and Lotz collected from the locality in 1909, and supplied the original fossils studied by Böhm & Weissermel (1913). A Miocene age was initially assigned, based mainly on the molluscs and fish teeth. Böhm (1926) later revised the age to middle to upper Eocene, after obtaining a more extensive collection of fossils made by Kaiser and Beetz during 1914–19 (Haughton 1930*b*).

However, doubt remained in some quarters as to the age of these beds (see Siesser 1977 for a review). Siesser (1977) eventually confirmed the age as upper Eocene, based on calcareous nannofossils.

Macrofossils

Böhm & Weissermel (1913), Böhm (1926), and Weissermel (1926) provide an extensive list of the macrofossils found near Bogenfels. Bryozoans, bivalves,

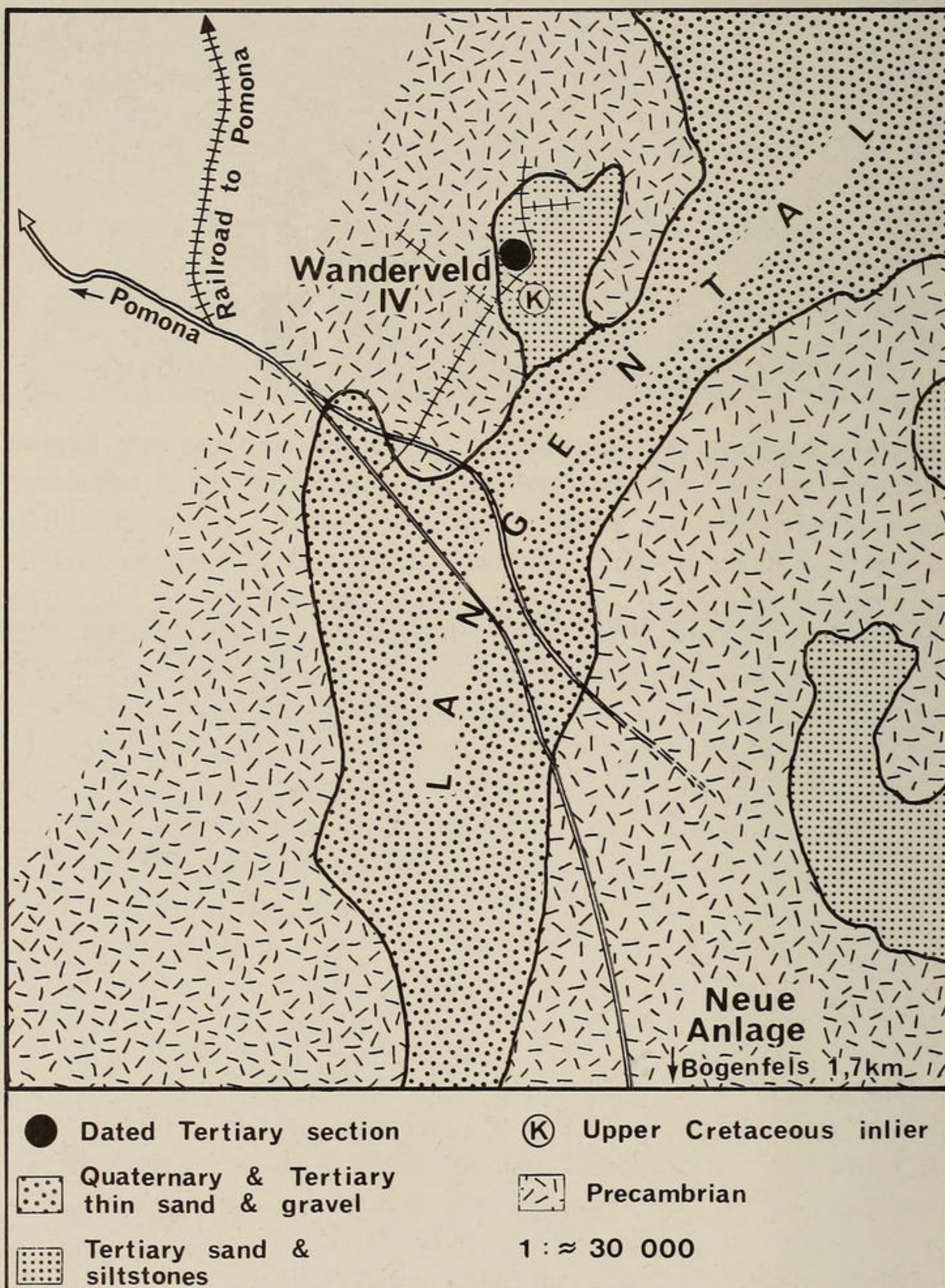

Fig. 7. Map showing location of upper Eocene rocks north and north-east of Bogenfels (from Kaiser 1926; Klinger 1977).

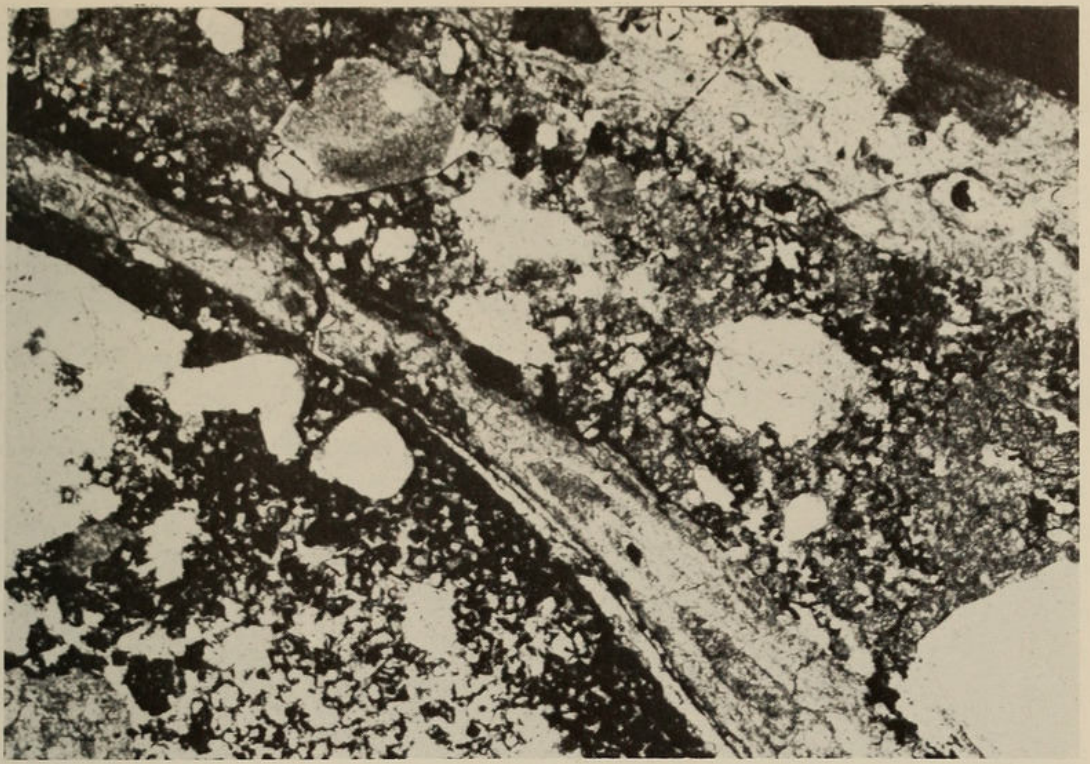

Fig. 8. Photomicrograph of the upper Eocene mollusc calcirudite at Wanderfeld IV (Fig. 7). Groundmass is micrite and microspar; light grains are quartz; large elongate grains are mollusc fragments neomorphosed to pseudospar.

gastropods, a nautiloid, cirripeds, a crab, corals, hydrozoans, fish teeth and *Callianassa* burrows are all present. Bivalves and gastropods are the most abundant fossils: Böhm (1926) named 9 new species in the former class and 13 in the latter from this locality; fish teeth are also numerous and diverse: Böhm (1926) named 13 new species here.

The abundance and diversity of the gastropod *Turritella* is especially striking. This genus litters the ground (Fig. 9) in the area, and prompted Haughton (1930*a*) to coin the term '*Turritella*-beds' for the Tertiary outcrops.

Microfossils

Calcareous nannofossils

Moderately to poorly preserved calcareous nannofossils (Figs 10–11) occur in the clayey siltstones. A list of the species identified follows. The relative percentage of each species, based on specimen counts in smear slides, is also listed. (These species are all well known and their taxonomy is not controversial; therefore a systematic palaeontology section is not included.)

	%
Braarudosphaera bigelowi (Gran & Braarud) Deflandre	1
Braarudosphaera discula Bramlette & Riedel	trace
Chiasmolithus spp	1

	%
Coccolithus eopelagicus (Bramlette & Riedel) Bramlette & Sullivan	28
Coccolithus formosus (Kamptner) Wise	6
Discoaster saipanensis Bramlette & Riedel	5
Discoaster tani Bramlette & Riedel	3
Isthmolithus recurvus Deflandre	3
Reticulofenestra bisecta (Hay, Mohler & Wade) Roth	37
Reticulofenestra coenura (Reinhardt) Roth	trace
Reticulofenestra umbilica (Levin) Martini & Ritzkowski	12
Zygrhablithus bijugatus (Deflandre) Deflandre	4

The age can be narrowly defined by the range overlap of *Discoaster saipanensis* and *Isthmolithus recurvus*. The former ranges from middle to upper Eocene and the latter from upper Eocene to lower Oligocene. They co-occur only in the NP 19 and NP 20 zones of Martini's (1971) biostratigraphic zonal scheme, and only in the *I. recurvus* subzone of Bukry's (1975) zonal scheme.

Fig. 9. Various species of *Turritella* weathered out of the upper Eocene rocks at Wanderfeld IV (Fig. 7).

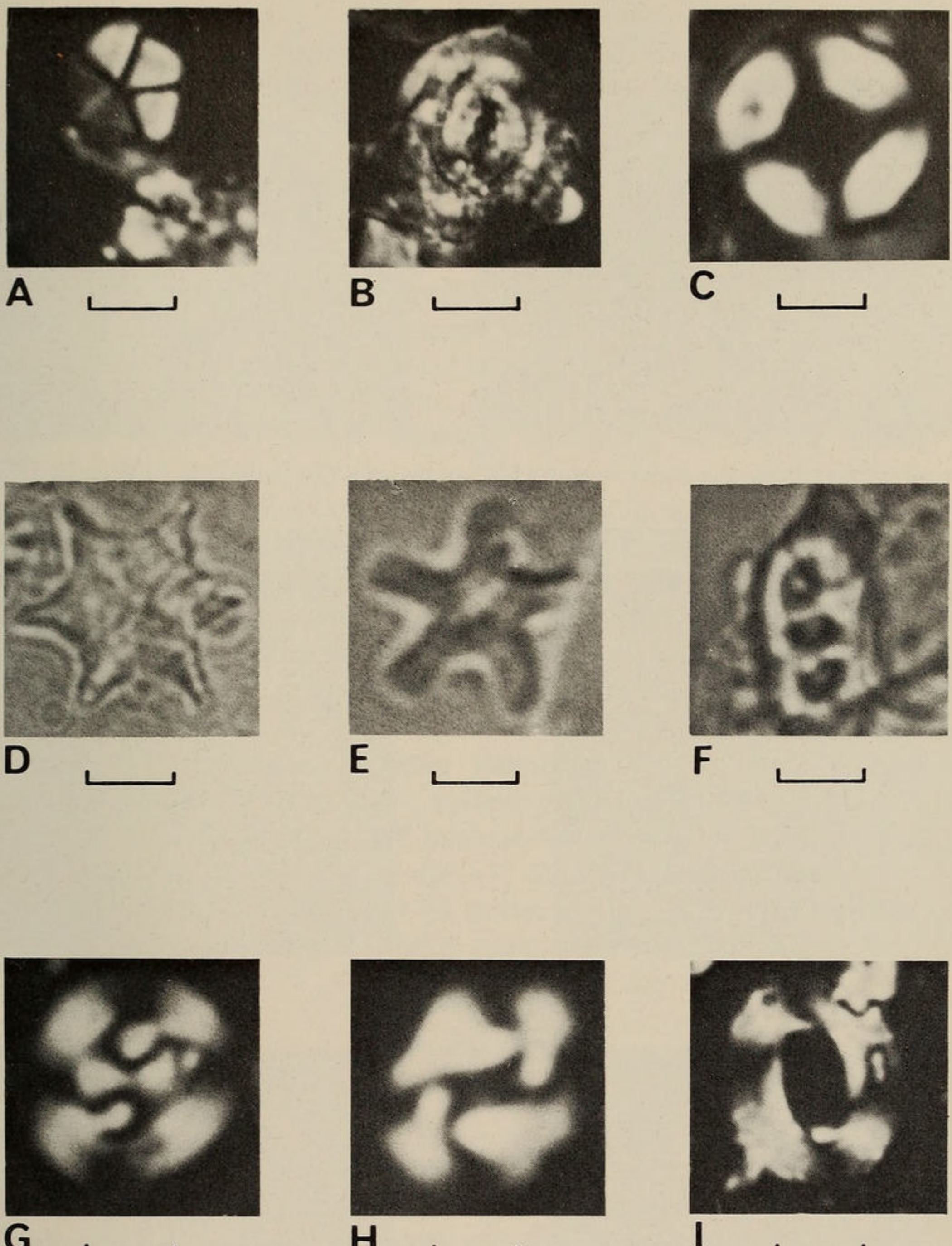

Fig. 10. Calcareous nannofossils from the upper Eocene rocks at Wanderfeld IV (Fig. 7). Light photomicrographs. A. *Braarudosphaera bigelowi*, crossed nicols, scale = 6μ. B. *Coccolithus eopelagicus*, crossed nicols, scale = 9μ. C. *Coccolithus formosus*, crossed nicols, scale = 5μ. D. *Discoaster saipanensis*, plane polarized light, scale = 6μ. E. *Discoaster tani*, plane polarized light, scale = 4μ. F. *Isthmolithus recurvus*, plane polarized light, scale = 5μ. G. *Reticulofenestra bisecta*, crossed nicols, scale = 5μ. H. *Reticulofenestra* cf. *R. coenura*, crossed nicols, scale = 3μ. I. *Reticulofenestra umbilica*, crossed nicols, scale = 6μ.

Vail *et al.* (1977) show the estimated time boundaries of NP 20–NP 19 as 37,2–39,5 m.y.B.P.; Bukry (1975) estimates the boundaries of the *I. recurvus* subzone as 38–41 m.y.B.P.

Benthic foraminifera

Poorly preserved benthic foraminifera occur in small numbers in the clayey siltstones at Wanderfeld IV. This is the first report of *in situ* upper Eocene benthic foraminifera on the mainland of South or South West Africa. (The 'upper Eocene' deposits recorded by Chapman (1930) in the eastern Cape Province are now known to be lower Eocene (Siesser & Miles in press).) The fauna is dominated by *Glandulina* sp. and *Lenticulina* spp. Most of the other taxa are represented by only a few specimens, or in some cases, a single specimen.

Rather formidable taxonomic problems plague the study of benthic foraminifera under the most favourable conditions (Boltovskoy & Wright 1976; Boltovskoy 1978). These difficulties are accentuated here, since specimens are relatively scarce and have been affected by diagenesis (Fig. 11c–f). All specimens have been variously affected by mechanical breakage, solution, recrystallization or test infilling. The variation noted among specimens of some of the better-known species suggests that there may be new species present. However, insufficient numbers of specimens available for study precludes describing them as new species.

Because there is little previously published information on southern African Palaeogene benthic foraminifera, and because of the taxonomic problems involved, a section on systematics follows, together with illustrations of the taxa identified at Wanderfeld IV (Figs 11–15). Generic assignments have been made following the classification of Loeblich & Tappan (1964). The preferred modern species name is given, followed by a brief synonymy.

Family **Textulariidae**

Textularia sp.

Fig. 12A

Remarks

A single arenaceous specimen from which the initial portion of the test is partly missing and the remainder indistinct; therefore the generic position is somewhat uncertain. The test is slightly elongate, biserial and rhomboidal in section. It is finely agglutinated and fourteen chambers are visible. Apertural details are obliterated.

Family **Nodosariidae**

Astacolus sp.

Fig. 12B

Remarks

A solitary specimen with slightly compressed planispiral test, the final chamber of which breaks away to become uniserial. The last chamber is shorter

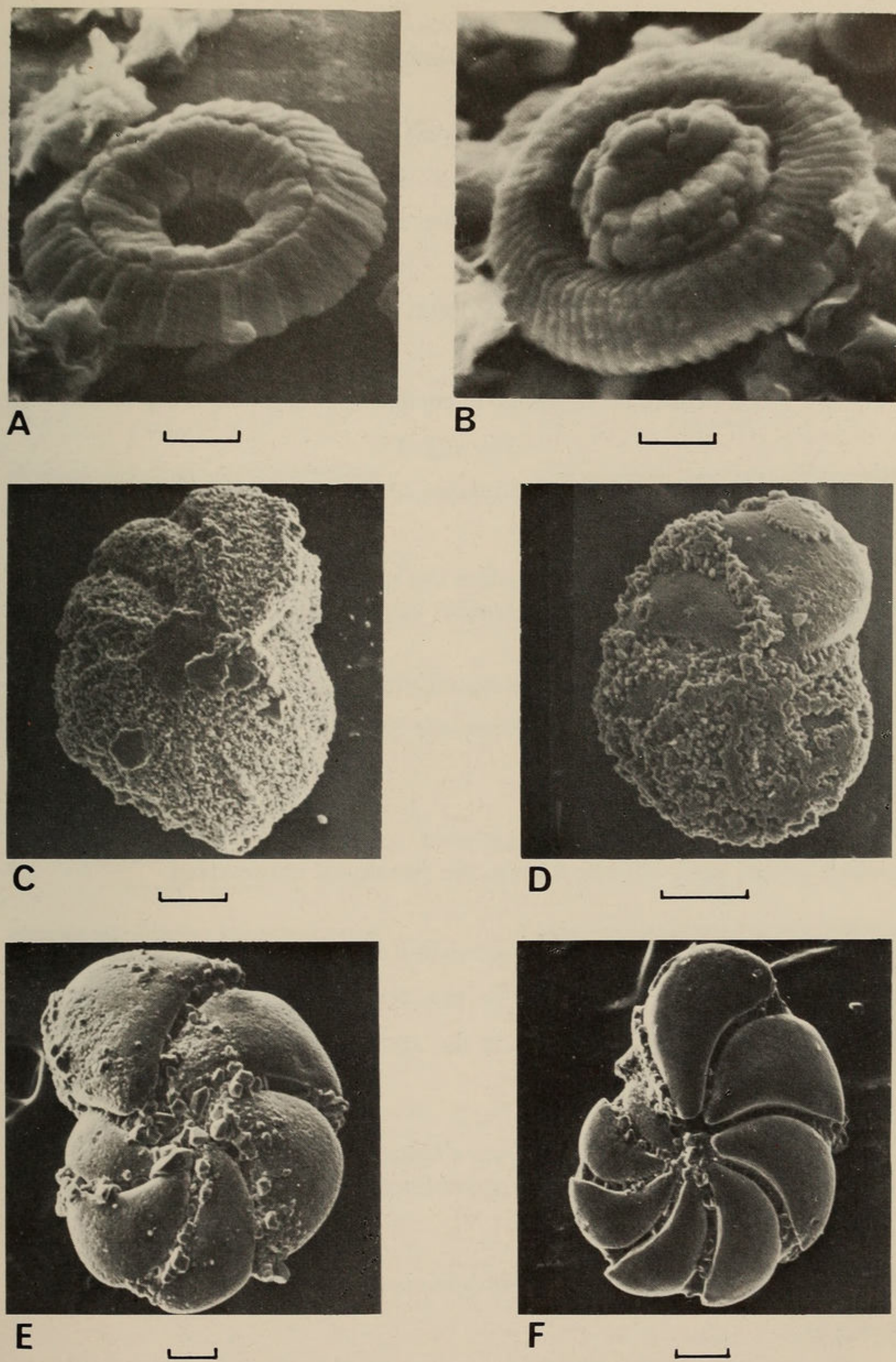

Fig. 11. Calcareous nannofossils and benthic foraminifera from the upper Eocene rocks at Wanderfeld IV (Fig. 7). Scanning electron micrographs. A. *Coccolithus formosus*, scale = 2μ. B. *Reticulofenestra bisecta*, scale = 2μ. Note dissolution effects on *C. formosus* and accretion of secondary calcite in the central area of *R. bisecta*. C–F. Test infilling and test dissolution in *Lenticulina*. Differential test dissolution is displayed in C (SAM–K5538) and D (SAM–K5539). The umbo and sutures are more resistant to dissolution and remain prominent. Dissolution eventually produces an internal mould as shown in E (SAM–K5540) and F (SAM–K5541). Scale = 100μ.

in height, but broader than the previous chambers. Twelve chambers are visible and the sutures are flush to very slightly raised.

Lenticulina simplex d'Orbigny, 1839

Fig. 12C–D

Robulus simplex (d'Orbigny) Cushman & Laiming, 1931: 98, pl. 10 (fig. 5a–b).

Remarks

A few well-preserved specimens occur, with thick, prominent umbos and keels.

Lenticulina cf. *L. pseudo-mamilligerus* (Plummer, 1926)

Fig. 12E–F

Robulus pseudo-mamilligerus (Plummer) Cushman, 1951: 13, pl. 4 (figs 1–5).

Remarks

The illustrated specimen resembles the species figured by Cushman (1951) in test outline and in suture and chamber disposition.

Lenticulina cf. *L. oblonga* (Coryell & Howe, 1930)

Lenticulina cf. *L. oblonga* (Coryell & Howe) *fide* Fairchild, Wesendunk & Weaver, 1969: 42, pl. 6 (fig. 4a–b).

Remarks

A poorly preserved eight-chambered specimen was found. The keel is present on the early chambers only, the remainder unpreserved.

Lenticulina subalata Reuss, 1854

Fig. 13A–B

Cristellaria subalata Reuss, 1854: 68, pl. 25 (fig. 13). Chapman, 1926: 65, pl. 4 (figs 19a–b, 25a–b, 26a–b).

Remarks

Two specimens of this species were found. This form has been noted from the Aptian by Reuss and from the upper Eocene of New Zealand by Chapman (1926).

Lenticulina spp

Remarks

Twelve very badly preserved specimens were found. None could be definitely identified to species level.

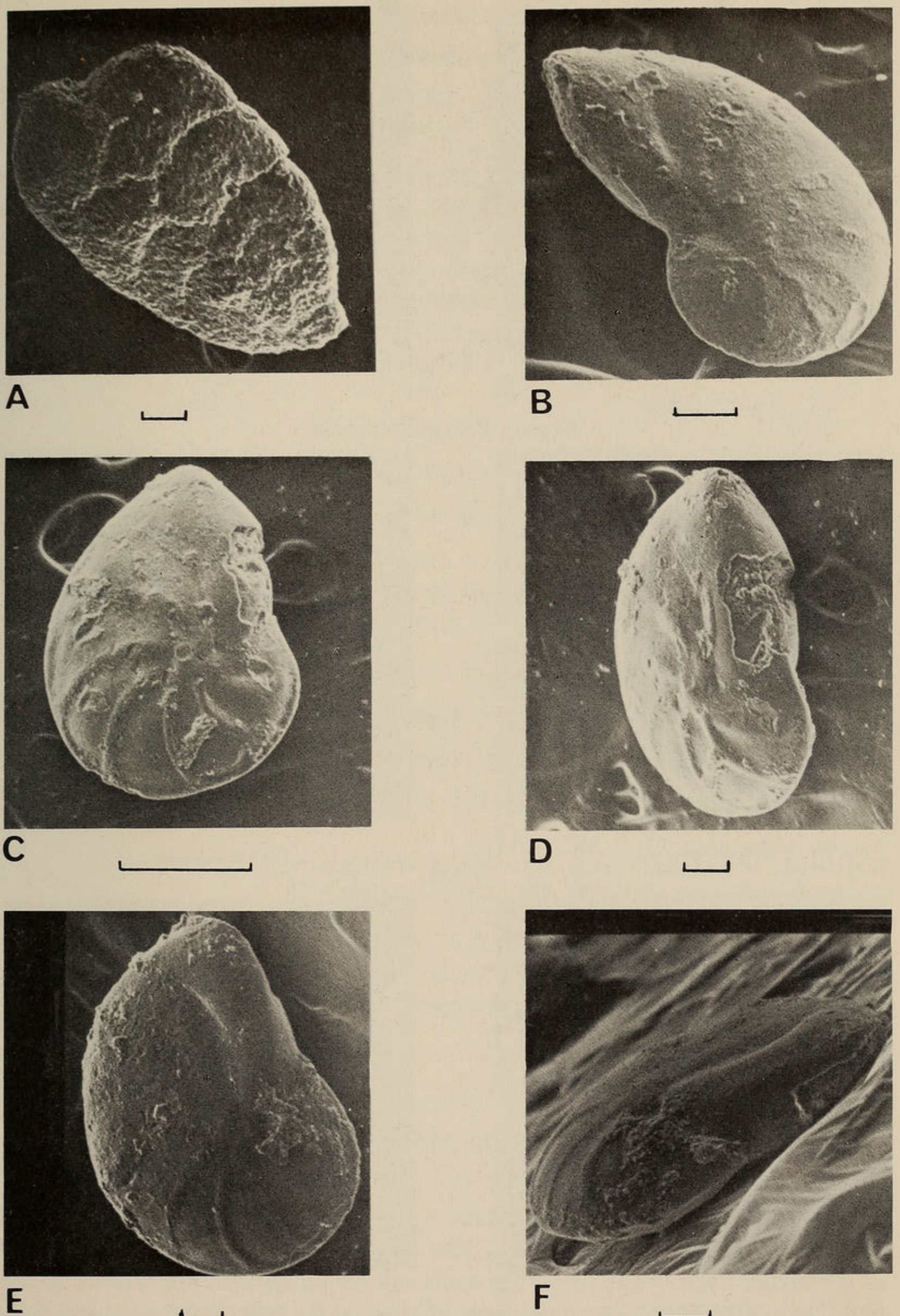

Fig. 12. Benthic foraminifera from the upper Eocene at Wanderfeld IV (Fig. 7). Scanning electron micrographs. All scales = 100μ, unless otherwise noted. A. *Textularia* sp. SAM–K5520. B. *Astacolus* sp. SAM–K5521. C. *Lenticulina simplex*, side view, SAM–K5522, scale = 300μ. D. *Lenticulina simplex*, peripheral view, SAM–K5522. E. *Lenticulina* cf. *L. pseudo-mamilligerus*, side view, SAM–K5523. F. *Lenticulina* cf. *L. pseudo-mamilligerus*, peripheral view, SAM–K5523.

Family **Glandulinidae**

Siphoglobulina ? sp.

Fig. 13C–D

Remarks

A single specimen appears referable to this genus, but the state of preservation does not allow an accurate diagnosis. The test is subfusiform and circular in cross-section. Chambers are strongly overlapping, the sutures depressed and the specimen has a terminal radiate aperture. In side view the specimen appears similar to *Marginulina,* a distinguishing feature of this genus noted by Parr (1950) in his description of the genoholotype *Siphoglobulina siphonifera.* The genus ranges from lower Tertiary to Holocene.

Family **Polymorphinidae**

Glandulina sp.

Fig. 13E

Remarks

The most abundant form present in the Bogenfels section. Chambers and sutures are indeterminate because of poor preservation. The terminal, radiate aperture, however, is often preserved.

Family **Elphidiidae**

Elphidium cf. *E. crispum* (Linné, 1758)

Fig. 13F

Nautilus crispus Linné, 1758: 709.
Polystomella crispa (Linné) Brady, 1884: 736, pl. 110 (figs 6–7).
Elphidium crispum (Linné) Barker, 1960: 220, pl. 110 (figs 6–7).

Remarks

A single, broken specimen was found. Although broken, the features of the central boss, chambers and sutures suggest *E. crispum,* rather than the closely related form *E. macellum.*

Elphidium sp. A

Fig. 14A–B

Remarks

A small *Elphidium* with subcircular outline has twelve chambers and raised sutures bridged by retral processes. The retral processes (four or five present) of the earlier parts of the whorl are confused, giving a pitted appearance to the test. The aperture consists of a number of pores at the base of the apertural face. This specimen is very similar to *E. saginatum* Finlay, but differs in not having a depressed central area.

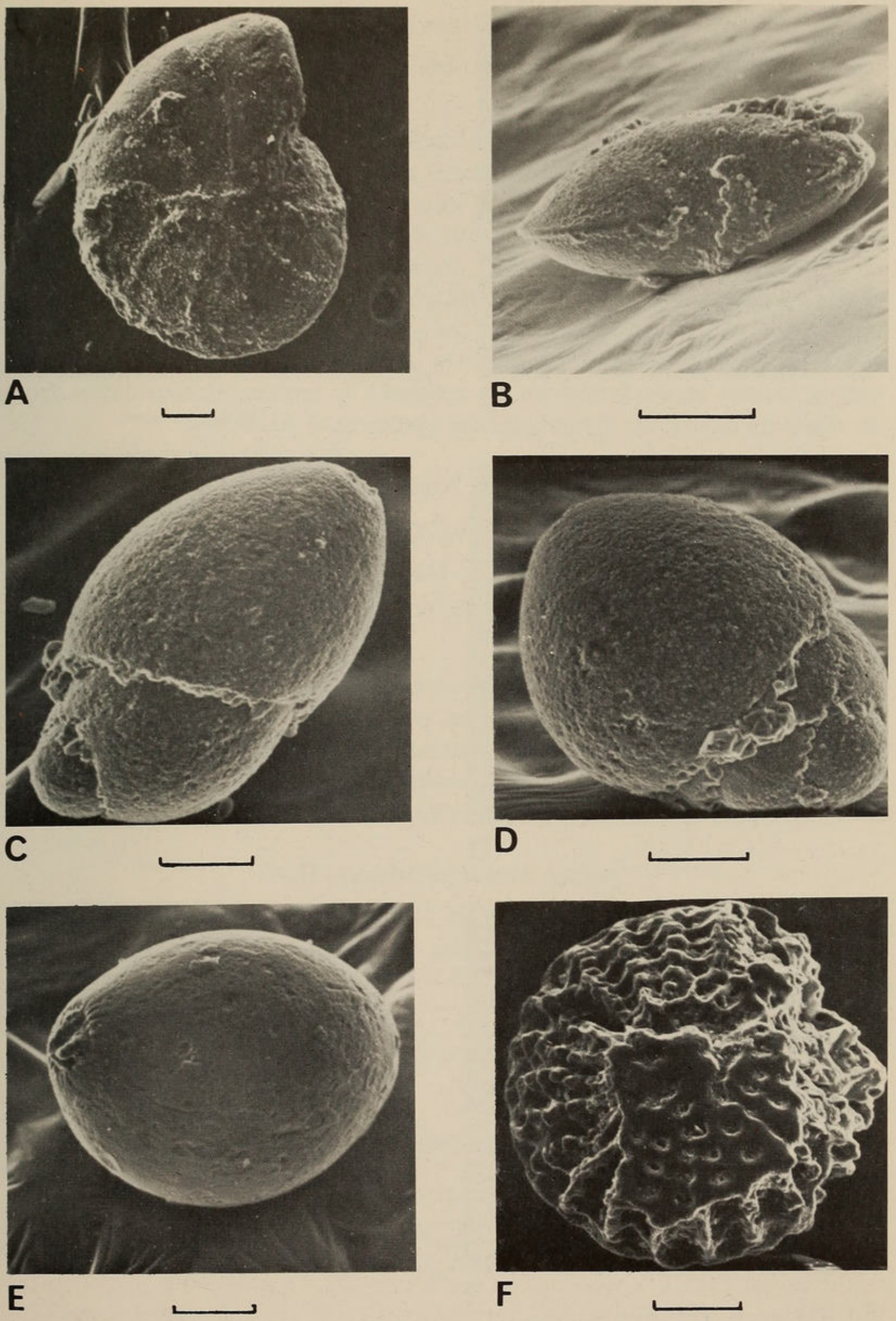

Fig. 13. Benthic foraminifera from the upper Eocene at Wanderfeld IV (Fig. 7). Scanning electron micrographs. A. *Lenticulina subalata*, side view, SAM–K5524. B. *Lenticulina subalata*, peripheral view, SAM–K5525. C. *Siphoglandulina?* sp., side view, SAM–K5526. D. *Siphoglandulina?* sp., front view, SAM–K5526. E. *Glandulina* sp. SAM–K5527. F. *Elphidium* cf. *E. crispum* side view, SAM–K5528. All scales = 100μ.

Elphidium sp. B

Fig. 14C–D

Remarks

This well-preserved specimen has a flattened test with near-parallel sides. Numerous chambers with raised sutures and retral processes are present, but detail of the earliest chambers of the whorl is confused because the specimen is broken. The umbilical area is slightly depressed and filled with calcareous nodules. Small papillae cover the chambers and the apertural face. The aperture consists of four pores in a circular position at the base of the apertural face and three pores in the areal position in the lower half of the apertural face. The specimen appears somewhat similar to *Discorotalia tenuis*, but trochospiral coiling cannot be confirmed as the specimen is broken. It also differs from *D. tenuis* by having the typical circular apertures of *Elphidium*.

Family **Nonionidae**

Nonion costiferum (Cushman, 1900)

Fig. 14E–F

Nonion costiferum (Cushman) *fide* Rau, 1964: 16, pl. 5 (fig. 5).

Remarks

Three specimens of this species were identified. The species is notable in having raised sutures and a depressed umbilical region. The specimens from Wanderfeld IV differ from those illustrated by Rau (1964) in possessing fewer chambers. The previously reported occurrence of this species in the U.S.A. is near the Oligocene–Miocene boundary (Rau 1964).

Nonion sloanii (d'Orbigny, 1839)

Fig. 15A

Nonionina sloanii d'Orbigny, 1839: 68, pl. 6 (fig. 18).
Nonion sloanii (d'Orbigny) Cushman, 1930: 9, pl. 3 (figs 6–8).

Remarks

This species is represented by a single specimen. It has been recorded in sediments of Eocene to Holocene age.

Family **Discorbidae**

Valvulineria aegyptina Le Roy, 1953

Fig. 15B

Valvulineria aegyptina Le Roy, 1953: 53, pl. 9 (figs 21–23).

Remarks

The specimen found differs from the type by having dorsal chambers which overlap strongly, making only eight chambers visible. Apertural features

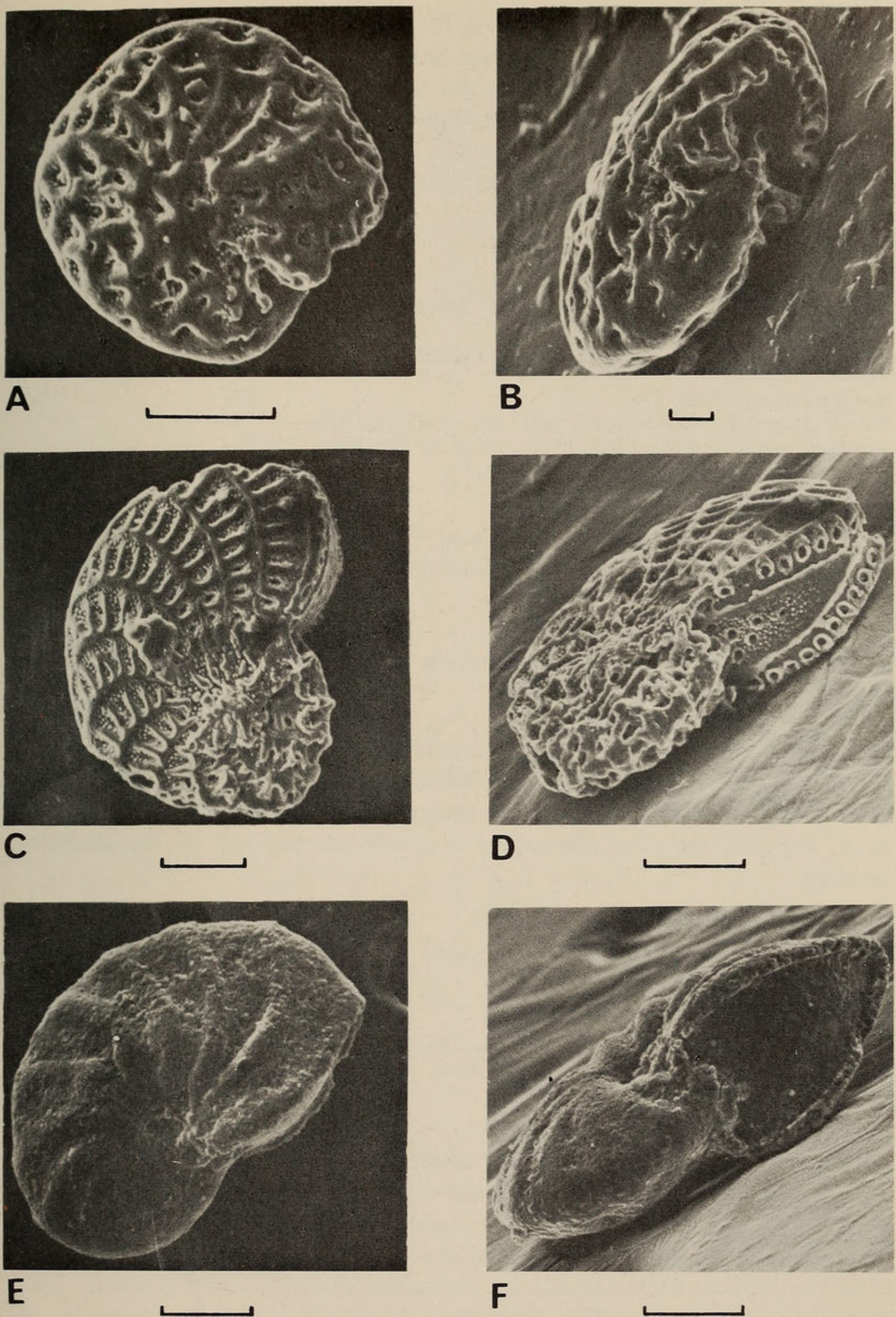

Fig. 14. Benthic foraminifera from the upper Eocene at Wanderfeld IV (Fig. 7). Scanning electron micrographs. All scales = 100μ, unless otherwise stated. A. *Elphidium* sp. A, side view, SAM–K5529. B. *Elphidium* sp. A, peripheral view, SAM–K5529, scale = 30μ. C. *Elphidium* sp. B, side view, SAM–K5530. D. *Elphidium* sp. B, peripheral view, SAM–K5530. E. *Nonion costiferum*, side view, SAM–K5531. F. *Nonion costiferum*, peripheral view, SAM–K5532.

are not distinct as the apertural flap is broken; therefore the full extent of the aperture is not known. Other features are typical of this species. A coarsely punctate wall occurs on both dorsal and ventral sides. A typically imperforate area occurs on the lower ventral part of the final chamber. The final chamber is inflated and extends over, and covers part of, the central umbilical region. The dorsal side is flat, the ventral side convex and umbilicate. This species is recorded from the Eocene in Egypt.

Family **Rotaliidae**

Ammonia cf. *A. beccarii* (Linné, 1767)

Nautilus beccarii Linné, 1767: 1162.
Rotalia beccarii (Linné) Cushman, 1928: 104, pl. 15 (figs 3–7).
Ammonia beccarii (Linné) Cifelli, 1962: 119, pl. 21 (figs 1–6).

Remarks

This genus occurs in two forms at Bogenfels. *A. beccarii* has a ventral umbilical area which lacks an umbilical boss, but this is not unusual in this species.

Ammonia sp.

Remarks

Broken specimens occur which were impossible to identify because of poor preservation. The features visible are typical of the genus. The umbilical area is closed but a small protruding plug is present. This is not the typical plug found in *A. beccarii*; the plug appears as a nodule of material on the umbilical covering.

Pararotalia inermis (Terquem) emend. Le Calvez, 1949

Fig. 15C–D

Rotalia inermis Terquem, 1882: 68, pl. 6 (fig. 1a–c).
Pararotalia inermis (Terquem) emend. Le Calvez, 1949: 32, pl. 3 (figs 54–56).

Remarks

Badly broken specimens of this species were found. The tests are eroded into the typical mushroom shape in side view. Perforate chambers are separated by flush, oblique, imperforate sutures, and an imperforate central area occurs on the dorsal side. The umbilical plug has been eroded out by removal of some or all the chamber flaps. This species was originally described by Terquem (1882) from the middle Eocene of the Paris Basin. McMillan (1974) described a closely related form, *Pararotalia* cf. *P. inermis*, from Holocene sediments on the Agulhas Bank.

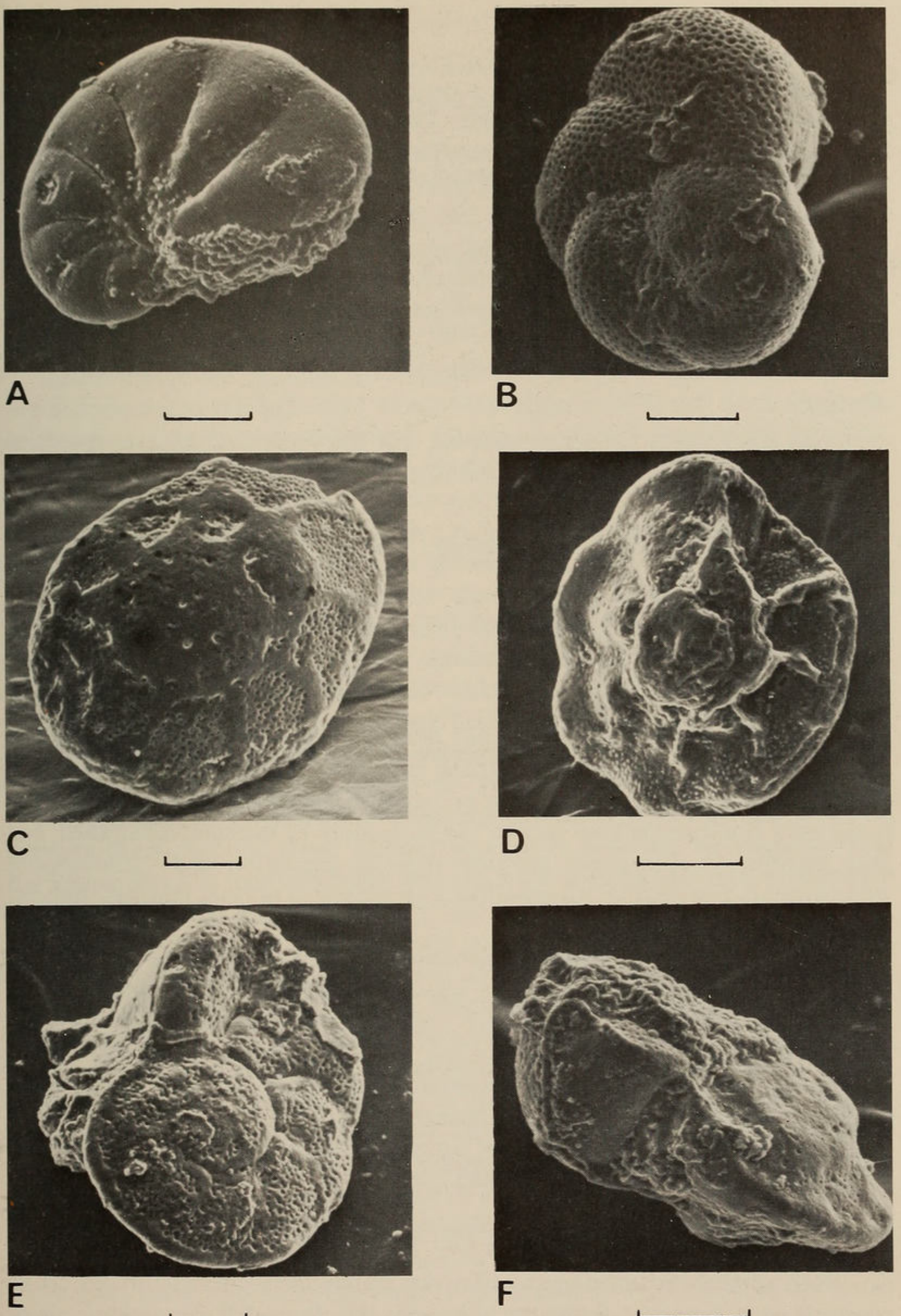

Fig. 15. Benthic foraminifera from the upper Eocene at Wanderfeld IV (Fig. 7). Scanning electron micrographs. A. *Nonion sloanii*, side view, SAM–K5532. B. *Valvulineria aegyptina*, dorsal view, SAM–K5533. C. *Pararotalia inermis*, dorsal view, SAM–K5534. D. *Pararotalia inermis*, ventral view, SAM–K5535. E. *Cibicides pseudoungerianus*, dorsal view, SAM–K5536. F. *Cibicides* sp., peripheral view, SAM–K5537. All scales = 100μ.

Family **Cibicididae**

Cibicides pseudoungerianus (Cushman, 1922)

Fig. 15E

Truncatulina pseudoungeriana Cushman, 1922: 97, pl. 20 (fig. 9).
Cibicides pseudoungerianus (Cushman) Cushman, 1931: 123, pl. 22 (figs 3–7).

Remarks

A species that ranges from the Eocene to Holocene; only a single specimen was found.

Cibicides sp.

Fig. 15F

Remarks

This specimen is not well preserved, but has features similar to the form *Cibicides* sp. illustrated by Van Hinte (1963), viz. a central raised area on the dorsal side.

Cibicides spp

Remarks

A number of poorly preserved forms were found which fit the basic description of this genus.

PALAEOECOLOGY

Members of the nannofossil genus *Braarudosphaera* are virtually absent in open-ocean deposits, and are thus strong indicators of nearshore environments; *Zygrhablithus bijugatus* is also most common in nearshore waters. These taxa make up a small percentage only of the nannoflora in the samples studied, but their presence in even minor amounts suggests deposition in a shallow-water environment. The benthic foraminifera also suggest a normal marine, shallow-water environment.

The nannoflora may in general be considered a temperate-water assemblage. However, *Isthmolithus recurvus* is a cool-water nannoplankter. Miliolid and peneropolid foraminifera, which are normally common, are conspicuously absent among the benthic foraminifera, and this also suggests that 'cool–temperate' may be the most appropriate designation for the water mass overlying this site during the upper Eocene.

The benthic foraminifera are not closely age diagnostic, but do corroborate a Palaeogene age for the Wanderfeld IV beds.

STRATIGRAPHIC STATUS OF THE TERTIARY DEPOSITS

Early workers assumed age equivalency among the scattered Tertiary rocks cropping out between Buntfeldschuh and the Bogenfels–Granitberg area. Haughton (1930*a*) first expressed doubt, on palaeontologic grounds, noting that the fish teeth reported at Buntfeldschuh do not prove these beds are contemporaneous with the Bogenfels exposures. Böhm (1926: 55), refers to abundant fish remains at Buntfeldschuh in the introductory remarks to his paper on the Bogenfels fossils. But he does not designate any teeth specifically from Buntfeldschuh in the text of his paper, and his summary table on p. 86 lists teeth from Bogenfels only. Based on published reports, the numerous geologists who have subsequently visited Buntfeldschuh have failed to find a single marine body fossil (e.g. Haughton 1930*a*; Stocken 1962; Ziegler 1969; Martin 1973; Siesser 1977), although C. G. Stocken (pers. comm. 1979) has confirmed the presence of fish teeth in the pebble layers. The Buntfeldschuh section is therefore considered to be essentially unfossiliferous, and in marked contrast to the highly fossiliferous sections near Bogenfels.

Nor can the two localities be correlated on lithologic grounds: dissimilarities are as apparent as similarities (cf. Beetz 1926; Klinger 1977; and the descriptions in this paper). In fact, the chief basis for age correlation seems to be that both contain lenses of agates and other pebbles (Beetz 1926; Kaiser 1926; Martin 1973). Against this, Haughton (1930*a*) points out that the Buntfeldschuh beds contain pebbles and boulders of the Pomona beds (pre-Oligocene, possibly Cretaceous (Stocken 1962)), whereas the exposures near Wanderfeld IV do not (Haughton 1930*a*). Descriptions by Beetz (1926) also suggest lithologic similarity among the various non-fossiliferous outcrops in the area, and among the fossiliferous outcrops, but less similarity between the two. A significant point is the relative elevations of the fossiliferous and non-fossiliferous beds. The base of the exposures at Buntfeldschuh lie 65 m above those at Wanderfeld IV, and those at Advokat Bake and Eisenkieselklippenbake lie up to 100 m above Wanderfeld IV (Kaiser 1926; Haughton 1930*a*; Stocken 1962).

Haughton (1963) has already suggested that there may be an age difference between the higher and lower Tertiary deposits in this area. He suggested that the higher deposits may be Eocene and the lower may be Miocene, presumably believing, with Du Toit (1954), that the original age (Miocene) assigned by Böhm & Weissermel (1913) to the lower deposits was more likely to be correct. The writers also think the higher, non-fossiliferous deposits are probably older than the lower, fossiliferous deposits. But there is now an unequivocal date for the lower deposits: upper Eocene. Therefore the higher deposits may be upper Paleocene–lower Eocene. This suggestion is based on evidence for a late Paleocene–early Eocene transgression of the Cape Province south coast recently documented by Siesser & Miles (1979). Moreover, Siesser & Dingle (1979) have suggested that this transgression was higher and more extensive than the late Eocene transgression around the coast of southern Africa.

The writers frankly admit that assigning the Buntfeldschuh outcrops to the upper Paleocene–lower Eocene is based on circumstantial evidence. But it is no more speculative than to assign them to the middle or upper Eocene, or to the Miocene for that matter, as has been done in the past. In fact, what little evidence there is for the age of these unfossiliferous beds (viz. topographically higher than the known upper Eocene deposits; known major late Paleocene–early Eocene transgression in southern Africa) supports the age assignment suggested here.

Whatever the age relationship of these two units, their lithologic dissimilarity precludes their inclusion in a single lithostratigraphic unit. The generally higher, and essentially non-fossiliferous beds are best exposed at Buntfeldschuh, and this can be regarded as the type locality for this unit. A 'Buntfeldschuh Formation' is thus potentially available, but is not herein proposed. SACS (1977: 21) has set out strict requirements for establishing a formal lithostratigraphic unit, and the writers do not have sufficient data on this unit to describe a stratotype. However, the 1977 South African Stratigraphic Code makes clear provision for the erection of informal lithostratigraphic units in such cases. Thus it is proposed that this unit be informally termed the 'Buntfeldschuh beds'. This name can be upgraded to the 'Buntfeldschuh Formation' if and when the requirements for formal status can be met.

Topographically lower and richly fossiliferous outcrops occur near Bogenfels, with the best-known exposures at Wanderfeld IV. This unit is also a potential formation, but again cannot be formally proposed in this paper for the same reason: insufficient data available to satisfy requirements for erection of a formal stratotype. It is proposed that this unit also be given informal status. As with a formal unit, an informal unit should carry a geographic name. 'Bogenfels' is unsuitable, as it already is used for the Precambrian dolostone formation in the area. Similarly, 'Wanderfeld IV' has already been pre-empted for the Cretaceous informal lithostratigraphic unit occurring in the same area (Klinger 1977).

The writers suggest that this unit be informally called the 'Langental beds', referring to the long valley adjacent to which the best exposures occur. This name can later be upgraded to the 'Langental Formation'.

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