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Roveacrinidae (Crinoidea, Articulata) from the Cenomanian and Turonian of North Africa (Agadir Basin and Anti-Atlas, Morocco, and central Tunisia): biostratigraphy and taxonomy

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ABSTRACT:

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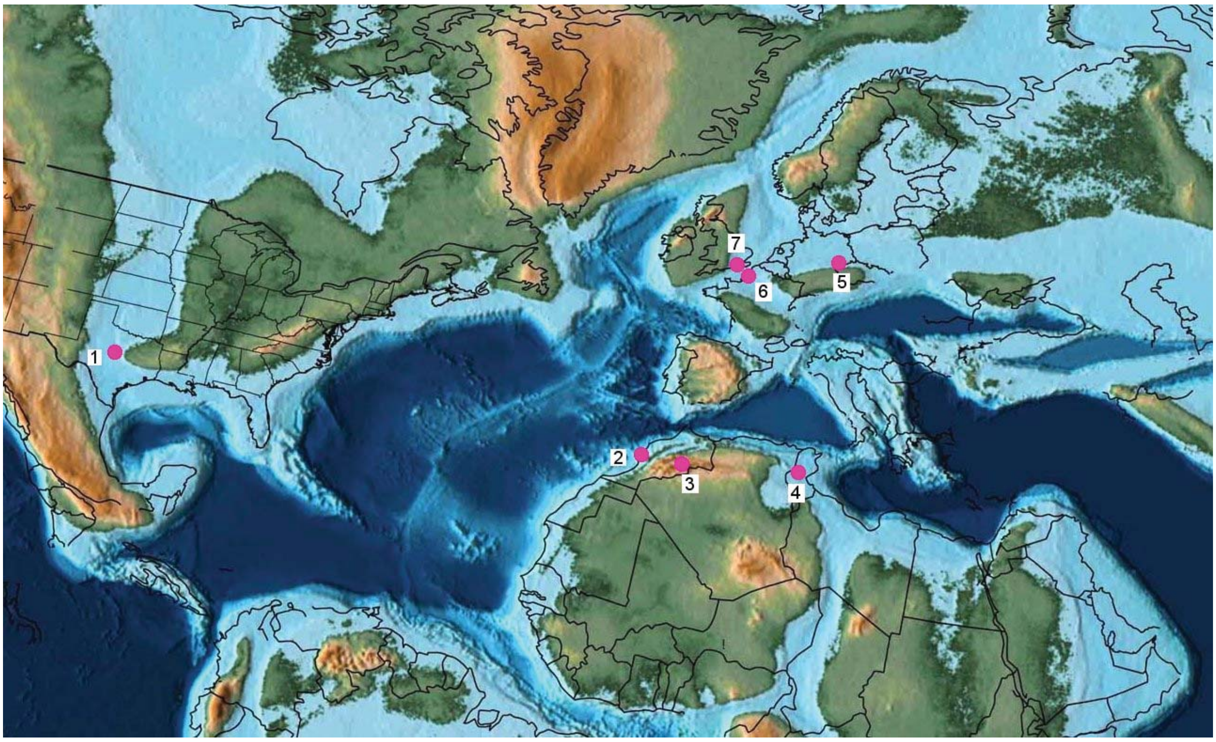
Successions exposed in the Agadir Basin (upper Albian to middle Turonian), in the Anti-Atlas (lower Turonian) in Morocco and in central Tunisia (Cenomanian–Turonian) yield abundant microcrinoids of the family Roveacrinidae, which are described and assigned to 32 species and formae, in ten genera. The following new taxa are described: *Fenestracrinus* gen. nov. with the type species *F. oculifer* sp. nov., *Discocrinus africanus* sp. nov., *Styracocrinus rimafera* sp. nov., *Lebenharticrinus quinvigintensis* sp. nov., *L. zitti* sp. nov., *Euglyphocrinus cristagalli* sp. nov., *E. jacobsae* sp. nov., *E. truncatus* sp. nov., *E. worthensis* sp. nov., *Roveacrinus gladius* sp. nov., *R. solisoccasum* sp. nov. and *Drepanocrinus wardorum* sp. nov. In addition, the new subfamily Plotocrininae is erected. The stratigraphical distribution of the taxa in two important localities, Taghazout in the Agadir Basin (Morocco) and Sif el Tella, Djebel Mhrila (central Tunisia), is provided. The faunas from the uppermost Albian and lowermost Cenomanian of the Agadir Basin are nearly identical to those recorded from central Texas, USA, some 5,300 km away, and permit a detailed correlation (microcrinoid biozones CeR1 and CeR2) to be established across the southern part of the Western Tethys, independently supported by new ammonite records. For the middle and upper Cenomanian, rather few detailed records of microcrinoids are available elsewhere, and the North African record forms the basis for a new zonation (CeR3–CeR6). The distribution of Turonian Roveacrinidae in North Africa is evidently very similar to that described in the Anglo-Paris Basin, and zones TuR1–3, TuR9, 10 and 14 are recognised for the first time in the Tethys.

Key words: Cretaceous; Microcrinoids; Correlation, North Africa; New taxa.

INTRODUCTION

Pelagic microcrinoids of the order Roveacrinida are common in Albian to Maastrichtian marine sediments in Europe and North America, and commonly form a significant part of coarser (0.5–2.5 mm) residues derived from washing clays, marls and chalks (Gale 2016, 2018, 2019; Gale *et al*. 2018). Early studies on material from the Albian to Maastrichtian of the US Gulf coast and of the United Kingdom (Peck 1943, 1955, 1973) provided a firm taxonomic basis for future work. Bruno Ferré has pioneered the identification of microcrinoids in thin section (Ferré and Berthou 1994; Ferré and Granier 2000, 2001; Dias-Brito and Ferré 2001; Ferré *et al*. 2005, 2017), but relating slices to three-dimensional material remains challenging. However, these studies do clearly demonstrate the widespread abundance of Roveacrinida in Tethyan pelagic and hemipelagic facies.

The extensive outcrops of marine sediments of Albian, Cenomanian and Turonian age across North Africa have been a source of abundant macro- and



Text-fig. 1. Cenomanian palaeogeography of the western Tethys (after Scotese 2014, map 22a, o), showing localities from which material described or cited in the present paper originates. 1. Fort Worth, Texas, USA; 2. Agadir Basin, Morocco; 3. Goulmima, Morocco; 4. central Tunisia; 5. Dresden, Germany and Předboj, Czech Republic; 6. Dieppe, France; 7. Beachy Head, United Kingdom.

microfossils, and important biostratigraphical studies have been undertaken particularly in Tunisia, on the Albian to Coniacian succession (Robaszynski *et al.* 1990, 1993,1994, 2000, 2008; Chancellor *et al.* 1994; Amédro *et al.* 2005; Kennedy and Gale 2015). However, few papers have documented the presence of microcrinoids in the region. Robaszynski *et al.* (1990) noted the presence of "saccocomids" in residues of Turonian marls from Kalaat Senan in western Tunisia, and Ettachfini and Andreu (2004) recorded the presence of roveacrinids in lower Turonian limestones around Goulmima in southeast Morocco. Well-preserved material washed from marls from the nearby locality of Asfla was described by Gale (2019). Ferré *et al*. (2017) described roveacrinids and saccocomids in thin sections of Cenomanian–Turonian limestones from the Ksour Mountains and Guir Basin in western Algeria.

The present study was stimulated by fortuitous sampling of the Albian to Cenomanian Marnes d'Aït Lamine (Aït Lamine Formation) in a roadcut on the N1 road north of Taghazout (Agadir Basin) in western Morocco (Essafraoui *et al*. 2015) in October 2017, which yielded a diverse and exceptionally well-preserved microcrinoid assemblage. Subsequent visits in 2018 and 2019, and extensive further sampling, proved the presence of a nearly continuous record of roveacrinids from the upper Albian to the middle Turonian, which permits detailed comparison with successions in Texas and western Europe. A series of Cenomanian and Turonian samples from central Tunisia deposited in the Oxford Natural History Museum by the late Jake M. Hancock, were processed and also yielded abundant roveacrinids. The Tunisian localities have yielded a rich ammonite fauna (Kennedy and Gale 2015; Gale *et al.* 2017), which permits precise dating of the microcrinoid assemblages. The material from these three regions forms the basis of the present paper. The distribution of localities studied or discussed is shown on a reconstruction of upper Albian palaeogeography (Text-fig. 1).

METHODS

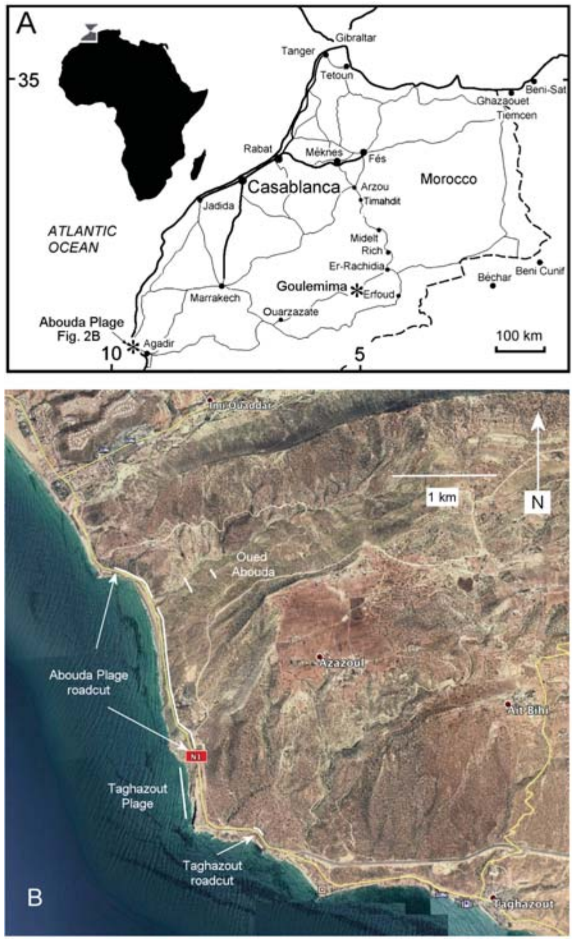
Samples from the marls and clays in central Tunisia and in the Agadir Basin (Morocco) were washed in water, and the residues graded. Hard limestones from Sif el Tella and Taghazout were processed using the acetic acid method described by Gale (2019). Material was picked from the 0.5–2.5 mm fraction, and selected specimens were placed on stubs for SEM study.

LOCALITIES, STRATIGRAPHY AND DISTRIBUTION OF FAUNAS

Morocco

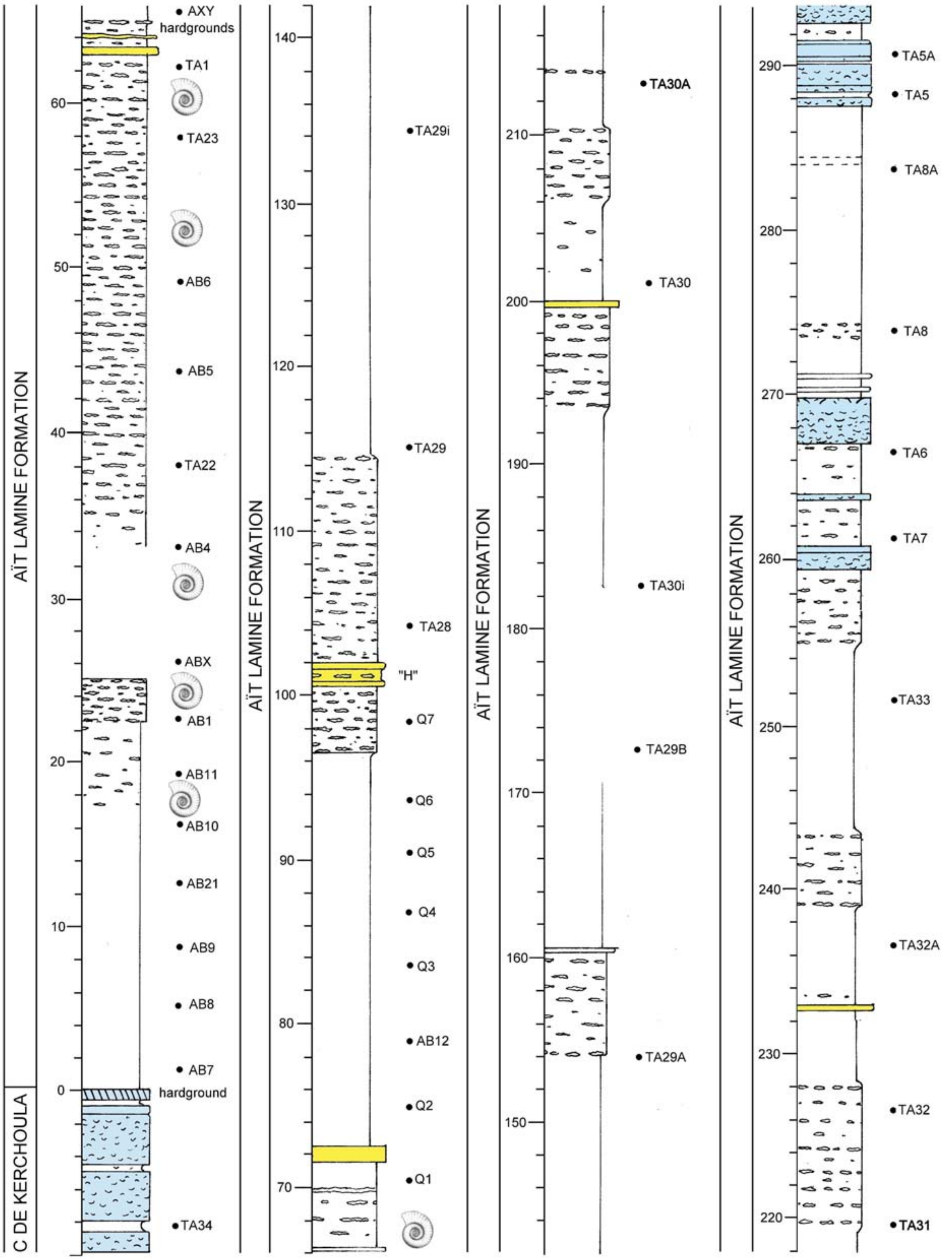
Abouda Plage to Taghazout Plage, Agadir Basin

In the Agadir Basin (Text-fig. 2A), dolomitic limestones and interbedded marls, referred to as the "Calcaires dolomitiques du Kechoula" have been dated as late Albian ("barre Vraconnien"; see Jati *et al.* 2010), the only published support for which was a *Mortoniceras* sp. from the top of this unit at 135 m in the Tanhaoute section (north of Agadir) which was said to be "indicative of the *fallax* to *rostratum* Zones", and thus not latest Albian (Essafraoui *et al.* 2015, p. 12). The limestones are overlain by a considerable thickness (370–510 m) of marls containing small, flat carbonate concretions, and interbedded oyster coquina limestones in the upper part, called the Aït Lamine Formation (Ambroggi 1963), assigned largely to the Cenomanian. At the inland section at Tanhaoute, Essafraoui *et al.* (2015) considered the lowest 110 m of the marls to be Albian, guided by the *Mortoniceras* sp. record, and the absence of diagnostic Cenomanian planktonic foraminiferans. At Taghazout, the section studied in the present paper (here referred to as the Abouda Plage roadcut), the Albian–Cenomanian boundary was taken by Essafraoui *et al.* (2015) at the base of the Aït Lamine Formation based on planktonic foraminiferan assemblages from the basal level, and approximately 40 m above the base. However, the diagnostic Cenomanian species that was taken as the boundary marker (Kennedy *et al.* 2004), *Thalmaninella globotruncanoides* (Sigal, 1948), was not found until approximately 80 m above the base of the marls, beneath a distinctive orange-brown marker bed ("H" of Essafraoui *et al.* 2015). The middle part of the marls did not yield diagnostic planktonic taxa, but the species *Rotalipora cushmani* (Morrow, 1934) was recovered from 545–572 m, up to a supposedly karstified surface representing the base of the carbon isotope excursion of OAE2. Jati *et al.* (2010) published a carbon isotope curve for the upper part of the Aït Lamine Formation which demonstrated the presence of the positive carbon excursion of OAE2. This formation is overlain by limestones containing black chert nodules, called the "Calcaires de la Casbah d'Agadir". These have yielded ammonites and inoceramids at Taghazout during the present study, indicating the presence of the *Mammites nodosoides* Zone.

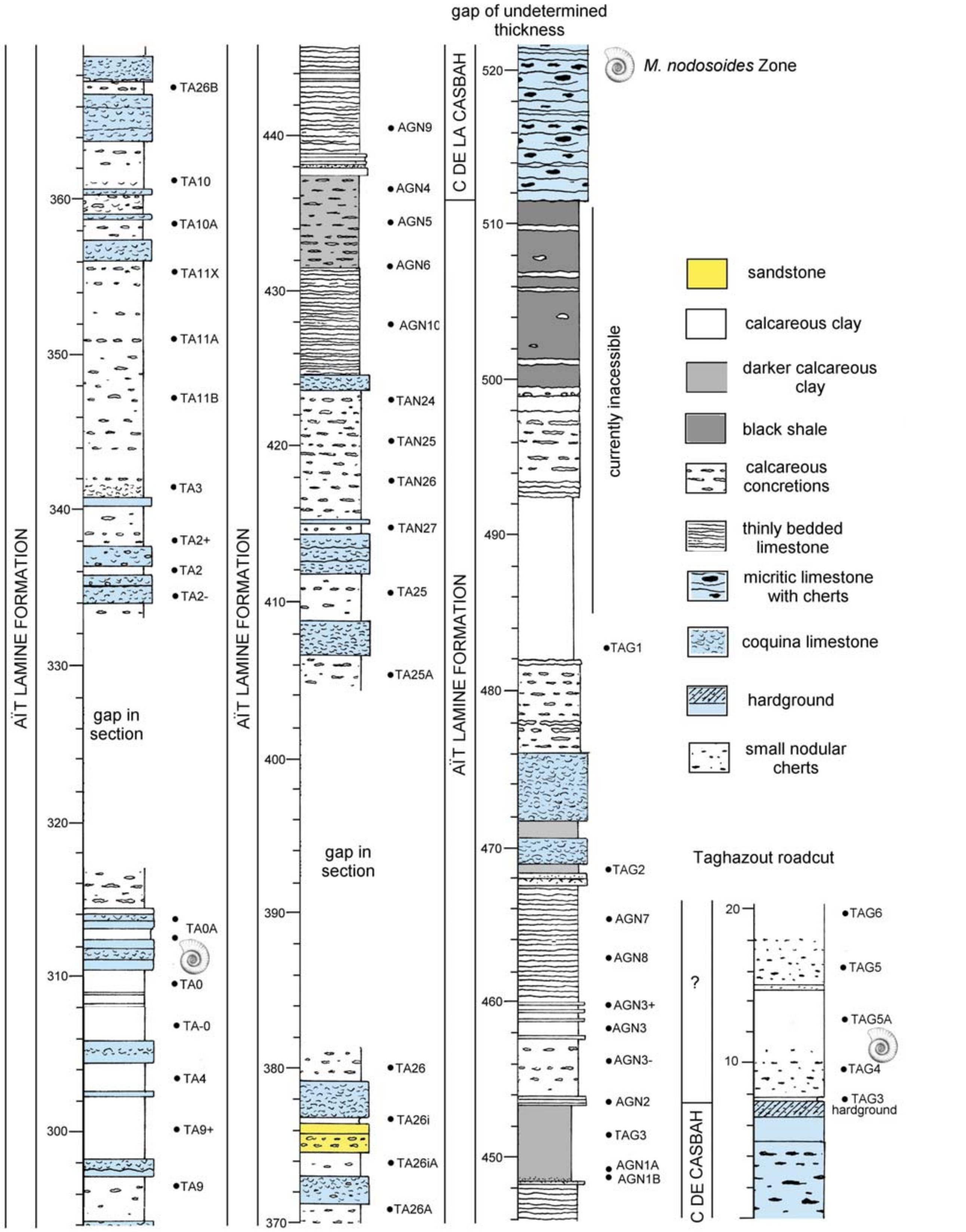


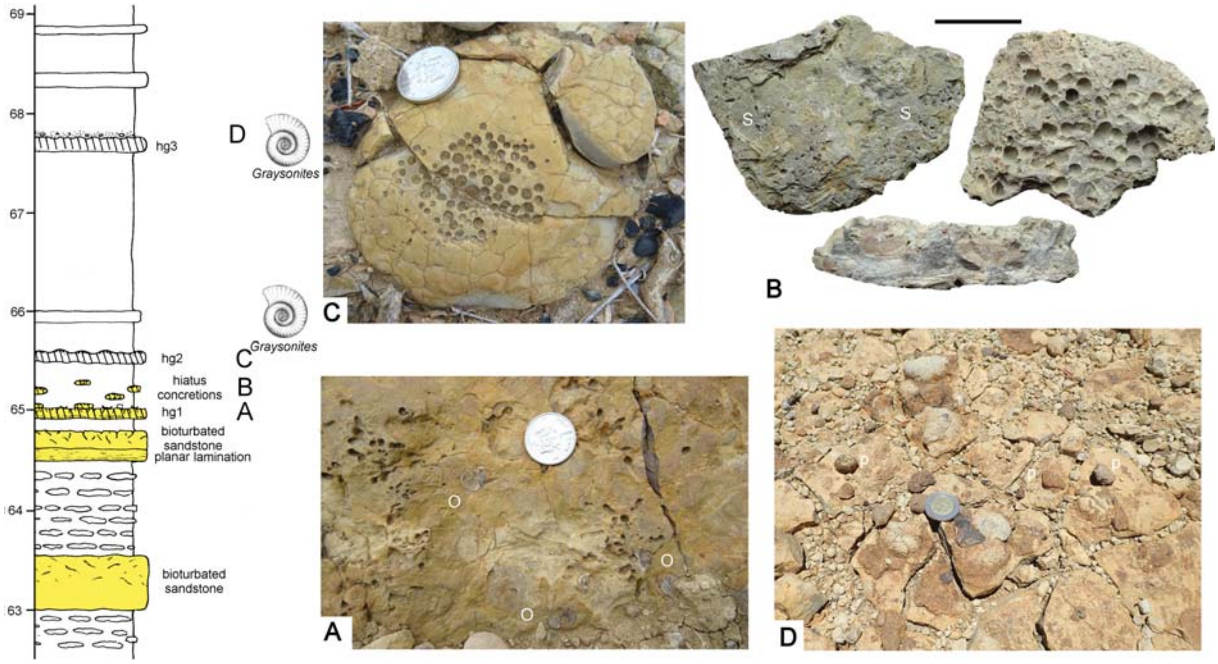
Text-fig. 2. A – Map of Morocco, to show localities cited in the text. B – detail of localities between Imi Ouaddar and Taghazout, Agadir Basin (Google Earth image).

The lower part of the succession was logged (Text-figs 3, 4) and sampled in a road cutting along the N1 road from Agadir to Essaouira, between Taghazout and Imi Ouaddar, and adjacent to Abouda Plage PK 25, which provides an almost complete section through the Aït Lamine Formation described by Essafraoui *et al.* (2015), but the uppermost part is here truncated by the overlying sub-Miocene unconformity. A critical interval, from 65–100 m, is not exposed in the road section, but was logged and sampled in the Oued Abouda, immediately east of



Text-figs 3–4. Composite log of the section exposed in the Abouda Plage roadcut, Oued Abouda, Taghazout Plage and log of the section exposed in the Taghazout roadcut, to show lithologies and sampled levels. The underlying limestone unit is the Calcaires de Kerchoula, the overlying one the Calcaires de la Casbah d'Agadir.


gap of undetermined thickness
M. nodosoides Zone
C DE LA CASBAH
AÏT LAMINE FORMATION
AÏT LAMINE FORMATION
AÏT LAMINE FORMATION
currently inacessible
gap in section
gap in section
TA26B
TA10
TA10A
TA11X
TA11A
TA11B
TA3
TA2+
TA2
TA2-
TA0A
TA0
TA-0
TA4
TA9+
TA9
AGN9
AGN4
AGN5
AGN6
AGN10
TAN24
TAN25
TAN26
TAN27
TA25
TA25A
TA26
TA26i
TA26iA
TA26A
TAG1
TAG2
AGN7
AGN8
AGN3+
AGN3
AGN3-
AGN2
TAG3
AGN1A
AGN1B
sandstone
calcareous clay
darker calcareous clay
black shale
calcareous concretions
thinly bedded limestone
micritic limestone with cherts
coquina limestone
hardground
small nodular cherts
Taghazout roadcut
?
C DE CASBAH
TAG6
TAG5
TAG5A
TAG4
TAG3
hardground



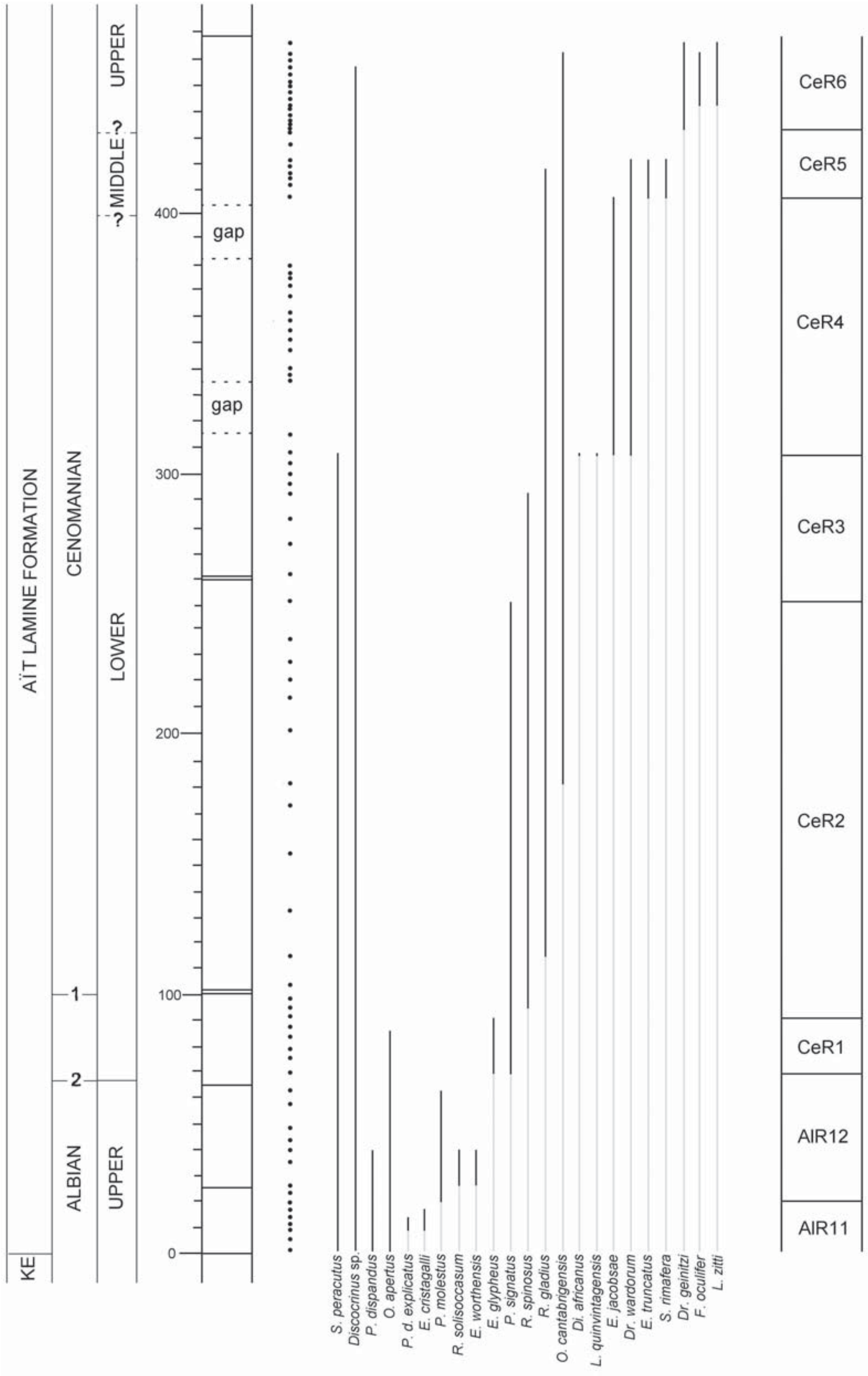
Text-fig. 5. Log of succession in the Aït Lamine Formation, between 63 and 69 m, based on the Abouda Plage roadcut and Oued Abouta valley in Morocco (see Text-fig. 2B). A – detail of oyster-encrusted (O) and bored hardground; B – bored (*Gastrochaenolites* ispp.) and serpulid-encrusted (S) hiatus concretion from 65 to 65.3 m; C – hardground boss with borings assigned to *Gastrochaenolites* ispp., 63.6 m; D – oyster-encrusted hardground overlain by lag of phosphatised intraclasts and a gravel matrix. Ammonites of the *Graysonites adkinsi* Zone occur at 66 and 67.8 m. See text for discussion. Scale bar (B) equals 5 cm; 1-dirham coin (A, C) diameter 25 mm; 10-dirham coin (D) 28 mm.

the road section (Text-fig. 2B). The succession is continued upwards on Taghazout Plage (Jati *et al*. 2010; Essafraoui *et al*. 2015), where the contact with the overlying Turonian “Calcaires de la Casbah d’Agadir” is exposed. The top of that unit and the overlying marls containing siliceous nodules were sampled in a roadcut north of Taghazout (Text-fig. 2B).

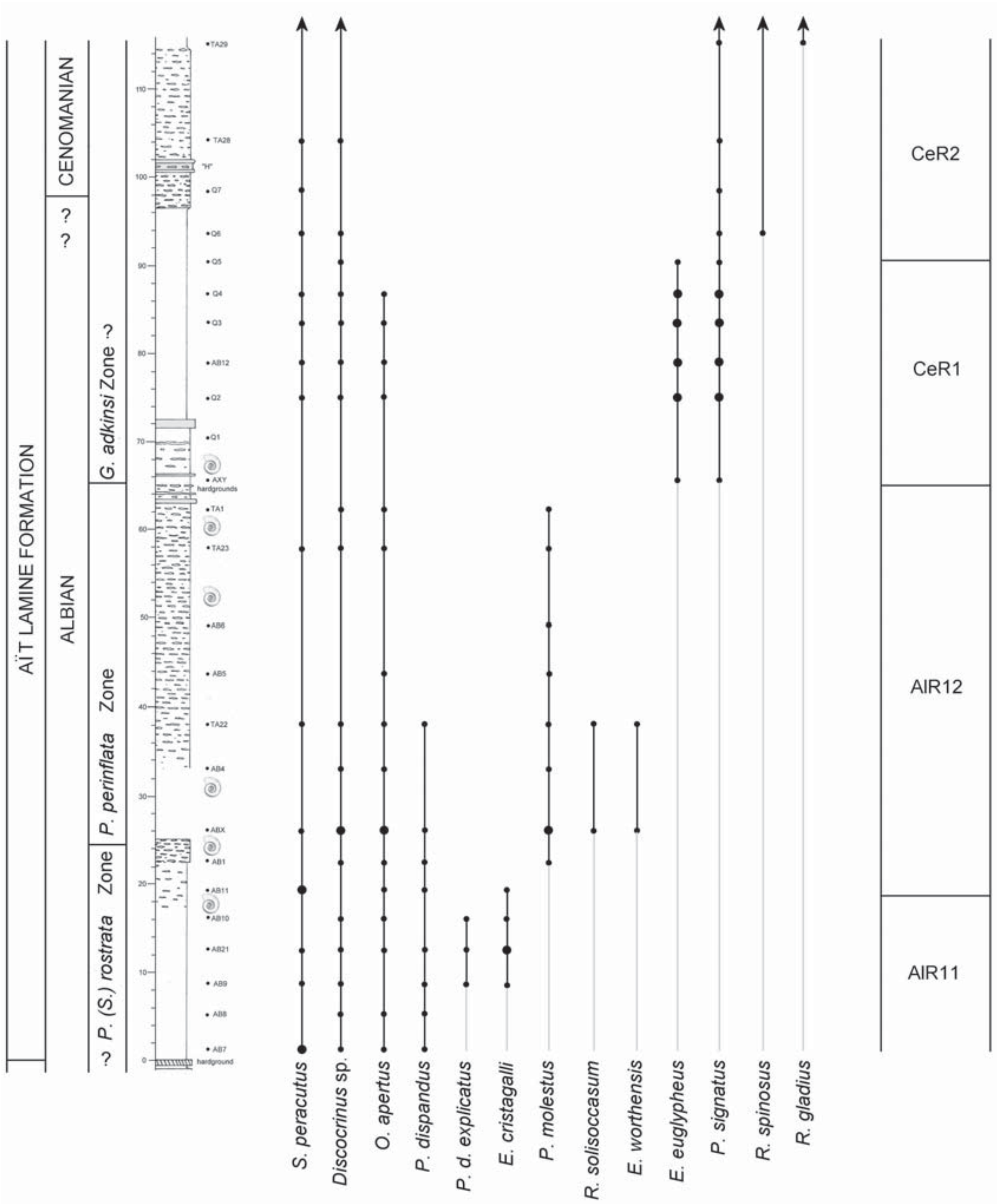
In addition to providing a complete section of the lower part of the Aït Lamine Formation, the succession exposed in Oued Abouda also yielded a number of ammonites, which allow precise dating for this part of the succession. Faunas of the *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone were recovered from 18–24 m above the base of the formation, and those of the *Pervinquieria* (*Subschloenbachia*) *perinflata* Zone at 25 m. The 25–60-m-interval yielded late Albian species not diagnostic of any zone. An early Cenomanian fauna of the *Graysonites adkinsi* Zone was collected between 65 and 67 m, immediately overlying a succession of hardgrounds and a layer of hiatus concretions (Text-fig. 5), which represent significant breaks in sedimentation, not recorded by Essafraoui *et al*. (2015). Finally, a single specimen of *Mantelliceras cantianum* Spath, 1926 indicative of an early Cenomanian age, was collected in the shore section at 311 m. The ammonite faunas will be described in a separate paper.

The section yielded abundant microcrinoids at some levels (Text-fig. 6), separated by barren or sparsely fossiliferous intervals. The detailed distribution of taxa in the lower part of the section is shown in Text-fig. 7. The lowest 18 m yielded abundant *Poecilocrinus dispandus* Peck, 1943, *P. dispandus* forma *explicatus* Peck, 1943, *Euglyphocrinus cristagalli* sp. nov. and *Styracocrinus peracutus* (Peck, 1943). The level between 19 and 62 m yielded *P. dispandus*, *P. molestus* Peck, 1943, *Roveacrinus solisoccasum* sp. nov. and *Euglyphocrinus worthensis* sp. nov.

Between 66 and 90 m, an abundant roveacrinid fauna was collected, including *Euglyphocrinus euglypheus* (Peck, 1943) and *Poecilocrinus signatus* (Peck, 1943). A considerable interval, from 90 to 240 m, yielded sparse faunas, which include *P. signatus*, *Roveacrinus spinosus* Peck, 1943 and *Styracocrinus peracutus*. At 310 m abundant *Roveacrinus gladius* sp. nov., *Discocrinus africanus* sp. nov., *Euglyphocrinus jacobsae* sp. nov., *Orthogonocrinus cantabrigensis* Gale, 2019 and *Styracocrinus peracutus* are present,



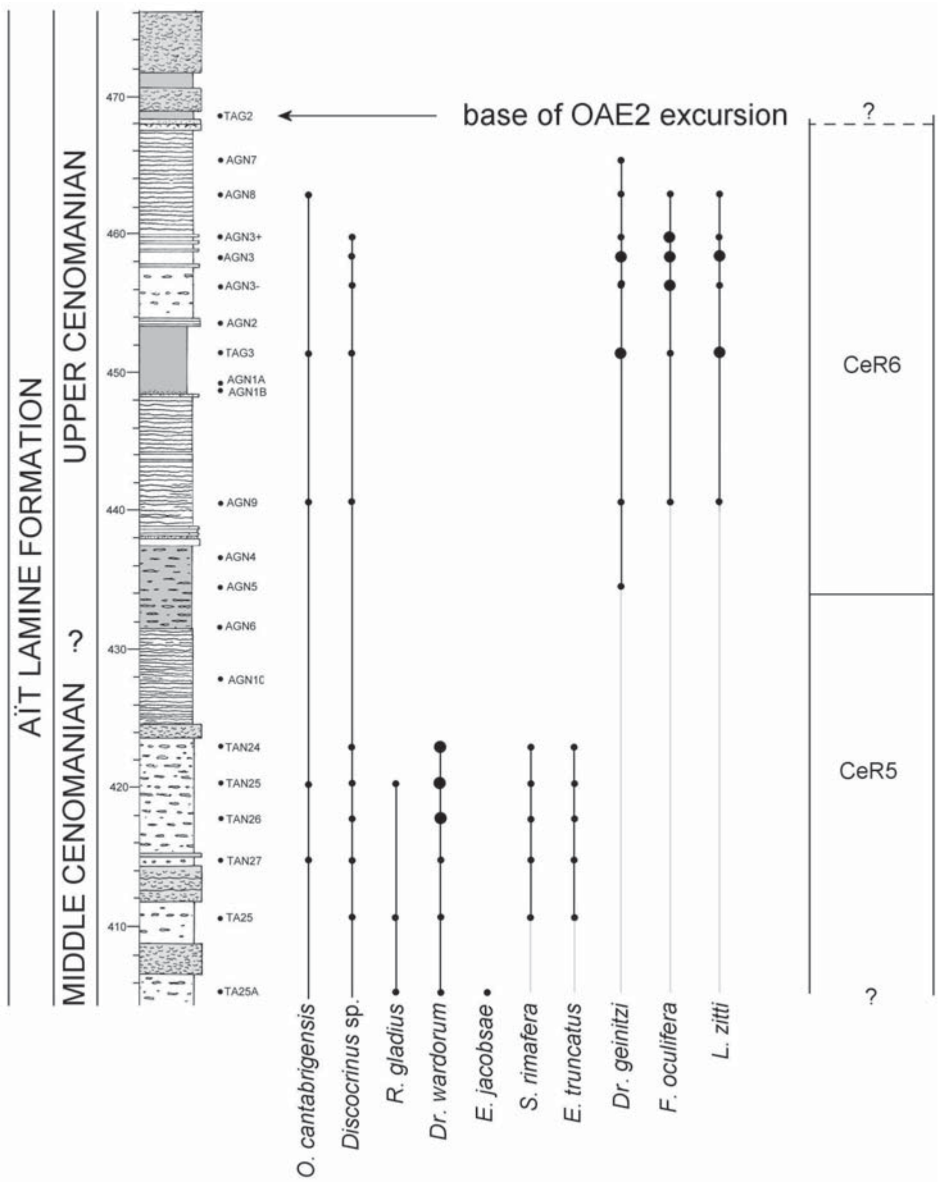
Text-fig. 6. Distribution of microcrinoids in the Aït Lamine Formation, Abouda Plage roadcut to Taghazout. *Di.* = *Discocrinus*; *Dr.* = *Drepanocrinus*; *E.* = *Euglyphocrinus*; *F.* = *Fenestracrinus*; *L.* = *Lebenharticrinus*; *O.* = *Orthogonocrinus*; *P. d.* = *Poecilocrinus dispandus*; *P.* = *Poecilocrinus*; *R.* = *Roveacrinus*; *S.* = *Styracocrinus*.



Text-fig. 7. Distribution of microcrinoids in the lowest 100 m of the Aït Lamine Formation shown in Text-fig. 3, Abouda Plage roadcut. The base of the Cenomanian is taken at the lowest occurrence of *Thalmaninella globotruncanoides*, following Essafroui *et al*. (2015). However, the species may occur at lower levels, because those authors did not sample the section between 62 and 99 m. *E*. = *Euglyphocrinus*; *G*. = *Graysonites*; *O*. = *Orthogonocrinus*; *P*. = *Poecilocrinus*; *P. d*. = *Poecilocrinus dispandus*; *P.* (*S.*) = *Pervinquieria* (*Subschloenbachia*); *R*. = *Roveacrinus*; *S*. = *Styracocrinus*.

accompanied by rare *Lebenharticrinus quinvigintensis* sp. nov.

The detailed distribution of taxa in the upper part of the section is provided in Text-fig. 8. From 405 to 423 m, *Drepanocrinus wardorum* sp. nov., *Styracocrinus rimafera* sp. nov., *Euglyphocrinus truncatus* sp. nov. and rare *Orthogonocrinus cantabrigensis* are present. The youngest Cenomanian



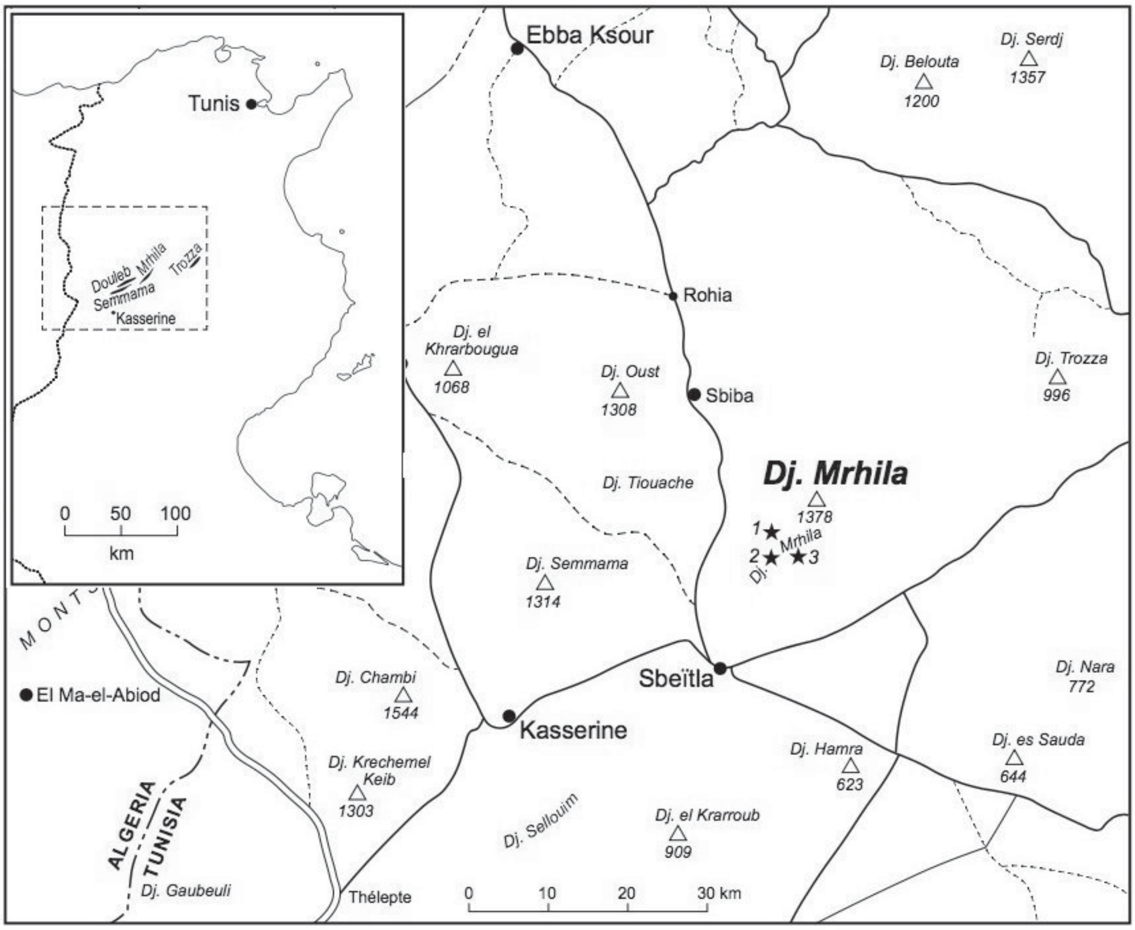
Text-fig. 8. Distribution of microcrinoids in the upper part of the Aït Lamine Formation, between 405 and 470 m in Text-fig. 4, Taghazout. See Text-fig. 4 for details of lithology. *Dr.* = *Drepanocrinus*; *E.* = *Euglyphocrinus*; *F.* = *Fenestracrinus*; *L.* = *Lebenharticrinus*; *O.* = *Orthogonocrinus*; *R.* = *Roveacrinus*; *S.* = *Styracocrinus*.

microcrinoid fauna found in the section occurs between 540 and 580 m, and includes *Drepanocrinus geinitzi* (Schneider, 1989), *Lebenharticrinus zitti* sp. nov., *Fenestracrinus oculifer* gen. et sp. nov. and *Discocrinus* sp. No microcrinoids were found in the higher samples TAG1 and TAG2.

In the Taghazout roadcut (Text-figs 2B, 4), sample TAG4 (9.5 m) yielded common cups and brachials of *Drepanocrinus striatulus* Gale, 2019, and *Roveacrinus falcifer* Gale, 2019 was found in TAG5A (2 cups, brachials).

Asfla, province of Er-Rachidia

The Cenomanian–Turonian succession near Goulmima in the High Atlas (Text-fig. 2A) was described by Ettachfini and Andreu (2004), and ammonites of late Cenomanian to early Turonian age



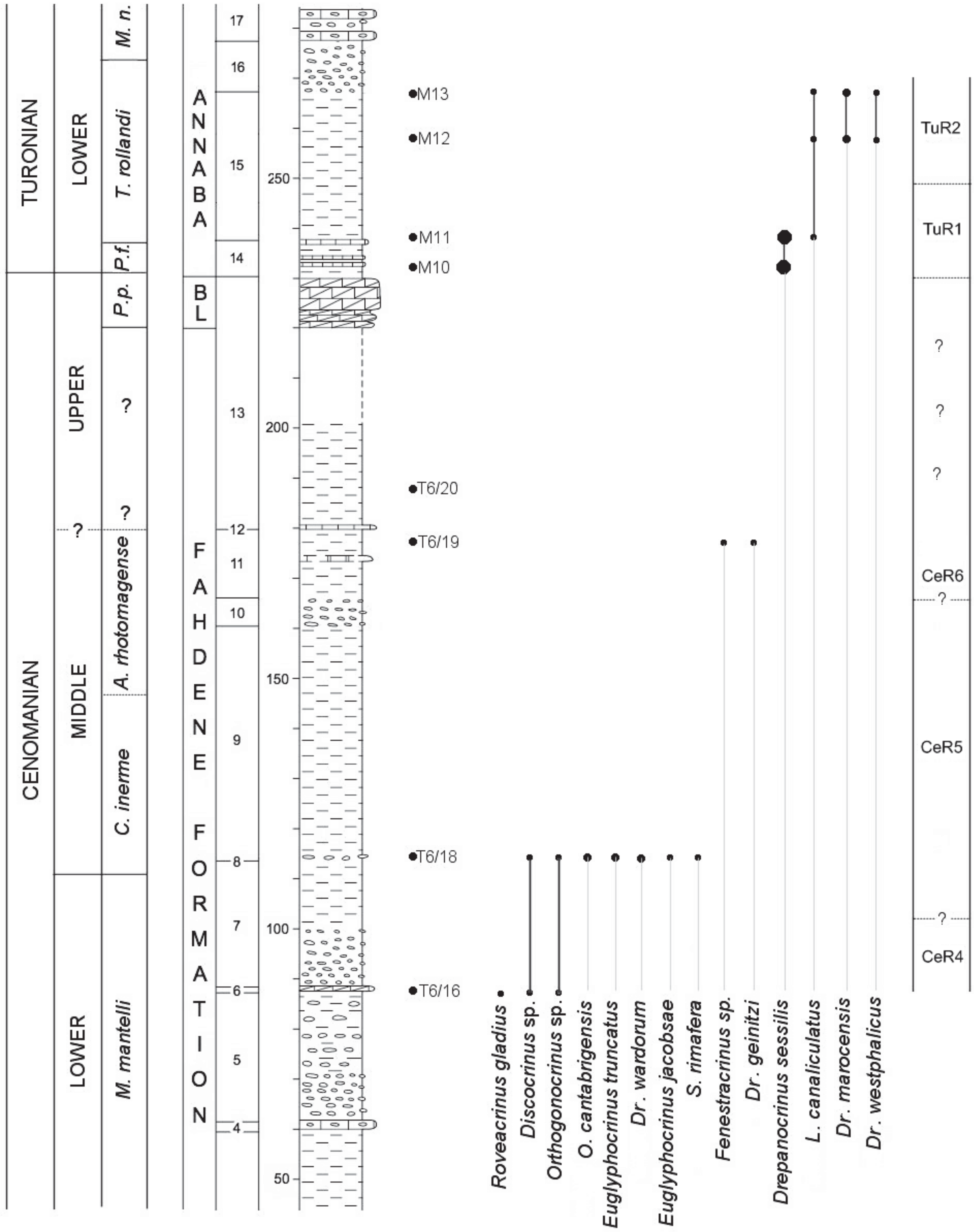
Text-fig. 9. Map of Tunisia (inset) to show the position of Djebel Mhrila.

have been described from the region (Meister and Rhalmi 2002; Kennedy *et al.* 2008; Meister *et al.* 2017). Logs were provided by Kennedy *et al.* (2008) and Villalobos-Segura *et al.* (2019). The main ammonite fauna is of early Turonian *Mammites nodosoides* Zone age, and occurs in nodules within laminated marls underlying a thick, scarp-forming limestone. Microcrinoids were found in the residue from preparation of fish-bearing nodules, and subsequent sampling from marls in the section at the Palmeria, Asfla (15 m on log of Villalobos-Segura *et al.* 2019, fig. 1) yielded abundant material, in part described by Gale (2019). This can be dated by ammonites as belonging to the lower *Mammites nodosoides* Zone, and yields abundant material of *Drepanocrinus marocensis* Gale, 2019, *Roveacrinus* aff. *labyrinthus* Gale, 2019 and *Lebenharticrinus canaliculatus* Žítt, Löser, Nekvasilová, Hradecká and Švábenická, 2019.

Central Tunisia

Sif el Tella, Djebel Mrhila

The Cenomanian succession south of Sif el Tella, Djebel Mrhila (Text-figs 9, 10), was described and illustrated by Kennedy and Gale (2015, fig. 5). Ammonites are abundant and permit the identification of successive zones. The lower part of the succession comprises marls and rubbly limestones of the Fahdene Formation (Albian, lower, middle and upper Cenomanian), overlain by dolomites of the Bahloul Formation (uppermost Cenomanian). These in turn are overlain by marls and thin limestones of the Annaba Formation (lower Turonian), described by Chancellor *et al.* (1994, text-fig. 5). A summary log with sampled levels is provided here (Text-fig. 10). The lowest fauna, from sample T6/16, yielded *Roveacrinus gladius* sp. nov. and *Orthogonocrinus* sp., and occurs



Text-fig. 10. Composite log of Djebel Mhrila, Tunisia, based on Chancellor *et al*. (1994, text-fig. 5) and Kennedy and Gale (2015, fig. 5), to show distribution of microcrinoids. *A. rhotomagense* = *Acanthoceras rhotomagense* Zone; BL = Bahloul Formation; *C. inerme* = *Cunningtoniceras inerme* Zone; *Dr.* = *Drepanocrinus*; *L.* = *Lebenharticrinus*; *M. mantelli* = *Mammites mantelli* Zone; *M. n.* = *Mammites nodosoides* Zone; *O.* = *Orthogonocrinus*; *P.f.* = *Pseudaspidoceras flexuosum* Zone; *P.p.* = *Pseudaspidoceras pseudonodosoides* Zone; *S.* = *Styracocrinus*; *T. rollandi* = *Thomasites rollandi* Zone.

within the lower Cenomanian *Mantelliceras mantelli* Zone, *Sharpeiceras schlueteri* Subzone (Kennedy and Gale 2015). Sample T6/18 contains abundant microcrinoids, including *Roveacrinus* sp., *Euglyphocrinus jacobsae* sp. nov., *E. truncatus* sp. nov., *Drepanocrinus wardorum* sp. nov., *Styracocrinus rimafera* sp. nov. and *Discocrinus* sp., and represents the middle Cenomanian *Cunningtoniceras inerme* Zone (Kennedy and Gale 2015). Sample T6/19 contained only a few microcrinoids, *Drepanocrinus geinitzi* and *Fenestracrinus* sp., and is either middle or late Cenomanian in age (Kennedy and Gale 2015).

The Turonian succession, in the Annaba Formation, overlying the Bahloul dolomites, proved to be very fossiliferous. Samples M10 and M11 yielded abundant *Drepanocrinus sessilis* Jækel, 1918 and rare *Lebenharticrinus canaliculatus.* These samples fall within the lowest Turonian *Pseudaspidoceras flexuosum* Zone (Chancellor *et al.* 1994). M12 and M13 yielded *Drepanocrinus westphalicus* (Sieverts, 1933), *D. marocensis* and *Lebenharticrinus* sp. Both samples fall in the lower Turonian *Thomasites rollandi* Zone. The base of the *Mammites nodosoides* Zone occurs in the section above, but was not sampled.

Djabel Sidi ben Adjeroud, near Kalaat-es-Senam

Upper Turonian marls and thin limestones belonging to the *Hemitissotia morreni* Zone are exposed at this locality (Chancellor *et al.* 1994, text-fig. 9). A single sample from the level marked "Mass occurrence of *Hemiaster*" in Chancellor *et al.* (1994, text-fig. 9) was processed. This yielded microcrinoids including *Hessicrinus thoracifer* Gale, 2019 and *Drepanocrinus communis* forma *dubrisiensis* Gale, 2019. Sample Y yielded *D. communis* forma *dubrisiensis*. Both samples are of late Turonian *Hemitissotia morreni* Zone age (Chancellor *et al.* 1994).

MICROCRINOID ZONATION AND CORRELATION OF THE NORTH AFRICAN SUCCESSION

The records provided above form the basis for a microcrinoid zonation in the uppermost Albian, Cenomanian and Turonian of Morocco and Tunisia. This is integrated into the ammonite stratigraphy provided by Chancellor *et al.* (1994) and Kennedy and Gale (2015). For the Albian and lowest Cenomanian, the very similar faunas from the Main Street Limestone and Grayson Marl in Texas, provide important comparisons, and furthermore, furnish ammonite ages (Kennedy *et al.* 2005). For the Turonian, direct comparison can be made with the microcrinoid succession described for the Anglo-Paris Basin (Gale 2019).

AlR11 (upper Albian)

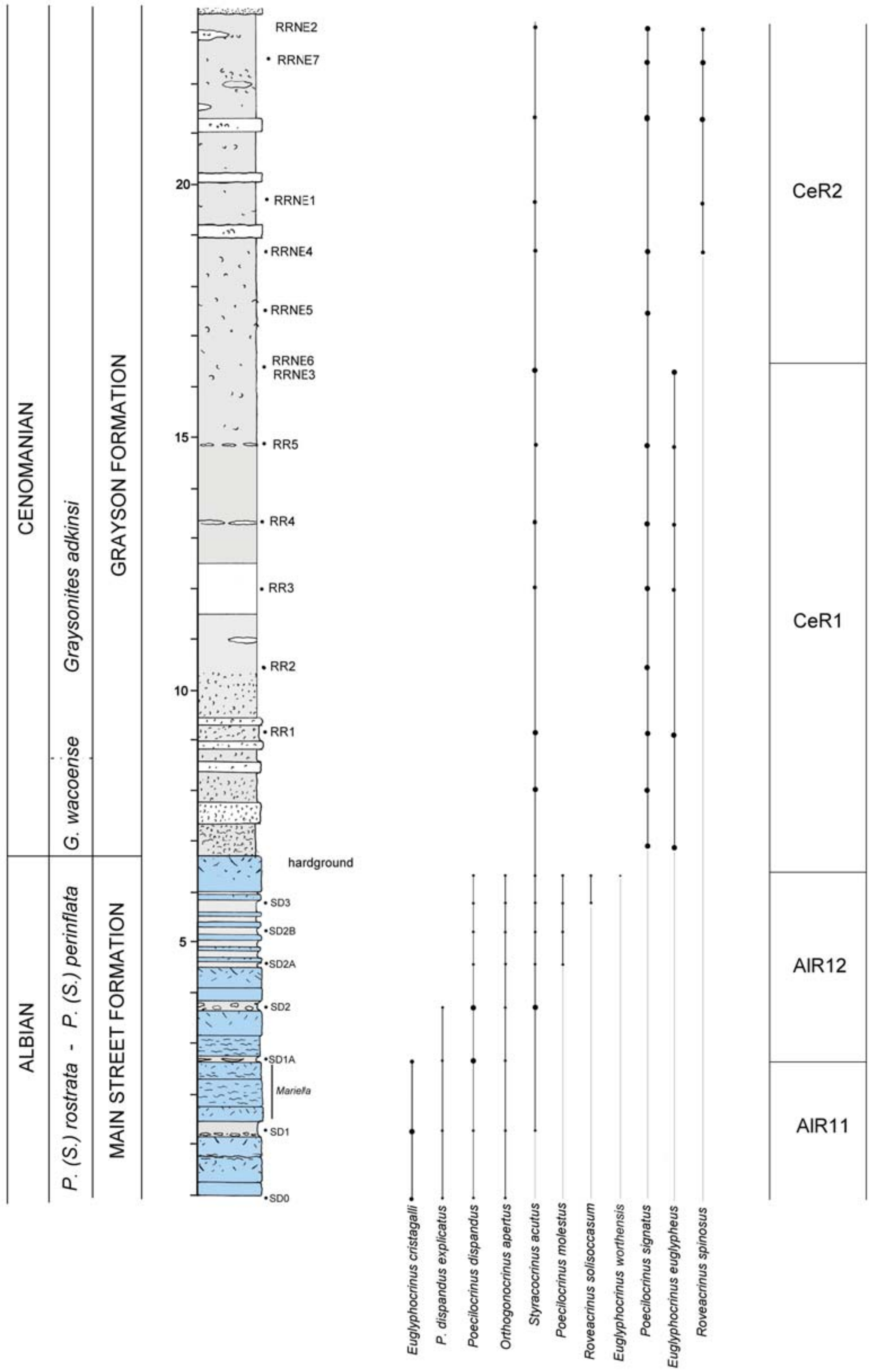
This fauna is best known from central Texas, where *Poecilocrinus dispandus* (including *P. d.* forma *explicatus*), *Euglyphocrinus cristagalli* sp. nov. and *Styracocrinus peracutus* are characteristic of the lower part of the Main Street Limestone (Text-fig. 11). This level yields ammonites of the *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone (Kennedy *et al.* 2005). The microcrinoid fauna is only known in Africa from the lowest 20 m of the Aït Lamine Formation in the Abouda Plage roadcut section, Morocco (Text-fig. 7). The base is uncertain, but the top is marked by the highest occurrence of *E. cristagalli* sp. nov.

AlR12 (upper Albian)

In central Texas, *Poecilocrinus molestus*, *P. dispandus*, *Euglyphocrinus worthensis* sp. nov. and *Roveacrinus solisoccasum* sp. nov. occur in the uppermost 1–2 m of the Main Street Limestone of Fort Worth (Text-fig. 11). The age of this fauna is late Albian (Kennedy *et al.* 2005), including the *Pervinquieria* (*Subschloenbachia*) *perinflata* Zone. This microcrinoid fauna is present from 35–50 m in the lower Aït Lamine Formation in the Abouda roadcut section (Text-fig. 7). The base of the zone is taken at the highest occurrence of *Euglyphocrinus cristagalli* sp. nov., the top by the lowest occurrence of *Poecilocrinus signatus* and *Euglyphocrinus euglypheus*.

CeR1 (? lower Cenomanian, *Graysonites adkinsi* Zone)

The lower part of the Grayson Formation of central Texas yields an abundant microcrinoid fauna including *Poecilocrinus signatus*, *Styracocrinus peracutus* and *Euglyphocrinus euglypheus* (Peck 1943; Text-fig. 11 herein). The associated ammonites are of *Graysonites adkinsi* Zone age (Kennedy *et al.* 2005). These microcrinoid species are common in the Agadir Basin section (65–90 m; Text-fig. 7), in and above levels where finds of *Graysonites adkinsi* Young, 1958 have been made. There are minor differences between the Moroccan and Texan faunas, as representatives of *Orthogonocrinus* are not present in Texas above the Albian but extend through the Cenomanian in Morocco. However, the base of the Cenomanian



Text-fig. 11. Distribution of latest Albian and early Cenomanian microcrinoids in central Texas, USA. The log of the Main Street Limestone, with sample levels, is from Sunset Oak Drive, Fort Worth (Tarrant County); that of the Grayson Formation is based on the Rayzor Ranch section in Denton County. Note the close similarity with the distribution in the lower part of the Aït Lamine Formation in the Agadir Basin sections (Text-fig. 7). *G.* = *Graysonites*; *P.* = *Poecilocrinus*; *P.* (*S.*) = *Pervinquieria* (*Subschloenbachia*).

is taken at the lowest occurrence of the planktonic foraminiferan *Thalmaninella globotruncanoides* (see Kennedy *et al*. 2004), the lowest occurrence of which in the Abouda Plage section is at approximately 98 m on the section (Text-fig. 7 herein, just beneath "H" of Essafraoui *et al*. 2015, fig. 3). These latter authors did not sample between 65 and 98 m, so the earliest occurrence remains to be determined. Zone CeR1 represents the total range of *E. euglypheus*.

CeR2 (lower Cenomanian, *Mantelliceras mantelli* Zone)

In the Aït Lamine Formation at Taghazout, levels between 80 and 250 m (Text-fig. 6) yielded *Poecilocrinus signatus*, *Roveacrinus gladius* sp. nov., *R. spinosus*, *Styracocrinus peracutus* (common), *Orthogonocrinus cantabrigensis*, *Discocrinus* sp. (brachials, common) and *Euglyphocrinus* sp. (rare). Elements of this fauna are present in the lowest Cenomanian of Cambridge, United Kingdom (Gale 2019), the equivalent, condensed level at Mülheim-Broich, Westphalia, Germany (Hess and Thiel 2015) and in the upper part of the Grayson Formation of central Texas (Text-fig. 11). The top of the zone is taken at the highest occurrence of *Poecilocrinus signatus*.

CeR3 (lower Cenomanian)

This zone extends from the highest occurrence of *Poecilocrinus signatus* at 250 m to the lowest occurrence of *Euglyphocrinus jacobsae* sp. nov. at 310 m (Text-fig. 6). It is currently only known from the Agadir Basin.

CeR4 (lower Cenomanian)

In the Aït Lamine Formation of the Abouda Plage roadcut, microcrinoids become abundant at 310 m (Text-figs 3, 6). The diverse fauna includes *Roveacrinus gladius* sp. nov., *Orthogonocrinus cantabrigensis*, *Styracocrinus peracutus*, *Discocrinus africanus* sp. nov., *Drepanocrinus wardorum* sp. nov. (rare), *Lebenharticrinus quinvigintensis* sp. nov. and *Euglyphocrinus jacobsae* sp. nov. A single specimen of the ammonite *Mantelliceras cantianum* from 311 m confirms the early Cenomanian age. At Djebel Mhrila, in central Tunisia, elements of this fauna are present in the *Sharpeiceras schlueteri* Subzone of the *Mantelliceras mantelli* Zone (Text-fig. 10). This microcrinoid fauna is not yet known outside North Africa, but is predicted to be present in the Buda Limestone of Texas. The base of the zone is marked by the lowest occurrence of *E. jacobsae* sp. nov., the top by the lowest occurrence of *Euglyphocrinus truncatus* sp. nov.

CeR5 (middle Cenomanian)

In the Abouta Plage roadcut section, a distinctive and abundant fauna of microcrinoids occurs between 405 and 425 m, including *Euglyphocrinus truncatus* sp. nov., *Drepanocrinus wardorum* sp. nov., *Styracocrinus rimafera* sp. nov., *Orthogonocrinus cantabrigensis* and *Discocrinus* sp., with rare *Roveacrinus gladius* sp. nov. An identical fauna occurs in the Fahdene Formation at Djebel Mhrila in the middle Cenomanian *Cunningtoniceras inerme* Zone (Text-fig. 10; Kennedy and Gale 2015). This fauna is so far not known outside North Africa. The zone is defined as the total range of *E. truncatus*.

CeR6 (upper Cenomanian)

The interval between 434 and 465.5 m at Taghazout Plage yields common to abundant *Fenestracrinus oculifer* gen. et sp. nov., *Lebenharticrinus zitti* sp. nov., *Drepanocrinus geinitzi*, rare *Orthogonocrinus cantabrigensis* and *Discocrinus* sp. Elements of this fauna are present in highly condensed deposits at the locality of Hoher Stein near Dresden (eastern Germany) and at Předboj, Czech Republic (Žítt *et al*. 2019), which cannot be dated precisely. From the stratigraphical position, this fauna is of late Cenomanian, probably *Calycoceras guerangeri* Zone age, but no ammonites have been recorded in association with the microcrinoids. The zone is defined by the total range of *D. geinitzi*.

CeR7 (upper Cenomanian) not recorded from North Africa

In the Anglo-Paris Basin, *Roveacrinus carinatus* (Nekvasilová and Prokop, 1963) and *Lebenharticrinus* sp. are characteristic of the latest Cenomanian *Metoicoceras geslinianum* and *Neocardioceras juddii* zones (Gale 2019). This fauna is present in condensed deposits at the locality of Hoher Stein near Dresden, Germany, and at Předboj, Czech Republic (Žítt *et al*. 2019).

TuR1 (lower Turonian, *Pseudaspidoceras flexuosum* Zone and lateral correlatives)

The basal Turonian is characterised by a flood abundance of *Drepanocrinus sessilis*, associated with rare *Lebenharticrinus canaliculatus*, in the *Watinoceras devonense* Zone and lowermost *Fagesia catinus* Zone of the Anglo-Paris Basin (Gale 2019). This fauna is found in central Tunisia at Djebel Mhrila in the correlative *Pseudaspidoceras flexuosum* Zone (Text-fig. 10). The fauna also occurs in the *Labiatus* Pläner of Germany (Gale 2019). The zone is defined as the total range of *D. sessilis*.

TuR2 (lower Turonian, *Thomasites rollandi* and *Fagesia catinus* zones)

In the Anglo-Paris Basin, the succeeding Turonian fauna is dominated by *Drepanocrinus westphalicus* with less common *Lebenharticrinus canaliculatus* (see Gale 2019), which occur in the *Fagesia catinus* Zone, immediately beneath the base of the *Mammites nodosoides* Zone. The fauna is present in the correlative *Thomasites rollandi* Zone at Djebel Mhrila, central Tunisia, in which early *Drepanocrinus marocensis* also occur (Text-fig. 10). The base of the zone is defined by the lowest occurrence of *D. westphalicus*, the top by the lowest occurrence of *Roveacrinus labyrinthus*.

TuR3 (lower Turonian, lower *Mammites nodosoides* Zone)

In the Anglo-Paris Basin, this zone, in the lower part of the *Mammites nodosoides* Zone, is characterised by *Roveacrinus labyrinthus*, *Lebenharticrinus canaliculatus* and, at one thin horizon, *Drepanocrinus marocensis* (Gale 2019). At Asfla, southeast Morocco, a similar fauna, but dominated by *D. marocensis,* with rarer *R.* cf. *labyrinthus* and *L. canaliculatus*, is abundant in the lower part of the *Mammites nodosoides* Zone (Gale 2019).

TuR9–TuR10

In the Anglo-Paris Basin, zone TuR9 extends from the highest occurrence of *Dentatocrinus dentatus* Gale, 2019 to the lowest occurrence of *Roveacrinus falcifer*, marking the base of TuR10 (Gale 2019). In the Taghazout roadcut (Text-figs 2B, 4), sample TAG4 yields abundant *Drepanocrinus striatulus*, and *R. falcifer* appears in sample TAG5A, 4 m higher, marking the base of TuR10.

TuR14 (upper Turonian)

In the Anglo-Paris Basin, this zone is characterised by common to abundant *Drepanocrinus communis* forma *dubrisiensis*, accompanied by *Lebenharticrinus incisurus* Gale, 2019 and *Hessicrinus thoracifer* Gale, 2019. *Hessicrinus thoracifer* and *D. communis* forma *dubrisiensis* are present in the upper Turonian *Hemitissotia morreni* Zone marls, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senan, Tunisia, and form the only record of this zone in North Africa.

Repositories of specimens

NHMUK, Natural History Museum, London, United Kingdom.
USNM, United States National Museum, Washington DC, USA.

SYSTEMATIC PALAEONTOLOGY

Family Roveacrinidae Peck, 1943

DIAGNOSIS: Roveacrinida in which a double thecal cavity is present, the lower of which is enclosed by basals, basals and radials, or radials; the basals (rarely the radials) form a transverse structure, either solid or perforated, separating the two cavities.

Subfamily Orthogonocrininae Gale, 2019

DIAGNOSIS: Cup pyriform or conical, elongated aborally; adoral surface bears high, usually bladed, interradial processes; radial cavity shallow, narrow, base formed by small basals, not visible on exterior of cup; basal cavity elongated, the adoral surface of the cavity bears five radially placed pits that each house a ball-shaped structure; brachials highly modified, IBr1 very short, IBr2 elongated, distal secundibrachials elongated, bearing pinnules.

Genus *Discocrinus* Peck, 1943

DIAGNOSIS: Cup low, broad, with tall muscle fossae on radials; radial cavity floored by thin perforated sheet; aboral margin of cup very fragile or probably non-mineralised.

TYPE SPECIES: *Discocrinus catastomus* Peck, 1943, by original designation.

INCLUDED SPECIES: *Discocrinus wrighti* Peck, 1955 and *D. africanus* sp. nov.

REMARKS: *Discocrinus* is a distinctive and unusual roveacrinid, which is locally common in the Albian of Texas, and known from two specimens from the lower Cenomanian of the United Kingdom (Peck 1955; Rasmussen 1961). It is abundant in the lower Cenomanian of the Agadir Basin (Morocco) and present in the Cenomanian of central Tunisia. Recognition of the highly distinctive brachials makes it possible to record the species in the absence of the rarer cups (Gale 2019). Detailed reassessment of the genus awaits description of abundant and exceptionally well-preserved material from the Weno Formation (upper Albian) of Texas, including over 200 cups which demonstrate ontogenetic changes. However, the Agadir Basin specimens achieve sizes over twice those attained by Texas specimens, and are morphologically distinctive.

OCCURRENCE: Upper Albian and Cenomanian of the United Kingdom, Texas, Oklahoma, Morocco and Tunisia.

Discocrinus africanus sp. nov.
(Pl. 1, Figs 1–5, 7, 8; Pl. 2, Figs 9–21)

2019. *Discocrinus* sp.; Gale, pl. 36, fig. 1.

DIAGNOSIS: Cup as tall as broad, radial facets occupying almost the entire lateral surfaces of the radials; interradial ridges well developed; interradial processes large, bearing broad lateral radial tubes.

DERIVATION OF NAME: Latin *africanus*, in allusion to the source of the material.

TYPES. The large specimen in Pl. 1, Figs 1–3 is the holotype (NHMUK PI EE 17357). The smaller individual (Pl. 1, Figs 4–7; NHMUK PI EE 17358) and the broken cup (NHMUK PI EE 16146) are paratypes.

MATERIAL: Six cups and numerous brachials from the lower Cenomanian samples TA0 (Text-fig. 4, 309 m); Aït Lamine Formation, Abouda Plage roadcut.

DESCRIPTION. The largest cups (Pl. 1, Figs 1–3) have equal height/breadth, are square in lateral view and pentagonal in aboral/adoral views, with gently concave sides. They are constructed entirely of radial plates, and the radial articular facets occupy almost all of the sides. The interradial contacts bear rounded ridges which extend from the aboral margin of the cup to the adoral margins of the interradial processes. The radial facets are U-shaped and parallel with the axis of the cup, and the transverse articular ridge is positioned slightly less than half way up the side of the cup. It carries a central, transverse narrow groove; the central canal and aboral ligament pit are rounded and of equal size. The muscle fossae are triangular and concave and positioned adoral to two large lateral radial tubes, best seen in specimens in which the fossae and interradial processes are broken away (Pl. 1, Fig. 8). The interradial processes are robust and triangular. In aboral view, the cup has a deep, rounded concavity; in adoral view, a broad, deep radial cavity is present. Cups of smaller individuals (Pl. 1, Figs 4, 5, 7) are low and broad, and taper slightly adorally. The radial facets form processes which stand out from the sides of the cup and the interradial regions between the articular facets are as broad as the facets, and bear a ridge at the interradial suture. Broad, rounded openings are present both adorally and aborally, and overgrown remains of the transverse sheet separating the ab- and adoral cavities are visible (compare with well-preserved specimens of *D. catastomus* from the Weno Formation of Texas, Pl. 1, Figs 12, 13 herein). The proximal brachials are individually distinctive and the arms can be reconstructed up to IIBr2 (see also Gale 2019). IBr1 (Pl. 2, Figs 9–11) is trapezoidal in lateral view, and internally bears tall muscle facets. In distal view, the synarthrial articulation for IBr2 is flat. Axillary IBr2 (Pl. 2, Figs 19–21) is three times as tall as broad, very robust, and constructed of openly reticulate stereom; the distal end is triangular, with facets for two IIBr1. IIBr1 (Pl. 2, Figs 13, 14) are triangular in lateral view, and distally carry a synarthrial facet for IIBr2. IIBr2 (Pl. 2, Fig. 12) proximally have a flat, synarthrial articulation and distally a muscular one. Distal brachials have well-developed muscular articulations (Pl. 2, Fig. 17) and some bear a single, oval pinnular facet (see also Pl. 1, Fig. 9).

REMARKS: Two other species of *Discocrinus* have previously been described (N.B., *D. integer* Hess in Hess and Gale, 2010, is an unrelated form with affinities to *Plotocrinus*), namely *D. catastomus* from the upper Albian of Texas and *D. wrighti* Peck, 1955 from the lower Cenomanian of Cambridge, United Kingdom. These were refigured by Gale (2019, pl. 35, figs 1, 3 [*D. wrighti*]; pl. 35, figs 2, 4, 7–10 and pl. 36, figs 2–6 [*D. catastomus*]). All species achieve a maximum cup breadth of 2–2.5 mm; *D. catastomus* is low in height, with a maximum height (to the adoral margin of the radial facets) of 0.5–0.6 mm, whereas *D. wrighti* achieves a height of 1 mm. The three large specimens of *D. africanus* sp. nov. have a maximum breadth of 2.5 mm and a height of 2 mm. Small specimens of this species have a height of 0.75 mm and a breadth of 1.5 mm. It therefore appears that there is a phyletic height increase in successive species through the Albian–Cenomanian, reflected in the ontogeny of *D. africanus* sp. nov. There is also an evolutionary increase in the size of the radial facets and a concomitant decrease in the size of the interradial regions between these.

OCCURRENCE: *Discocrinus africanus* sp. nov. occurs in the lower Cenomanian of the Abouda Plage roadcut, Morocco, and is commonest in sample TA0 (Text-fig. 4).

Discocrinus sp.
(Pl. 2, Fig. 17)

MATERIAL: Over 250 brachial plates.

REMARKS: Brachials assignable to the genus *Discocrinus*, but specifically indeterminate, occur commonly throughout the Cenomanian Aït Lamine Formation.

Genus *Orthogonocrinus* Peck, 1943

DIAGNOSIS: Cup tall, radial facets divided into surfaces set at right angles and separated by the articular ridge. Radials in contact only in adoral portion of cup; aborally, they separate into strips. Interradial processes tall and bladed, radial cavity narrow.

TYPE SPECIES: *Orthogonocrinus apertus* Peck, 1943, by original designation.

INCLUDED SPECIES: *Orthogonocrinus cantabrigensis* Gale, 2019.

REMARKS: Two species of *Orthogonocrinus* have been described to date. The type species, from the middle to upper Albian of Texas and Oklahoma, also occurs in the middle Albian of the United Kingdom (Smith *et al*. in Young *et al*. 2010, fig. 18.1a). The other, *O. cantabrigensis*, is widespread but uncommon in the lower Cenomanian of Europe (Germany, United Kingdom), but has a longer range in Morocco, occurring from 183 m through to the upper Cenomanian (Text-fig. 6).

Orthogonocrinus apertus Peck, 1943
(Pl. 4, Figs 7–9, 11, 12)

*1943. *Orthogonocrinus apertus* Peck, p. 464, pl. 76, figs 2–8.
2010. *Orthogonocrinus apertus* Peck; Young *et al*., p. 256, text-fig. 18.1a.
2015. *Orthogonocrinus apertus* Peck, Hess, fig. 12a–l.
2019. *Orthogonocrinus apertus* Peck; Gale, pl. 39, figs 1–4.

DIAGNOSIS: Cup cylindrical, radials carrying median blade extending from the radial facet aborally. Lateral surface of radial facet large, U-shaped. Cup weakly and finely rugose.

TYPES: The cup figured by Peck (1943, pl. 76, figs 4, 6, 7; specimen E-21-5) is the holotype from the Duck Creek Formation, upper Albian, H.T. Loeblich locality 57, roadcut on US Highway 77 just south of bridge over Red River, Texas, USA. University of Missouri collection; not found, presumed lost.

MATERIAL: 24 cups and 15 brachials from the upper Albian and lower Cenomanian Aït Lamine Formation, from base to 87 m (sample Q4; see Text-fig. 7).

REMARKS: This distinctive species, redescribed by Hess (2015), occurs commonly in the upper Albian of Texas and Oklahoma; one cup is recorded from the middle Albian Gault Clay of the United Kingdom (Young *et al*. 2010). The new records from the upper Albian and lower Cenomanian of the Agadir Basin represent a considerable extension of the palaeogeographical range of the species. Note that the distinctively elongated brachials figured by Hess (2015) as belonging to *Roveacrinus pyramidalis* Peck, 1943 actually belong to *O. apertus*, as discussed by Gale (2019). Material from the Cenomanian of the United Kingdom referred to this species by Peck (1955) should be placed in *O. cantabrigensis* Gale, 2019 (see below).

Orthogonocrinus cantabrigensis Gale, 2019
(Pl. 3, Figs 1–7)

v1955. *Orthogonocrinus apertus* Peck, p. 1022, pl. 106, figs 7–9.
1961. *Orthogonocrinus apertus* Peck; Rasmussen, p. 56, pl. 56, fig. 4.
2015. *Orthogonocrinus apertus*; Hess and Thiel, p. 52, fig. 3k.
*2019. *Orthogonocrinus cantabrigensis* Gale, p. 478, pl. 42, figs 5–7.

DIAGNOSIS: *Orthogonocrinus* in which the adoral cup is reticulate and rugose; the median radial margins are very coarsely reticulate. The lateral surfaces of the radial facets are low, V-shaped and deep.

TYPES: The cup (NHMUK E 15507) from the Chalk Marl of Cambridge, United Kingdom, figured by Peck (1955) is the holotype, the other specimens from the same locality (NHMUK E 45869–70) are paratypes.

MATERIAL: Twenty cups from the Aït Lamine Formation, Taghazout, Agadir Basin, Morocco. Three cups from the middle Cenomanian *C. inerme* Zone of Djebel Mhrila, Tunisia.

DESCRIPTION: The cup is tall and conical, tapering markedly aborally, and the aboral portion is never completely preserved. The adoral part is cylindrical and robust and the radial sutures are slightly inset (Pl. 3, Figs 1, 2). The lateral portions of the radial facets are V-shaped and the central region posesses a large, deep aboral ligament pit (Pl. 3, Figs 4, 6); the central canal is of moderate size and circular (Pl. 3, Fig. 3). The interradial processes are narrow and form blade-like structures which extend from the lateral margins of the cup to the narrow radial cavity (Pl. 3, Figs 1, 2). The external sculpture comprises rugosities on the lateral surfaces of the radials, and a coarsely reticulate region on the concave median part of the radials (Pl. 3, Figs 1, 2, 4, 6). Aborally, the radials separate and consist of trifoliate spikes which taper slowly aborally (Pl. 3, Fig. 2).

REMARKS: *Orthogonocrinus cantabrigensis* differs from *O. apertus* in the coarsely rugose, reticulate surface of the cup, the deep V-shaped radial facets and the aborally tapering cup. It is a long-ranging species which occurs through almost the entire Cenomanian Stage, and probably evolved from *O. apertus*. There appears to be very little stratigraphical variation in its morphology.

OCCURRENCE: Lower Cenomanian (*Neostlingoceras carcitanense* Subzone) of Cambridge, United Kingdom and Mülheim-Broich, Westphalia, Germany. Lower to upper Cenomanian of the Agadir Basin, Morocco; middle Cenomanian of Djebel Mhrila, Tunisia.

Genus *Styracocrinus* Peck, 1955

DIAGNOSIS: Cup tall, conical, extended aborally to an acute point. Interradial processes tall, pointed. IBr2 elongated, flattened, bearing narrow rounded central ridge and lateral flanges.

TYPE SPECIES: *Styracocrinus peracutus* (Peck, 1943), by the subsequent designation of Peck (1955).

INCLUDED SPECIES: *Styracocrinus peracutus* and *S. rimafera* sp. nov.

Styracocrinus peracutus (Peck, 1943)
(Pl. 1, Fig. 6, Pl. 2, Figs 1, 2, Pl. 5, Figs 1–11)

* 1943. *Drepanocrinus peracutus* Peck, p. 463, pl. 76, figs 9–22, 26, 28.
1955. *Styracocrinus peracutus*; Peck, p. 1022, pl. 106, figs 10–12.
1961. *Styracocrinus peracutus* (Peck); Rasmussen, p. 383, pl. 56, figs 1–3.
?1971. *Styracocrinus peracutus* (Peck); Schmid, p. 73, pl. 1, figs 1–15.
2015. *Roveacrinus peracutus* Peck; Hess, fig. 17a–f.
part 2015. *Roveacrinus spinosus* Peck; Hess, fig. 14a–c only.
2019. *Styracocrinus peracutus* (Peck); Gale, p. 476, pl. 37, figs 1–9.

DIAGNOSIS: *Styracocrinus* in which the radials articulate closely and form an acuminate aboral pole.

HOLOTYPE: The cup, figured by Peck (1943, pl. 76, fig. 21), from the lower Cenomanian Grayson Formation of Grayson Bluff, Roanoke, Denton County, Texas, USA (H.T. Loeblich locality HTL1) is the holotype. University of Missouri Collection, not found, presumed lost.

MATERIAL: Numerous cups from the upper Albian and lower Cenomanian of the Abouda Plage roadcut.

DESCRIPTION: There is evidently considerable variation in the height of the cups, but the aboral portions are mostly broken away, so this cannot be quantified. Low, bi-conical individuals are present (Pl. 5, Fig. 8) which fall within the range of the Texas material. The lateral surfaces of the cups are smooth, but carry fine, irregular rugosities on the median ridges of the radials. The inset adoral, interradial regions of the cups are finely reticulate. Narrow, sharp median radial ridges extend from the aboral margins of the radial facets to the aboral pole. Irregular depressions are present on the radial ridges at the level of the base of the radial facets (e.g., Pl. 5, Figs 1, 2). The radial facets are inclined at approximately 45° to the cup axis, and are triangular, narrowing aborally. The central canal and aboral ligament pits are small, rounded and the interradial processes are moderately tall and triangular. Exceptionally well-preserved broken cups provide details of the basals, which form a pentagonal, transverse roof to the basal cavity in the centre of the cups (Pl. 5, Figs 5, 7). Deep, rounded recesses are present in the aboral surfaces of the radials, which housed sub-basal balls in related taxa (Gale 2019, pl. 38, figs 2, 3). The primibrachials IBr2 (Pl. 2, Figs 1, 2) are elongated and oval, and bear a narrow median ridge, flanked by thin flanges. The articular region for the secundibrachials is robust and has a small central depression. The inner surface (Pl. 2, Fig. 2) has an oval, synarthrial articulation surface for IBr1 close to the proximal margin.

REMARKS: The species will be redescribed in detail in a paper dealing with Texas microcrinoids at a later date, because that material is exceptionally well-preserved. The specimens from the Agadir Basin conform in all morphological details with topotypical material.

Styracocrinus rimafera sp. nov.
(Pl. 6, Figs 10, 12, 13, Pl. 10, Fig. 8)

DIAGNOSIS: *Styracocrinus* in which the aboral portions of the radial plates are of different lengths and breadths, and do not all extend to the aboral pole; the aboral margins of the radials do not articulate closely and are separated by narrow slits, leaving an aboral opening.

TYPES: A well-preserved cup (Pl. 6, Fig. 10) is the holotype (NHMUK PI EE 17416) and two other cups (Pl. 6, Figs 12, 13), one retaining IBr1, are paratypes (NHMUK PI EE 17417, 17418). Middle Cenomanian, Aït Lamine Formation, Abouda Plage road cutting, samples TAN 24 and TAN 25 (Text-fig. 4).

MATERIAL: 15 cups from the middle Cenomanian of the Abouda Plage road cutting, Agadir Basin, Morocco. One cup from the middle Cenomanian *Cunningtoceras inerme* Zone of Djebel Mhrila, central Tunisia.

DERIVATION OF NAME: From the Latin *rima*, meaning a slit, with reference to the space between the aboral portions of the radials.

DESCRIPTION: The cups are approximately twice as tall as broad, with the maximum breadth at the base of the radial facets (Pl. 6, Figs 10, 12, 13). The aboral portion of the cups is elongated and tapers gradually to the aboral margin. All cups are slightly asymmetrical, caused by the variable length and breadth of the aboral parts of the radials, some of which do not extend to the aboral pole. The aboral margins of the radials are separated by narrow slits which extend from the base to about half way up the radials and leave a small cavity in the aboral portion of the cup. The external surfaces of the radials are smooth to weakly and finely rugose and carry a rounded central ridge. The interradial adoral regions have reticulate surfaces and a low interradial ridge at the contact between adjacent plates. The radial facets are triangular and possess very small transverse articular ridges, and small aboral ligament pits and central canals. The surface of the radial facet aboral to the transverse ridge is large, oval and flat. It is supported by a robust, rounded radial buttress. The interradial processes are short and bladed (Pl. 6, Fig. 10). IBr1 are still articulated in one specimen (Pl. 6, Fig. 12); they are taller than broad and possess rounded external surfaces.

REMARKS: *Styracocrinus rimafera* sp. nov. differs from *S. peracutus* in the asymmetrical form of the radials and the presence of a slit aborally between radials. Additionally, the IBr1 are quite different; in *S. peracutus*, these are laterally compressed and very low in this species (see Peck 1943, pl. 76, fig. 9). *Styracocrinus rimafera* sp. nov. is the youngest species of *Styracocrinus* known to date, and is possibly ancestral to *Fenestracrinus oculifer* gen. et sp. nov. from the upper Cenomanian (see below).

OCCURRENCE: Middle Cenomanian of the Agadir Basin and *Cunningtoceras inerme* Zone of central Tunisia.

Genus *Fenestracrinus* gen. nov.

DIAGNOSIS: Orthogonocrinine in which the low cup bears large, oval interradial fenestrae, and the aboral surface of the cup is a broad opening, around the margins of which are short aborally and axially converging projections of the radials.

TYPE SPECIES: *Fenestracrinus oculifer* sp. nov.

REMARKS: This distinctive form is abundant in the upper Cenomanian of the Agadir Basin. The morphology of the associated IBr2, and aspects of the cup structure (aborally slanted radial facets), suggest derivation from *Styracocrinus*, and the aboral opening of the cup is perhaps a continuation of the trend observable in *S. rimafera* sp. nov. (see above) in which openings are present between the aboral parts of the radials. The presence of large interradial fenestrae, conjoined aborally by a robust bar, is a unique morphological innovation.

Fenestracrinus oculifer sp. nov.
(Pl. 6, Figs 3–6, 9, 11, 14, Pl. 7, Figs 1–12)

DIAGNOSIS: As for genus.

TYPES: The cup illustrated in Pl. 7, Figs 1–3 (NHMUK PI EE 17419) is the holotype. The other figured cups (NHMUK EE 17420, 17421) are paratypes. All are from sample AGN3 (480 m in Text-fig. 4).

MATERIAL: Approximately 20 cups, numerous fragmentary cups and brachials. All from the upper Cenomanian Aït Lamine Formation, Taghazout Plage, Agadir Basin (between 440.5 and 463 m; Text-fig. 8). A single IBr2 from sample T6/19 at Djebel Mhrila, Tunisia may belong to this species.

DERIVATION OF NAME: *oculifer*, Latin for eye-bearing, in allusion to the orbit-like appearance of the interradial fenestrae.

DESCRIPTION: The cup is broad and low, either slightly broader than high, or of equal dimensions, and square to rectangular in lateral profile (Pl. 7). In aboral and adoral views, the cup is pentagonal and the radial facets protrude slightly. Large, transversely oval to rounded interradial fenestrae are present at the level of the radial facets. These are closed aborally by a transverse bar, which is strongly swollen at the interradial contact (Pl. 6, Figs 5, 6, 9). The aboral portions of the radials comprise either a short, rounded spur (Pl. 6, Fig. 4, Pl. 7, Figs 1–3) or a flattened, bladed process (Pl. 7, Figs 10, 11). These do not contact each other, but converge aborally and adaxially; the aboral side of the cup is open, with a breadth approximately half that of the cup. Small foramina are present in the radials aboral to the interradial fenestra (Pl. 7, Figs 1, 3). The radial facets are slanted aborally and the triangular surface aboral to the transverse ridge is parallel with the axis of the cup. Small transverse articular ridges separate the relatively large central canal and aboral ligament pit. The interradial processes are low and triangular. Broken cups (Pl. 7, Fig. 12) appear to possess a very broad ring canal. Associated IBr2 are elongated and approximately four times as long as broad (Pl. 2, Figs 3–5, Pl. 6, Figs 8, 11, 14). They taper aborally, and carry a central rounded median ridge flanked on each side by thin flanges. The synarthrial articulation for IBr1 is positioned at the base of an interior median ridge and is angled to the axis of the brachial (Pl. 2, Figs 4, 5). The articular facets for IIBr1 are separated by a depression. Probable IIBr1 (Pl. 2, Fig. 8) possess deep grooves on either side of the central external ridge.

OCCURRENCE: Upper Cenomanian, Aït Lamine Formation, Taghazout Plage, Agadir Basin, Morocco.

Genus *Lebenharticrinus* Žítt, Löser, Nekvasilová, Hradecká and Švábenická, 2019

DIAGNOSIS: Orthogonocrinine in which a deep interradial fenestra (slit or rounded hole) is present between the radial facets, which connects with an internal interradial cavity extending inside the interradial processes. Muscle fossae of radial facets fused adorally.

TYPE SPECIES: *Lebenharticrinus canaliculatus* Žítt, Löser, Nekvasilová, Hradecká and Švábenická, 2019, by original designation.

REMARKS: *Lebenharticrinus* has recently been described from the Cenomanian of Dresden (Germany) and Předboj (Czech Republic) by Žítt *et al*. (2019) and is now known to be a common taxon in Cenomanian to Santonian chalks of northwest Europe (Gale 2019). Material belonging to the genus had previously been identified as various species of *Orthogonocrinus*, *O. apertus* Peck, 1943 and *O. excavatus* Peck, 1955. The latter has now been referred to *L. incisurus* Gale, 2019. *Lebenharticrinus canaliculatus* (lower and middle Turonian) and *L. incisurus* (upper Turonian–Coniacian) are common in the chalks of the Anglo-Paris Basin.

INCLUDED SPECIES: In addition to the type species, *Lebenharticrinus quinvigintensis* sp. nov., *L. zitti* sp. nov., *L. incisurus* Gale, 2019 and *L. ultimus* Gale, 2019.

Lebenharticrinus quinvigintensis sp. nov.
(Pl. 3, Figs 10, 11)

DIAGNOSIS: *Lebenharticrinus* in which the interradial fenestra is small and the adoral part is bisected by an interradial ridge; lateral radial tubes very large, radial facet rimmed by a low ridge.

DERIVATION OF NAME: Latin *quinviginti*, slang for 25, in reference to the type locality, Abouda Plage, 25 km.

TYPES: The figured cup is the holotype (NHMUK PI EE 17383).

MATERIAL: Two cups from sample TA0, 310 m Aït Lamine Formation, Abouda Plage road cut, lower Cenomanian.

DESCRIPTION: Only the adoral portion of the cup is preserved; the interradial suture is marked by a low ridge, which extends adorally into the base of the weakly developed, but deeply inset interradial fenestrae. The surface of the cup is finely reticulate, and the radial facets are large, triangular and steeply inclined. The margin of the radial facet bears a raised rim, and the large central canal and aboral ligament pit are surrounded by raised regions of stereom. In adoral view, the radial facets protrude from the edge of the cup and large openings to the lateral radial tubes are present. The interradial processes are low but may be partly broken.

REMARKS: This species can be distinguished from the succeeding *Lebenharticrinus zitti* sp. nov. by the weakly reticulate surface sculpture, the raised interradial ridge and the very broad, rounded, lateral radial tubes (compare Pl. 3, Figs 8, 11).

OCCURRENCE: Lower Cenomanian, Aït Lamine Formation, Abouda Plage, Agadir Basin, Morocco.

Lebenharticrinus zitti sp. nov.
(Pl. 3, Figs 8, 9, Pl. 6, Figs 1, 2, 7)

DIAGNOSIS: *Lebenharticrinus* in which the cup is weakly and irregularly reticulate, the interradial fenestra is circular and the radials remain in contact aborally in the adoral part of the cup. Median radial ridges sharp and narrow.

TYPES: The well-preserved cup figured here (Pl. 6, Figs 1, 2) is the holotype (NHMUK PI EE 17382), upper Cenomanian, Aït Lamine Formation, Taghazout Plage, sample AGN3. The other figured cups are paratypes (NHMUK PI EE 17576, 17408).

DERIVATION OF NAME: In honour of the excellent work on roveacrinids of Jiří Žítt of Prague.

MATERIAL: Numerous cups from the upper Cenomanian Aït Lamine Formation of Taghazout Plage, Morocco (440–467.5 m in Text-fig. 8).

DESCRIPTION: The cup is pentagonal in adoral view, with strongly protruding radial facets, and the adoral part of the cup is parallel sided in lateral view. The interradial fenestrae are rounded to oval in outline and deeply inset in the side of the cup between the radial facets. The surface of the cup is irregularly reticulate, and the median radial ridges are bladed and narrow. Larger, symmetrically positioned foramina are present on each side of the radial ridge (Pl. 6, Fig. 1). The radials remain in contact for some distance aboral to the radial facets (approximately twice the height of the facets), but separate more aborally. The interradial processes are flattened laterally, narrow and triangular and of the same height as the radial facets; they diverge adorally (Pl. 3, Fig. 9). The lateral radial tubes are large and have oval openings. The muscle fossae are fused adorally (Pl. 6, Fig. 1).

REMARKS: *Lebenharticrinus zitti* sp. nov. is morphologically and stratigraphically intermediate between the early Cenomanian *L. quinvigintensis* sp. nov. and the Turonian *L. canaliculatus*. It differs from the former in its stronger and more irregular reticulation, lack of a raised interradial seam and its narrower lateral radial tubes. From the latter, it differs in its rounded foramina (large, few and oval, parallel with the axis of the cup in *L. canaliculatus* – see Pl. 18, Fig. 12 and Žítt *et al*. 2019, fig. 10A–E), less elongated interradial fenestra and the contact of the radials aborally.

OCCURRENCE: Upper Cenomanian of Taghazout Plage, Agadir Basin, Morocco.

Lebenharticrinus canaliculatus Žítt, Löser, Nekvasilová, Hradecká and Švábenická, 2019
(Pl. 10, Fig. 10, Pl. 18, Figs 8, 11, 12)

*2019. *Lebenharticrinus canaliculatus* Žítt, Löser, Nekvasilová, Hradecká and Švábenická, p. 95, figs 9H–O, 10A–G.
2019. *Lebenharticrinus canaliculatus* Zitt *et al.*; Gale, p. 480, pl. 39, figs 5–9, 11–14; pl. 40, figs 1–8; pl. 42, fig. 4.

DIAGNOSIS: *Lebenharticrinus* in which the cup is coarsely and irregularly reticulate, bearing oval foramina on the radials; the radials have strong, rounded median ridges. The radials become narrow, rib-like structures aboral to the radial facets and not all extend to the aboral pole.

MATERIAL: The species is abundant in the microcrinoid level in the lower Turonian *Mammites nodosoides* Zone at Asfla, High Atlas, Morocco, from which 36 cups and numerous cup fragments and brachials have been collected. It is also present in the Annaba Formation, lower Turonian *Thomasites rollandi* Zone of Djebel Mhrila, Tunisia (samples M12, M13; see Text-fig. 10).

REMARKS: The species has recently been described in detail by Žítt *et al*. (2019) and Gale (2019), and the material from Asfla corresponds well in detail with specimens from Germany, the Czech Republic and the Anglo-Paris Basin. Key features are the very irregularly reticulate cup containing variable elongated openings and the strong median radial ridge.

OCCURRENCE: Lower to middle Turonian of the Anglo-Paris Basin (England, France), Germany, the Czech Republic, Morocco and Tunisia.

Genus *Euglyphocrinus* Gale, 2019

DIAGNOSIS: Cup conical to aborally truncated conical, very coarsely reticulate, with tall interradial processes. Five small globular structures (sub-basal balls) are present in cavities in the radials in the roof of the basal cavity. Brachials bear thorn-like spines.

TYPE SPECIES: *Euglyphocrinus euglypheus* (Peck, 1943), by original designation.

REFERRED SPECIES: *Euglyphocrinus pyramidalis* (Peck, 1943), *E. cristagalli* sp. nov., *E. jacobsae* sp. nov., *E. truncatus* sp. nov. and *E. worthensis* sp. nov.

REMARKS: The genus is here transferred from the Roveacrininae to the Orthogonocrininae on account of the presence of sub-basal balls in *E. pyramidalis*, a synapomorphy of the Orthogonocrininae (Gale 2019). Large external basals are present in *E. euglypheus* and *E. worthensis* sp. nov., a characteristic of juvenile roveacrinids of genera such as *Poecilocrinus* (see below) and may be evidence that paedomorphic evolution took place in *Euglyphocrinus*.

Euglyphocrinus euglypheus (Peck, 1943)
(Pl. 8, Figs 7–12; Text-fig. 12C–E)

*1943. *Roveacrinus euglypheus* Peck, p. 469, pl. 72, figs 18–23.
1961. *Roveacrinus euglypheus* Peck; Rasmussen, p. 370, pl. 53, fig. 13.
2019. *Euglyphocrinus euglypheus* (Peck); Gale, p. 472, pl. 35, fig. 11.

DIAGNOSIS: *Euglyphocrinus* in which the external basals form a rosette surrounding a centrale; the sutures of the plates are slightly raised.

TYPES. The specimen figured by Peck (1943, pl. 72, fig. 22), from HTL locality 94, Grayson Formation, Barton Creek, Austin, Travis County, Texas, USA, is the holotype. University of Missouri collections, not found, presumed lost.

MATERIAL: Several hundred cups and brachials from samples ABY, AB12, G2–G5 (Aït Lamine Formation, 65.5–90.5 m; see Text-fig. 7).

REMARKS: *Euglyphocrinus euglypheus* is a highly distinctive species, in which the external basals form a rosette surrounding a centrale (Pl. 8, Figs 9, 10, 12; Text-fig. 12C, E). The species was previously known only in the lower half of the Grayson Formation in central Texas (*Graysonites adkinsi* Zone; Kennedy *et al*. 2005), so its discovery in the Agadir Basin, within the range of and immediately overlying finds of *G. adkinsi*, permits precise transatlantic correlation. The species will be redescribed in full at a later date, including the Texan material. Whether the interval in which it occurs is Albian or Cenomanian in age is discussed above.

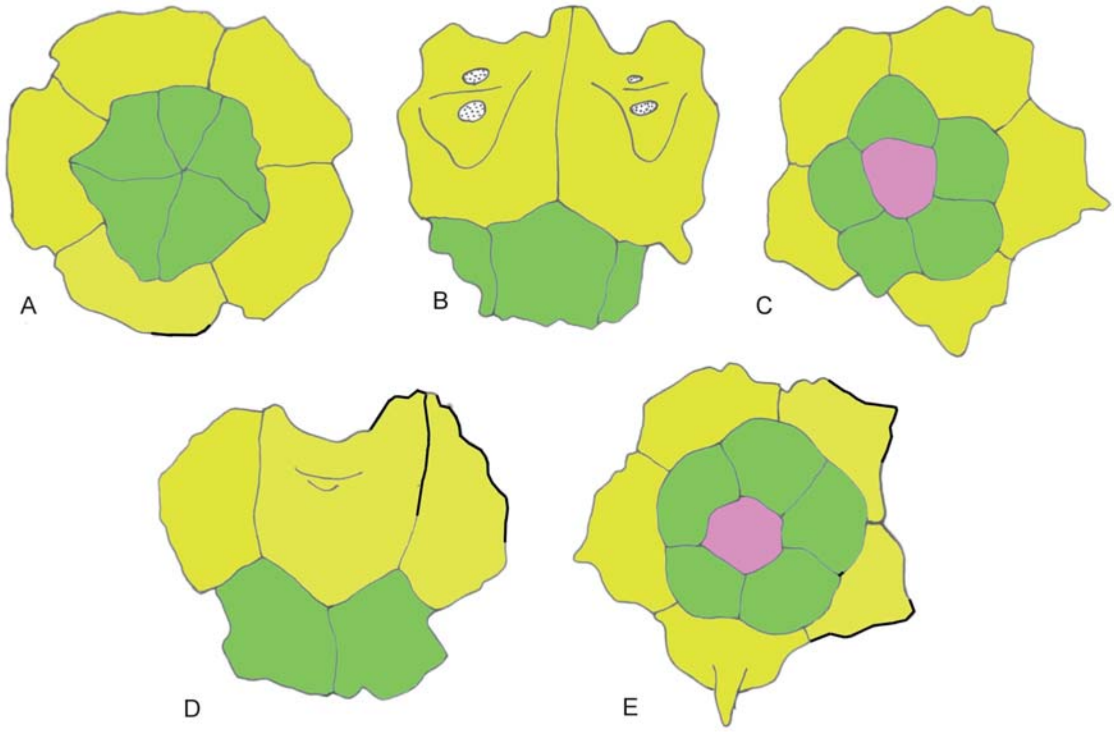
Euglyphocrinus cristagalli sp. nov.
(Pl. 4, Figs 1–6, 10, 13)

DIAGNOSIS: *Euglyphocrinus* in which a denticulate ridge of irregular, laterally-aborally deflected spines is present on the median crest of each radial; a cluster of short, aborally directed spines is present on the aboral pole. Stereom very coarse, irregular.

DERIVATION OF NAME: *cristagalli*, Latin meaning cockscomb, in allusion to the form of radial sculpture.

TYPES: The cup from sample SD1, Main Street Formation, Sunset Oaks Drive, Fort Worth, Texas, USA (Pl. 4, Fig. 10) is the holotype (NHMUK PI EE 17384). The other figured cups from the same locality (Pl. 4, Figs 1–3) are paratypes (NHMUK PI EE 17385–17387).

MATERIAL: 26 cups from the upper Albian part of the Aït Lamine Formation, Abouda Plage roadcut 9–16 m above base (Text-fig. 7). Over 100 cups and brachials from the Main Street Limestone of the Sunset Oak Drive cutting, Fort Worth, Tarrant County, Texas, USA.



Text-fig. 12. Plating in species of *Euglyphocrinus*. **A**, **B** – *E. worthensis* sp. nov., based on holotype individual figured in Pl. 8, Figs 1-3. Sample SD4, Sunset Oak Drive, Fort Worth, Texas, USA. **C** – *E. euglypheus* (Peck, 1943), from sample AB12, Oued Abouta, Agadir Basin, Morocco. **D**, **E** – *E. euglypheus* (Peck, 1943), from the Grayson Formation at Grayson Bluff, Denton County, Texas, USA, based on specimens figured in Pl. 8, Figs 7, 10. Basals green, radials yellow, centrale pink.

DESCRIPTION: The cup is slightly taller than broad, and the aboral pole is rounded (Pl. 8, Fig. 5). Strong mid-radial ridges composed of smooth, imperforate stereom extend from the base of each radial facet to the aboral margin. These bear 3–5 blunt spines, which are directed aborally-laterally and are variable in size and development; the more adoral spines are longest and aborally recurved (Pl. 4, Figs 4–6). In some individuals, they are of more regular length (Pl. 4, Figs 1, 2). A cluster of short, aborally directed spines is present on the aboral portion of the cup; these develop lateral and aboral to the mid-radial spines. The region between the radial ridges is made up of very coarse, irregular trabeculae. IBr1 is laterally compressed, with an obliquely inclined distal synarthrial facet and a lateral lip which overhangs the rounded lateral margin. IBr2 is triangular, with a prominent median process and bears two pairs of aborally directed short spines.

REMARKS: *Euglyphocrinus cristagalli* sp. nov. differs from *E. pyramidalis* in the strongly developed spines on the median radial ridges and in the cluster of aborally directed spines on the aboral pole of the cup. Although the Agadir Basin material is partially overgrown by epitaxial calcite, it is certain that it belongs to the same species as found in Texas.

OCCURRENCE. Upper Albian, zone AlR12, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, Aït Lamine Formation, Agadir Basin, and lower part of Main Street Limestone, central Texas (Text-fig. 11).

Euglyphocrinus worthensis sp. nov.
(Pl. 8, Figs 1–3, 4, 6, 13, 14)

DIAGNOSIS: *Euglyphocrinus* in which the flattened aboral surface is formed by a pentagonal arrangement of five basals; a centrale is not present. Interradial regions concave.

TYPES: The specimen figured in Pl. 8, Figs 1–3 is the holotype (NHMUK PI EE 17424). Uppermost Main Street Limestone, Sunset Oak Drive, Fort Worth, Texas, USA (sample SD4 in Text-fig. 11).

DERIVATION OF NAME: After Fort Worth, Texas, USA, where the holotype was found.

MATERIAL: A single cup from the upper Albian Main Street Limestone, Fort Worth, Texas; six cups from the upper Albian part of the Aït Lamine Formation, Abouda Plage roadcut, samples ABX (26 m) and TA 22 (38 m) (see Text-fig. 7).

DESCRIPTION: The very well-preserved holotype (Pl. 8, Figs 1–3) was gold coated for SEM study and thus revealed the plating of the base (Pl. 8, Figs 13, 14). The specimen is slightly taller than broad in lateral view, conical, and the aboral margin is flat. The median radial ridges bear short, aborally deflected spines, and the interradial regions are concave. The radial facets are large and broad, and large, rounded aboral ligament pits and central canals are present; the radial cavity is broad adorally. The surface of the cup is coarsely reticulate. The aboral portion of the cup is made up of the five basal plates, which form the aboral third of the cup in lateral view. In aboral view, the basal are triangular, and together have a pentagonal outline (Pl. 8, Fig. 13). Specimens from Morocco (Pl. 8, Figs 4, 5) are not as well preserved, but the truncated aboral surface, concave interradial regions and reticulated sculpture are very similar.

REMARKS: *Euglyphocrinus worthensis* sp. nov. differs from the later *E. euglypheus* in the pentagonal, rather than rosette-like form of the basal portion of the cup, the absence of a centrale, and the lack of narrow raised ridges at plate sutures (compare Pl. 8, Figs 1–3 with Pl. 8, Figs 7, 8, 10, 13–17). It is likely that *E. worthensis* sp. nov. gave rise to *E. euglypheus* around the Albian–Cenomanian boundary.

OCCURRENCE: *Euglyphocrinus worthensis* sp. nov. occurs in the uppermost Albian zone AlR12 in central Texas and in the Agadir Basin, Morocco.

Euglyphocrinus jacobsae sp. nov.
(Pl. 9, Figs 9, 16–21, Pl. 10, Figs 6, 7)

DIAGNOSIS: *Euglyphocrinus* with a tall, aborally tapering, conical cup that has a blunt aboral termination; sides weakly concave, interradial processes very elongated.

TYPES: A figured cup (Pl. 9, Fig. 17) is the holotype (NHMUK PI EE 17437). The other figured cups are paratypes (NHMUK PI EE 17438–17442). All are from the lower Cenomanian Aït Lamine Formation, Abouda Plage road cut, Morocco, sample TA0 (310 m in Text-fig. 4).

DERIVATION OF NAME: For Megan Jacobs, who assisted the author in the field in the Agadir Basin.

MATERIAL: Approximately 50 cups from the lower Cenomanian Aït Lamine Formation, Abouda Plage road cutting, Morocco, samples TA0 (310 m in Text-fig. 4), three cups from the middle Cenomanian sample TA25A (405 m in Text-fig. 4). Ten cups from the middle Cenomanian *Cunningtoceras inerme* Zone, sample T6/18, Sif el Tella, Djebel Mhrila, Tunisia.

DESCRIPTION: The cup is conical, rather taller than broad, with a narrow, flat aboral margin and straight to gently concave sides. The external surface is composed of coarsely reticulate stereom, and the ridged trabeculae are oriented subparallel with the axis of the cup in some specimens (Pl. 9, Fig. 19). The size of the pores in the stereom increases adorally, and two to four large pairs are present at the level of the radial facets in some specimens (e.g., Pl. 10, Figs 6, 7). A single, aborally recurved spine extends from the base of each radial facet in most individuals, but is absent or broken off in others. The radial facet is equilaterally triangular, and a narrow transverse ridge is present. Both the central canal and aboral ligament pit are large and deep. The interradial processes are very tall and thin (e.g., Pl. 9, Fig. 18) and weakly divergent adorally.

REMARKS: *Euglyphocrinus jacobsae* sp. nov. can be distinguished from *E. pyramidalis* by the absence of the raised, toothed, mid-radial ridge present in the latter species (Pl. 9, Fig. 15; see also Peck 1943, pl. 72, figs 24, 26–28) and by the shape of the cup in lateral profile. It differs from the later *E. truncatus* sp. nov. in the tall, conical, aborally tapering form of the cup.

OCCURRENCE: Lower and middle Cenomanian of the Agadir Basin, Morocco, and central Tunisia.

Euglyphocrinus truncatus sp. nov.
(Pl. 9, Figs 1–8, 10–14, Pl. 10, Figs 1–5)

DIAGNOSIS: *Euglyphocrinus* in which the cup is constructed of very coarse reticulate stereom; aboral margin of cup broad, made up of converging radial ridges which meet at the aboral pole under an angle of 120–150º.

TYPES: The specimen in Pl. 9, Figs 3, 7 and 12 is the holotype (NHMUK EE 17432). The other figured cups are paratypes (NHMUK PI EE 17431, 17433, 17434). All are from the middle Cenomanian Aït Lamine Formation, Agadir Basin, Morocco, samples TAN24 and TAN25 (Text-fig. 4).

DERIVATION OF NAME: *truncatus*, Latin for cut off, in reference to the short aboral margin of the cup.

MATERIAL: 25 cups from the Abouda Plage roadcut, Aït Lamine Formation, Agadir Basin, Morocco (TAN24–TAN27, 410.5–421.5 m), middle Cenomanian. Sixteen cups from sample T6/18, Djebel Mhrila, Tunisia, *C. inerme* Zone, middle Cenomanian.

DESCRIPTION: The cups are as tall or slightly taller than broad, and the maximum breadth is near to the aboral margin of the cup. Strongly developed, broad median radial ridges extend from the articular facets, and carry weak, aborally directed spines in some individuals. The radial ridges inflect towards the aboral pole at 90º, and subtend an angle at the pole of 130–160º. The interradial sutures are deeply inset on the sides of the cup. The external surface of the cups is coarsely reticulate and partially overgrown by diagenetic calcite in many specimens. The radial facets are triangular and large aboral ligament pits and central canals are separated by a short articular ridge. The interradial processes are tall and diverge slightly adorally. Muscle fossae extend up the aboral portion of the processes. Numerous proximal brachials are present in the material. IBr1 (Pl. 9, Figs 10, 11, Pl. 10, Fig. 13) are slightly waisted in lateral view, and the distal margin bears an oval, strongly sloping synarthrial surface for articulation of IBr2. IBr2 are robust and triangular and carry two short, blunt, laterally-aborally directed spines which are symmetrically positioned about the median line (Pl. 9, Figs 1, 5, Pl. 10, Fig. 12). IIBr2 (Pl. 9, Fig. 14) are triangular and possess a very broad aboral ligament pits and central canals.

REMARKS: *Euglyphocrinus truncatus* sp. nov. differs from *E. jacobsae* sp. nov. in the shape of the cup, which broadens aborally and has a short, obtusely angled base. In comparison, *E. jacobsae* sp. nov. has an elongated, conical lateral profile.

OCCURRENCE: Middle Cenomanian, Agadir, Morocco and *Cunningtoceras inerme* Zone, central Tunisia.

Subfamily Roveacrininae Peck, 1943

DIAGNOSIS. Roveacrinidae in which the radial cavity is floored by solid basals; the primibrachials IBr2 and IIBr2 are flat and proportionately low and broad.

INCLUDED GENERA: *Roveacrinus* Douglas, 1908; *Drepanocrinus* Jækel, 1918; *Caveacrinus* Gale, 2019 and *Dentatocrinus* Gale, 2019.

Genus *Roveacrinus* Douglas, 1908

DIAGNOSIS: Roveacrininae characterised by delicately constructed, adorally broad cups which bear elongated, aborally flanged, alar extensions from each lateral radial margin and possess a globular basal cavity clearly visible on the exterior of the cup. IBr2 and IIBr1 triangular, possess lateral spines and flanges. Basals completely internal.

Roveacrinus spinosus Peck, 1943
(Pl. 11, Figs 7–16)

part *1943. *Roveacrinus spinosus* Peck, p. 467, pl. 74, figs 6, 9 only; pl. 76, figs 37, 39.
1943. *Roveacrinus spinalatus* Peck, p. 467, pl. 74, figs 8, 10.
1961. *Roveacrinus spinosus* Peck; Rasmussen, p. 373, pl. 54, figs 5, 6.
1961. *Roveacrinus spinalatus* Peck; Rasmussen, p. 373, pl. 54, fig. 7.
part 2015. *Roveacrinus spinosus* Peck; Hess, fig. 14e–s only.
2019. *Roveacrinus spinosus* Peck; Gale, p. 440, pl. 7, figs 5–7.

DIAGNOSIS: *Roveacrinus* bearing elongated radial spines, the robust adoral margins of which are declined at approximately 50–60º to the axis of the cup. A thin flange extends from the aboral margin of the spines to the base of the cup, narrowing laterally towards the tips of the spines. Exterior of basal cavity swollen, perforate.

HOLOTYPE: The cup figured by Peck (1943, pl. 74, fig. 9) from the lower Cenomanian Grayson Formation of Grayson Bluff, Roanoke, Denton County, Texas, USA (H.T. Loeblich locality HTL1) is the holotype. University of Missouri collections, not found, presumed lost.

MATERIAL: Complete and fragmentary cups and brachials from the Aït Lamine Formation, Abouda Plage roadcut Agadir Basin (83 to 280 m in Text-figs 6, 7).

REMARKS: Fragmentary cups and brachials (IBr2) from the lower Cenomanian of Abouda Plage belong to this species, but add nothing to the descriptions of Hess (2015) and Gale (2019).

OCCURRENCE: Lower Cenomanian Grayson Formation, Texas (Peck 1943; Hess 2015), Chalk Marl, Cambridge, United Kingdom (Gale 2019) and Aït Lamine Formation, Abouda, Morocco.

Roveacrinus solisoccasum sp. nov.
(Pl. 11, Figs 1–6)

part 1943. *Roveacrinus spinosus* Peck, pl. 74, fig. 7 only.

DIAGNOSIS: *Roveacrinus* in which a spearhead-shaped radial process, bearing an aboral median ridge, is present on each radial.

TYPES: The well-preserved cup from the top of the Main Street Limestone, Sunset Oaks Drive, Fort Worth, Texas, USA, is the holotype (Pl. 11, Figs 1–3). Sample SD3 in Text-fig. 11 (NHMUK PI EE 17456).

DERIVATION OF NAME: *solisoccasum*, Latin meaning sunset, after the type locality of the holotype, Sunset Oak Drive, Fort Worth, Texas, USA.

MATERIAL: Ten cups from the uppermost metre of the Main Street Limestone, Sunset Oaks Drive, Fort Worth, Texas, USA (sample SD3). Four cups from the lower part of the Aït Lamine Formation, Abouda Plage roadcut, Morocco, samples ABX (26 m) and TA 22 (38 m) (see Text-fig. 7).

DESCRIPTION: Cup stellate in adoral and aboral views, the extremities formed by spearhead-shaped radial flanges which are concave on both ad- and aboral surfaces. A strong ridge extends from the aboral pole of the cup to the tips of flanges, weaking aborally and defining symmetrical concavities on either side of the lateral portions of the flanges. In lateral view, the cup is broader than high, and the aboral portion is swollen and coarsely perforate; the perforations are irregularly aligned with the radial flanges and interradial sutures. The adoral interradial regions are inset and concave, and a low, raised ridge marks the interradial suture. The adoral margin of the radial cavity is broad, and the radial facets are broad and short. Large, rounded aboral ligament pits and central canals are present.

REMARKS: The species differs from the stratigraphically younger *Roveacrinus spinosus* in the broad, strongly and coarsely perforate aboral portion of the cup, and the short, concave, spearhead-shaped radial flanges which carry a median aboral ridge. It is the oldest *Roveacrinus sensu stricto*, and probably evolved from a forma of *Poecilocrinus dispandus* which possesses petal-like radial processes, and occurs in the (older) Pawpaw Formation of central Texas.

OCCURRENCE: Uppermost Albian, zone AlR12 in Texas and Morocco.

Roveacrinus gladius sp. nov.
(Pl. 12, Figs 1–14; Pl. 13, Figs 1–12; Pl. 14, Fig. 1)

DIAGNOSIS: *Roveacrinus* in which the radial cavity is very broad and deep; smooth, bladed flanges extend from the radial plates, which bear variably developed striiae adorally and lateral processes on the aboral part of the cup. IBr2 and IIBr2 composed externally of smooth imperforate stereom and bearing flanges.

TYPES: The individual figured in Pl. 12, Fig. 1 is the holotype (NHMUK PI EE 17465). The other figured specimens from sample TA0 (310 m) are paratypes (NHM UK EE 17466–17469). Aït Lamine Formation, Abouda Plage roadcut.

DERIVATION OF NAME: Latin *gladius*, meaning a blade, with reference to the blade-like process on the radials.

MATERIAL: Numerous cups (more than 50) and brachials from the lower Cenomanian Aït Lamine Formation, especially from sample TA0 (310 m). Cups and brachials from the middle Cenomanian, sample TAN25 (420.5 m in Text-fig. 4).

DESCRIPTION: The cups are approximately as tall as broad, and the adoral margin of the radial cavity is broad. There is considerable, continuous variation in the lateral profile of the cups, from rather tall, narrow forms (Pl. 12, Figs 2, 3) through to those which are very broad adorally (e.g., Pl. 13, Fig. 6). The radials bear thin, broad, smooth flanges, which extend from the radial facet to the base of the cup (e.g., Pl. 12, Figs 5, 8; Pl. 13, Figs 11, 14) but are never completely preserved. The inner part of the flanges carry irregular fine ridges, which extend onto the aboral swelling in some individuals (Pl. 12, Fig. 11). Variably developed lateral processes develop from the flanges aborally, and join in some specimens (Pl. 12, Figs 2, 3; Pl. 13, Fig. 10) to form a sheath around the cup. The interradial portions of the radials, between the flanges, are finely perforate and a raised suture between adjacent radials is present in some cases (Pl. 12, Figs 3, 4). The aboral portion of the cup is swollen and is either made of coarsely perforate stereom (Pl. 12, Figs 1, 4), or striated (Pl. 12, Fig. 11). The aboral surface of the cup bears short ridges converging on the aboral pole (Pl. 12, Fig. 10). Where the aboral part of the cup is broken away, the basals are visible (Pl. 14, Fig. 1; Pl. 12, Fig. 12); these form a circular disc, separating radial and basal cavities, composed of fine stereom, which contrasts with the coarser stereom of the radial wall. The triangular radial facets are slanted to the axis of the cup at about 45º, and there is a broad, thin articular ridge, which separates the large central canal from the aboral ligament pit. The interradial processes are triangular and relatively low.

IBr1 are rectangular (Pl. 13, Fig. 3) and carry a large, oval distal synarthrial facet which has a broad central canal. IBr2 are rectangular in external view, strongly concave and the external face is made of imperforate stereom (Pl. 13, Figs 2, 12, 13). They carry two adorally diverging flanges sometimes separated and flanked by smaller flanges. On the interior surface (Pl. 13, Fig. 8) a central region carries an oval, synarthrial proximal articulation surface. IIBr1 (Pl. 13, Figs 4, 5) are triangular, and the external surface carries a large synarthrial articulation surface, flanked by regions of coarse stereom. The interior surface bears diverging ribs of imperforate stereom (Pl. 13, Fig. 4). IIBr2 are similar in overall construction to the IBr1, but are triangular in outline. The figured specimen preserves the delicate, feather-like interior processes similar to those described in *Drepanocrinus marocensis* (compare with Gale 2019, fig. 21A, B). The distal brachials (Pl. 13, Fig. 7) bear a laterally compressed blade.

REMARKS: *Roveacrinus gladius* sp. nov. is distinguished from all other *Roveacrinus* species by the simple, striated bladed processes on the radials. It compares most closely with *R. multisinuatus* Peck, 1943 from the lower Cenomanian Grayson Formation of Texas, which has complex, multiple flanges on the radials and also has concave, flanged IBr2. Some comparison exists with *R. bispinosus* (Gale 2019, pl. 7, figs 1, 2) from the lower Cenomanian of Cambridge, United Kingdom, which has bifid flanges on the radials.

OCCURRENCE: Lower and middle Cenomanian, Agadir Basin in Morocco and central Tunisia.

Roveacrinus aff. *labyrinthus* Gale, 2019
(Pl. 18, Figs 4, 7)

aff. *2019. *Roveacrinus* aff. *labyrinthus* Gale, p. 444, pl. 19, figs 10, 12, 13.

MATERIAL: Five cups and numerous brachials from the lower Turonian *Mammites nodosoides* Zone of Asfla, Morocco.

REMARKS: The cups (Pl. 18, Fig. 7) are crushed and partly broken, but carry thin, broad radial flanges around a central axis. In *R. labyrinthus* (Gale 2019, pl. 9, figs 1, 2, 4) the cup is more elongated and the radial flanges carry a sculpture of irregular, coalescing ridges. The brachials IBr2 (Pl. 18, Fig. 4) are elongated and triangular, and similar in shape to those of *R. labyrinthus* (see Gale 2019, pl. 9, figs 7, 11, 13), but differ in the external sculpture; the external surface of the Asfla plates is coarsely reticulate whereas topotypical *R. labyrinthus* bear strong, adorally diverging flanges.

OCCURRENCE: Lower Turonian, *Mammites nodosoides* Zone, level of 22–23 m in Kennedy *et al.* (2008, fig. 2), Asfla, Goulmima, Morocco.

Roveacrinus falcifer Gale, 2019
(Pl. 14, Figs 2, 3)

*2019. *Roveacrinus falcifer* Gale, p. 446, pl. 10, figs 1−13; pl. 11, figs 1−13.

DIAGNOSIS: Cup robust, reticulate; radials possess elongated, adorally deflected and laterally flattened process, adoral to short spur; IBr1 and IIBr1 very robust, distal articular facets of IBr2 very broad.

MATERIAL: Two cups from the middle Turonian of Taghazout roadcut, sample TAG5A (Text-fig. 4).

REMARKS: The cups from Taghazout closely resemble material of this species from the Anglo-Paris Basin in the form of the radial flanges, which bear an aborally recurved blade immediately aboral to the radial facet. The interradial portion of the cup is coarsely rugose.

OCCURRENCE: In the Anglo-Paris Basin, *R. falcifer* is characteristic of microcrinoid zones TuR9 and TurR10 (Gale 2019). At Taghazout, the species occurs immediately above the occurrence of *Drepanocrinus striatulus* forma *cuspidatus* Gale, 2019, which defines zone TuR8.

Roveacrinus sp. nov.
(Pl. 14, Fig. 10)

MATERIAL: Two well-preserved IBr2 from the upper Turonian *Hemitissotia morreni* Zone marls, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senam, Tunisia, level of mass occurrence of *Hemiaster* (Chancellor *et al*. 1994).

DESCRIPTION: The IBr 2 are triangular in external view, and aborally bear a central ridge which divides adorally into two separate structures, which extend to each of the distal articulation facets. The divergent ridges are separated by a concavity. The external surface of the brachials are coarsely reticulate.

REMARKS: The coarsely reticulate structure of the brachials is not present in any known species of *Roveacrinus*.

Genus *Drepanocrinus* Jækel, 1918

TYPE SPECIES: *Drepanocrinus sessilis* Jækel, 1918, by original designation.

DIAGNOSIS: Cups conical, robust, with radial buttresses lacking extensions or flanges. Basal cavity inconspicuous on cup exterior. Basals highly variable, internal or with small external surfaces. 1Br1 and 1Br2 triangular to trapezoidal, flat, sculpture ridged or reticulate, lacking spines or flanges. Cenomanian–mid-Coniacian.

REFERRED SPECIES: *Drepanocrinus communis* (Douglas, 1908); *D. geinitzi* (Schneider, 1989); *D. marocensis* Gale, 2019; *D. striatulus* Gale, 2019; *D.westphalicus* (Sieverts, 1933) and *D. wardorum* sp. nov.

REMARKS: *Drepanocrinus* evolved from *Roveacrinus* during the Cenomanian by the development of flattened, triangular or trapezoidal IBr2 and 2Br2, and a cup which lacks radial spines or extended flanges. This is the first description of precisely located Cenomanian material of the genus. The new North African material is important, because it demonstrates that a similar succession of forms to those in the Turonian of the Anglo-Paris Basin are present, even if the story is not complete because of limited exposure of Turonian rocks in the sections studied.

Drepanocrinus wardorum sp. nov.
(Pl. 14, Figs 4, 6, 7, 11, 12; Pl. 15, Figs 1–9)

DIAGNOSIS: Cup conical, height equal to breadth, with broad, rounded, irregularly striate radial ridges which carry smaller lateral swellings; IBr2 trapezoidal, with numerous irregular striations, double central ridge bifid, flattened.

TYPES: The cup figured here (Pl. 15, Figs 1, 5, 9) from the Aït Lamine Formation, Abouda Plage roadcut, sample TAN25 (Text-fig. 4; 420.5 m) is the holotype (NHMUK PI EE 17501); the figured brachials from the same sample are paratypes (NHMUK PI EE 17502–17504, 17506, 17507). The figured cup from the middle Cenomanian *Cunningtoceras inerme* Zone of Djebel Mrhila, Tunisia, sample T6/18 (Text-fig. 10; see Pl. 14, Figs 11, 12) is also a paratype (NHMUK PI EE 17496).

DERIVATION OF NAME: In honour of David and Alison Ward of Orpington, Kent, United Kingdom, who helped to collect the samples from which the type material from Agadir came.

MATERIAL: Ten cups and fragmentary cups, plus numerous (more than 50) brachials from the middle Cenomanian of Taghazoute, Agadir Basin, Morocco. Four cups and numerous brachials from the middle Cenomanian *Cunningtoniceras inerme* Zone of Djebel Mhrila, central Tunisia, sample T6/18.

DESCRIPTION: The cup (Pl. 15, Figs 1, 5, 9; Pl. 14, Figs 10, 11) is conical, as tall as broad and the aboral margin is gently rounded. Broad, robust, rounded radial ridges extend from the radial facet and narrow aborally, to converge at the aboral pole. These bear short, rather irregular striae, best developed on a swelling immediately aboral to the radial facet. Small, paired lateral swellings are also present on each radial. The radial ridges flatten aborally, and co-join at the radial pole. The interradial regions are smooth and rather deeply inset adoral to the basal cavity and the interradial suture is raised. The basal cavity is marked on the exterior of the cup by a small swelling. The radial facets are broad and rounded laterally, with a small central canal and aboral ligament pit. The interradial processes are low and rounded. The IBr2 brachials associated with the cups (Pl. 14, Figs 4, 6, 7; Pl. 15, Figs 2–4, 6–8) are trapezoidal to rectangular in outline, flattened, and the lateral surfaces bear numerous, fine, irregular ridges. The raised distal central complex is triangular, flattened and divided centrally by a groove. IIBr2 are rounded-triangular in outline and bear numerous fine striations (Pl. 14, Fig. 7; Pl. 15, Figs 6, 7).

REMARKS: *Drepanocrinus wardorum* sp. nov. differs from the succeeding species *D. geinitzi* in the morphology of the cup, with robust, striated radial ridges and the strongly striated, flattened form of the IBr2. Compare the IBr2 of *D. wardorum* sp. nov. (Pl. 15, Figs 2–6) with those of *D. geinitzi* (Pl. 15, Figs 14–17); note the cavities on each side of the central ridge in *D. geinitzi*.

OCCURRENCE: Rare in the lower Cenomanian (two brachials found), the species is abundant in association with middle Cenomanian ammonites at Djebel Mhrila, and the Agadir fauna is believed to be of the same age. It is succeeded in the upper Cenomanian by *D. geinitzi* to which it is ancestral.

Drepanocrinus geinitzi (Schneider, 1989)
(Pl. 15, Figs 10–19; Pl. 16, Figs 9–11, 14–17)

*1989. *Roveacrinus geinitzi* Schneider, p. 171, figs 3.1–3, 4, 5a, b.
2016. *Roveacrinus geinitzi* Schneider; Niebuhr and Ferré, fig. 1q, r.
2019. *Roveacrinus geinitzi* Schneider; Žítt *et al.*, p. 91, figs 8A–H, K–S, 12A–H.

DIAGNOSIS: *Drepanocrinus* in which the radial flanges bear a number of delicate lateral wings, usually imbricated; IBr2 with rather few ridges, and a pair of tall central flanges, lateral to which are broad concavities.

NEOTYPE: In view of the fact that Schneider's original material cannot be located, the specimen originally figured by Geinitz (1871) from the upper Cenomanian of Hoher Stein, Dresden, was designated neotype by Niebuhr and Ferré (2016). It is housed in the Senckenberg Naturhistorische Sammlung, Dresden, Germany, no. SAK 883.

MATERIAL: Numerous IBr2, IIBr2 and cup fragments from Taghazout Plage, upper part of Aït Lamine Formation, samples AGN9–AGN7, 440.5–465 m (Text-figs 4, 8).

DESCRIPTION: The cup material from Taghazout Plage consists of fragments and isolated radial plates (Pl. 15, Figs 10–13). The sharp radial ridges carry strong, obliquely oriented subsidiary ridges and irregular lateral flanges, as seen in the topotypical material figured by Žítt *et al.* (2019, fig. 8). IBr2 (Pl. 15, Figs 14–19; Pl. 16, Figs 9–11, 14, 15) possess short, raised, paired central flanges, which in some specimens carry multiple lateral flanges (Pl. 16, Fig. 10), paralleling those developed on the radials of some specimens (e.g., Žítt *et al.* 2019, fig. 8K–M). The regions lateral to the flanges are deeply depressed and flanked laterally by one to several raised ridges (e.g., Pl. 16, Figs 9, 11, 15). IIBr2 (Pl. 15, Fig. 14; Pl. 16, Fig. 14) bear a central ridge, which terminates adorally in a swelling.

REMARKS: Cup fragments and IBr2 from the upper Cenomanian at Taghazout Plage agree in important details with the topotypical material from Dresden figured by Žítt *et al.* (2019). In particular, the form of IBr2 (compare Pl. 15, Fig. 18 herein with fig. 12A, B of Žítt *et al.* 2019), with tall, striate central processes and lateral concavities, are very close. Also, the cup fragments figured here (Pl. 15, Figs 10–13) compare with the superbly preserved material of Žítt *et al.* (2019, fig. 8L, R), particularly in the presence of lateral flanges on the radials. *Drepanocrinus geinitzi* can be distinguished from its probable middle Cenomanian ancestor, *D. wardorum* sp. nov. by the sharp-edged radial flanges on the cup and the distinctive form of IBr2, with elevated central ridges and lateral depressions. In *D. wardorum* sp. nov., IBr2 is strongly striate and the radial ridges are flattened and rounded. These differences are stratigraphically consistent; compare the assemblages of IBr2 of *D. wardorum* sp. nov. illustrated in Pl. 15, Figs 2, 4, 6–8 from the middle Cenomanian with those of *D. geinitzi* from the upper Cenomanian (Pl. 15, Figs 14–19; Pl. 16, Figs 9–11, 15).

It is important to note that the imbricated lateral flanges, sometimes with ridged lateral margins on the radial ridges, are not unique to *D. geinitzi*, as these develop on extreme morphological variants of other *Drepanocrinus* species. Gale (2019, pl. 18, figs 10–12) illustrated specimens of the Turonian *D. westphalicus* forma *meadsensis* Gale, 2019, with complex radial ridges, and in *D. striatulus* (Gale 2019, pl. 24, fig. 6) individuals with laterally swollen radial structures are also found. The material in thin section recorded as *D. geinitzi*, *D.* aff *geinitzi* and *D.* cf. *geinitzi* by Ferré *et al.* (2005, fig. 2A–D) may therefore not be closely related to this species.

OCCURRENCE: Upper Cenomanian of Germany, the

Czech Republic, Morocco and Tunisia. In Morocco, the species occurs only beneath the carbon isotope excursion of OAE2. Its precise horizon in Europe is not known as the sections which yield material of the species are highly condensed (Žítt *et al*. 2019).

Drepanocrinus sessilis Jækel, 1918
(Pl. 17, Figs 10–17)

*1918. *Drepanocrinus sessilis* Jækel, p. 72, fig. 66a–g.
part 1932. *Drepanocrinus sessilis* Jaekel; Sieverts, p. 599, figs 1–5, 7–19, non fig. 6, 6a.
1933. *Roveacrinus sessilis* Jaekel; Sieverts, p. 58.
part 1955. *Roveacrinus communis* Douglas; Peck, p. 1024, pl. 105, fig.1 only.
part 1961. *Roveacrinus communis* Douglas; Rasmussen, pp. 366–369, pl. 53, figs 1–5 only.
part 1987. *Roveacrinus communis* Douglas; Schneider, p. 193, pl. 3, figs 1, 2 only.
?1989. *Roveacrinus communis* Douglas; Schneider, p. 39, pl. 1, figs 1a–2c.
2019. *Roveacrinus communis* Douglas; Žítt *et al*., p. 93, fig. 9B–G.
2019. *Drepanocrinus sessilis* Jaekel; Gale, p. 450, pls 13–15.

DIAGNOSIS: Cup elongated, conical, simple pointed aboral termination, the radial buttresses carry irregular fine ridges parallel to the axis of the cup; IBr2 low, broad, triangular in outline with irregular coarse ridges on the lateral surfaces.

TYPES: The material figured by Jækel (1918) was from the lower Turonian *Labiatus* Pläner from Broich, near Mülheim, Germany (shallow-marine klippenfazies; Dr Frank Wiese, pers. comm., September, 2018). Supposedly, the material is in the collections of the University of Greifswald, but cannot be found (Stefan Meng, pers. comm., 2017). Topotypical material in the NHMUK collections (NHMUK E22664), part of an exchange with Otto Jækel in 1920, includes a well-preserved cup. This was selected as neotype and figured by Gale (2019, pl. 14, fig. 11).

MATERIAL: Abundant radials, fragmentary cups and brachials from the lower Turonian *Pseudaspidoceras flexuosum* Zone, Annaba Formation, at Sif El Tella, Djebel Mhrila, central Tunisia (samples M10 and M11 in Text-fig. 10).

REMARKS: The morphology of the radials, aboral spikes and proximal brachials in the Tunisian specimens is close to that of material from the Anglo-Paris Basin (compare the aboral spikes, radials and IBr2: Pl. 17, Figs 10, 12, 13 and 16 from Tunisia; Pl. 17, Figs 11, 14 and 17 from Eastbourne, United Kingdom). The North African specimens do not add significant detail to the extensive material known from the Anglo-Paris Basin (Gale 2019). However, its occurrence in the *P. flexuosum* Zone in Tunisia is directly comparable with its early Turonian age in the United Kingdom and France. It is the marker species for microcrinoid zone TuR1.

Drepanocrinus westphalicus (Sieverts, 1933)
(Pl. 17, Figs 1–9)

*1933. *Roveacrinus westphalicus* Sieverts, p. 56, figs 1, 2.
1987. *Roveacrinus communis* Douglas; Schneider, p. 39, fig. 1a–2c.
2019. *Drepanocrinus westphalicus* (Sieverts); Gale, p. 452, pls 16–18.

DIAGNOSIS: Cup hourglass shaped, elongated, with five low, strong, mid-radial ridges which terminate aborally in short, divergent spines, in some cases connected by flanges. IBr2 low, triangular to trapezoidal, reticulate.

MATERIAL: Fragmentary cups and brachials from the lower Turonian *Thomasites rollandi* Zone, Sif el Tella, Djebel Mhrila, central Tunisia, samples M12, M13 (Text-fig. 10).

REMARKS: The material from Sif el Tella comprises fragmentary cups and brachials. The cup fragments (Pl. 17, Figs 3, 4) are typical of specimens from the lower part of the range of the species in the Anglo-Paris Basin in the possession of short, aborally diverging radial spines – compare with Pl. 17, Fig. 9 from Eastbourne, United Kingdom. The strongly reticulate IBr2 (Pl. 17, Figs 1, 2) are consistent with those of *D. westphalicus*. In both Djebel Mhrila and at Eastbourne, this form occurs immediately beneath the first occurrence of the ammonite *Mammites nodosoides* and is characteristic of zone TuR2.

Drepanocrinus marocensis Gale, 2019
(Pl. 10, Fig. 11; Pl. 18, Figs 1–3, 5, 6, 9, 10)

*2019. *Drepanocrinus marocensis* Gale, p. 454, pl. 19, figs 1–5, 7, 8; pl. 20, figs 1–13.

DIAGNOSIS: Cup low, broad, conical, with prominent, strongly striated, robust radial buttresses and tall interradial processes. IBr2 tall, trapezoidal, bearing a raised, bifid, triangular buttress to the distal facets, and coarsely striated lateral surfaces.

TYPES: The IBr2 figured by Gale (2019, pl. 20, fig. 4a, b; NHMUK PI EE 16889) is the holotype.

MATERIAL: Abundant cups and brachials from the region of Asfla, Morocco, lower *Mammites nodosoides* Zone, lower Turonian. Brachials form the uppermost *Thomasites rollandi* Zone in samples M12, M13 from Djebel Mhrila, Tunisia.

REMARKS: The species was described in detail by Gale (2019) on the basis of extensive material from the lower part of the *Mammites nodosoides* Zone of Asfla, Morocco. The new records from Tunisia indicate that the species ranges down into the *Thomasites rollandi* Zone. The species is also present, albeit uncommonly, in a single bed in the Anglo-Paris Basin, Gun Gardens Marl 1 (Gale 2019), which evidently represents a brief northerly incursion of Tethyan species.

Drepanocrinus striatulus Gale, 2019
(Pl. 16, Figs 1–8, 12, 18)

part 1961. *Roveacrinus communis* Douglas; Rasmussen, pl. 53, fig. 6 only.
*2019. *Drepanocrinus striatulus* Gale, p. 456, pls 21–24.

DIAGNOSIS: *Drepanocrinus* in which the striated cup bears tiny external basals which form an interradial grill. The proximal brachials 1Br1 are tall, trapezoidal in outline, delicately constructed, bear numerous fine ridges, subparallel to the lateral margins. A deeply grooved central ridge is present.

MATERIAL: Numerous (more than 30) cups and brachials from the middle Turonian, Taghazout roadcut, sample TAG4 (Text-fig. 4), Agadir Basin, Morocco.

REMARKS: The species is abundant in the Anglo-Paris Basin in the middle Turonian (Gale 2019). The material from the Agadir Basin, Morocco (Pl. 16, Figs 1–6) includes cups and IBr2; the cups are typical of the species (evenly, obliquely striated radial ridges, small interradial grill containing basal plates) and rather similar to the forma *cuspidatus* Gale, 2019 (Gale 2019, pl. 22; see Pl. 16, Fig. 18 herein), but lack the prolonged, tapering aboral processes developed in that form. Rather, the base of the cup appears to be sharply and transversely truncated, as is found in specimens from higher horizons in the Anglo-Paris Basin (Pl. 16, Fig. 7). The IBr2 (Pl. 16, Figs 4–6) have a deep, elongated central groove, and thin lateral flanges bearing fine raised ridges, typical of the species (compare with material from Dover, United Kingdom; Pl. 16, Figs 8, 12). Overall, the morphology is suggestive of zone TuR9.

OCCURRENCE: Middle Turonian of the Anglo-Paris Basin, United Kingdom and France, and the Agadir Basin, Morocco.

Drepanocrinus communis forma *dubrisiensis* Gale, 2019
(Pl. 19, Figs 1–6, 8)

*2019. *Drepanocrinus communis* (Douglas) forma *dubrisiensis* Gale, p. 478, pl. 25, figs 7, 9, 11, 13, 14.

DIAGNOSIS: *Drepanocrinus communis* in which IBr2 bear a pair of very broad, rounded ribs which run proximally from the distal facets and are separated by a deep concavity.

TYPES: The IBr2 from the upper Turonian of Dover, United Kingdom, figured by Gale (2019, pl. 25, fig. 11) is the holotype (NHMUK PI EE 16912).

MATERIAL: Ten proximal brachials from the upper Turonian *Hemitissotia morreni* Zone, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senam, Tunisia, level of mass occurrence of *Hemiaster* (Chancellor *et al.* 1994).

REMARKS: *Drepanocrinus communis* forma *dubrisiensis* is a distinctive form, in which the rectangular to slightly trapezoidal IBr2 bear a pair of robust, rounded ridges, which strengthen towards the distal margin and are separated by a deep cavity. The lateral surfaces bear fine ridges which converge axially towards the proximal margin. The morphology of the Tunisian material (Pl. 19, Figs 1, 2, 4) is very similar to that from the Anglo-Paris Basin, where the forma is restricted to the uppermost Turonian zone TuR14 (Gale 2019).

Subfamily Plotocrininae subfam. nov.

DIAGNOSIS: Roveacrinids in which the external surfaces of the brachials bear regions of smooth imperforate stereom which forms dish-shaped concavities on the proximal brachials, and paired divergent spines united by a narrow flange on brachials of the mid-arm.

INCLUDED GENERA: *Poecilocrinus* Peck, 1943 and *Plotocrinus* Peck, 1943.

REMARKS: The brachial structure in the two included genera is distinctive and consistently present in all species, even though cup morphology is more diverse. *Plotocrinus* is present in the lower Albian of Bully, France (Destombes 1984), and is abundant in the middle Albian to low upper Albian of Texas and Oklahoma (Peck 1943). It gave rise to *Poecilocrinus*, via the species *Plotocrinus modulatus* Peck, 1943, which developed a short, bifid concave process aboral to the radial facets. In the probable descendant, *Poecilocrinus spiculatus* Peck, 1943, the process is enlarged and develops a concave aboral surface.

Genus *Poecilocrinus* Peck, 1943

TYPE SPECIES: *Poecilocrinus dispandus* Peck, 1943, by original designation.

DIAGNOSIS: Plotocrinines in which a shelf-like flange is present immediately aboral to each radial facet; the flanges fuse in fully-grown specimens to form a rounded to petaloid or circular rosette, and, aborally, an outer wall to the cup.

REMARKS: *Poecilocrinus* is a typical genus of the upper Albian and lower Cenomanian of Texas and Oklahoma, where it is locally extremely abundant, and one species (*P. dispandus*) reaches a sufficiently large size (6 mm) that it can be collected in the field. No new material of the genus has been figured since Peck's (1943) paper, and therefore a description of the cup structure and ontogeny is presented here. The complex ontogeny of *P. dispandus* is depicted here in Pl. 20; the smallest cups found (0.6–0.7 mm diameter; Pl. 20, Figs 3, 4) are small and conical in form. By a diameter of 1 mm, aborally concave flanges develop on the radials (Pl. 20, Figs 5, 6), which expand laterally (Pl. 20, Fig. 7) and eventually fuse to form a petaloid to subcircular, shelf-like margin to the cup (Pl. 20, Figs 8, 9). In individuals in which the aboral portion of the cup is elongated (e.g., Text-fig. 12A, C, E; *P. dispandus elongatus* Peck, 1943), the flanges extend aborally and form a secondary outer wall to the cup, best seen in individuals which have broken longitudinally (Pl. 20, Figs 1, 2). The interradial cavities formed between the cup and the outer wall open on the aboral pole of the cup (Text-fig. 12A–E), between the mid-radial ridges.

Dias-Brito and Ferré (2001) recorded *P. dispandus elongatus* in thin sections from wells in the Santos Basin, offshore from southeast Brazil, but I cannot confirm their determinations. The items they illustrate (Dias-Brito and Ferré 2001, fig. 6A, C) certainly lack the characteristic double wall structure of *Poecilocrinus,* are very elongated and thin-walled but are indeterminable.

The discovery of *Poecilocrinus* in the Agadir Basin, western Morocco, was an unexpected surprise.

Poecilocrinus dispandus Peck, 1943
(Pl. 21, Figs 7–12; Text-fig. 13B, D)

*1943. *Poecilocrinus dispandus* Peck, p. 471, pl. 75, figs 1, 2, 6, 8, 12.
1961. *Poecilocrinus dispandus* Peck; Rasmussen, p. 378, pl. 55, fig. 7.
1977. *Poecilocrinus dispandus* Peck; Scott *et al*., p. 346, pls 1, 2.

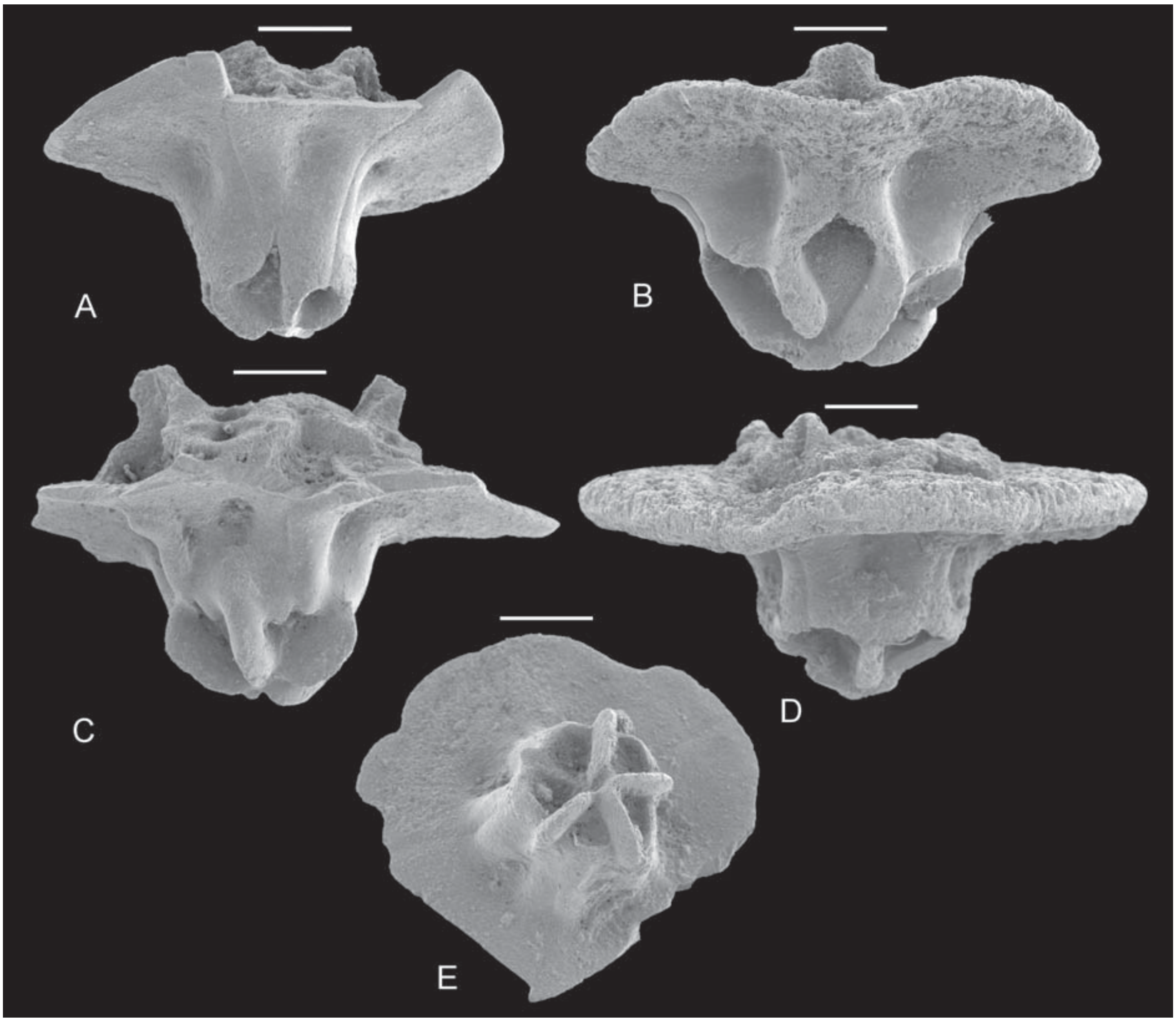
DIAGNOSIS: *Poecilocrinus* in which a broad, horizontally oriented, fused flange is present aboral to the radial facets, which has a circular to petaloid margin. The aboral process of the cup bears five, interradially positioned notches.

HOLOTYPE: The specimen from the Upper Fort Worth Limestone (upper Albian, probably *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone of Fort Worth, Tarrant County, Texas, USA, H.T. Loeblich locality 43, figured by Peck (1943, pl. 75, fig. 2) is the holotype. University of Missouri collections, presumed lost.

MATERIAL. Numerous specimens (more than 100 cups and cup fragments) from 1.5 to 38 m of the Aït Lamine Formation roadcut on road N1 adjacent to Abouda Plage (Text-fig. 8), Agadir Basin, Morocco.

REMARKS. *Poecilocrinus dispandus* will be redescribed in detail in a subsequent paper, based upon extensive new collections from Texas and Oklahoma, which demonstrate stratigraphical variation through the upper Albian. The Agadir Basin specimens are mostly typical of the low form of the species (Pl. 21, Fig. 12; compare with paratype specimen from Texas, Pl. 21, Figs 7–9), and a few specimens approach the morphology of *P. dispandus* forma *elongatus* Peck, 1943 (Pl. 21, Figs. 10, 11; see also Text-fig. 13A, C, E).

OCCURRENCE: Upper Albian, *Pervinquieria* (*Sub-*



Text-fig. 13. **A**, **C**, **E** – *Poecilocrinus dispandus* forma *elongatus* Peck, 1943, cups. A – oblique lateral view, note smooth outer layer formed by fused radial flanges (NHMUK PI EE 17572; compare Pl. 20, Fig. 1); C – lateral view of cup with shorter aboral extension (NHMUK PI EE 17573); E – aboral view to show interradially placed holes marking the exits of tubes between the inner and outer walls (NHMUK PI EE 17572; see Pl. 20, Fig. 1). **B**, **D** – *Poecilocrinus dispandus* Peck, 1943. Cups in lateral view (NHMUK PI EE 17574, 17575). Weno Formation, upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone. A, C, E from a roadcut in Claiburn, Johnson County, Texas, USA; B and D from a drainage ditch off Heritage Trace Parkway, Fort Worth, Tarrant County, Texas, USA. Scale bars equal 0.5 mm.

schloenbachia) *rostrata* and *Pervinquieria* (*Subschloenbachia*) *perinflata* zones, central Texas, Oklahoma, and Agadir Basin, Morocco.

Poecilocrinus dispandus forma *explicatus* Peck, 1943
(Pl. 21, Figs 1–6)

*1943. *Poecilocrinus dispandus explicatus* Peck, p. 472, pl. 75, figs 11, 14.

1961. *Poecilocrinus dispandus explicatus* Peck; Rasmussen, p. 379, pl. 55, fig. 8.

DIAGNOSIS: *Poecilocrinus dispandus* in which the cup is conical and the radial flanges are strongly concave with a central depression.

TYPE: The specimen figured by Peck (1943, pl. 75, figs 11, 14) from the Main Street Limesone, locality 55 of H.T. Loeblich, southeast of Fort Worth, Texas, USA. University of Missouri collections, no. 1012, not found, presumed lost.

MATERIAL: Fifteen cups from the lower part of the Aït Lamine Formation, Abouda Plage roadcut, samples AB9, AB21 and AB10 (8.5 to 16 m in Text-fig. 7).

REMARKS: The material from Abouda compares closely with specimens from Texas (compare a paratype, Pl. 21, Figs 1–3, with a Moroccan specimen, Pl. 21, Figs 4–6). New collecting in Texas has demonstrated that this forma is restricted to the lower part of the Main Street Limestone Formation, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone (Text-fig. 11), where it co-occurs with *Euglyphocrinus cristagalli* sp. nov. (see above), which is also present in Abouda and is characteristic of zone AlR11.

Poecilocrinus molestus Peck, 1943
(Pl. 22, Figs 1–6)

*1943. *Poecilocrinus dispandus molestus* Peck, p. 472, pl. 75, fig. 4.
1961. *Poecilocrinus dispandus molestus* Peck; Rasmussen, p. 379, pl. 55, fig. 10.

DIAGNOSIS: *Poecilocrinus* in which the upper parts of the radial flanges are concave and triangular and bear a short, central strut; the aboral portions of the radial flanges are broad and bladed.

MATERIAL: 23 cups from the upper Albian lower part of the Aït Lamine Formation, Abouda Plage roadcut (22–62 m in Text-fig. 7).

REMARKS: Peck (1943) had a single specimen of this species, now lost, but new collecting has shown that it is restricted to and common in the uppermost part (1 m) of the Main Street Limestone in central Texas and appears to be a distinctive species. Scott *et al*. (1977) discussed Peck's varieties of *P. dispandus*, and suggested that more material and future refinement of their stratigraphical distribution might justify their elevation to species rank. The discovery of this form at Abouda in the lower Aït Lamine Formation in the Agadir Basin, associated with other species of the AlR12 fauna (e.g., *Roveacrinus solisoccasum* sp. nov., *Euglyphocrinus worthensis* sp. nov.) and overlying a typical AlR 11 fauna typical of the lower Main Street (*Euglyphocrinus cristagalli* sp. nov., *Poecilocrinus dispandus* forma *explicatus, Styracocrinus* sp.) provides a remarkably precise microcrinoid correlation between North Africa and North America.

Poecilocrinus signatus (Peck, 1943)
(Pl. 22, Figs 7–12)

*1943. *Roveacrinus signatus* Peck, p. 466, pl. 74, figs 1–5, 11–14.
1961. *Poecilocrinus signatus* (Peck); Rasmussen, p. 381, pl. 55, figs 2, 3.
part 2015. *Roveacrinus alatus* Douglas; Hess, fig. 14d, t only

DIAGNOSIS: *Poecilocrinus* in which a narrow, sharp-edged radial ridge extends from the aboral pole, along the mid-line of each radial plate, terminating within the concave aboral surface of the flanged radial extensions.

HOLOTYPE: The specimen figured by Peck (1943, pl. 74, figs 3, 5, 14), from the lower Cenomanian Grayson Formation of Grayson Bluff, Roanoke, Denton County, Texas, USA (H.T. Loeblich locality HTL1) is the holotype. University of Missouri collections, not found, presumed lost.

MATERIAL: 27 cups, fragmentary cups and brachials. The species extends from 68 to 240 m in the lower Cenomanian part of the Aït Lamine Formation at Abouda Plage.

REMARKS: *Poecilocrinus signatus* will be redescribed in detail on the basis of extensive new material from Texas. The species is distinguished from its probable ancestor, *P. molestus* (see above), by the presence of a strong, narrow ridge which extends unbroken from the aboral pole to the aboral edge of the radial flange (e.g., Pl. 22, Fig. 9). In *P. molestus*, the ridge is interrupted by a lateral growth from the flange (e.g., Pl. 22, Fig. 5). This small morphological difference is quite consistent in both Texas and in the Agadir Basin, Morocco. *Poecilocrinus signatus* appears at the base of the *Graysonites adkinsi* Zone, together with *Euglyphocrinus euglypheus*, and together these species characterise zone Ce1.

Subfamily Hessicrininae Gale, 2016

Genus *Hessicrinus* Gale, 2016

TYPE SPECIES: *Hessicrinus filigree* Gale, 2016.

DIAGNOSIS: Cup with large adoral opening and deep radial cavity; radials perforated by numerous foramina.

REMARKS: The records here from the upper Turonian of Tunisia are the first records of the genus outside Europe.

Hessicrinus thoracifer Gale, 2019

part 1955. *Roveacrinus bairstowi* Peck, p. 1027, pl.106, fig. 2 only.
part 1961. *Roveacrinus bairstowi* Peck; Rasmussen, p. 366, pl. 53, fig. 14 only.
2016. *Roveacrinus bairstowi* Peck; Gale, fig. 11F, G.
2019. *Hessicrinus thoracifer* Gale, p. 488, pl. 43, figs 2, 3; pl. 45, figs 1–4; pl. 47, figs 1–11, 13.

DIAGNOSIS: *Hessicrinus* in which an aborally directed spur-like spine is present on each radial plate, aboral to the radial extension.

TYPES: The cup figured by Gale (2019, pl. 43, fig. 3), from the Coniacian *Micraster cortestudinarium* Zone, at Sline's Oak Pit, Worms Heath, Warlingham, Surrey, United Kingdom, is the holotype (NHMUK E 15634).

MATERIAL: One complete cup and numerous isolated radial plates and brachials, from the upper Turonian *Hemitissotia morreni* Zone, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senam, Tunisia, level of mass occurrence of *Hemiaster* (Chancellor *et al*. 1994).

REMARKS: The Tunisian specimens agree in all details with material from the Anglo-Paris Basin.

DISCUSSION

Palaeogeographical distribution of Cretaceous microcrinoids

The evidence presented here shows that the abundant and diverse late Albian–early Cenomanian microcrinoid faunas described originally by Peck (1943) from Texas and Oklahoma are present also in North Africa. This fact, plus their absence (or considerable scarcity) in western Europe, suggests that they are primarily a west Tethyan fauna, and only appear to have extended northwards during the initial Cenomanian transgression. Roveacrinids are present in some abundance in the lower Cenomanian condensed deposit of Mülheim-Broich, Westphalia, Germany (Hess and Thiel 2015) and less commonly in the basal Chalk Marl of Cambridgeshire, United Kingdom (Gale 2019), but only a few species are present. These include *Roveacrinus spinosus*, which is present in northwest Europe, North Africa and Texas. Roveacrinids have yet to be found in the uppermost lower Cenomanian, and the middle and upper Cenomanian of Texas.

During the latest Cenomanian and early Turonian, roveacrinids increased greatly in abundance and successive species of *Roveacrinus* and *Drepanocrinus* have extended ranges northwards from Tethys into the northwestern European shelf region (Anglo-Paris Basin, North Sea Basin). These are not yet recorded from North America.

Dating of the Cenomanian succession in the Agadir Basin

Ammonites provide a highly refined subdivision of the Cenomanian, and seven zones and five subzones can be identified (Wright *et al*. 2017). Detailed dating of Cenomanian successions in the absence of ammonites is difficult, because the resolution provided by planktonic foraminiferans is rather low (Gilardoni 2016), including, successively, the zones of *Thalmaninella globotruncanoides* (PRZ), *T. reicheli* (TRZ), *Rotalipora cushmani* (TRZ) and *Whiteinella archaeocretacea* (PRZ). In the section at Taghazout, Essafraoui *et al*. (2015) recorded *T. globotruncanoides* from a single sample (their fig. 3; 183 m, sample 3), and *R. cushmani* from 545–583 m, and found no evidence of the middle Cenomanian *T. reicheli* Zone. The discovery of an ammonite, *Mantelliceras cantianum*, at 311 m (Text-fig. 4) demonstrates that this level is still within the lower Cenomanian, but the species is not zonally diagnostic.

The microcrinoid assemblages from the Agadir Basin provide some indirect evidence of age, because similar assemblages are found in central Tunisia associated with ammonite faunas (Kennedy and Gale 2015). The fauna characterised here as CeR5, which occurs between 405 and 423 m (Text-fig. 8), is found only in the middle Cenomanian *Cunningtoniceras inerme* Zone in Djebel Mhrila (Text-fig. 10) and permits tentative placement of the lower−middle Cenomanian boundary within the unexposed gap at Taghazout Plage (381–405 m; see Text-fig. 6). In Djebel Mhrila (Text-fig. 10), there is evidence of the overlying zone CeR6 in sample T6/19, which is also middle Cenomanian. Thus, there is only very limited evidence for the placement of the middle−upper Cenomanian boundary within the microcrinoid succession. Zone CeR6, however, is probably mostly late Cenomanian in age, because it ranges up to the base of the OAE2 carbon isotope excursion.

What is evident from these new data is that the bulk (approximately 335 m) of the Aït Lamine Formation in the Abouda-Taghazout section (6–400 m in Text-fig. 6) is of early Cenomanian age (the Albian age of the lower part of the formation is discussed above); the middle Cenomanian is perhaps 30 m in thickness and the upper Cenomanian 50–60 m. Moreover, a large part of the lower Cenomanian (150 m) falls within a single microcrinoid zone (Text-fig. 6; zone CeR2), which probably represents only a small part of the *Mantelliceras mantelli* Zone. Sedimentation rates were evidently highly variable in the Agadir Basin during the Cenomanian.

Correlation between the Agadir Basin and central Texas

The discovery of a succession of microcrinoid species in the Agadir Basin previously known only from the Albian and lower Cenomanian of central Texas, provides high-resolution correlation between the two regions which were 5,300 km apart during the late Albian (C. Scotese, pers. comm., July 2019), independently supported by ammonite biostratigraphy. The lower 65 m of the Aït Lamine Formation, which overlies limestones of the Kechoula Formation, is of late Albian age and yields abundant roveacrinids of zones AlR11 and AlR12, associated with ammonites of the *Pervinquieria* (*Subschloenbachia*) *rostrata* and *Pervinquieria* (*Subschloenbachia*) *perinflata* zones, respectively. The traditional view that the Kechoula Formation on the Atlantic coast represents the uppermost Albian ("barre Vraconnien"), overlain by lower Cenomanian marls of the Aït Lamine Formation (Essafraoui *et al*. 2015) is thus incorrect.

In central Texas (Tarrant and Denton counties; see Text-fig. 11), the microcrinoid zones AlR11 and AlR12 are present in the Main Street Limestone Formation, which also yields ammonites of the *Pervinquieria* (*Subschloenbachia*) *rostrata* and *Pervinquieria* (*Subschloenbachia*) *perinflata* zones, although the precise stratigraphical location of these within the formation is uncertain (Kennedy *et al*. 2005). The Main Street is capped by a major hardground, overlain by marls and clays of the Grayson Formation, which yields Cenomanian ammonites of the *Graysonites adkinsi* and succeeding *Graysonites wacoense* zones (Kennedy *et al*. 2005) and microcrinoids of zones CeR1 and CeR2 (Text-fig. 11). There is thus a remarkably close comparison to the succession in the Agadir Basin, where a level containing hardgrounds and hiatus concretions is present immediately beneath the *Graysonites adkinsi* Zone (Text-fig. 5) and the base of microcrinoid zone CeR1.

There is a widespread view that the transition from limestone-dominated to clay-dominated facies is coincident with the Albian−Cenomanian boundary, and represents a major flooding surface overlying a sequence boundary across the Gulf coast region (Al SB Wa6; Scott *et al*. 2019) and in the Agadir Basin (e.g., Essafraoui *et al*. 2015). However, the present work demonstrates that the transition to clay-dominated sedimentation in the Agadir Basin commenced significantly earlier than in the Gulf Coast of North America, probably within the *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, and predates the Albian–Cenomanian boundary by approximately 1 myr (Gale *et al*. 1996, 2011).

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PLATES 1–22

PLATE 1

1-5, 7, 8 – *Discocrinus africanus* sp. nov. 1-3 – holotype, cup in adoral, lateral, and aboral views, respectively (NHMUK PI EE 17357); 4, 5, 7 – paratype, cup in aboral, adoral and lateral views, respectively (NHMUK PI EE 17358); 8 – paratype, fragmentary cup in lateral view (NHMUK PI EE 16146), the original of Gale (2019, pl. 36, fig. 1).

6 – *Styracocrinus peracutus* (Peck, 1943), cup in adoral view (NHMUK PI EE 17359).

9-13 – *Discocrinus catastomus* Peck, 1943, cups (10-13) and distal brachial (9). 9 – distal brachial to show pinnule attachment site, the original of Gale (2019, pl. 36, fig. 5; NHMUK PI EE 16150); 10 – cup in lateral view, showing form of interradial projections; the original of Gale (2019, pl. 36, fig. 6; NHMUK PI EE 16151); 11 – cup in lateral view, the original of Gale (2019, pl. 35, fig. 9; NHMUK PI EE 16140); 12 – cup in adoral view, the original of Gale (2019, pl. 36, fig. 4; NHMUK PI EE 16149); 13 – cup in aboral view to show sheet of thin stereom extending across interior of cup, the original of Gale (2019, pl. 36, fig. 2; NHMUK PI EE 16148).

Figures 1-8 are from the lower Cenomanian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA0 (310 m in Text-fig. 4). Figures 9, 10, 12, 13 are from the upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, Weno Formation, Claiburn, Johnson County, Texas, USA. Figure 11 is from the Duck Creek Formation, upper Albian, Horseshoe Bend, Red River, Bryan County, Oklahoma, USA.

Scale bars equal 0.2 mm (6, 7, 9, 10-13) and 0.5 mm (1-5, 7, 8)

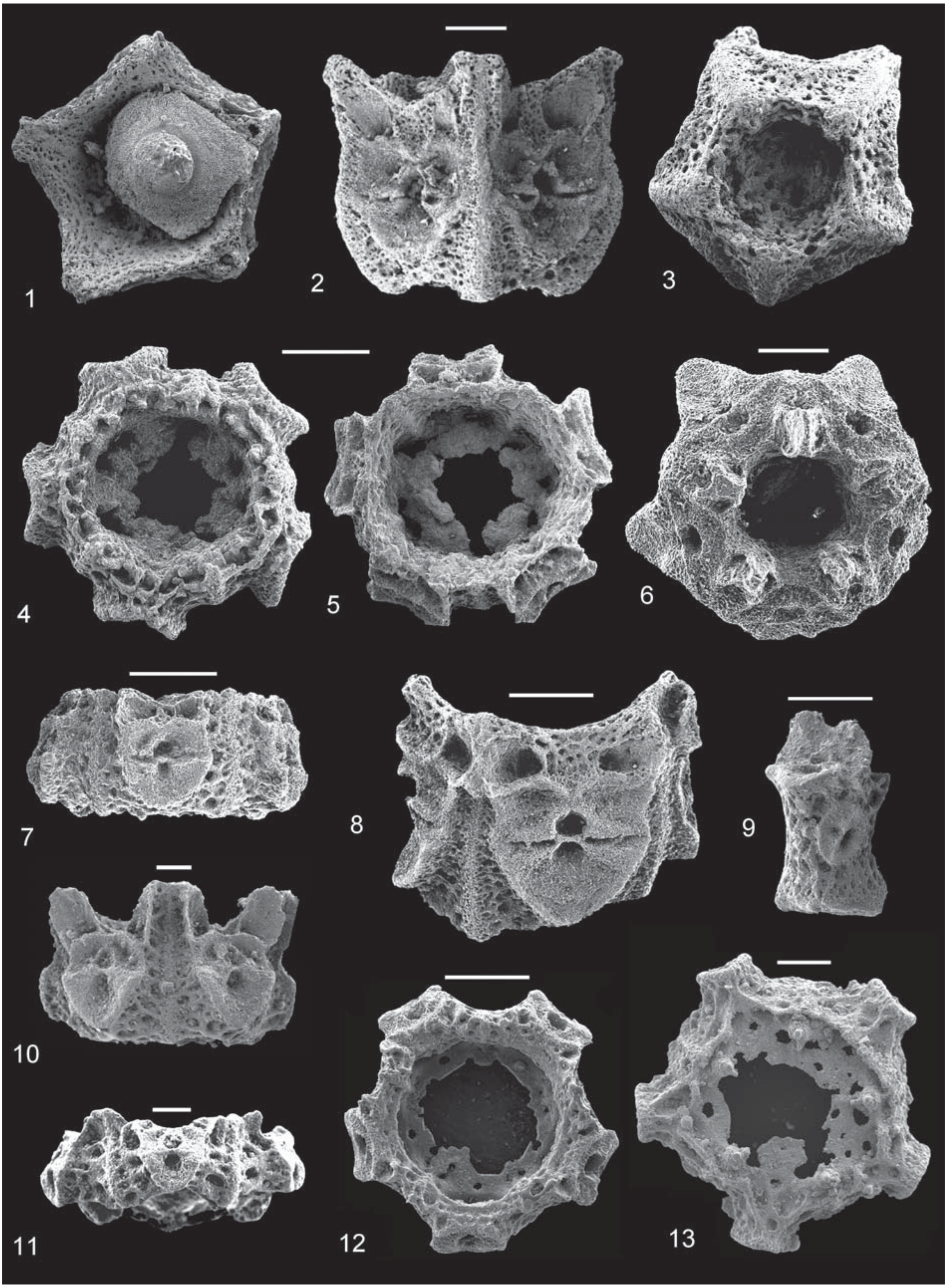
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PLATE 2

1, 2 – *Styracocrinus peracutus* (Peck, 1943), primibrachial IBr2 in external and internal views, respectively (NHMUK PI EE 17360).

3-5, 8 – *Fenestracrinus oculifer* gen. et sp. nov. 3-5 – primibrachials IBr2 in external, oblique internal, and lateral views, respectively (NHMUK PI EE 17361–17363); 8 – secundibrachial IIBr2 (NHMUK PI EE 17364).

6, 7 – *Lebenharticrinus zitti* sp. nov., fragmentary primibrachials IBr2 (NHMUK PI EE 17365, 17366).

9-21 – Brachials of *Discocrinus africanus* sp. nov. 9-11 – primibrachial IBr1 in lateral, proximal and distal views, respectively (NHMUK PI EE 17367); 12, 13 – secundibrachial IIBr2 (NHMUK PI EE 17368); 14, 18 – IIBr1 (NHMUK PI EE 17369); 15-17 – distal brachials (NHMUK PI EE 17370–17372); 19-21 – primibrachials IBr2 in internal, external and lateral views, respectively (NHMUK PI EE 17373–17375).

Figures 1, 2, 13, 15 are from lower Cenomanian, Aït Lamine Formation, roadcut behind Abouda Plage, Morocco, sample TA 9 (296.6 m in Text-fig. 4). Figures 3-8 are from sample AGN3 (459 m in Text-fig. 4), upper Cenomanian, Taghazout Plage, Morocco. Figures 9-12, 14, 16-21 are from the lower Cenomanian, Aït Lamine Formation, roadcut behind Abouda Plage, Morocco, sample TA0 (310 m in Text-fig. 4).

Scale bars equal 0.2 mm (2, 5-8, 11, 13, 17) and 0.5 mm (1, 2, 4, 9, 10, 12, 14-16, 18-21)

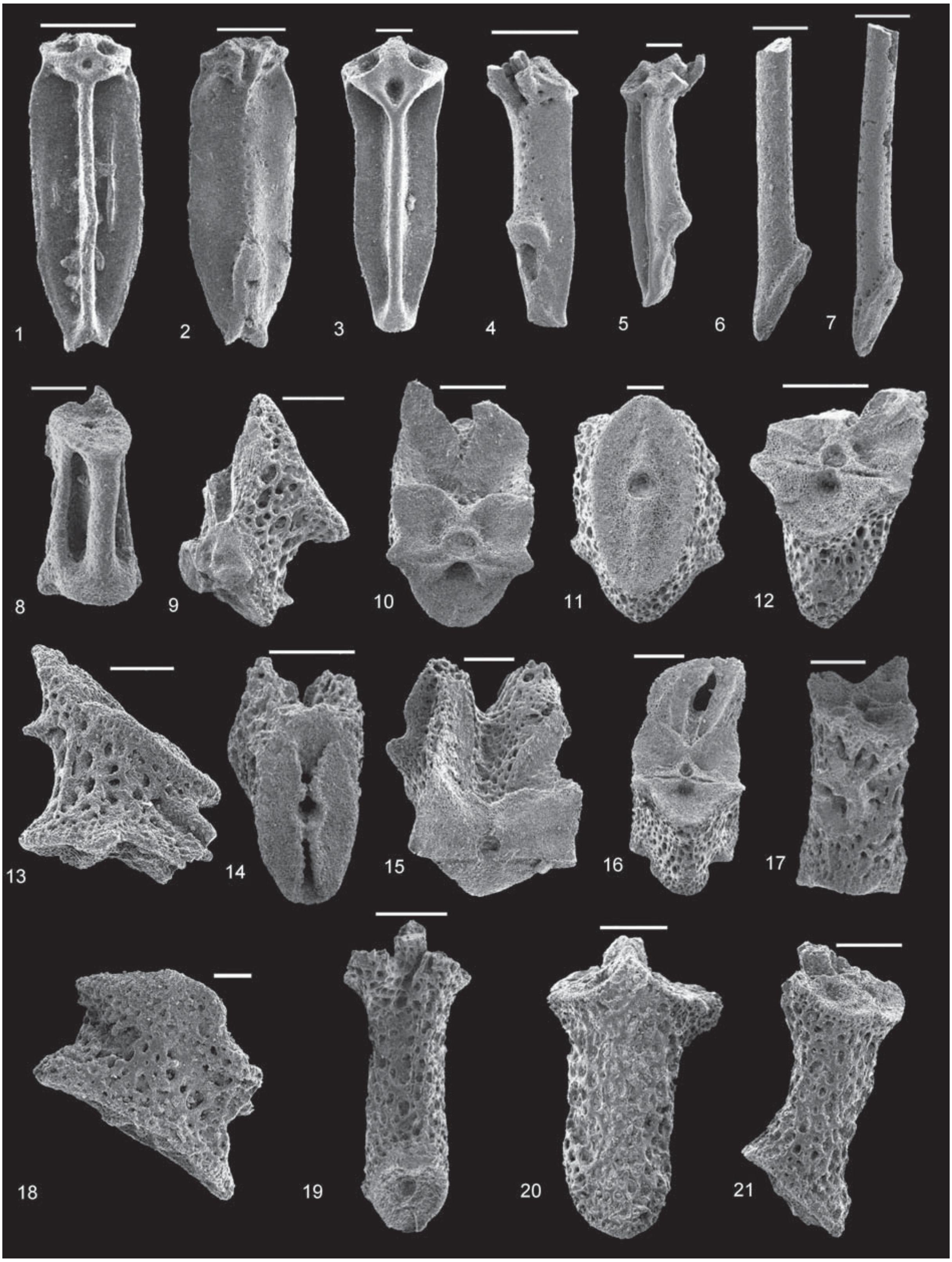
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PLATE 3

1-7, 12 – *Orthogonocrinus cantabrigensis* Gale, 2019. 1, 2, 4-7 – cups in lateral view; 1, 5-7 – specimens NHMUK PI EE 17377–17380; 2 – the original of Gale (2019, pl. 42, fig. 5; NHMUK PI EE 16912); 4 – the original of Gale (2019, pl. 42, fig. 7; NHMUK PI EE 16913); 3 – cup in adoral view (NHMUK PI EE 17376); 12 – broken cup in aboral view to show basals (NHMUK PI EE 17381).

8, 9 – *Lebenharticrinus zitti* sp. nov. 8 – adoral view of holotype, to compare with that of *Lebenharticrinus quinvigintensis* sp. nov. (NHMUK PI EE 17382); 9 – cup in lateral view (NHMUK PI EE 17576).

10, 11 – *Lebenharticrinus quinvigintensis* sp. nov., holotype in lateral and adoral views, respectively (NHMUK PI EE 17383).

Figures 1-4, 6, 10-12 are from the lower Cenomanian, Aït Lamine Formation, roadcut behind Abouda Plage, Morocco, sample TA0, 310 m in Text-fig. 3. Figures 5, 7, 8, 9 are from the upper Cenomanian, Aït Lamine Formation Taghazout Plage, Morocco, sample AGN3 (458 m in Text-fig. 4).

Scale bars equal 0.1 mm (12), 0.2 mm (3, 6-8, 10, 11) and 0.5 mm (1, 2, 4, 5, 9)

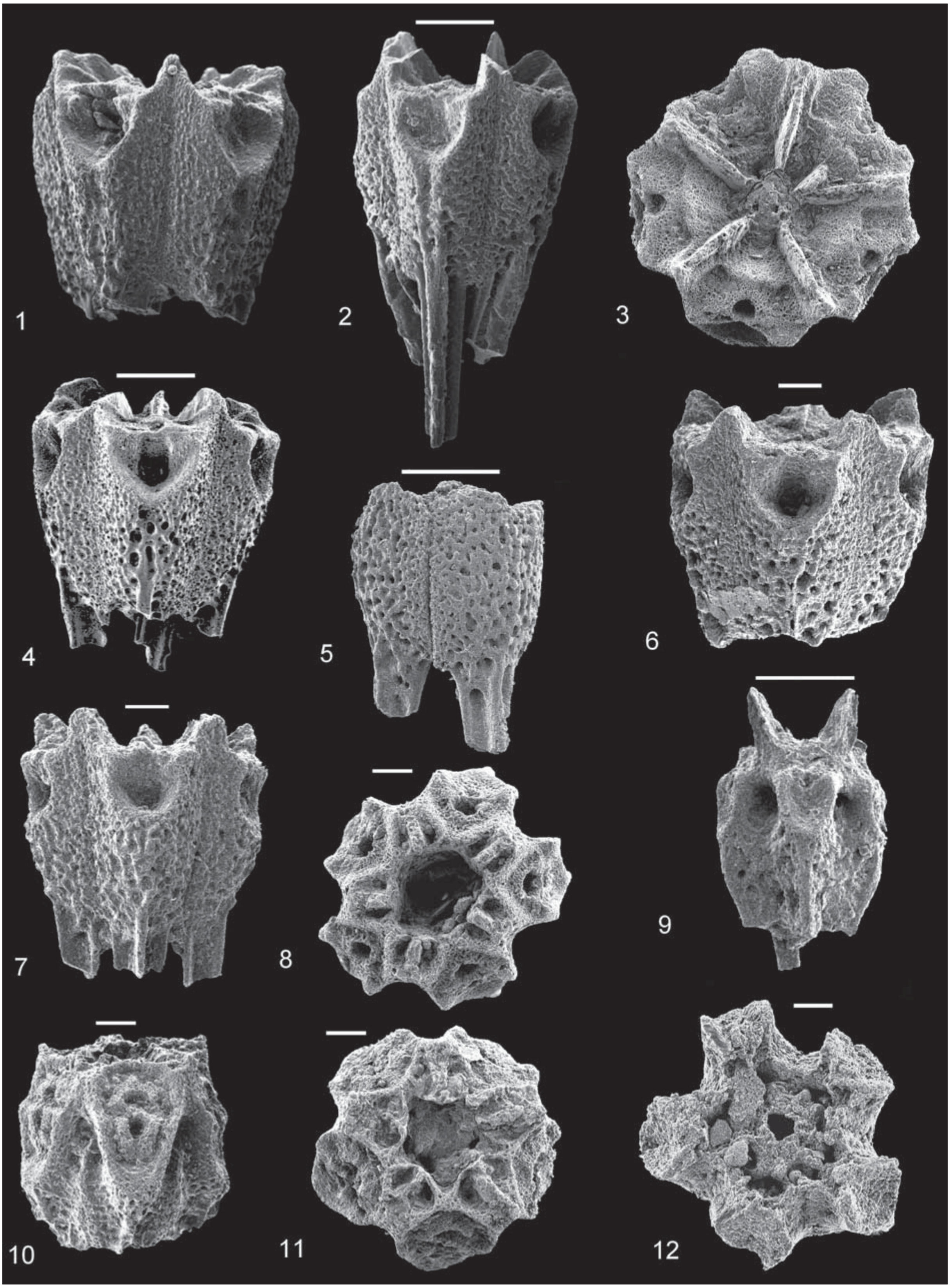
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PLATE 4

1-6, 10, 13 – *Euglyphocrinus cristagalli* sp. nov. 1, 2 – paratype cups in lateral view (NHMUK PI EE 17385–17386). 3 – partial cup in which aboral part has broken away, in order to show internal structure (NHMUK PI EE 17387); 4, 5, 10, 13 – cups in lateral view (NHMUK PI EE 17388–17391); 6 – cup in aboral view (NHMUK PI EE 17393); 10 –holotype cup in lateral view (NHMUK PI EE 17384). Note the calcite overgrowth in 4, 6 and 13, a typical style of preservation in the lower part of the Aït Lamine Formation.

7-9, 11, 12 – *Orthogonocrinus apertus* Peck, 1943. 7 – small cup with aboral part preserved (NHMUK PI EE 17394); 8, 9, 12 – fragmentary cups in lateral views (NHMUK PI EE 17395–17397); 11 – cup in adoral view (NHMUK PI EE 17398).

Figures 1-3, 10 are from the upper Albian, Main Street Limestone Formation, Sunset Oak Drive, Fort Worth, Texas, USA, sample SD1 (Text-fig. 11). Figures 4-6, 13 are from the upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, Aït Lamine Formation, Abouda Plage roadcut, Morocco; 4, 6, 13 – sample AB9 (9 m in Text-fig. 3); 5 – sample AB 10 (16 m in Text-fig. 3). Figures 7-11 are from the upper Albian *Pervinquieria* (*Subschloenbachia*) *perinflata* Zone, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample ABX (26 m in Text-fig. 3). Figure 12 is from the lower Cenomanian, Aït Lamine Formation, sample Q4 (87 m in Text-fig. 3).

Scale bars equal 0.1 mm (3), 0.2 mm (1, 2, 4-6, 10, 13), and 0.5 mm (7-9, 11, 12)

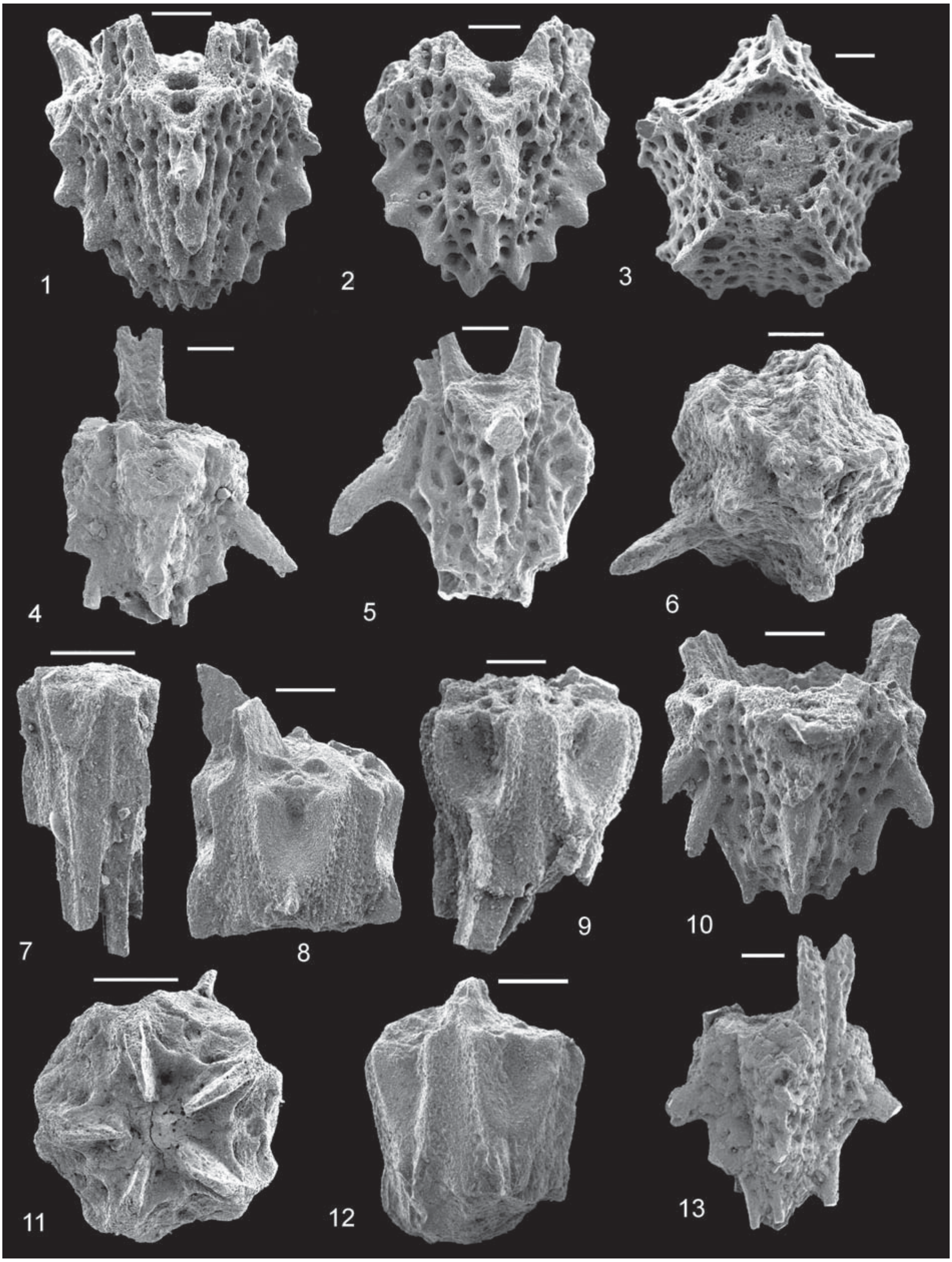
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PLATE 5

1-11 – *Styracocrinus peracutus* (Peck, 1943). 1-3, 6, 8, 10 – fragmentary cups in lateral view (NHMUK PI EE 17399–17404); 4, 9 – paratype cups in lateral view (USNM 128355a, b); 5, 7 – aboral views of broken cups, to show ring of basals in centre of cup, and pits in radials for radial balls (NHMUK PI EE 17405, 17406); 11 – cup in adoral view to show interradial processes (NHMUK PI EE 17407).

Figures 1-3, 6-8, 10-11 are from the lower Cenomanian, Aït Lamine Formation, roadcut behind Abouda Plage, Taghazout, Morocco, sample TA0, 310 m in Text-fig. 3. Figures 4, 9 are from the upper Albian Duck Creek Formation, Cooke County, Texas, USA.

Scale bars equal 0.1 mm (2), 0.2 mm (1, 3, 4, 6, 7-11), and 0.5 mm (5)

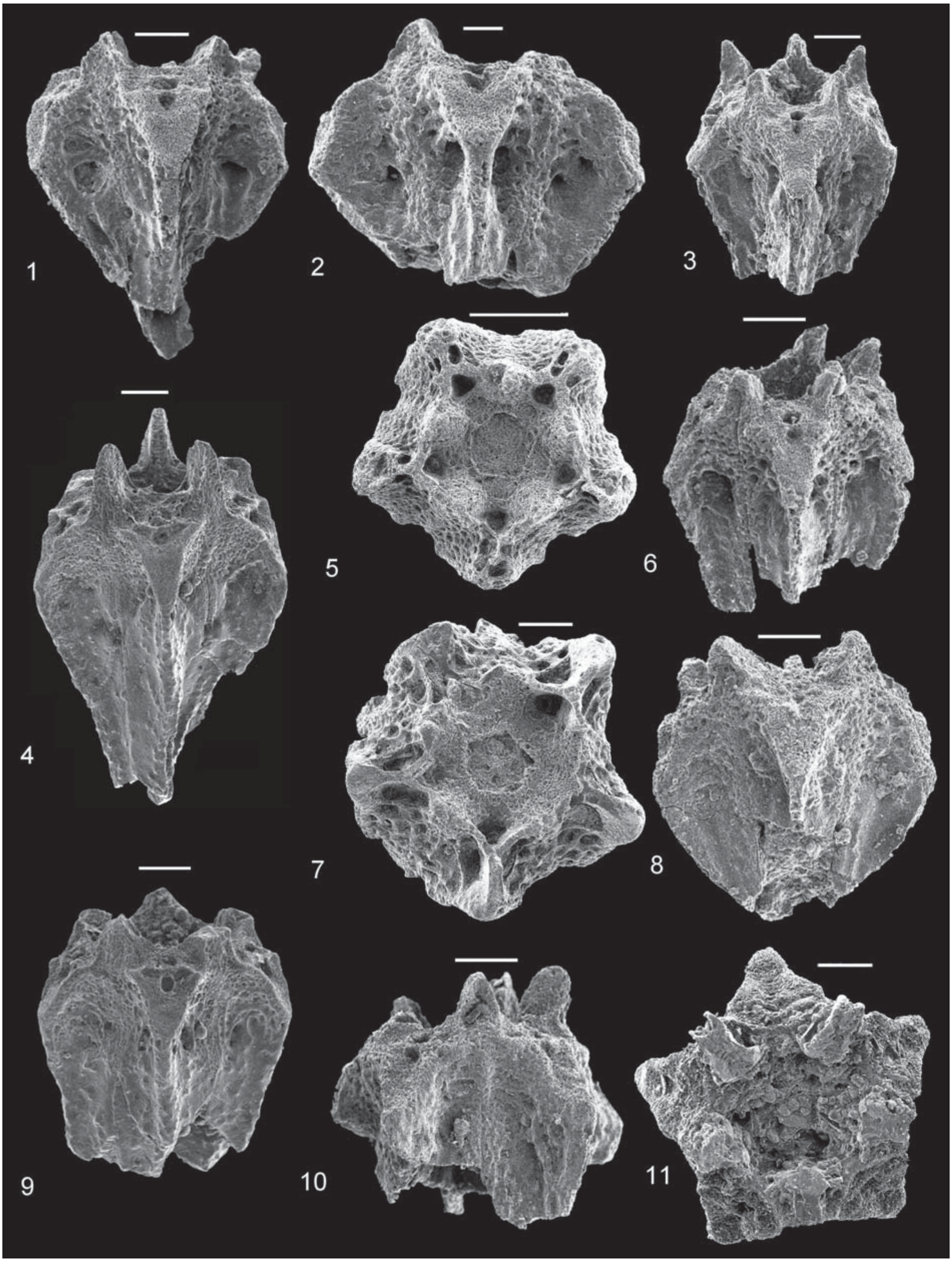
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PLATE 6

1, 2, 7 – *Lebenharticrinus zitti* sp. nov. 1, 2 – holotype cup in lateral and adoral views, respectively (NHMUK PI EE 17382); 7 – paratype cup in lateral view (NHMUK PI EE 17408).

3-6, 8, 9, 11, 14 – *Fenestracrinus oculifer* gen. et sp. nov. 3-6, 9 – broken cups in lateral view, to show large interradial fenestrae and open aboral cup (NHMUK PI EE 17409–17413); 8, 11, 14 – axillary primibrachials IBr2 (NHMUK PI EE 17413–17415).

10, 12, 13 – *Styracocrinus rimafera* sp. nov., cups in lateral view. 10 – holotype (NHMUK PI EE 17416); 12, 13 – paratypes (NHMUK PI EE 17417, 17418). Note articulated IBr1 in 12.

Figures 1-9, 11 and 14 are from the upper Cenomanian Aït Lamine Formation, Taghazout Plage, sample AGN3 (458 m in Text-fig. 4). Figures 10, 12 and 13 are from the middle Cenomanian, Aït Lamine Formation, Abouda Plage roadcut, samples TAN24 (10 and 13; 423 m in Text-fig. 4), and TAN 25 (12, 420.5 m in Text-fig. 4), Morocco.

Scale bars equal 0.5 mm (10) and 0.2 mm (all others)

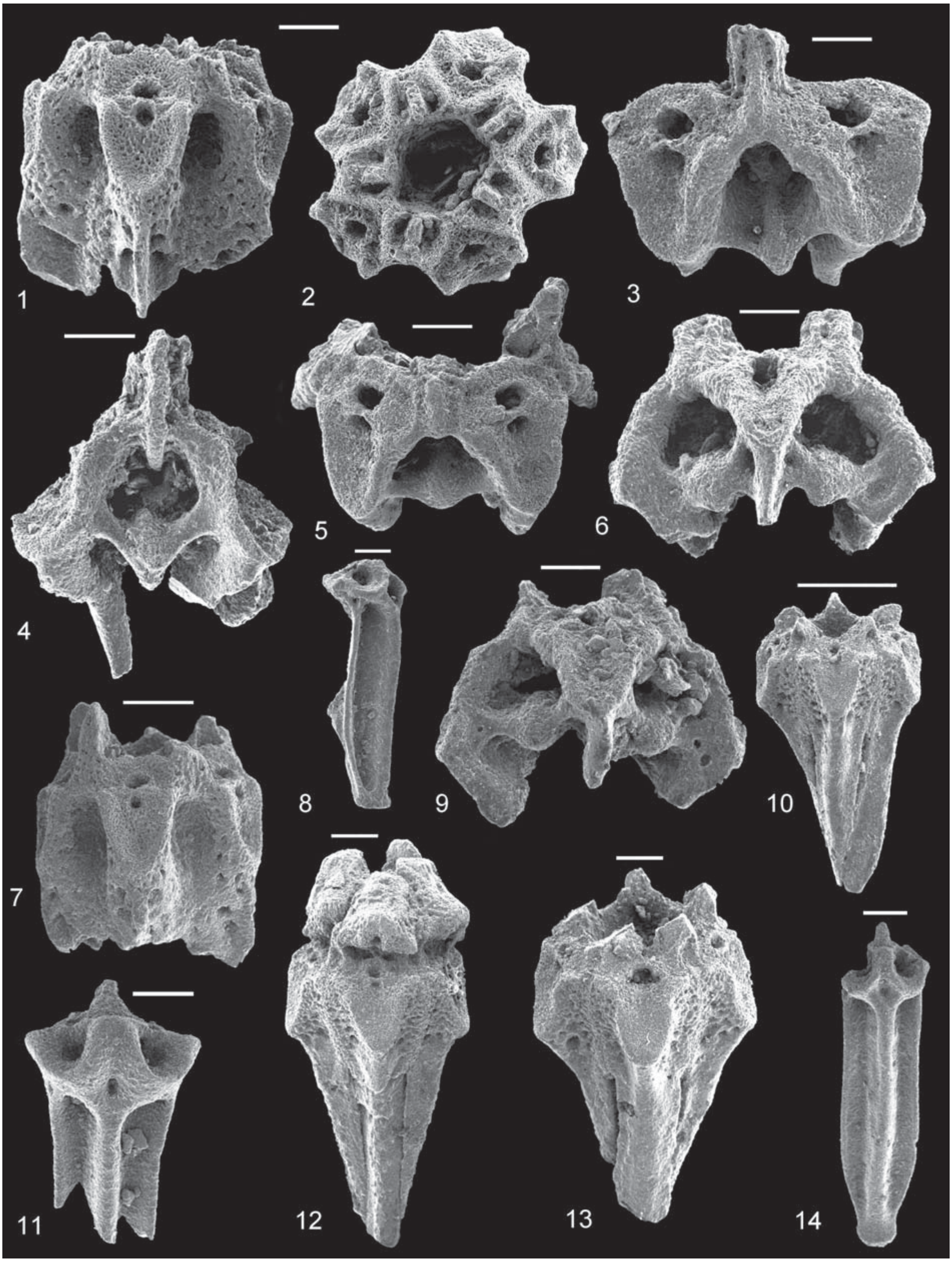
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PLATE 7

1-12 – *Fenestracrinus oculifer* gen. et sp. nov. 1-3 – holotype cup in lateral, adoral and aboral views, respectively (NHMUK PI EE 17419); 4-6, 7-9 – paratype cups in same views, respectively (NHMUK PI EE 17420, 17421); 10-11 – fragmentary cup, in external and internal views, respectively; note bladed aboral process (NHMUK PI 17422); 12 – fragmentary cup, internal view to show canals (NHMUK PI EE 17423).

All specimens are from the upper Cenomanian, Aït Lamine Formation, Taghazout Plage, Morocco, sample AGN3 (458 m in Text-fig. 4).

Scale bars equal 0.2 mm

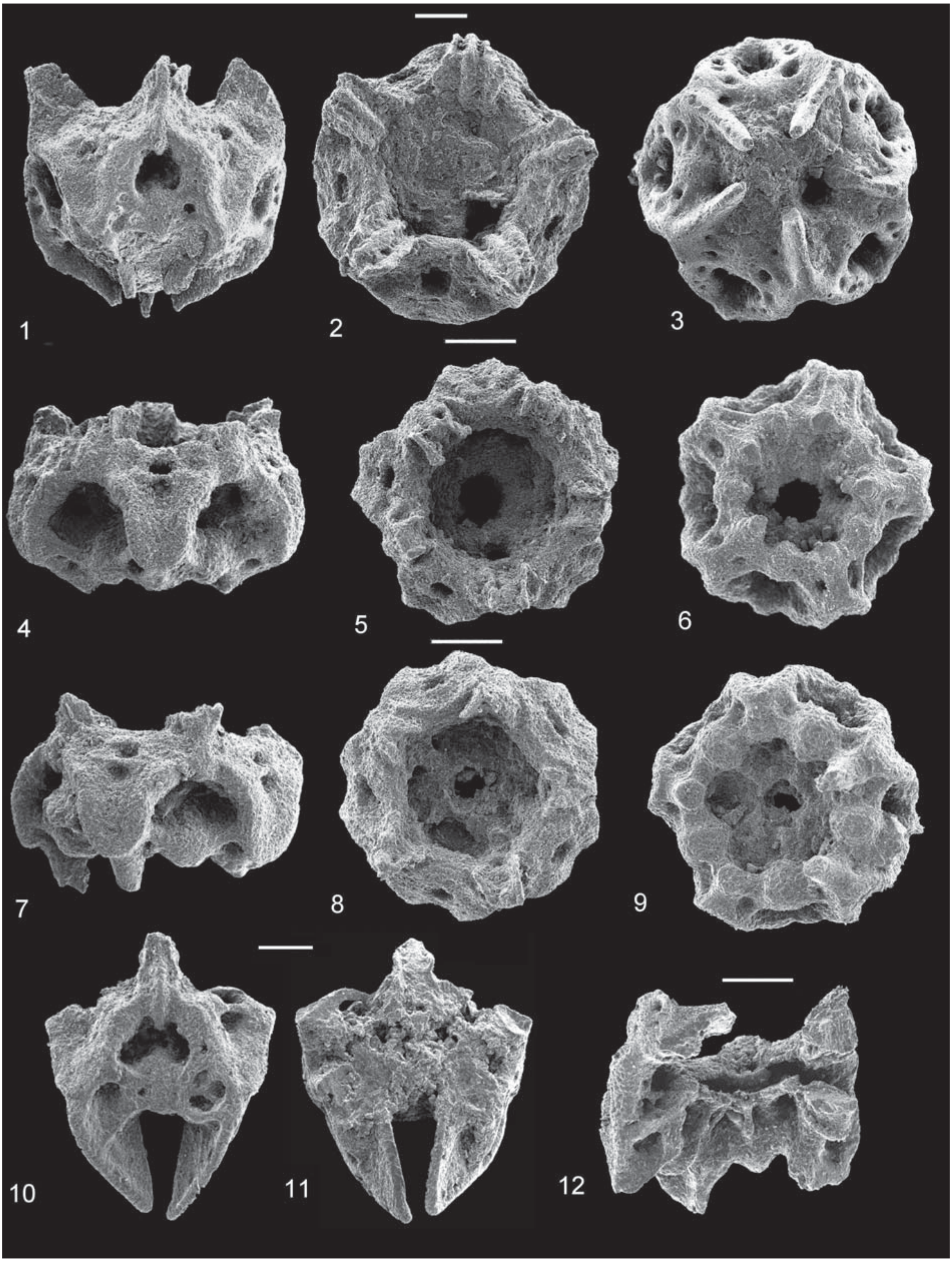
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PLATE 8

1-4, 6 – *Euglyphocrinus worthensis* sp. nov. 1-3 – holotype cup, in lateral, adoral and aboral views, respectively (NHMUK PI EE 17424); 4, 6 – cups in lateral and aboral views, respectively (NHMUK PI EE 17425, 17426).

5 – *Euglyphocrinus cristagalli* sp. nov., cup in aboral view (NHMUK PI EE 17427).

7-12 – *Euglyphocrinus euglypheus* (Peck, 1943). 7 – paratype cup in lateral view (USNM 128335b); 8 – cup in lateral view (NHMUK PI EE 17428); 9, 10, 12 – cups in aboral view (NHMUK PI EE 17429–17431); 11 – cup in adoral view (NHMUK PI EE 17429).

Figures 1-3 are from the upper Albian, Main Street Limestone Formation, Sunset Oak Drive, Fort Worth, Texas, USA, sample SD4 (Text-fig. 11). Figure 5 is from the same locality, sample SD1. Figures 4, 6 are from the upper Albian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample ABX (26 m in Text-fig. 3). Figures 7, 10, 11 are from the lower Cenomanian, Grayson Formation, Grayson Bluff, Roanoke, Tarrant County, Texas, USA. Figures 8, 12 are from the lower Cenomanian, Aït Lamine Formation, Oued Abouda, sample Q2 (75 m in Text-fig. 3). Figure 9 is from the same locality, sample Q4.

Scale bars equal 0.2 mm

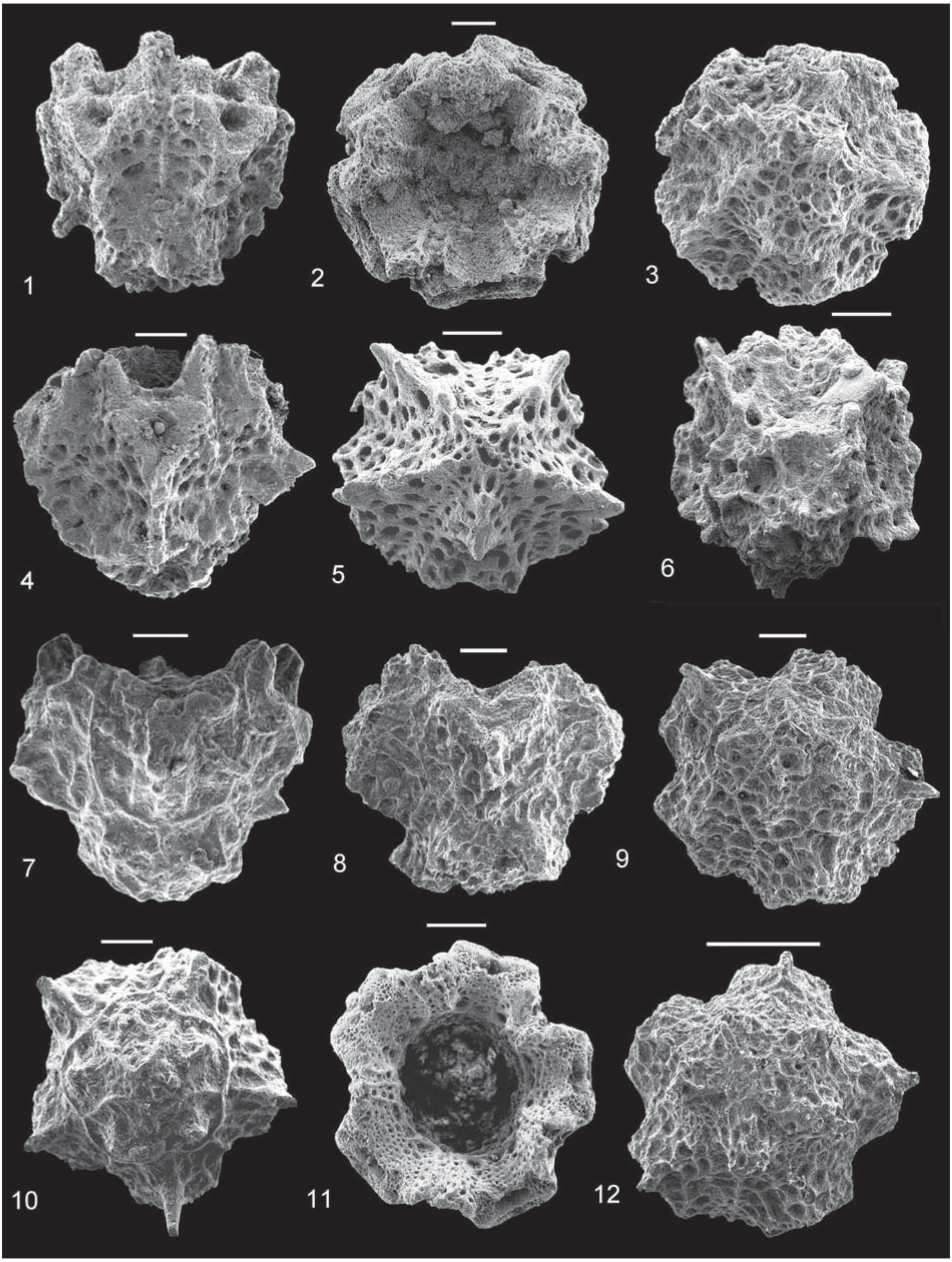
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PLATE 9

1-8, 10-14 – *Euglyphocrinus truncatus* sp. nov. 1, 5 – axillary IBr2 in external and lateral views, respectively (NHMUK PI EE 17430); 2, 6 – paratype cup in lateral (2) and aboral (6) views (NHMUK PI EE 17431); 3, 7, 12 – holotype cup in lateral aboral and adoral views, respectively (NHMUK PI EE 17432); 4 – paratype cup in lateral view (NHMUK PI EE 17433); 8, 13 – paratype cup in lateral (8) and aboral (13) views (NHMUK PI EE 17434); 10, 11 – IBr1 in external (10) and lateral (11) views (NHMUK PI EE 17435); 14 – IIBr2 in oblique external view (NHMUK PI EE 17436).

9, 15 – *Euglyphocrinus pyramidalis* (Peck, 1943), paratype cup in aboral (9) and lateral (15) views; the original of Gale (2019, pl. 35, fig. 10; USNM 128339a).

16-21 – *Euglyphocrinus jacobsae* sp. nov., cups in lateral view. 16 – holotype (NHMUK PI EE 17437); 17-21 – paratypes (NHMUK PI EE 17438–17442).

Figures 1-9, 10-14 are from the middle Cenomanian Aït Lamine Formation, Abouda Plage roadcut, sample TAN25 (420.5 m in Text-fig. 4). Figures 16-21 are from the lower Cenomanian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA0 (310 m in Text-fig. 3). Figure 15 is from the upper Albian, Duck Creek Formation, Fort Worth, Tarrant County, Texas, USA.

Scale bars equal 0.2 mm (1, 2, 5, 6, 9-11, 14-21) and 0.5 mm (3, 4, 7, 8, 12, 13)

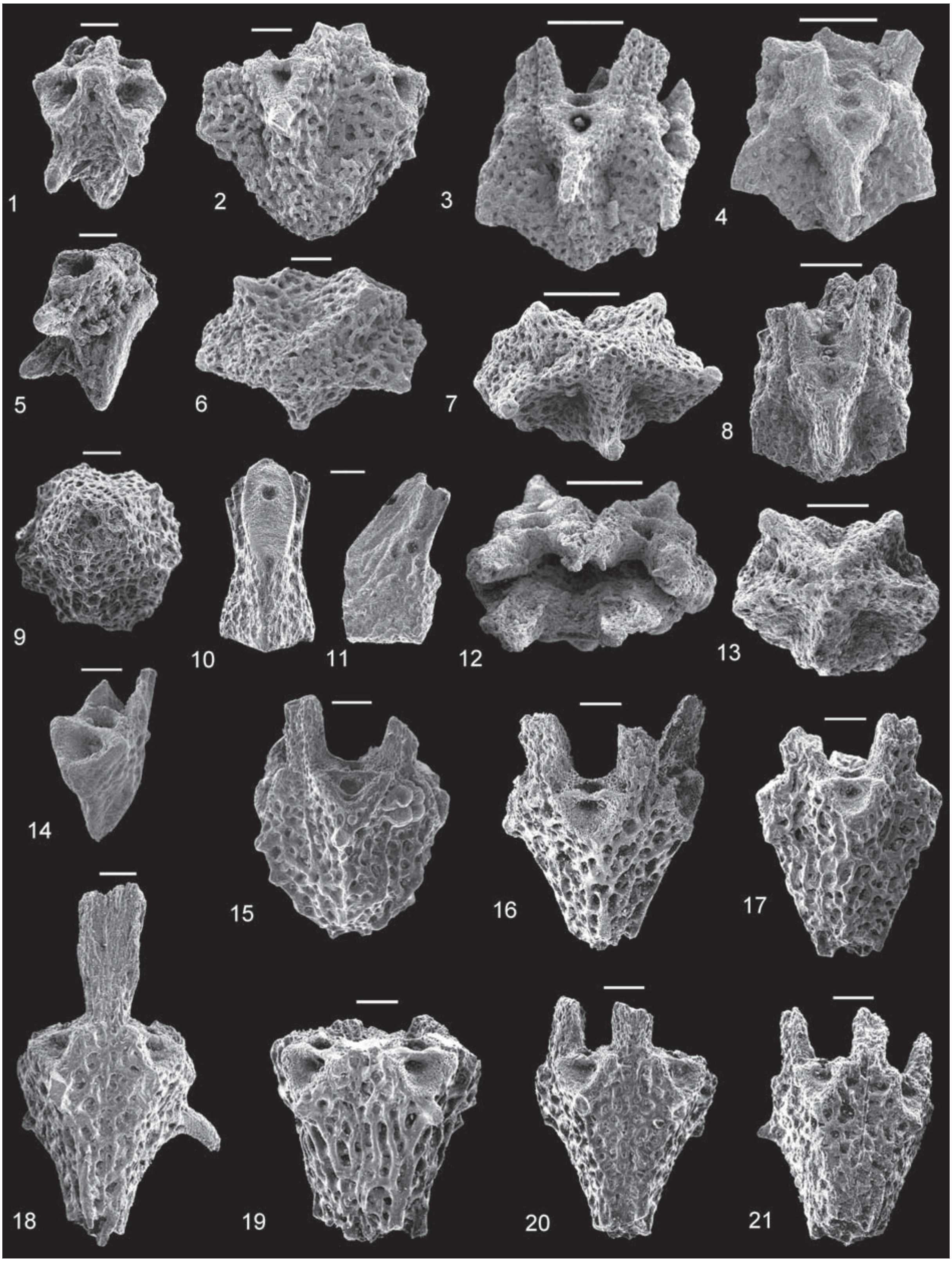
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PLATE 10

1-5, 12, 13 – *Euglyphocrinus truncatus* sp. nov. 1-5 – cups in lateral view (NHMUK PI EE 17443–17447); 12 – IBr2 axillary in external view (NHMUK PI EE 17448); 13 – IBr1 in external view (NHMUK PI EE 17449).

6, 7 – *Euglyphocrinus jacobsae* sp. nov., cups in lateral view (NHMUK PI EE 17450, 17451).

8 – *Styracocrinus rimafera* sp. nov., cup in lateral view (NHMUK PI EE 17452).

9 – *Orthogonocrinus cantabrigensis* Gale, 2019, partial cup in lateral view (NHMUK PI EE 17453).

10 – *Lebenharticrinus canaliculatus* Žítt, Löser, Nekvasilová, Hradecká and Svabenická, 2019, cup in lateral view (NHMUK PI EE 17454).

11 – *Drepanocrinus marocensis* Gale, 2019, axillary IBr2 in external view (NHMUK PI EE 17455).

Figures 1-9, 12, 13 are from the middle Cenomanian, *Cunningtoceras inerme* Zone, Fahdene Formation, sample T6/18 (114 m in Text-fig. 10), Sif el Tella, Djebel Mhrila, central Tunisia. Figures 10, 11 are from the lower Turonian, *Thomasites rollandi* Zone, Annaba Formation, sample M12, same locality.

Scale bars equal 0.2 mm (3, 7-10, 12, 13) and 0.5 mm (1, 2, 4-6, 11)

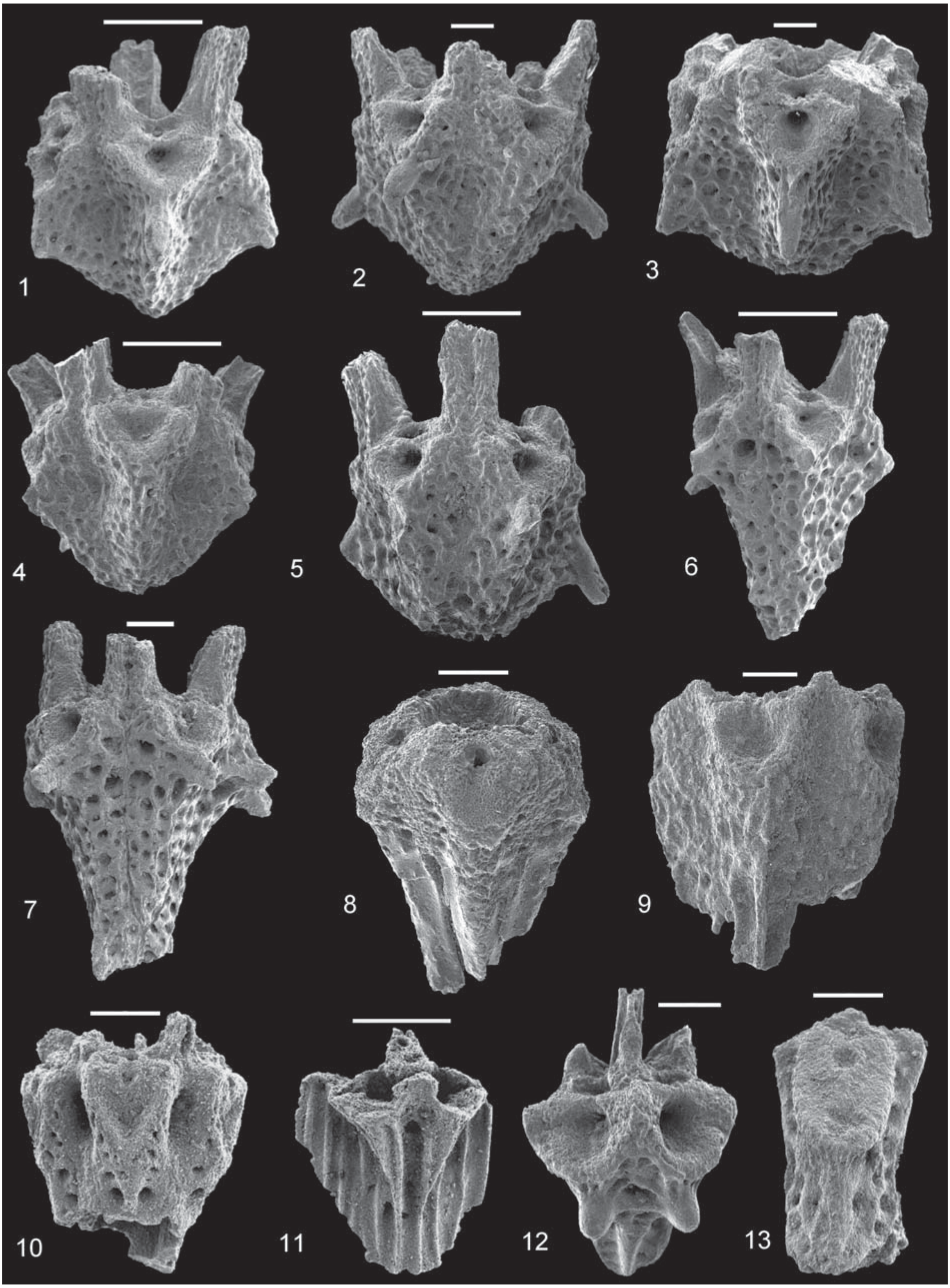
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PLATE 11

1-6 – *Roveacrinus solisoccasum* sp. nov. 1-3 – holotype cup in aboral, lateral and adoral views, respectively (NHMUK PI EE 17456); 4, 5 – cup in aboral and lateral views, respectively (NHMUK PI EE 17457); 6 – cup in aboral view (NHMUK PI EE 17458).

7-16 – *Roveacrinus spinosus* Peck, 1943. 7 – fragmentary cup (NHMUK PI EE 17459); 8 – IBr2 with paired IIBr1 attached (NHMUK PI EE 17460); 9 – cup in oblique lateral view (NHMUK PI EE 17461); 10 – IBr2 (NHMUK PI EE 17462); 11-13 – cup in aboral, lateral and adoral views, respectively (NHMUK PI EE 17463); 14-16 – cup in aboral, lateral and adoral views, respectively (NHMUK PI EE 17464).

Figures 1-3 are from the upper Albian, Main Street Limestone, Sunset Oak Drive, Fort Worth, Texas, USA, sample SD3 (Text-fig. 11). Figures 4-6 are from the upper Albian, *Pervinquieria* (*Subschloenbachia*) *perinflata* Zone, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample ABX (26 m in Text-fig. 3). Figure 7 is from the lower Cenomanian, same formation and locality, sample TA31 (219.5 m in Text-fig. 3). Figure 8 is from the lower Cenomanian, same formation and locality, sample Q6 (94 m in Text-fig. 3). Figure 9 is from the lower Cenomanian, same formation and locality, sample TA32A (237 m in Text-fig. 3). Figures 10-16 are from the lower Cenomanian Grayson Formation, Dottie Lynn Lane, Fort Worth, Texas, USA (see Hess 2015, fig. 3 for details).

Scale bars equal 0.2 mm (4-6), 0.5 mm (1-3, 8-13) and 1 mm (14-16)

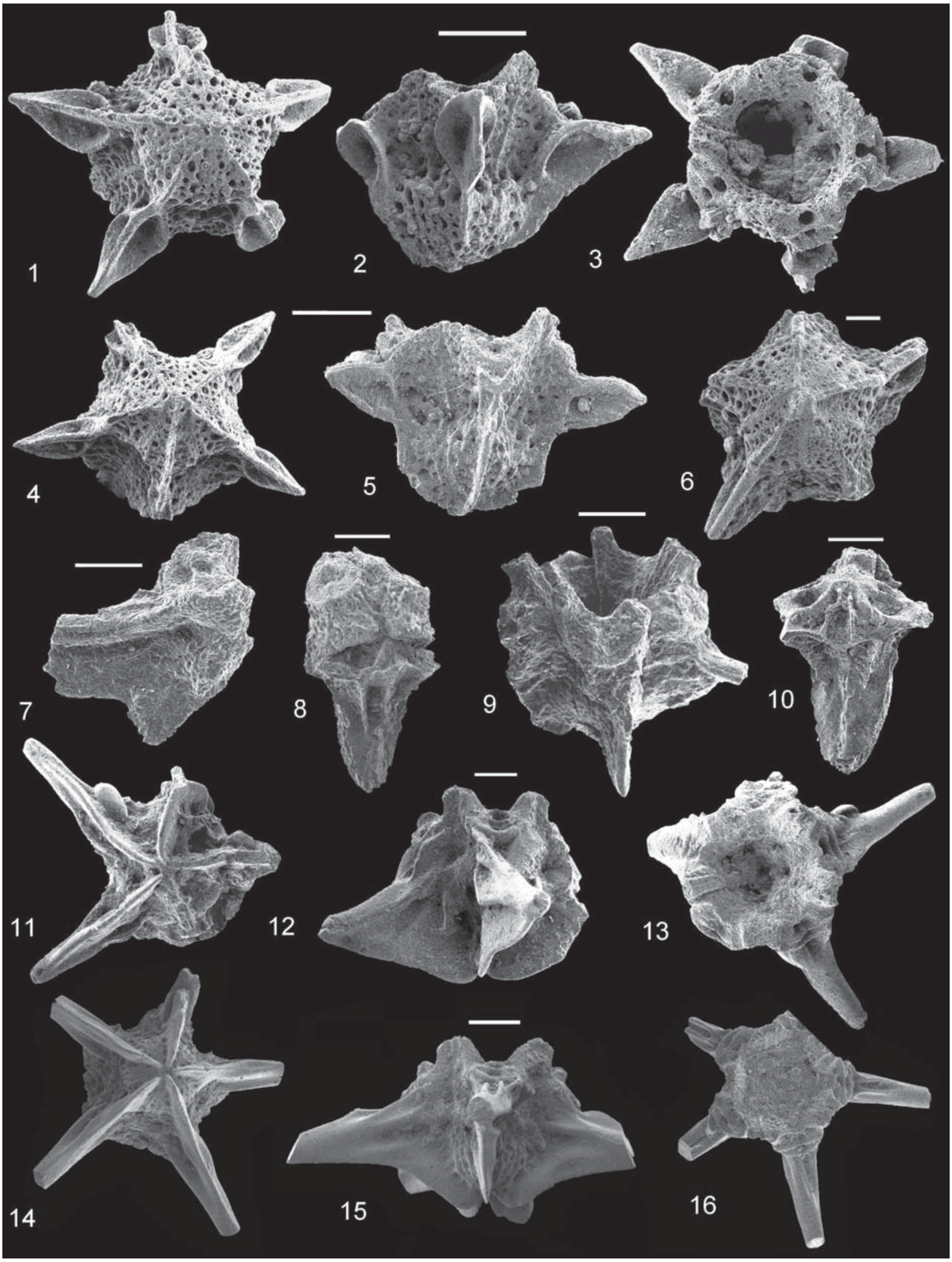
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PLATE 12

1-12 – *Roveacrinus gladius* sp. nov., cups and fragmentary cups. 1 – holotype cup in lateral view (NHMUK PI EE 17465); 2, 3, 4, 7 – paratype cups in lateral view (NHMUK PI EE 17466–17469); 5, 6, 8, 11 – fragmentary cups to show bladed radial process which bears coarse striations adjacent to attachment (NHMUK PI EE 17470–17473); 9 – isolated radial plate (NHMUK PI EE 17474); 10 – cup in aboral view (NHMUK PI EE 17475); 11 – enlarged view of cup also illustrated in Pl. 14, Fig. 1, in which the aboral portion is broken away, showing basal plates (with denser stereom) (NHMUK PI EE 17476).

All specimens are from the lower Cenomanian Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA0 (310 m in Text-fig. 3).

Scale bars equal 0.1 mm (12), 0.2 mm (3, 4, 8, 9) and 0.5 mm (1, 2, 5-7, 10, 11)

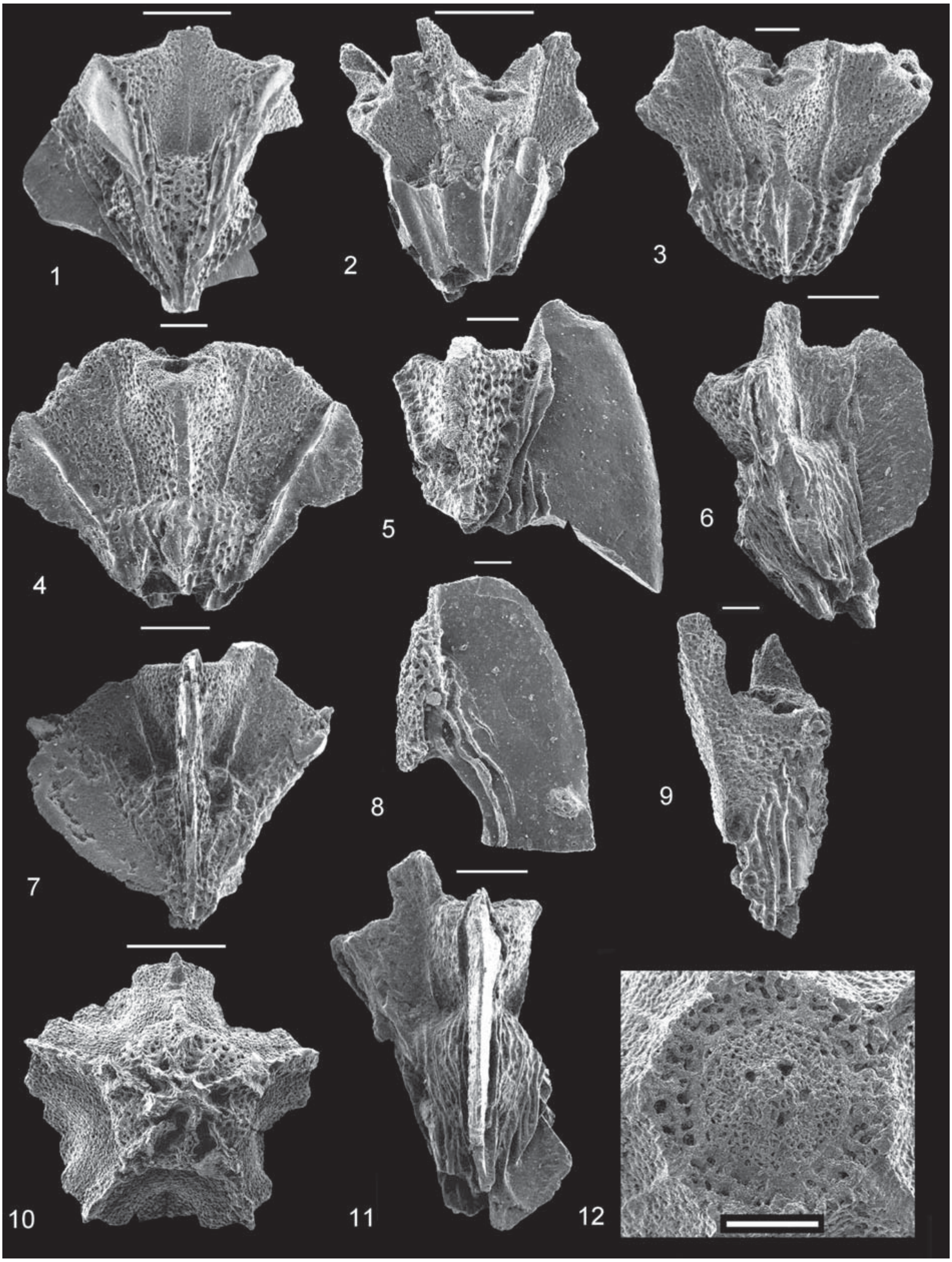
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PLATE 13

1-14 – *Roveacrinus gladius* sp. nov. 1 – brachial IIBr2 (NHMUK PI EE 17477); 2, 12, 13 – axillary IBr2, external views (NHMUK PI EE 17478–17480); 3 – IBr2 (NHMUK PI EE 17482); 4, 5 – IIBr1, internal (4) and external (5) views (NHMUK PI EE 17483, 17484); 6, 9-11, 14 – cups and fragmentary cups; 6 – broad cup in lateral view (NHMUK PI EE 17486); 9 – cup in adoral view (NHMUK PI EE 17487); 10 – cup in lateral view (NHMUK PI EE 17488); 11, 14 – cup fragments in lateral views to show bladed radials (NHMUK PI EE 17489, 17490); 7 – distal brachial (NHMUK PI EE 17485); 8 – internal view (NHMUK PI EE 17481).

Figures 1-5, 7-14 are from the lower Cenomanian Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA0 (310 m in Text-fig. 3). Figure 6 is from the middle Cenomanian Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TAN25 (420.5 m in Text-fig. 4).

Scale bars equal 0.2 mm (4-7, 9, 11, 14) and 0.5 mm (1-3, 8, 10, 12, 13)

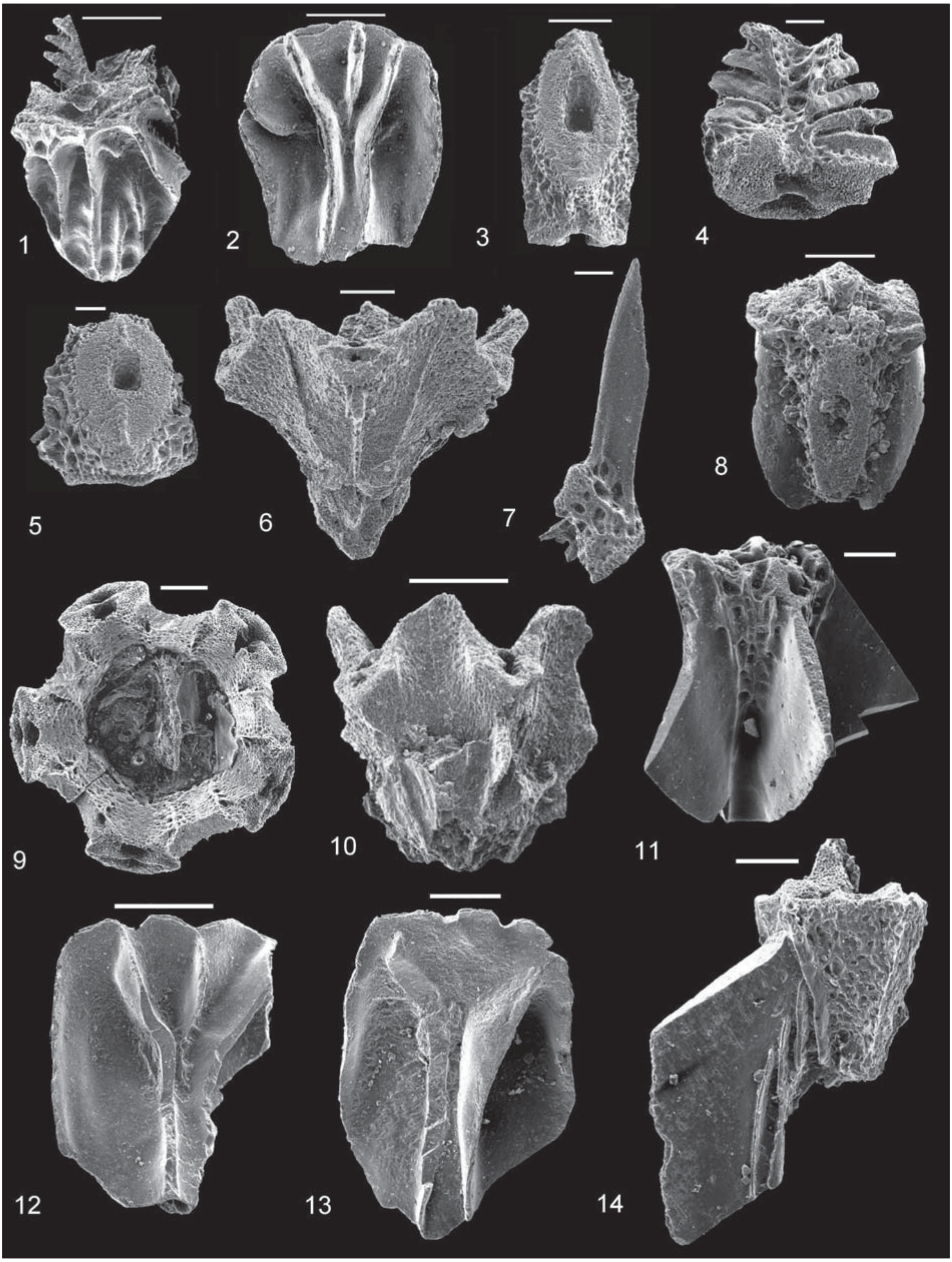
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PLATE 14

1, 5 – *Roveacrinus gladius* sp. nov. 1 – cup in which the aboral portion is broken away, showing basal plates, also illustrated (enlarged) in Pl. 12, Fig. 12 (NHMUK PI EE 17476); 5 – broken radial plate (NHMUK PI EE 17491).

2, 3 – *Roveacrinus falcifer* Gale, 2019, cup in lateral views (NHMUK PI EE 17492).

4, 6, 7, 11, 12 – *Drepanocrinus wardorum* sp. nov. 4, 6 – IBr2 in external view (NHMUK PI EE 17493, 17494); 7 – IIBr2 in external view (NHMUK PI EE 17495); 11, 12 – paratype cup in aboral and lateral views, respectively (NHMUK PI EE 17496).

8 – *Drepanocrinus geinitzi* (Schneider, 1989), IBr2 (NHMUK PI EE 17498).

9 – *Roveacrinus* sp., cup in lateral view (NHMUK PI EE 17499).

10 – *Roveacrinus* sp. nov. IBr2 in external view (NHMUK PI EE 17500).

13 – *Drepanocrinus* sp., cup in lateral view (NHMUK PI EE 17497).

Figure 1 is from the lower Cenomanian Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA0 (310 m in Text-fig. 3). Figures 2, 3 are from the middle Turonian, roadcut north of Taghazout, sample TAG5A (Text-fig. 4). Figures 4, 6, 7, 9, 11, 12 are from the middle Cenomanian, *Cunningtoceras inerme* Zone, Fahdene Formation, sample T6/18, Djebel Mhrila. Figure 5 is from the lower Cenomanian, Fahdene Formation, sample T6/16 (Text-fig. 10), Djebel Mhrila, central Tunisia. Figure 8 is from the middle Cenomanian, Fahdene Formation, sample T6/19, Djebel Mhrila. Figure 10 is from the upper Turonian *Hemitissotia morreni* Zone, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senam, Tunisia, level of mass occurrence of *Hemiaster* (Chancellor *et al.* 1994). Figure 13 is from the middle Cenomanian Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TAN25 (420.5 m in Text-fig. 4).

Scale bars equal 0.5 mm (2, 3) and 0.2 mm (all others)

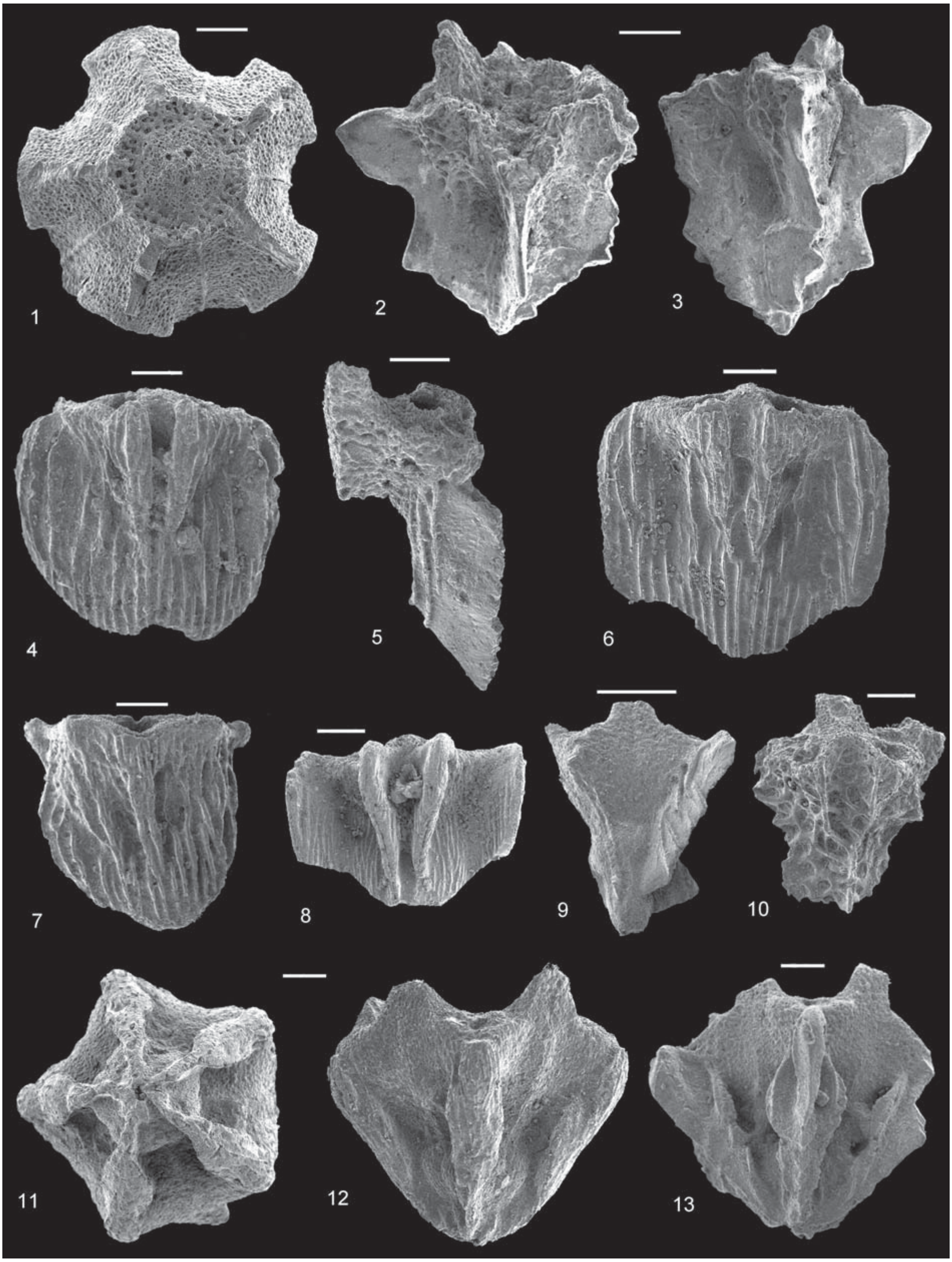
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PLATE 15

1-9 – *Drepanocrinus wardorum* sp. nov. 1, 5, 9 – holotype cup in lateral, aboral and adoral views, respectively (NHMUK PI EE 17501); 2, 4, 8 – IIBr2 in external view (NHMUK PI EE 17502–17504); 3 – isolated radial plate (NHMUK PI EE 17505); 6, 7 – IIBr2 (NHMUK PI EE 17506, 17507).

10-19 – *Drepanocrinus geinitzi* (Schneider, 1989). 10, 13 – fragmentary cup (NHMUK PI EE 17508); 11, 12 – isolated radial (NHMUK PI EE 17509); 14 – IIBr2 (NHMUK PI EE 17510); 15-19 – IBr2, axillary primibrachials (NHMUK PI EE 17511–17515).

Figures 1-9 are from the middle Cenomanian, Aït Lamine Formation, Abouda Plage roadcut, sample TAN 25 (420.5 m in Text-fig. 4). Figures 10-19 are from the upper Cenomanian, Aït Lamine Formation, Taghazout Plage, Morocco, sample AGN3 (458.5 m in Text-fig. 4).

Scale bars equal 0.2 mm (2-4, 6-8, 10-19) and 0.5 mm (1, 5, 9)

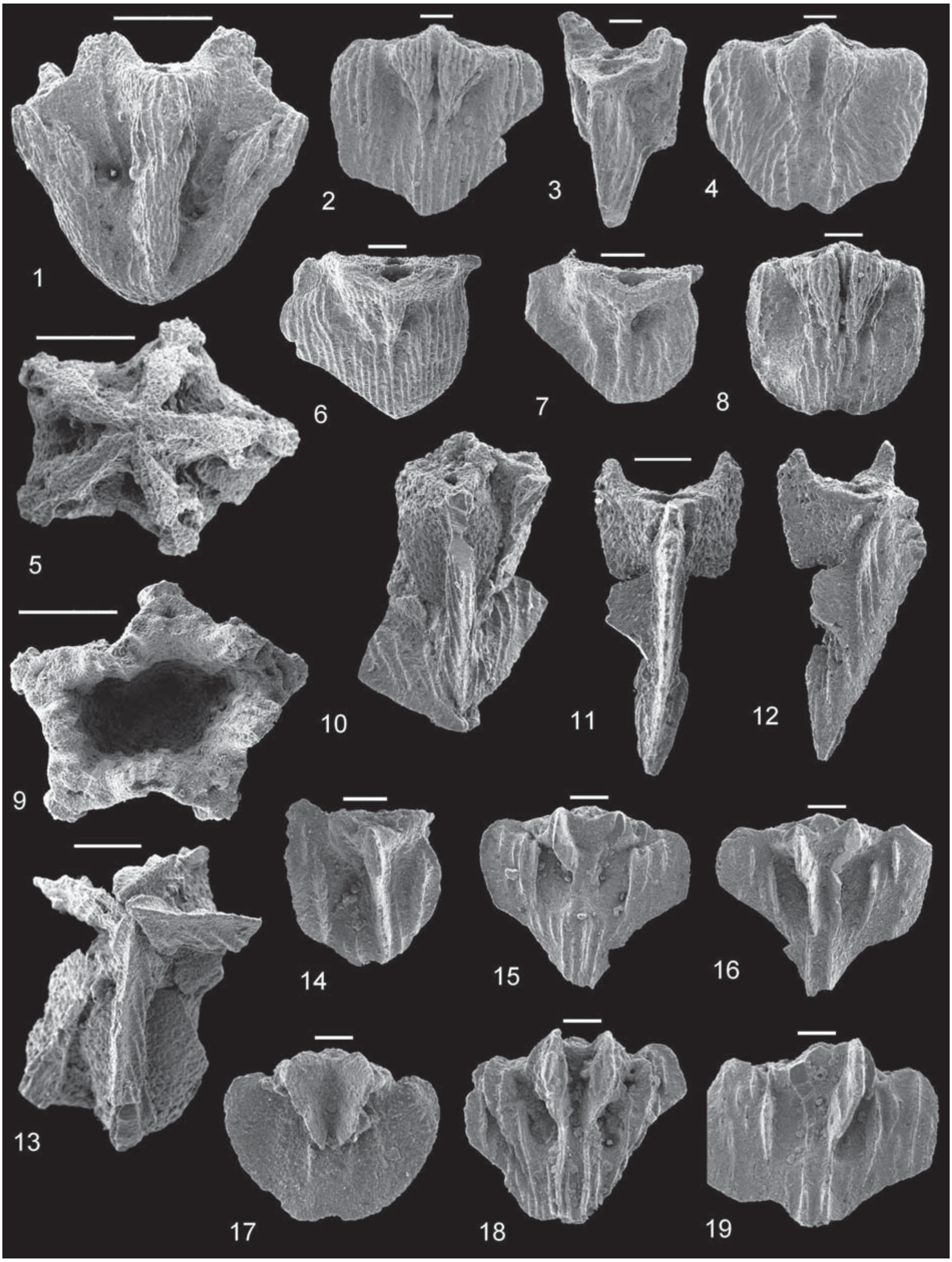
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PLATE 16

1-8, 12 – *Drepanocrinus striatulus* Gale, 2019. 1-3 – cups in lateral view; 3 has IBr1 attached (NHMUK PI EE 17516–17518); 4-6 – fragmentary IBr2 (NHMUK PI EE 17519–17521); 7 – cup, the original of Gale (2019, pl. 24, fig. 3; NHMUK PI EE 16901); 8, 12 – IBr2 in external view; 8 – original of Gale (2019, pl. 24, fig. 10; NHMUK PI EE 16908); 12 – NHMUK PI EE 17522.

9-11, 14, 15 – *Drepanocrinus geinitzi* (Schneider, 1989). 9-12, 15 – IBr2 (NHMUK PI EE 17523–17527); 14 – IIBr2 (NHMUK PI EE 17528).

13 – *Roveacrinus* sp., IBr1 (NHMUK PI EE 17529).

16, 17 – *Drepanocrinus wardorum* sp. nov., IBr2 (NHMUK PI EE 17530, 17531).

18 – *Drepanocrinus striatulus* forma *cuspidatus* Gale, 2019, holotype, the original of Gale (2019, pl. 22, fig. 1; NHMUK PI EE 16880).

Figures 1-6 are from the middle Turonian, sample TAG4, roadcutting north of Taghazout, Morocco (Text-fig. 4). Figures 7, 8, 12 are from the middle Turonian, New Pit Formation, *Terebratulina lata* Zone, Dover, Kent, United Kingdom. Figures 9-15 are from the upper Cenomanian, Aït Lamine Formation, Taghazout Plage, Morocco, sample AGN3 (Text-fig. 4). Figures 16, 17 are from the lower Cenomanian, Aït Lamine Formation, Abouda Plage roadcut, sample TA0 (310 m in Text-fig. 4). Figure 18 is from the middle Turonian, New Pit Formation, *Terebratulina lata* Zone, Lydden Spout path, near Dover, United Kingdom.

Scale bars equal 0.2 mm (9-11, 13-17) and 0.5 mm (1-8, 12, 18)

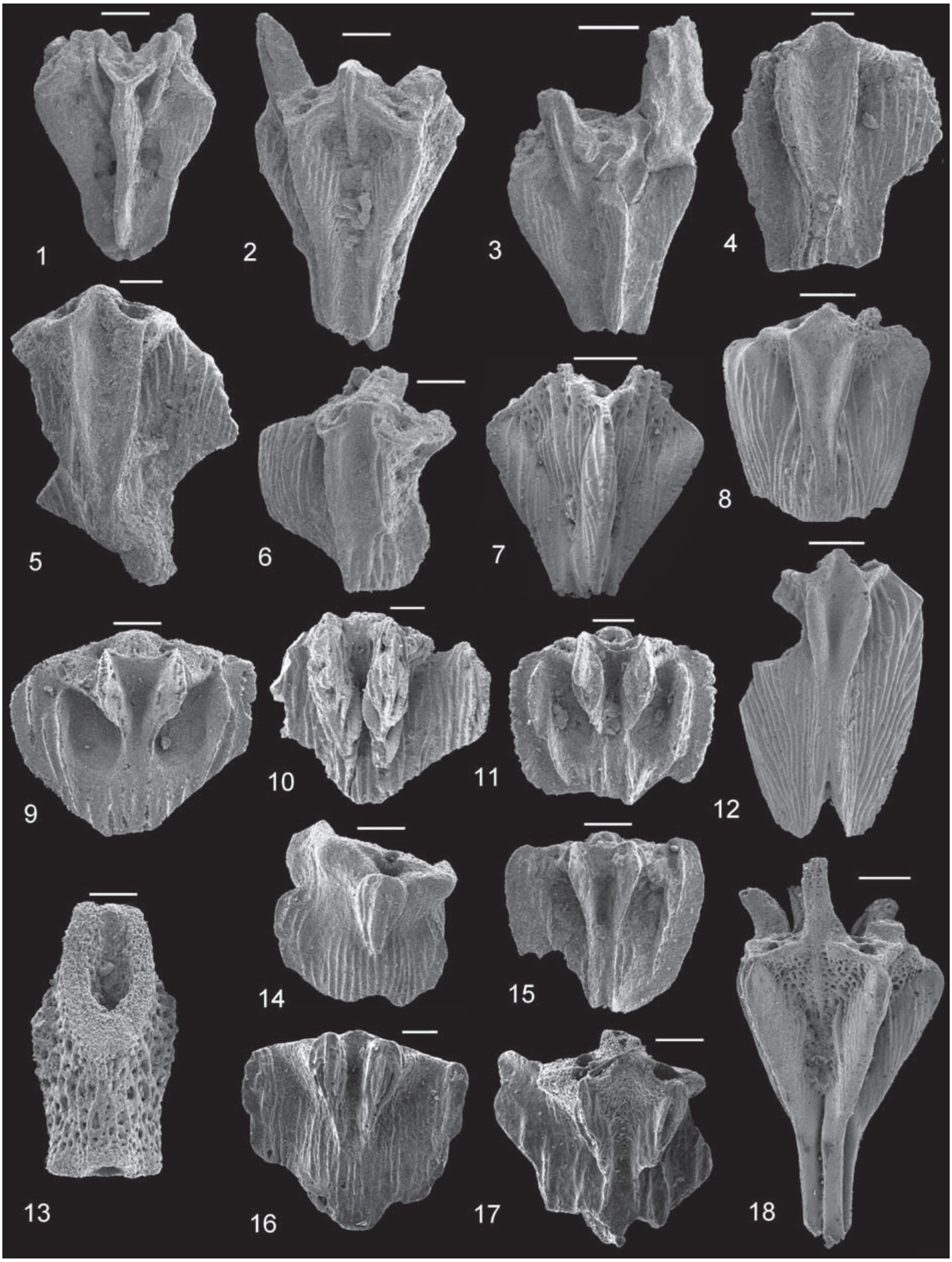
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PLATE 17

1-9 – *Drepanocrinus westphalicus* (Sieverts, 1932). 1, 2, 5, 6 – axillary brachials IBr2; 1, 2 – (NHMUK PI EE 17532, 17533); 5, 6 – the originals of Gale (2019, pl. 16, figs 6, 14; NHMUK PI 16830a, 16841a); 3, 4, 7, 8 – fragmentary cups (NHMUK PI EE 17534–17537); 9 – cup, the original of Gale (2019, pl.16, fig. 4; NHMUK PI EE 16830).

10-17 – *Drepanocrinus sessilis* Jækel, 1918. 10, 11 – aboral portions of cups; 10 – NHMUK PI EE 17538; 11 – the original of Gale (2019, pl. 15, fig. 3; NHMUK PI EE 16814); 12-14 – axillary primibrachials IBr2; 12, 13 – NHMUK PI EE 17539, 17540; 14 – the original of Gale (2019, pl. 15, fig. 15; NHMUK PI EE 16827); 15 – IIBr2 (NHMUK PI EE 17541); 16, 17 – isolated radial plates; 16 – specimen NHMUK PI EE 17533a; 17 – the original of Gale (2019, pl. 15, fig. 12; NHMUK PI EE 16824).

Figures 1-4 are from the Annaba Formation, lower Turonian, *Thomasites rollandi* Zone, Sif el Tella, Djebel Mhrila, central Tunisia, sample M12 (Text-fig. 10). Figure 9 is from the lower Turonian Holywell Formation, *Fagesia catinus* Zone, Eastbourne, United Kindgom. Figures 10, 12, 13, 15, 16 are from the Annaba Formation, lower Turonian, *Pseudoaspidoceras flexuosum* Zone, same locality, sample M11 (Text-fig. 10). Figures 11, 14, 17 are from the lower Turonian Holywell Formation, *Watinoceras devonense* Zone, Eastbourne, United Kindgom.

Scale bars equal 0.5 mm (9, 15) and 0.2 mm (all others)

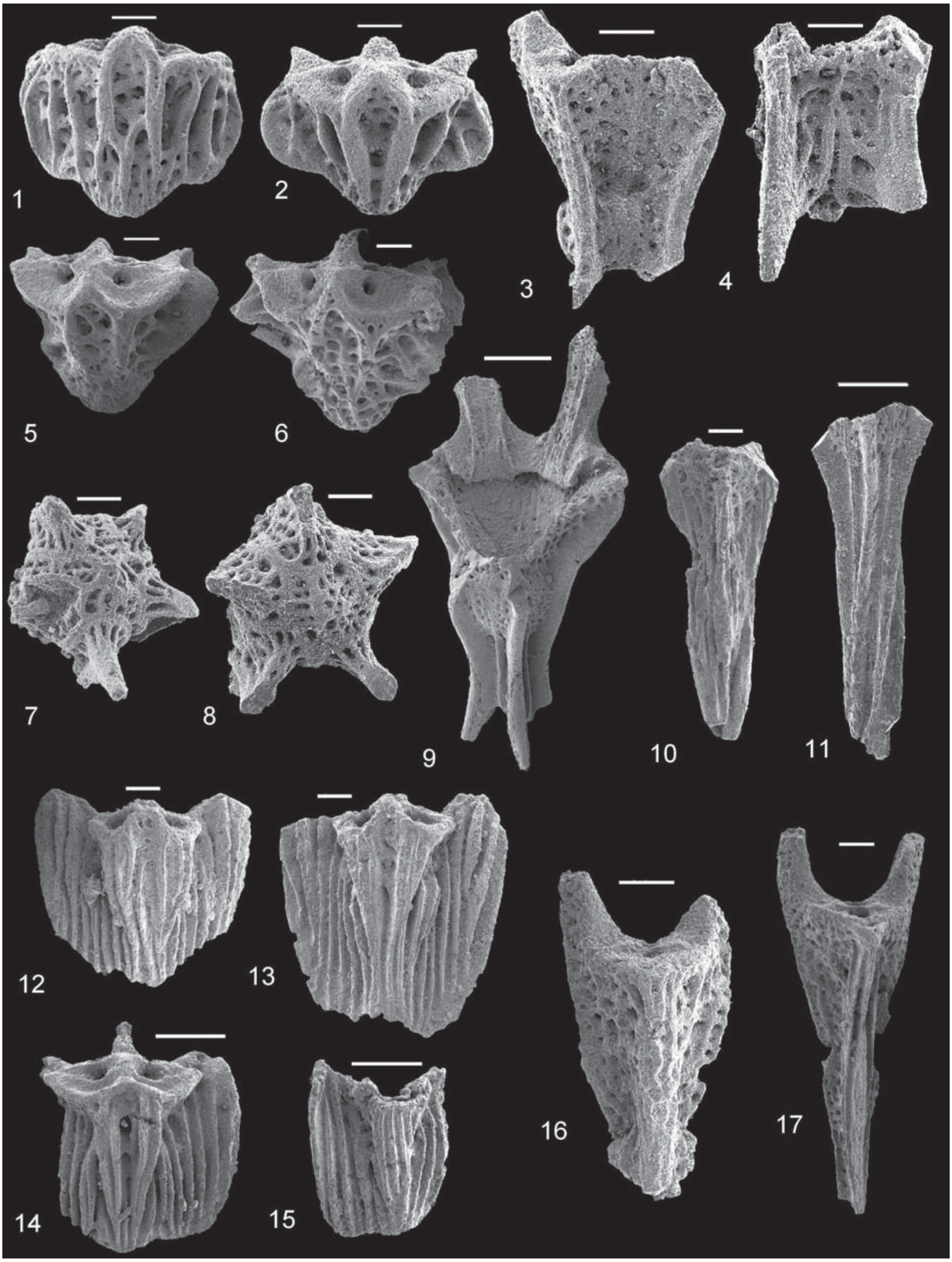
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PLATE 18

1-3, 5, 6, 9, 10 – *Drepanocrinus marocensis* Gale, 2019. 1 – cup, the original of Gale (2019, pl. 20, fig. 1; NHMUK PI EE 16886); 2 – IIBr2, the original of Gale (2019, pl. 20, fig. 10; NHMUK PI EE 16895); 3, 5, 6 – axillary IBr2; 3 – the original of Gale (2019, pl. 19, fig. 4; NHMUK PI EE 16876); 5, 6 – holotype, the original of Gale (2019, pl. 20, figs 4a, 4b; NHMUK PI EE 16889); 9, 10 – IIBr4, external (9) and internal (10), the original of Gale (2019, pl. 19, figs 9a and 9b; NHMUK PI EE 16881). Note synostosial IIBr3-4 articulation.

4, 7 – *Roveacrinus* cf. *labyrinthus* Gale, 2019. 4 – IBr2, the original of Gale (2019, pl. 19, fig. 13; NHMUK PI 16885); 7 – cup in lateral view (NHMUK PI EE 17542).

8, 11, 12 – *Lebenharticrinus canaliculatus* Žítt, Löser, Nekvasilová, Hradecká and Svabenická, 2019. 8, 11 – broken IBr2 (NHMUK PI EE 17543, 17544, respectively); 12 – cup in lateral view (NHMUK PI EE 17545).

All specimens from the lower Turonian, *Mammites nodosoides* Zone, the Palmeria, Asfla (15 m on log of Villalobos-Segura *et al*. 2019, fig. 1), near Goulmima, Morocco.

Scale bars equal 0.2 mm (2, 4, 8, 11, 12) and 0.5 mm (1, 3, 4-7, 9, 10)

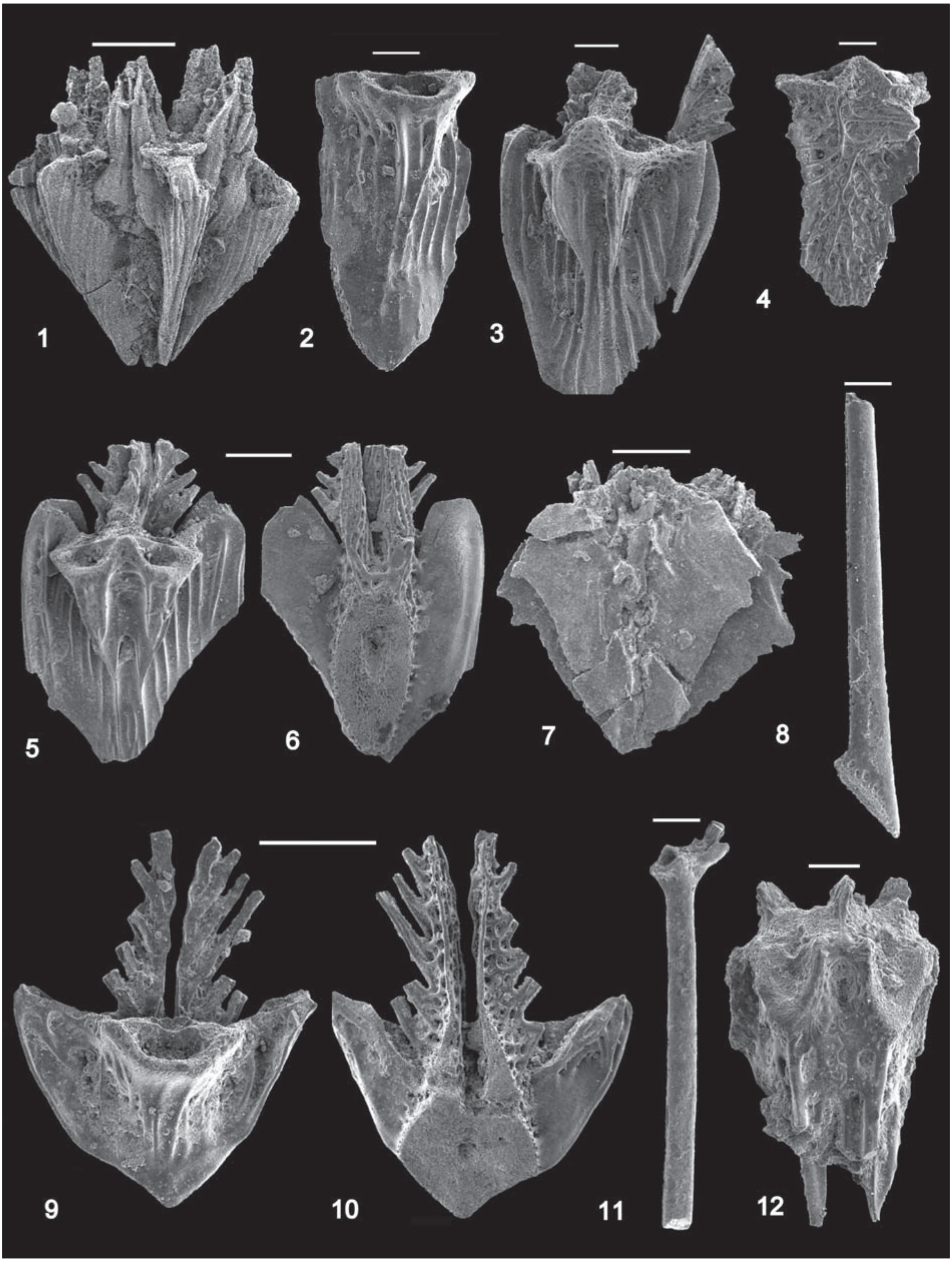
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PLATE 19

1-6, 8 – *Drepanocrinus communis* forma *dubrisiensis* Gale, 2019. 1, 2, 4 – axillary IBr2 (NHMUK PI EE 17546–17548); 3, 6 – axillary IBr2, the originals of Gale (2019, pl. 25, figs 7, 11; NHMUK PI 16916, 16912); 5, 8 – IIBr2; 5 – NHMUK PI EE 17549; 8 – the original of Gale (2019, pl. 25, fig. 9; NHMUK PI 16914).

7, 9, 10-13 – *Hessicrinus thoracifer* Gale, 2019. 7, 10 – cup in aboral and lateral views, respectively, the original of Gale (2019, pl. 45, figs 4a, b; NHMUK PI EE 16787); 9 – IBr2 (NHMUK PI EE 17551); 11 – fragmentary cup (NHMUK PI EE 17550); 12, 13 – secundibrachials (NHMUK PI EE 17552, 17553).

Figures 1, 2, 4, 5, 7, 9-13 are from the upper Turonian *Hemitissotia morreni* Zone, Djebel Ben Adjeroud, 9 km southeast of Kalaat-es-Senam, Tunisia, level of mass occurrence of *Hemiaster* (Chancellor *et al*. 1994). Figures 3, 6, 8 are from the upper Turonian Lewes Chalk Formation, beneath the Navigation Hardground, Langdon Stairs, Dover, United Kingdom.

Scale bars equal 0.2 mm (1-3, 5, 8, 9, 11) and 0.5 mm (4, 6, 7, 10, 12, 13)

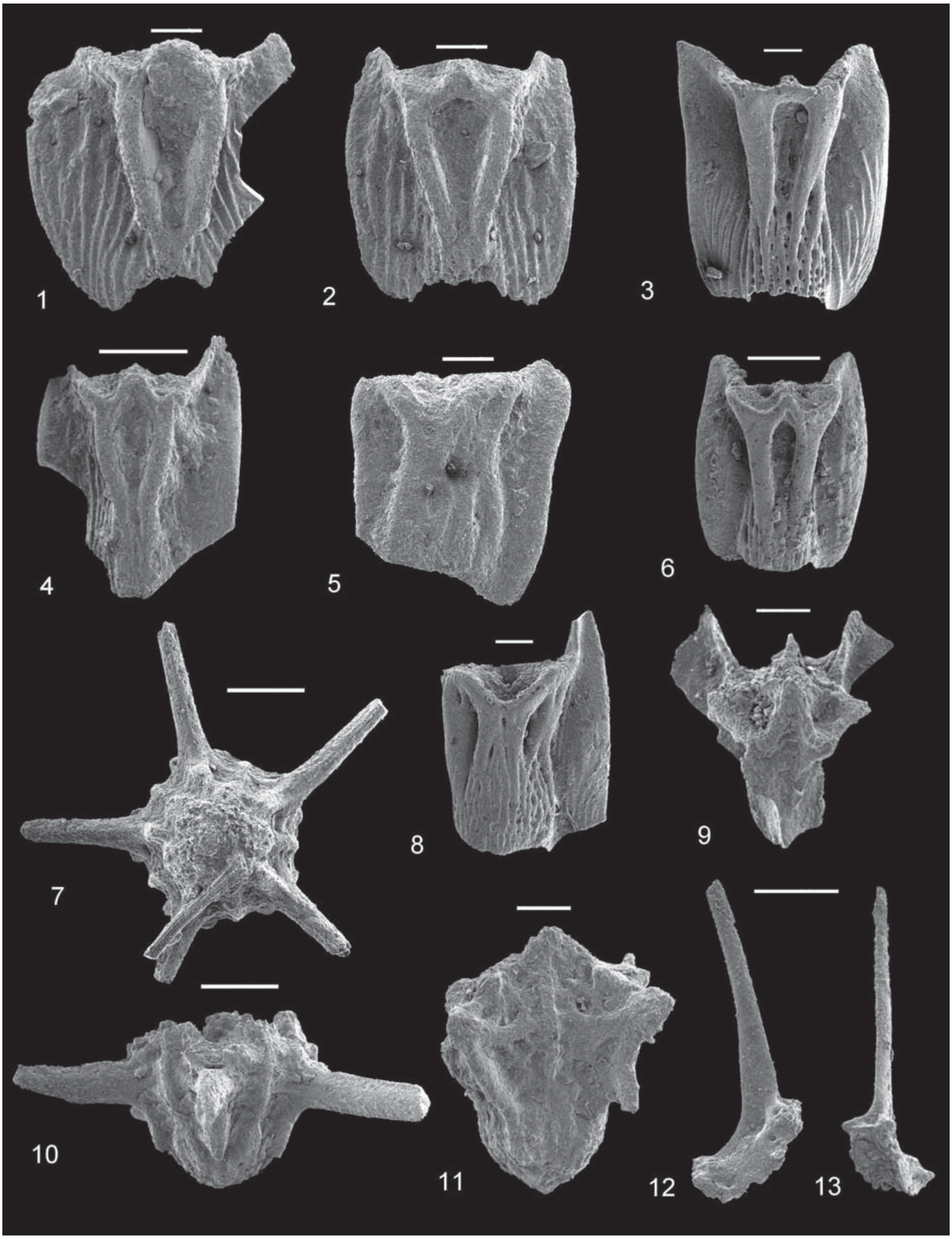
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PLATE 20

1 – *Poecilocrinus dispandus* forma *elongatus* Peck, 1943. Cup broken longitudinally (NHMUK PI EE 17554), to show internal structure; note **bc**, basal cavity and **rc**, radial cavity, separated by shelf of basal plates; the radial flanges have fused to form a cylindrical outer wall (**ow**) around the cup, separated from the inner wall by tubes which exit around the aboral pole (Text-fig. 12A-E).

2-9 – *Poecilocrinus dispandus* Peck, 1943. 2 – broken cup to show internal structure (NHMUK PI EE 17555); 3-9 – ontogenetic sequence to show morphological changes with growth; 3 and 4 have simple conical cups (NHMUK PI EE17576, 17577), but with increasing size radial flanges, aborally concave, develop (5 and 6; NHMUK PI EE 17556, 17557); eventually, these become spoon-shaped (7; NHMUK PI EE 17558), then fuse to form a peripheral shelf (8, 9; NHMUK PI EE 17559, 17560).

All specimens are from the Weno Formation, upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone. Figures 1-5 are from a roadcut in Claiburn, Johnson County, Texas, USA. Figures 7-9 are from a drainage ditch off Heritage Trace Parkway, Fort Worth, Tarrant County, Texas, USA.

Scale bars equal 0.2 mm (2) and 0.5 mm (all others)

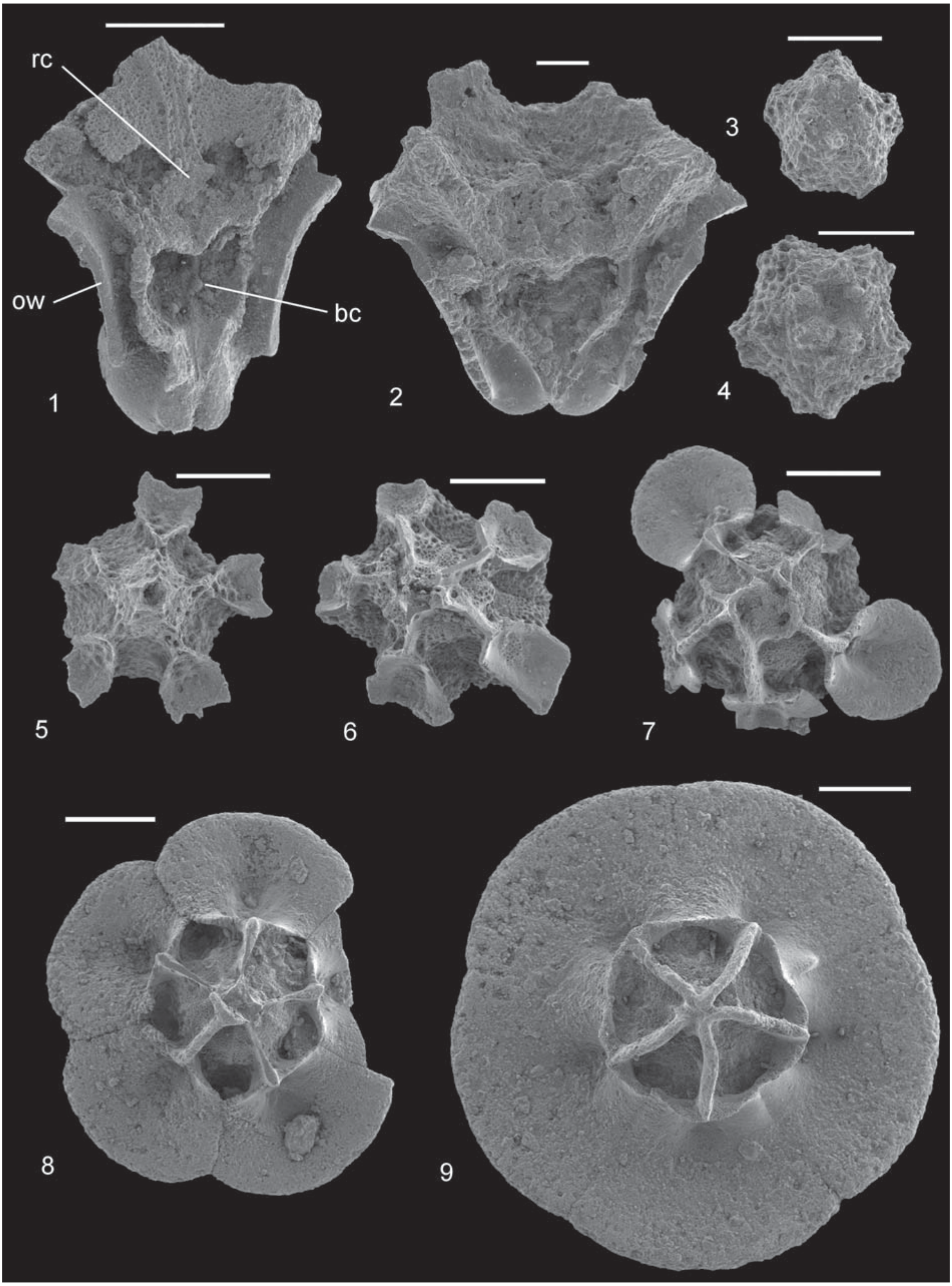
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PLATE 21

1-6 – *Poecilocrinus dispandus* forma *explicatus* Peck, 1943. 1-3 – paratype cup in aboral, lateral and adoral views, respectively (USNM 128348a); 4-6 – cups in lateral view (NHMUK PI EE 17561–17563).

7-9, 12 – *Poecilocrinus dispandus* Peck, 1943. 7-9 – paratype cup in lateral, adoral and aboral views, respectively (USNM 128344a); 12 – fragmentary cup in aboral view (NHMUK PI EE 17564).

10, 11 – *Poecilocrinus dispandus* forma *elongatus* Peck, 1943. 10 – paratype cup in lateral view (USNM 128347a); 11 – cup in lateral view (NHMUK PI EE 17565).

Figures 1-3 are from the upper Albian, Main Street Limestone, southeast of Fort Worth, Tarrant County, Texas, USA. Figures 4-6 are from the upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, Aït Lamine Formation Abouda Plage roadcut, sample TA21 (12.7 m above base of formation; Text-fig. 3). Figures 7-9 are from the upper Albian, *Pervinquieria* (*Subschloenbachia*) *rostrata* Zone, Weno Formation, Sycamore Creek, Fort Worth, Tarrant County, Texas, USA. Figure 10 is from the upper Albian, Weno Formation, Fort Worth, Tarrant County, Texas, USA. Figure 11 is from the upper Albian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample ABX (26 m in Text-fig. 3). Figure 12 is from the upper Albian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA22 (38 m in Text-fig. 3).

Scale bars equal 0.5 mm (1-6, 10-12) and 1 mm (7-9)

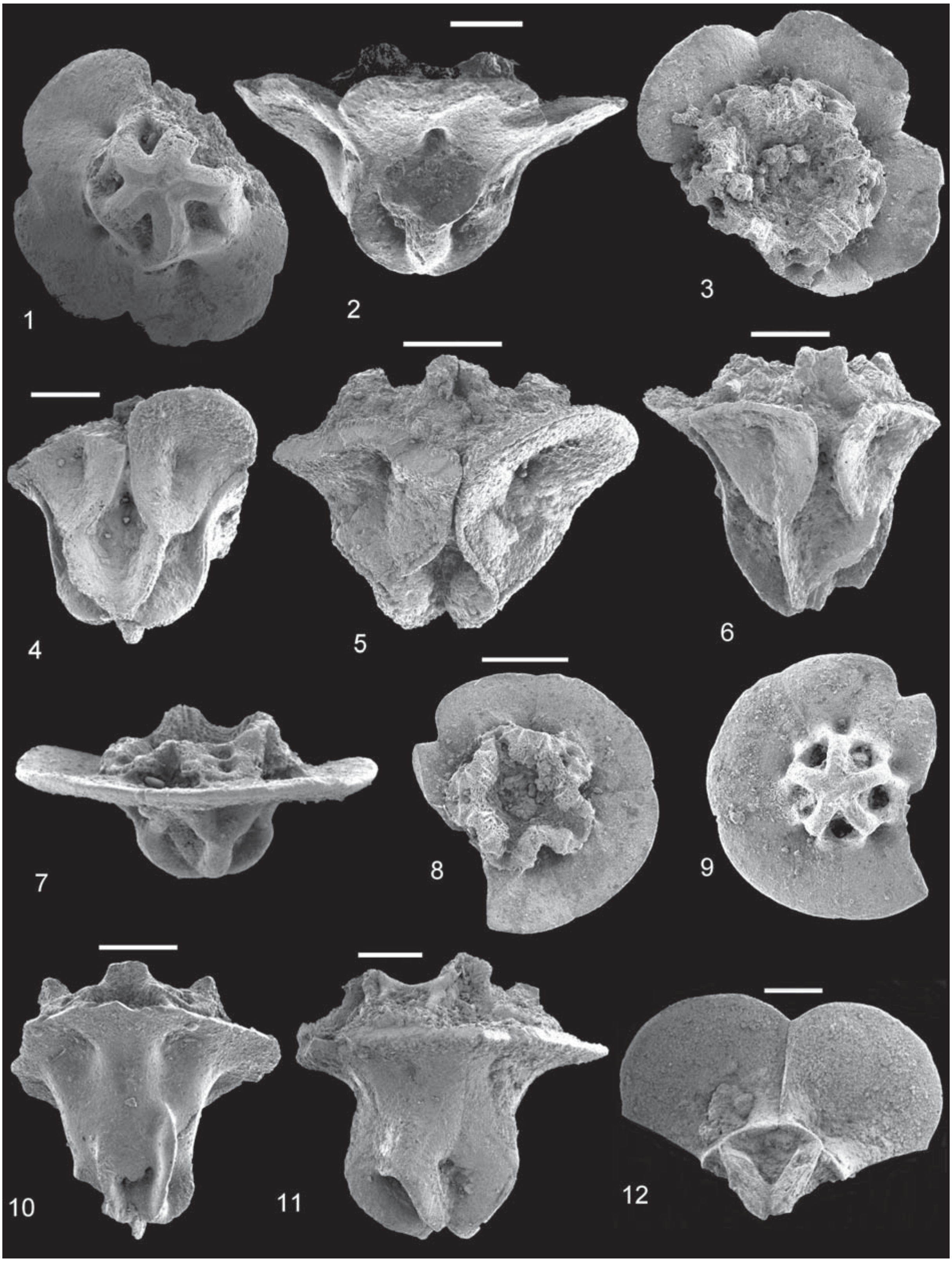
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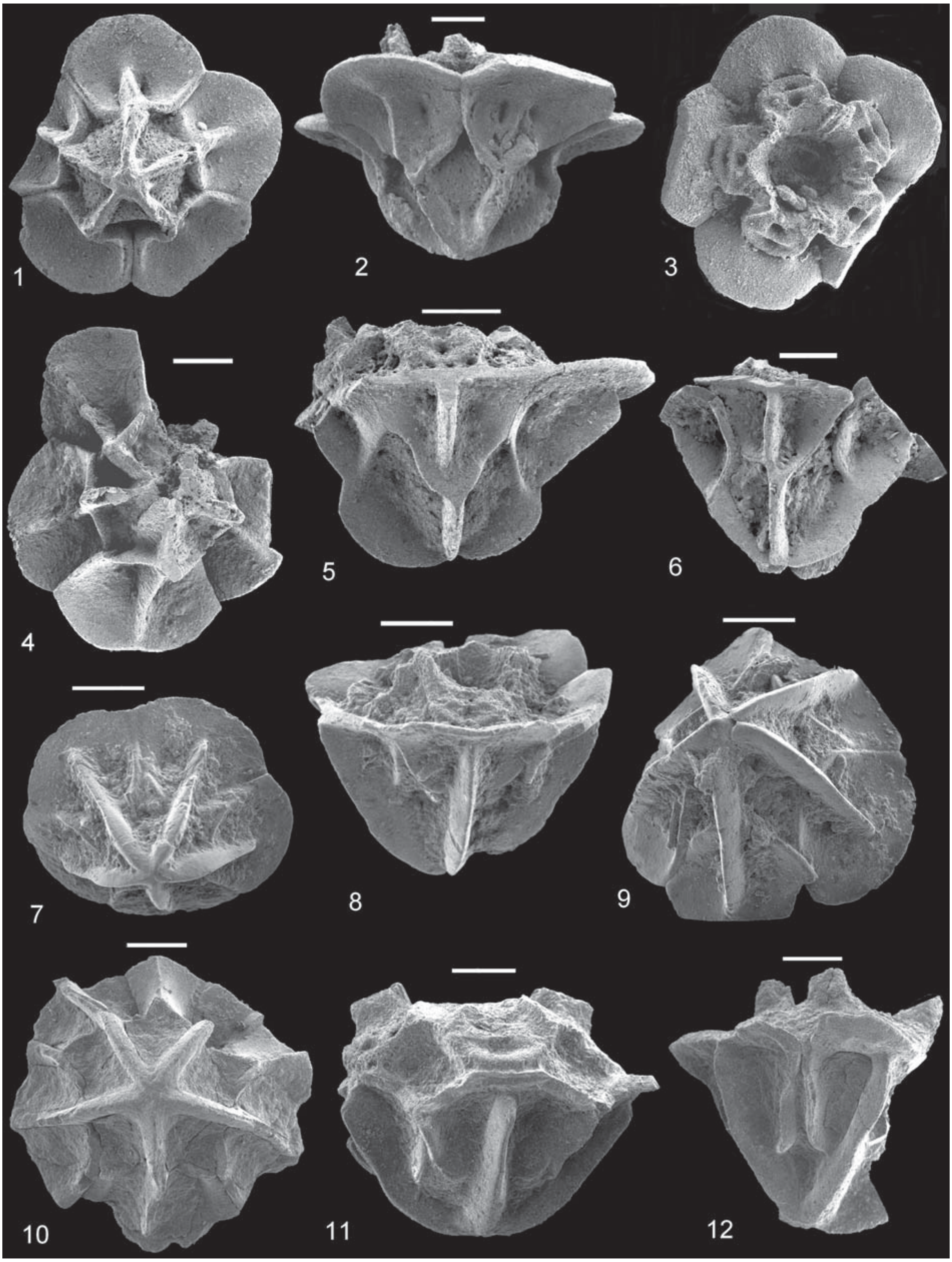
PLATE 22

1-6 – *Poecilocrinus molestus* Peck, 1943. 1-3 – cup in aboral, lateral and adoral views, respectively (NHMUK PI EE 17566); 4 – cup in aboral view (NHMUK PI EE 17567); 5, 6 – fragmentary cups in lateral view (NHMUK PI EE 17568, 17569).

7-12 – *Poecilocrinus signatus* (Peck, 1943). 7-9 – paratype cups in aboral and lateral views (USNM 140175); 10-12 – cups in aboral and lateral views (NHMUK PI EE 17570, 17571).

Figures 1-3 are from the upper Albian, Main Street Limestone Formation, Sunset Oak Drive, Fort Worth, Texas, USA, sample SD4 (Text-fig. 11). Figures 7-9 are from the lower Cenomanian Grayson Formation, Denton County, Texas, USA. Figures 4, 6 are from the upper Albian, Aït Lamine Formation Abouda Plage roadcut, Morocco, sample ABX (26 m in Text-fig. 3). Figure 5 is from the upper Albian, Aït Lamine Formation, Abouda Plage roadcut, Morocco, sample TA22 (38 m in Text-fig. 3). Figures 10-12 are from the lower Cenomanian, Aït Lamine Formation, Oued Abouda, Morocco, adjacent to N1 road, sample Q2 (75 m in Text-fig. 3).

Scale bars equal 0.5 mm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