New deep-water agglutinated foraminifera from the Upper Oligocene of offshore Angola

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ABSTRACT: Seven new species and a new genus of deep-water agglutinated foraminifera (DWAF) are reported from the Upper Oligocene of the Congo submarine canyon area, offshore Angola. The new taxa *Ammodiscus kenderi* n.sp., *Haplophragmoides volati* n.sp., *Ammobaculites duponti* n.sp., *Spiropsammia primitiva* n.sp, *Tetrataxiella subtilissima,* n. sp., *Discamminoides evolutus,* n. sp., and *Plectoverneuilinella angolaensis* n.gen., n.sp. (belonging to the new family Plectoverneuilinellidae), are described herein. The new species are sometimes common components of a "flysch-type" agglutinated foraminiferal assemblage associated with deep marine clastic sediments.

INTRODUCTION

Despite the publication of recent studies (Kender et al. 2008a; 2008b) the deep-water Oligocene foraminifera still remain poorly documented. Oligocene agglutinated foraminifera are more commonly known to occur in the northern North Atlantic on the Labrador Margin and North Sea (Gradstein et al. 1994) in the Norwegian Sea (Kaminski et al. 1989; Kaminski and Austin 1999) and the Arctic (Schröder-Adams and McNeil 1994), while the Atlantic DSDP and ODP sites (Clark and Wright 1984; Miller and Katz 1987) contain assemblages dominated by calcareous benthic foraminifera with just a minor component of agglutinated foraminifera. Marginal basins with high sedimentation rates and high organic flux such as the Congo fan, however, yield a different type of assemblage dominated almost completely in the Oligocene by agglutinated foraminifera. This type of assemblage is very similar to the Paleocene-Eocene cosmopolitan "flysch-type assemblage", which leads to the conclusion that the deep-sea clastic environment associated with submarine canyons may have served as a refuge for this type of fauna. Elsewhere in the Atlantic and Tethys the "flysch-type" fauna disappeared due to various causes, such as basins becoming restricted (the Carpathian basins), lowering of the CCD, or changes in oceanic deep circulation at the Eocene-Oligocene boundary (e.g., at Site 647, southern Labrador Sea, Kaminski et al. 1989).

The Congo fan reveals the most diverse agglutinated foraminiferal assemblage ever recorded in the Oligocene. Our new data add to the previous work of Kender et al. (2008a; 2008b), revealing that assemblages are comprised of at least 132 species belonging to 66 genera, including genera previously reported only from modern marine sediments such as *Tetrataxiella*. It is most probable that the Aquitanian (Early Miocene) high origination rate observed in the diversity curve of agglutinated foraminiferal genera compiled by Kaminski et al. (2008, 2010) had its starting point in the Chattian (Late Oligocene), which gives support to the idea that the diversity record is affected by observational biases and that additional studies are needed on particular stages such as the Chattian.

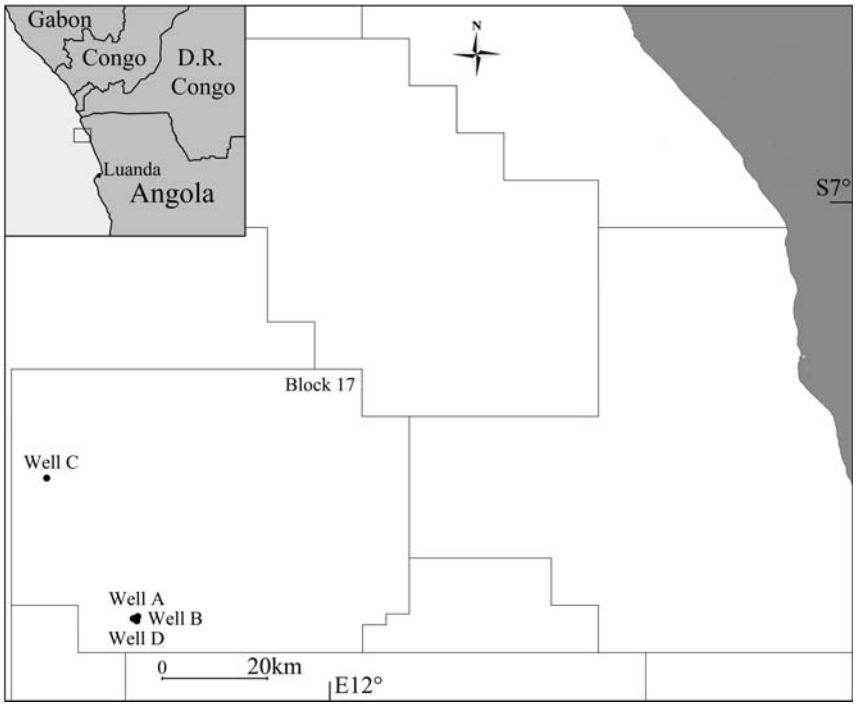
In addition to the four new species described by Kender et al. (2006) we report in this study seven new species and a new genus of agglutinated foraminifera. Two of the species described herein *Spiropsammia primitiva* and *Discamminoides evolutus* show a complex wall structure that can be considered an adaptation to low oxygen conditions (Kaminski and Crespo de Cabrera 1999). We regard these morphologies to be a consequence of increasing productivity and carbon burial in the South Atlantic during the Late Oligocene (Diester-Haass et al. 2010).

STUDY AREA

We studied well samples from four exploration wells drilled in Block 17, offshore Angola, by TOTAL S.A. (text-fig. 1). The wells sampled Upper Oligocene (Chattian) sediments infilling and overlying the Congo submarine canyon and associated channel levee systems, which formed during the Rupelian.

METHODS

Micropaleontological samples were collected from cored intervals in the exploration wells. Samples were disaggregated by soaking in tenside solution for several hours then sieving over a 63µm sieve. Specimens were photographed using a Zeiss Axiocam mounted on a Leica MZ16 microscope in the Natural History Museum, London and a Canon EOS500D mounted on a Nikon SMZ1500 microscope in the Institute of Geological Sciences (Kraków). Photographs of specimens in immersion oil were taken using both reflected and transmitted light. Additional imaging was realized using a JEOL JSM-6480LV SEM at University College London.



TEXT-FIGURE 1
Location map with the position of the four studied wells.

Primary types were deposited in the micropalaeontological collections of the Natural History Museum, London, and additional specimens are housed in the Grzybowski Library (Geological Museum of the Jagiellonian University), Kraków, Poland.

SYSTEMATIC PALEONTOLOGY

In this study we use the classification of the agglutinated foraminifera published by Kaminski (2004).

Class FORAMINIFEREA d'Orbigny 1826
Subclass TEXTULARIIA Mikhalevich 1980
Order ASTRORHIZIDA Lankester 1885
Suborder AMMODISCINA Mikhalevich 1980
Superfamily AMMODISCACEA Reuss 1862
Family AMMODISCIDAE Reuss 1862
Subfamily AMMODISCINAE Reuss 1862
Genus *Ammodiscus* Reuss 1862

Ammodiscus kenderi Cetean and Kaminski, **n. sp.**
Plate 2, figs 12-14

Ammodiscus sp. 2. – KENDER, KAMINSKI and JONES 2008a, p. 120, pl. 3, fig. 10 [non fig. 11].

Derivation of name: In honour of Dr. Severyn Kender (BGS), who first illustrated the species from offshore Angola.

Material: Thirteen specimens from 4 samples in well A.

Description: Test small to medium in size, flat, planispiral with 4-5 whorls, slightly irregular. Chamber increasing in size slowly, inflated, 'sausage-like', but does not increase in thickness. Coil suture is depressed. Wall contains visible agglutinated grains of medium size, with a smooth finish.

Remarks: This species is transitional between *Ammodiscus* and *Dolgenia*. Kender et al. (2008a) included a specimen that probably belongs to the latter genus. We restrict the definition of the species to the type of specimen illustrated by Kender et al. (2008a, pl. 3, fig. 10). The species is only slightly irregular.

Occurrences: Wells A, B and C.

Type Level: Upper Oligocene, Chattian, Zone P22, well A (2951,51m).

Type Specimens: Holotype (NHMUK PMPF70272) and two paratypes (NHMUK PMPF70272-73).

Order **LITUOLIDA** Lankester 1885
Superfamily LITUOLACEA de Blainville 1827
Family HAPLOPHRAGMOIDIDAE Maync 1952
Genus *Haplophragmoides* Cushman 1910

Haplophragmoides volati Cetean and Kaminski, n.sp.
Plate 1, figs 1a-b; Plate 2, figs. 15-16

Haplophragmoides sp. – KENDER, KAMINSKI and JONES 2008b, p. 501, pl. 6, fig. 1.

Derivation of name: In honour of Dr. Jean-Louis Volat, who helped initiate this study.

Material: Twelve specimens from 4 samples in well B. Rare in all wells.

Description: Test large, coiling involute, planispiral, with 5-6 globular chambers in the final whorl. Outline circular and lobate, periphery broadly rounded, sutures straight and depressed, wide and depressed umbilical area. Wall medium to coarsely agglutinated, wall thick, aperture a slit at base of the apertural face.

Occurrences: Wells A, B, C and D.

Type Level: Upper Oligocene, Chattian, Zone P22, well B (2749.36m).

Type Specimens: Holotype (NHMUK PMPF70278) and two paratypes (NHMUK PMPF70279-80).

Family LITUOLIDAE de Blainville 1827
Subfamily AMMOMARGINULINAE Podobina 1978
Genus *Ammobaculites* Cushman 1910

Ammobaculites duponti Cetean and Kaminski, **n. sp.**
Plate 1, figs 3-5; Plate 2 fig. 17

Derivation of name: In honour of Dr. Gerard Dupont, who originally found this species in the Angolan offshore.

Material: Nine specimens from 2 samples from well C. Rare in the other wells.

Description: Test initially planispiral with one and one-half whorls with 6 to 7 chambers in the final whorl, then uniserial with up to 8 chambers. The uniserial portion is circular in cross section and meanders, with chambers that become increasingly more pyriform with flat bases when viewed in immersion. Wall is thick, medium agglutinated. Aperture on a small collar or neck.

Remarks: The species resembles *Ammobaculites exiguus* in the early part of the test, but this species is a shallow-water form described from the mangroves of Trinidad. Cushman and Brönnimann (1948) reported the apertural face to be flat (truncated), and the aperture without a neck. It differs from *Ammobaculites exilis* Cushman and Brönnimann (1948) by having more chambers and a uniserial portion that can meander, by being rounded in outline and by having a round aperture rather than a slit-like one.

Occurrences: Wells A, B and C.

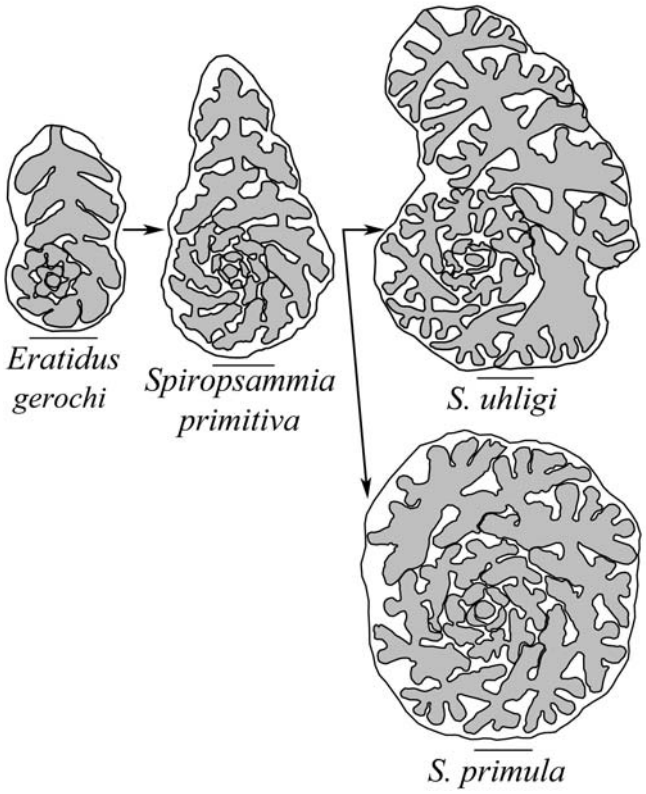
Type Level: Upper Oligocene, lower Chattian, upper part of Zone P21, well C (2929.36m).

Type Specimen: Holotype (NHMUK PMPF70269) and two paratypes (NHMUK PMPF70270-71).

Suborder SPIROPLECTAMMININA Mikhalevich 1992
Superfamily SPIROPLECTAMMINACEA Cushman 1927
Family PLECTOVERNEUILINELLIDAE Cetean and Kaminski, n.fam.

Test initially biserial, later trochospiral. Terminally may reduce to biserial. Wall simple, organically cemented.

Plectoverneuilinella Cetean and Kaminski, **n. gen.**
Type Species: Plectoverneuilinella angolaensis n.sp.



TEXT-FIGURE 2
Possible evolutionary transition from the genus *Eratidus* to the genus *Spiropsammia* using drawings of specimens from the studied wells (*Eratidus gerochi* from well A, *Spiropsammia primitiva* from well C, *Spiropsammia uhligi* from well B and *Spiropsammia primula* from well A). All scale bars = 100μm.

Description: Test elongate, tapered at both ends. Microsphaeric generation initially biserial, later trochospiral with 4 chambers per whorl, abruptly increasing in width at the transition. Macrosphaeric generation with proloculus followed by high trochospiral chamber arrangement comprised of 12 or more whorls with four chambers per whorl. Both generations may become terminally biserial with 1-3 pairs of biserial chambers. Aperture a low interiomarginal arch. Chambers are round and inflated, with depressed sutures, thin walled, finely agglutinated.

Remarks: Differs from *Verneuilinella* Tairov (1956) in possessing an initial biserial stage in the microsphaeric generation.

Plectoverneuilinella angolaensis Cetean and Kaminski, **n. sp.**
Plate 1, figs 6-10; Plate 2, figs. 18-20

Derivation of name: From the country of Angola.

Material: 1,373 specimens from 16 samples in well A. Common in all wells.

Description: Test elongate, tapered at both ends, finely agglutinated, usually compressed (of conical shape when not deformed). Microsphaeric generation initially biserial, up to 6 pair of chambers, followed by a trochospiral stage with 4 chambers per whorl, abruptly increasing in width. Macrosphaeric genera-

tion with proloculus followed by high trochospiral chamber arrangement comprised of 12 or more whorls with four chambers per whorl. Both generations may become terminally biserial with 1-3 biserial pairs. Aperture a low interiomarginal arch. Chambers are round and inflated, with depressed sutures, thin walled, finely agglutinated.

Occurrences: Wells A, B, C and D.

Type Level: Upper Oligocene, Chattian, upper part of Zone P22, well A (2956.10m).

Type Specimens: Holotype (NHMUK PMPF70290) and six paratypes (NHMUK PMPF70291-96).

Superfamily PAVONITINACEA Loeblich and Tappan 1961
Genus *Spiropsammia* Seiglie and Baker 1983

Spiropsammia primitiva Cetean and Kaminski, **n. sp.**
Plate 1, figs 11-15

Derivation of name: With reference to its very sparse and primitive internal structure.

Material: 42 specimens from 6 samples in well C.

Description: Test small, laterally compressed. Initial planispiral part with chambers in two to three evolute whorls, later uncoiled and rectilinear with a few increasingly arched chambers. Microsphaeric individuals have three whorls in the spiral part; megalosphaeric individuals have two whorls, with 9 chambers in the final whorl and up to 6 uniserial chambers. Chambers initially simple, later subdivided by short septula that project inward from the chamber roof as in *Pavonitina.* Wall finely agglutinated, thin, noncalcareous. Aperture terminal, rounded, produced, with a bordering neck.

Remarks: With its comparatively simple internal structure, this species may represent the evolutionary transition from the genus *Eratidus* to *Spiropsammia* (Fig. 2). In our opinion it represents the transitional form between a species of *Eratidus* with simple sutures and the type species of the genus *Spiropsammia uhligi* first described from the Oligocene of northern Italy. It differs from *S. uhligi* in its smaller size, narrower uniserial part and in the presence of short septula or hemiseptae extending from the roofs of the chambers that appear late in ontogeny, rather than having branching "alveoles" as described by Seiglie and Baker (1983). In the new species, the early planispiral portion has simple chamber interiors without partitions, with this structure appearing in the final chambers of the planispiral part. *Spiropsammia primula* Seiglie and Baker has a more advanced morphology, differing in having club-shaped alveoles that begin earlier in ontogeny and in lacking a terminal uniserial part.

Occurrences: Only observed in Well C.

Type Level: Upper Oligocene, lower Chattian, upper part of Subzone P21b, well C (2865.97m).

Type Specimens: Holotype (NHMUK PMPF70281) and two paratypes (NHMUK PMPF70282-83)

Suborder VERNEUILININA Mikhalevich and Kaminski 2004
Superfamily VERNEUILINACEA Cushman 1911
Family PROLIXOPLECTIDAE Loeblich and Tappan 1985
Genus *Tetrataxiella* Seiglie 1964

Tetrataxiella subtilissima Cetean and Kaminski, **n. sp.**
Plate 1, figs 16-17; Plate 2, figs 1-4, 21-22

Derivation of name: With reference to its thin, finely agglutinated wall.

PLATE 1

Figures 1, 2, 16 photographs in reflected light; Figures 3-6, 9-15, 17 immersion oil photographs in both transmitted and reflected light, 7-8 immersion oil photographs in transmitted light. All scale bars = 100μm.

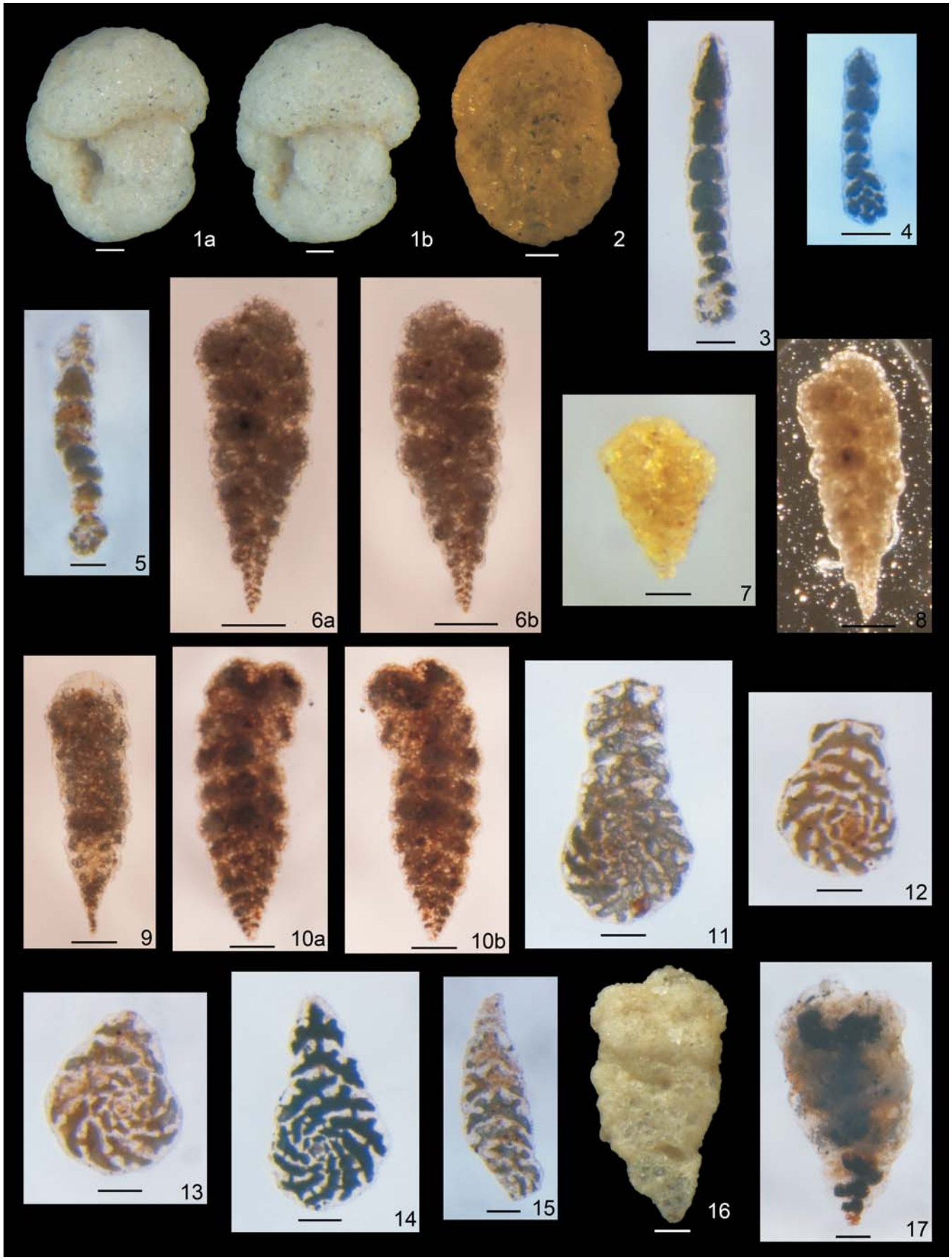
1-2 *Haplophragmoides volati* n. sp. 1a-b. Holotype (NHMUK PMPF70278), in oblique and lateral oblique views, well B (2749.36m); 2. Paratype (NHMUK PMPF70280), in lateral oblique view, well A (2944.45m).

3-5 *Ammobaculites duponti* n. sp. 3. Holotype (NHMUK PMPF70269), well C (2920,36m); 4. Paratype (NHMUK PMPF70271), well B (2757.29m); 5. Paratype (NHMUK PMPF70270), well A (2983,64m).

6-10 *Plectoverneuilinella angolaensis* n. gen., n. sp. 6a-b. Holotype (NHMUK PMPF70290), opposite sides, well A (2956.10m); 7. Paratype (NHMUK PMPF70291), undeformed specimen, well C (2839.24m); 8. Holotype (NHMUK PMPF70290), in transmitted light only; 9. Paratype (NHMUK PMPF70293), showing a long biserial initial part, well A (2956.10m); 10a-b. Paratype (NHMUK PMPF70294), opposite sides, well A (2977,75m).

11-15 *Spiropsammia primitiva* n. sp. 11. Holotype (NHMUK PMPF70281), well C (2865.97m); 12. Paratype (NHMUK PMPF70283), well C (2927.40m); 13. Paratype (NHMUK PMPF70282), well C (2927.40m); 14. Paratype (GF Collections), well C (2931.10m); 15. Broken specimen showing a long uniserial part, well C (2931.10m).

16-17 *Tetrataxiella subtilissima* n. sp. Holotype (NHMUK PMPF70284), in reflected light and immersion oil, well D (2883.75m).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Material: 84 specimens from 6 samples in well D. Rare in other wells.

Description: Test free, elongate conical, gradually enlarging in width, trochospiral with four chambers per whorl. Chambers strongly overlapping, so that final whorl occupies one-third the test length. Chambers are slightly inflated and aligned into rows, which may be straight or slightly twisted. Sutures depressed, wall finely agglutinated, non-calcareous, thin, often collapsed with a smooth finish. Aperture a low interiomarginal arch, opening into the umbilicus, often indistinct due to the collapsed wall.

Remarks: Differs from the type species *T. ayalai* Seiglie (1964) from the Holocene of Venezuela by having less overlapping chambers and a much thinner and finely agglutinated wall. Also, the chambers are not arranged so neatly in rows as in type species. The finding of this genus in the Angola offshore extends the known range of this genus into the Oligocene. It is very probable that this genus should not be included in the Ataxophragmiacea since it has a simple chamber interior and it does not have a calcareous cemented wall. We have observed the type specimens of *Tetrataxiella* in the Seiglie collection (Museo del Mar, Cumana, Venezuela), which have brownish organic cement although the type species agglutinates calcareous particles. In our opinion, Loeblich and Tappan (1987) incorrectly placed this genus in the Ataxophragmiacea; because of its organic cement and simple chamber interiors we reassign this genus to the superfamily Verneuilinacea.

Occurrences: Wells A, B and D.

Type Level: Upper Oligocene, Chattian, Zone P22, well D (2883.75m).

Type Specimens: Holotype (NHMUK PMPF70284) and five paratypes (NHMUK PMPF70285-89).

Order LOFTUSIIDA Kaminski and Mikhalevich 2004
Suborder LOFTUSIINA Kaminski and Mikhalevich 2004
Superfamily LOFTUSIACEA Brady 1884
Family CYCLAMMINIDAE Marie 1941
Subfamily ALVEOLOPHRAGMIINAE Saidova 1981
Genus *Discamminoides* Brönnimann 1951

Discamminoides evolutus Cetean and Kaminski, **n. sp.**
Plate 2, figs 5-11

Discamminoides sp. 1. – KENDER, KAMINSKI and JONES 2008a, p. 126, pl. 9, figs 1, 2; plate 15, figs 1-2c.

Derivation of name: With reference to its evolute coiling and tendency to uncoil.

Material: 48 specimens from four samples in well C.

Description: Test large, slightly evolute, planispiral becoming uniserial, flattened, with 6 or more chambers in last coil, and with adult specimens possessing an uniserial uncoiled portion with up to 4 chambers. Chambers increase in size steadily. Initial coiled part either large or small depending on micro- or megalospheric generation. Periphery subacute, sutures straight, seen as slight depression or undulation of test surface, or only

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PLATE 2

Figures 1, 5, 7, 9, 11 photographs in reflected light; Figures 2-4, 6, 8, 10 immersion oil photographs in both transmitted and reflected light. Figures 12-22 SEM. All scale bars = 100μm.

1-4 *Tetrataxiella subtilissima* n. sp. 1. Paratype (GF Collections), well D (2883.75m); 2a-b. Paratype (NHMUK PMPF70288), opposite sides, well D (2880.50m); 3. Paratype (NHMUK PMPF70286), well B (2752.54m); 4a-b. Paratype (NHMUK PMPF70287), opposite sides, well D (2883.75m).

5-11 *Discamminoides evolutus* n. sp. 5-6. Holotype (NHMUK PMPF70275), in reflected light and immersion oil, well C (2865.97m). 7-8. Paratype (NHMUK PMPF70276), in reflected light and immersion oil, well C (2867.96m); 9-10. Paratype (NHMUK PMPF70277), in reflected light and immersion oil, well C (2867.96m); 11. Paratype (GF Collections), Well C (2865.97m).

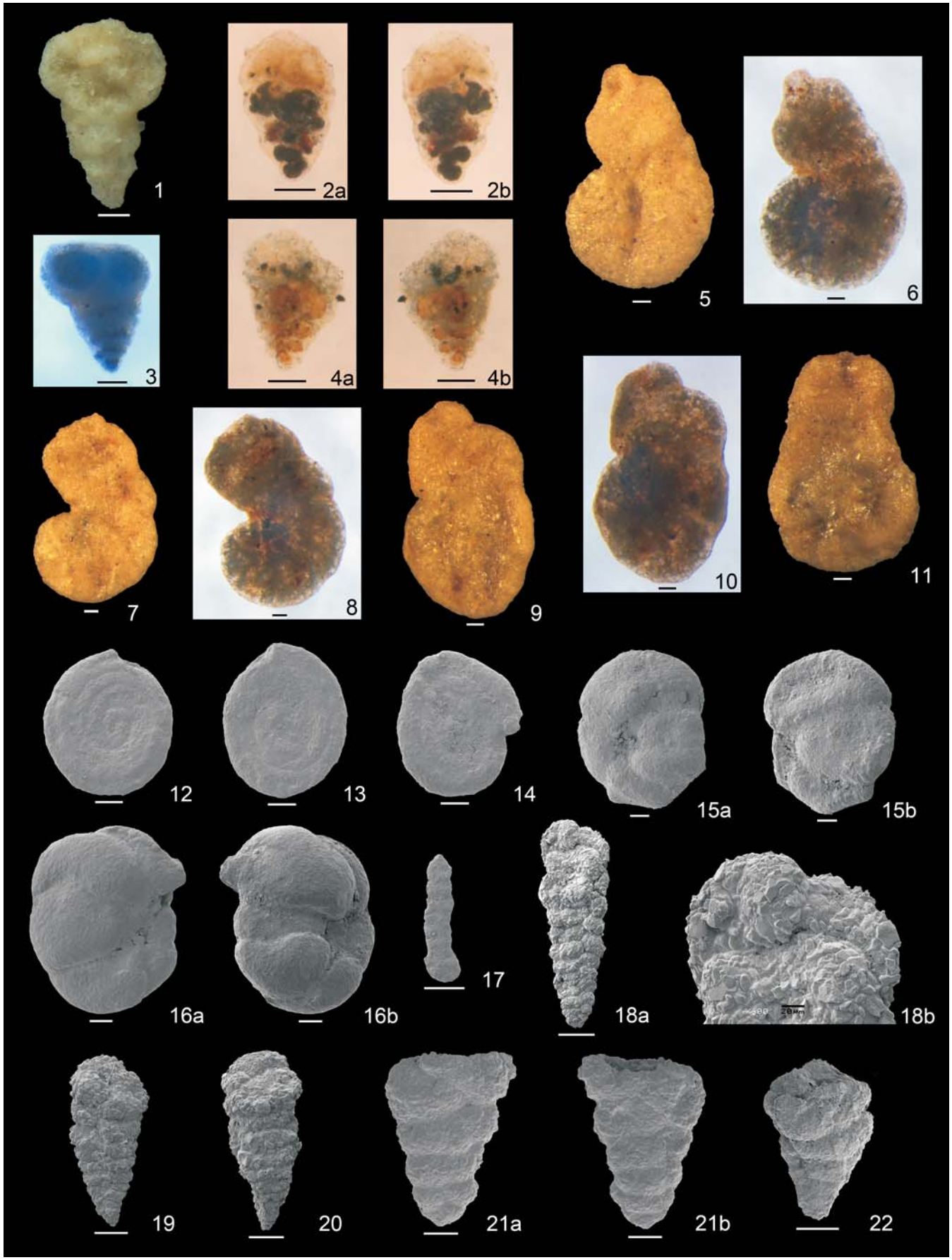
12-14 *Ammodiscus kenderi* n.sp. 12. Holotype (NHMUK PMPF70272), well A (2951.51m); 13. Paratype (NHMUK PMPF70274), well A (2960.95m); 14. Paratype (NHMUK PMPF70273) well A (2960.95m).

15-16 *Haplophragmoides volati* n. sp. 15a-b. Paratype (NHMUK PMPF70279), opposite sides, well A (2944.45m); 16a-b. Paratype (GF Collections), opposite sides, well A (2946,20m).

17 *Ammobaculites duponti* n. sp. Well A (2946.20m).

18-20 *Plectoverneuilinella angolaensis* n. g., n. sp., 18a-b. Paratype (NHMUK PMPF70296), whole specimen and detail of the apertural face, well A (2983.64m); 19. Paratype (NHMUK PMPF70295), well A (2977.75m); 20. Paratype (NHMUK PMPF70292), uncompressed specimen, well C (2839.24m).

21-22 *Tetrataxiella subtilissima* n.sp. 21a-b. Paratype (NHMUK PMPF70285), opposite sides, well B (2752.54m); 22. Paratype (NHMUK PMPF70289), well D (2883.75m).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visible as internal layer. Aperture a terminal slit in coiled portion, becoming terminal, circular, on a produced neck. Wall bilamellar alveolar, internal layer thicker at peripheral part, coarse and sometimes speculated, with thin tubular alveoles. Outer layer medium to coarse grained and thin.

Remarks: As part of this study we examined paratype specimens of the type species *Discamminoides tobleri* from the Lower Miocene of Trinidad housed in the Centro de Micropaleontologia "P.J. Bermúdez" at INTEVEP-PDVSA in Los Teques, Venezuela. Our new species differs from the type species *D. tobleri* in possessing a thinner and coarser wall, and a more well-developed uncoiled portion. *Glaphyrammina* resembles *Discamminoides* externally, but differs by having a coarsely agglutinated wall and by lacking alveoles, and in having an oval aperture without a neck.

Occurrences: Wells A and C.

Type Level: Upper Oligocene, lower Chattian, upper part of Subzone P21b, well C, (2865.97m).

Type Specimens: Holotype (NHMUK PMPF70275) and two paratypes (NHMUK PMPF70276-77).

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