

NEW CLADID CRINOIDS FROM THE LATE ORDOVICIAN OF GIRVAN, SCOTLAND

by STEPHEN K. DONOVAN

ABSTRACT. Two new species of cladid crinoids are described from the Starfish Bed (Ashgill, late Rawtheyan) at Threave Glen, near Girvan, southwest Scotland; this bed has yielded the most diverse crinoid fauna of any British Ordovician locality. *Euspirocrinus girvanensis* sp. nov. is based on a unique internal mould of the dorsal cup and anal series. The five infrabasal plates form a low circlet, the anal X plate is infolded and the short anal series comprises numerous small polygonal plates, *Dendrocrinus collapsus* sp. nov. is known from five specimens, all external moulds. The anal sac and dorsal cup of this species bear a distinctive ribbed sculpture.

THE Ashgill Starfish Bed of Threave Glen, near Girvan, Strathclyde, Scotland, is the most important crinoid locality in the British Ordovician. In an Ordovician crinoid fauna comprising only about fifty nominal species, a third are known only from this locality (Donovan 1989a). The species that have been described from this horizon are generally well-preserved crowns which retain the proximal column. Preservation is always as moulds. Exceptionally well-preserved echinoderms and calcichordates appear to be limited to a single horizon in Threave Glen (Harper 1982a; 1982b), representing catastrophic entombment of a life assemblage, although contrasting interpretations of the environment of deposition were given in Goldring and Stephenson (1972) and Ingham (1978). Ramsbottom (1961) published the first descriptions of Threave Glen crinoids, recognizing eleven species assigned to eight genera. To this total Brower (1974) added a second species of *Xenocrinus* and Donovan (1989b) described three new species of disparid (the known crinoid fauna is summarized in Table 1). Two further species of cladid from Threave Glen, which were discovered in the collections of the Hunterian Museum (HM), Royal Museum of Scotland (RMS) and the Natural History Museum, London (BMNH), are described herein.

Terminology herein is that of Moore *et al.* (1968), Ubaghs (1978) and Webster (1974). The synonymy annotations follow Matthews (1973).

SYSTEMATIC PALAEOLOGY

Class CRINOIDEA Miller, 1821
Order CLADIDA Moore and Laudon, 1943
Suborder CYATHOCRININA Bather, 1899
Superfamily CYATHOCRINITACEA Bassler, 1938
Family EUSPIROCRINIDAE Bather, 1890
Genus EUSPIROCRINUS Angelin, 1878

Type species. By monotypy; *Euspirocrinus spiralis* Angelin, 1878, from the Wenlock of Gotland (see Franzén 1983, p. 10).

Diagnosis. (Modified from Moore *et al.* 1978, p. T583). Attachment by encrusting terminal holdfast. Column holomeric proximally, pentameric more distally. Dorsal cup conical, bowl-shaped. Five (sometimes three?) infrabasals, five basals and five radials present. Radial and BC basal support the C radial; radial and CD basal support the anal X; anal X, radial and C radial support the anal series. Radial facets less than the full width of the plates. Arms branch isotomously and curve inwards. Anal series short.

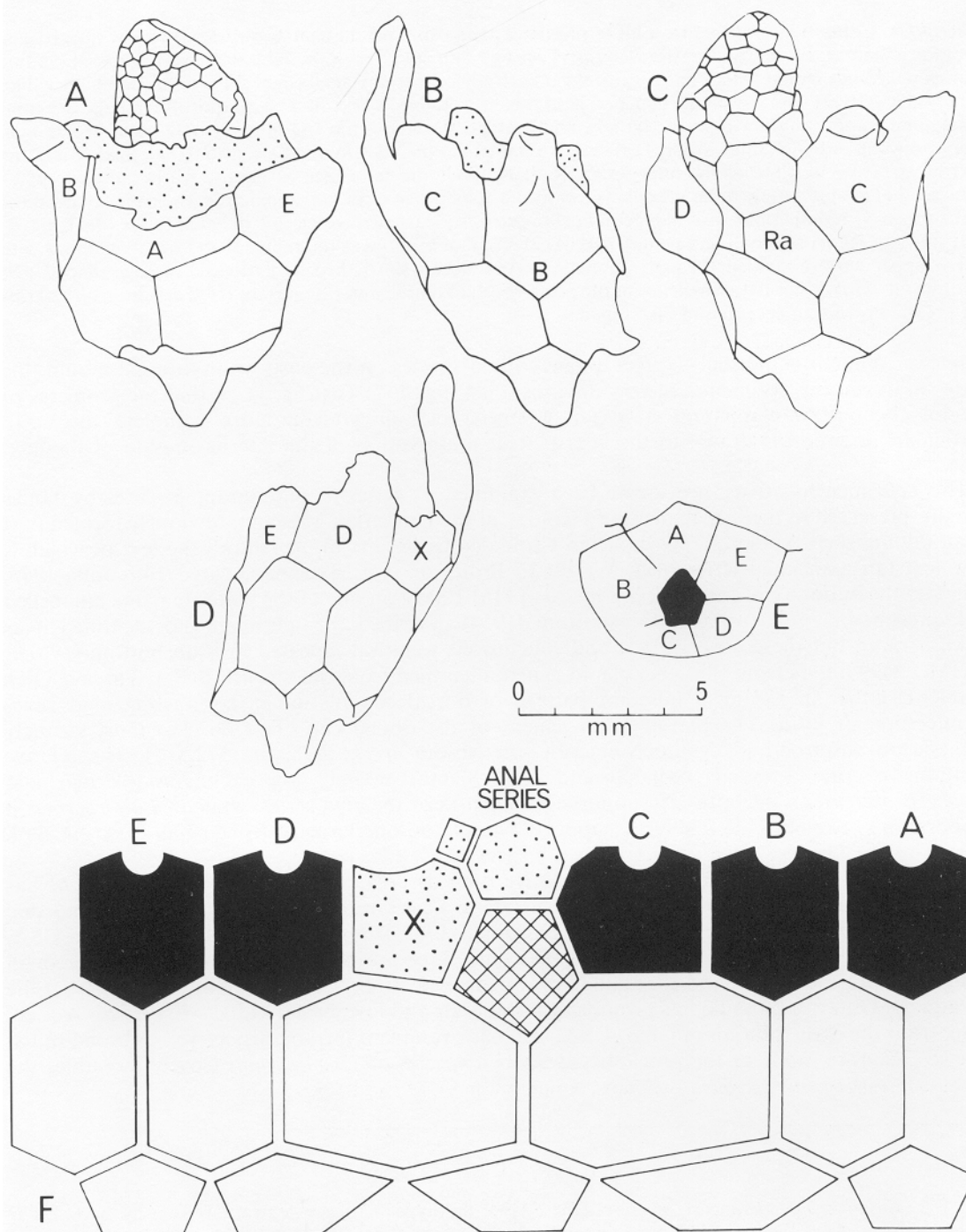
TABLE 1. The crinoid fauna of the Ashgill Starfish Bed, Threave Glen, near Girvan, Scotland.

Order DISPARIDA
Family IOCRINIDAE
<i>Westheadocrinus girvanensis</i> Donovan, 1989b
Family PISOCRINIDAE
<i>Eocicerocrinus sevastopuloi</i> Donovan, 1989b
Family CALCEOCRINIDAE
<i>Anulocrinus thraivensis</i> Ramsbottom, 1961
<i>Cremaocrinus drummuckensis</i> Ramsbottom, 1961
Incertae familiae
<i>Clavicularocrinus scoticus</i> Donovan, 1989b
Order CLADIDA
Family EUSPIROCRINIDAE
<i>Euspirocrinus girvanensis</i> sp. nov.
Family POROCRINIDAE
<i>Porocrinus scoticus</i> Ramsbottom, 1961
Family DENDROCRINIDAE
<i>Dendrocrinus granditubus</i> Ramsbottom, 1961
<i>Dendrocrinus collapsus</i> sp. nov.
Family CUPULOCRINIDAE
<i>Cupulocrinus drummuckensis</i> Kolata, 1975 (= <i>C. gracilis</i> Ramsbottom, 1961, non <i>C. [= Poteriocrinus] gracilis</i> (Hall, 1847))
<i>Cupulocrinus heterobrachialis</i> Ramsbottom, 1961
Order TAXOCRINIDA
Family TAXOCRINIDAE
<i>Protaxocrinus girvanensis</i> Ramsbottom, 1961
Order MONOBATHRIDA
Family XENOCRINIDAE
<i>Xenocrinus multiramus</i> Ramsbottom, 1961
<i>Xenocrinus breviformis</i> Brower, 1974
Family PATELLIOCRINIDAE
<i>Macrostylocrinus cirrifer</i> Ramsbottom, 1961
Order DIPLOBATHRIDA
Family RHODOCRINITIDAE
<i>Diabolocrinus</i> sp.
Incertae familiae
Diplobathrid(?) indet.

Euspirocrinus girvanensis sp. nov.

Plate 1, figs 1–2; Text-fig. 1

v*1954 *Euspirocrinus girvanensis* sp. nov., Ramsbottom, p. 44, pl. 10, fig. 5.*Derivation of name.* After Girvan, the nearest town to the type locality.*Type material, locality and horizon.* A unique holotype, HM E3499, part of the J. L. Begg collection; a slightly deformed internal mould of a dicyclic crinoid cup. From the late Rawtheyan (= early Gamachian in North American terminology) Starfish Bed of Threave Glen, Girvan district, Strathclyde (National Grid Reference NS 250 038).*Diagnosis.* *Euspirocrinus* with low infrabasal cirlet comprising five plates, narrow radial facets, infolded anal X plate and short, broad anal series, including numerous polygonal ossicles.



TEXT-FIG. 1. *Euspirocrinus girvanensis* sp. nov. A-E, HM E3499; holotype; camera lucida drawings of internal mould of the dorsal cup. A, A ray central. B, BC interray central. C, CD interray central. D, D ray central. E, basal view (axial canal of column shaded). Key: A to E, Carpenter rays; Ra, radianal; X, anal X plate. F, schematic plating diagram of the dorsal cup. Infrabasals and basals unshaded; radials black; radial cross-hatched; anal series stippled.

Description. Column unknown, but infill of proximal axial canal pentagonal in outline. Five low infrabasals, forming a flattened base to the dorsal cup (Text-fig. 1E), just visible in lateral view. Infrabasal outline pentagonal to hexagonal with a narrow, infolded base adjacent to the axial canal. Five basals, all higher than infrabasals. AB, DE and EA basals high and hexagonal (Pl. 1, fig. 1; Text-fig. 1D), supporting radials. BC basal heptagonal, supporting the B and C radials, and a radianal plate in the CD interray. CD basal heptagonal, supporting the radianal, anal X and D radial. Radial circlet includes five radials, a radianal, anal X and the next most proximal plate of the anal series. Radials about the same size as basals. All radials, except C, hexagonal (Text-fig. 1B), with an articular facet at the apex of the hexagon, apparently angled away from the oral surface. C radial apparently heptagonal, supporting at least two ossicles of the anal series (Pl. 1, fig. 2; Text-fig. 1C). Radianal small and pentagonal. Anal X about as large as the radianal and hexagonal, but with a free upper surface, folded through about 90°. Anal series short, broad, flattened, lozenge-shaped and multiplated, with rather larger ossicles on the posterior than on the anterior surface (cf. Text-fig. 1A, C). Arms not preserved. Mouth central and ?pentagonal.

Remarks. While it is unusual to erect a new crinoid species on the basis of an internal mould, the plate sutures of this specimen are very obvious (Pl. 1, figs 1–2; Text-fig. 1), so that the geometry of the dorsal cup is more apparent than that of some species known from more ‘complete’ thecae. In particular, attention is drawn to the near-perfect preservation of the internal mould of the anal series.

This specimen has twice previously been examined. A series of photographic plates by James Wright, preserved in the Department of Geology of the Hunterian Museum, obviously formed part of an unpublished typescript, ‘Ordovician Crinoidea from Girvan, Ayrshire’, the text of which is now lost (an associated letter from Wright to Professor A. E. Trueman, dated 14th June 1943, indicates the antiquity of the work). A figure of HM E3499 on one of the plates remains unlabelled and, presumably, unidentified. Ramsbottom (1954) described the specimen and identified it as *Euspirocrinus*, but these observations and conclusions were not repeated in Ramsbottom (1961).

HM E3499 differs from the other cladid genera identified from the Starfish Bed at Threave Glen (Table 1) either in having a different pattern of dorsal cup plating, a contrasting anal series architecture, or both. The plating arrangement of the dorsal cup (Text-fig. 1F) most strongly suggests an euspirocrinid cyathocrinitacean (see Moore *et al.* 1978, fig. 372.3–5). The relative positions of the C radial, radianal and anal X most closely approach *Euspirocrinus* and *Ampheristocrinus*. In the latter, X supports three plates of the anal series, while in *Euspirocrinus* it supports only two. In HM E3499, X supports two plates, one large and one small (Text-fig. 1F), indicating the Threave Glen species to be a species of *Euspirocrinus*.

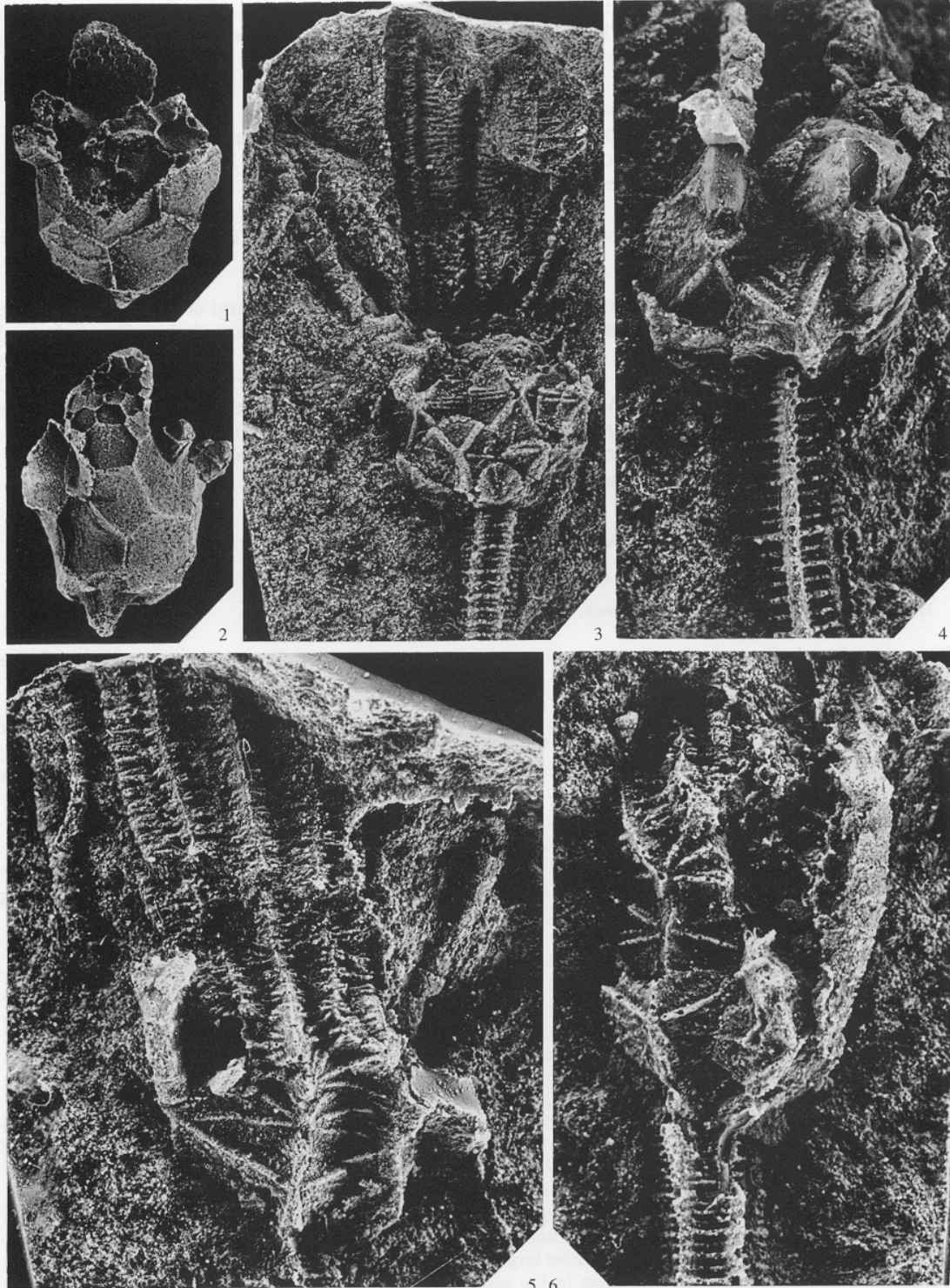
Only four other species of *Euspirocrinus* have been described. The type species, *E. spiralis* has prominent infrabasals that are plainly visible in lateral aspect, radials larger than basals and an anal series incorporating few plates. In *E. cirratus* Strimple, 1963, from the Wenlock of Oklahoma, USA, the infrabasals are apparently fused such that only three are present, the basal plates are small compared with the radials and the radianal is quadrangular. *E. obconicus* Billings, 1885, from the Caradoc of Ontario, Canada, has prominent infrabasals and low, broad radials. *E. heliktos* Ausich, 1986, from the early Silurian of Ohio, USA, also has prominent infrabasals, as well as broad radial facets. Therefore, none of the previously described species of *Euspirocrinus* closely resembles the

EXPLANATION OF PLATE I

Figs 1–2. *Euspirocrinus girvanensis* sp. nov. HM E3499; holotype. 1, A ray central (cf. Text-fig. 1A). 2, CD interray central (cf. Text-fig. 1C). Both internal moulds, both $\times 4$.

Figs 3–6. *Dendrocrinus collapsus* sp. nov. 3, BMNH E67901b; holotype; proximal column and crown, $\times 5$. 4, BMNH E47326b; paratype; proximal column and dorsal cup, $\times 6$. 5, BMNH E67901a; holotype; crown with well-preserved anal series, $\times 5.5$. 6, BMNH E47326a; paratype; proximal column, dorsal cup and proximal anal series, $\times 6$. All latex casts taken from natural moulds.

All specimens coated with ammonium chloride.



DONOVAN, *Euspirocrinus*, *Dendrocrinus*

Girvan species. The specimens discussed by Ausich (1986, pp. 728–729, figs 6.8, 6.13) as (?) *Euspirocrinus* sp. are too poorly known for discussion, although it is noted that the radial facets are much wider than in *E. girvanensis*.

Suborder DENDROCRININA Bather, 1899
Superfamily DENDROCRINACEA Wachsmuth and Springer, 1886
Family DENDROCRINIDAE Wachsmuth and Springer, 1886
Genus DENDROCRINUS Hall, 1852

Type species. By monotypy; *Dendrocrinus longidactylus* Hall, 1852, from the Wenlock of New York State, USA.

Diagnosis. (Modified from Moore *et al.* 1978, p. T608). Crown elongate and conical. Cup dicyclic, with five prominent infrabasals, five basals and five radials. Radial directly below C radial. Anal X in radial circlet, supported by CD basal and radial. Anal series comprising large plates posteriorly and proximally only, with several columns of small interlocking plates arranged laterally, anteriorly and distally. Arms slender, uniserial, apinnulate and branching isotomously several times. Articular facets of radials narrow and rounded, angled away from oral surface. Column holomeric or possibly pentameric in some species, heteromorphic proximally, circular, pentagonal or pentastellate in section.

Dendrocrinus collapsus sp. nov.

Plate 1, figs 3–6; Text-figs 2–3

1989a Dendrocrinid sp. nov.; Donovan, fig. 1.

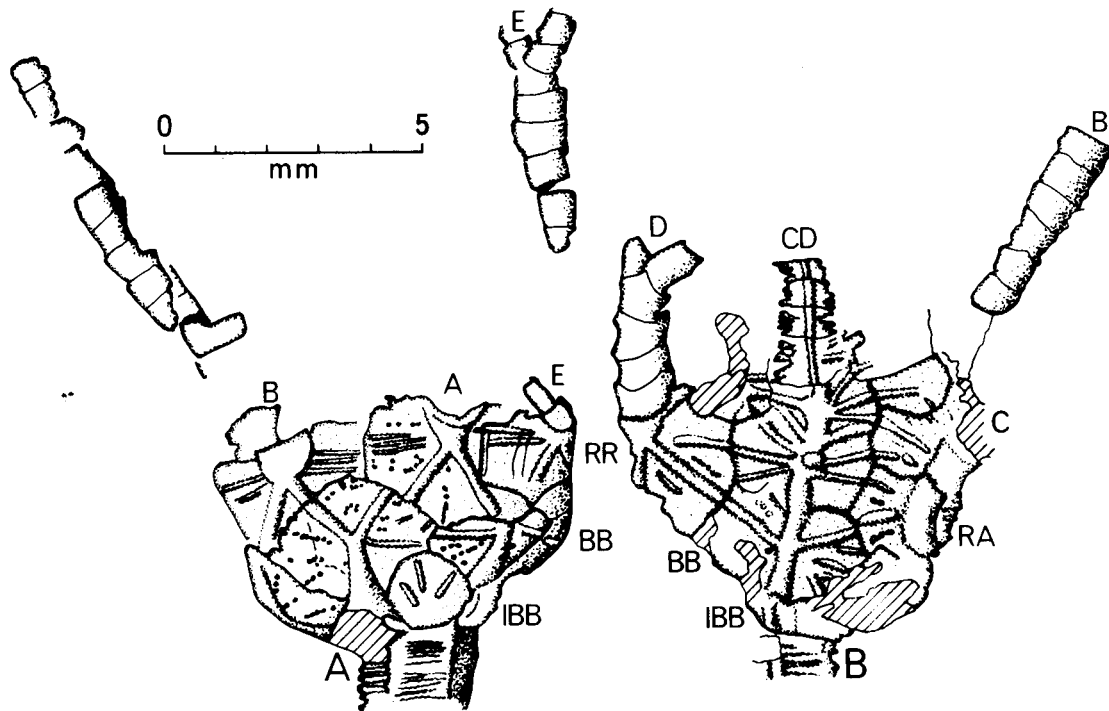
Derivation of name. From the Latin *col*, 'together' and *lapsus*, 'to slide or fall', alluding to the collapsed state of the dorsal cup in all available specimens.

Type material, locality and horizon. Species known from five specimens, four of which are part and counterpart external moulds: holotype, BMNH E67901a–b; paratypes, RMS 1957.1.28 (part and counterpart); BMNH E47326a–b; E67904a–b (anal tube), E68729 (anal tube). Locality and horizon as for *E. girvanensis* above.

Diagnosis. *Dendrocrinus* with slender, elongate pentastellate column, broad, moderately high, bowl-shaped dorsal cup with sculpture of radiating ribs which are particularly strongly developed on the basals, radials and anal X, broad anal sac composed of columns of plates with distinct radiating ribs, and moderately robust arms which branch at least twice.

Description. Attachment structure unknown. Proximal 40 mm of column preserved in the holotype (Pl. 1, fig. 3), while 18 mm is retained by BMNH E47326 (Pl. 1, fig. 4). The stem is slightly curved in both specimens, without any proximal taper away from the base of the cup. Stem pentastellate in section, heteromorphic N212, with nodals higher than priminternodals and secundinternodals. Latera are convex to angular at the angles of the 'star', but are otherwise strongly infolded. The latera of secundinternodals are planar, but strongly infolded, so that the more convex latera of nodals and priminternodals form narrow epifacets and give the stem a ladder-like appearance (Pl. 1, figs 3–4, 6). Features of the articular facet not seen.

Dorsal cup dicyclic (best seen in E67901b; Pl. 1, fig. 3; Text-fig. 2A). Five infrabasals, pentagonal in lateral view (Pl. 1, figs 3, 6; Text figs 2A, 3A–B) and folded under the cup with an angular geniculation. Centre of lateral face of infrabasal depressed parallel to long axis of crinoid. Fine, separated radial ridges or columns of tubercles extend adorally. Sutures between infrabasals correspond to the angles of the column. Five basals, larger than infrabasals, polygonal in outline, apparently hexagonal to heptagonal. Plates raised centrally, from which radiate a few stout ribs in a Y-shaped pattern (Pl. 1, figs 3–6; Text-figs 2–3). Two orders of finer radiating ribs and/or lines of tubercles also present. Five large radials, as large or slightly larger than basals, polygonal (octagonal?) in outline, with an arm facet in the central third of the adoral margin. Arm facet broad and



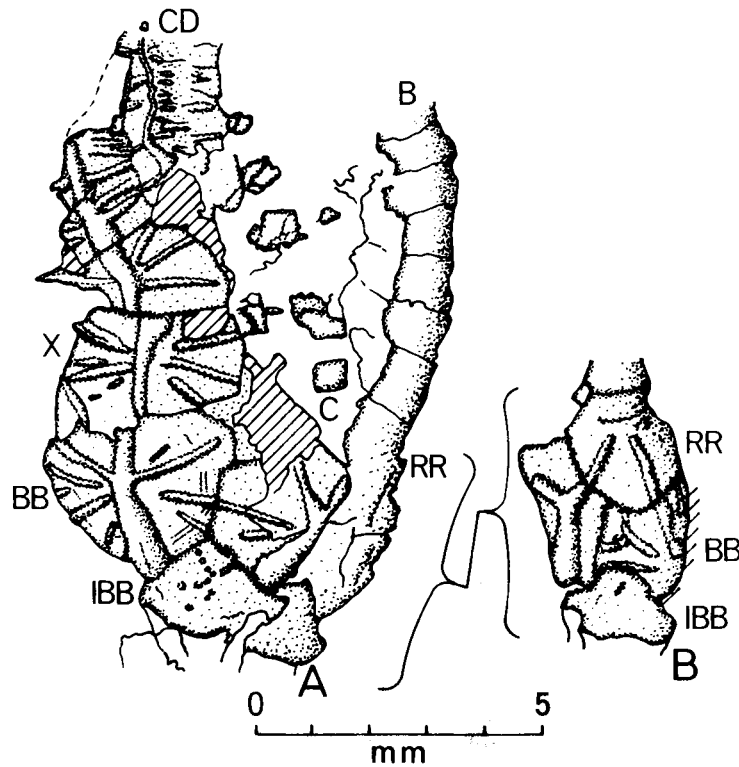
TEXT-FIG. 2. *Dendrocrinus collapsus* sp. nov.; holotype; dorsal cup. A, BMNH E67901b. B, BMNH E67901a; anal X is the large plate in the centre of the figure supported by the CD basal. Camera lucida drawings of latex casts taken from counterpart external moulds. Key: A to E, Carpenter rays; CD, CD interray (part of the anal series illustrated); RR, radials; BB, basals; IBB, infrabasals; RA, radial. Proximal parts of some arms illustrated.

V-shaped, wider than the U-shaped proximal facet of 1Br₁. Adoral groove narrow, U-shaped, associated with a broad, shallow V-shaped plate margin. Plate sculpture similar to that of basals.

Anal X supported by the hexagonal(?) basal in the CD interray, on which a particularly large central rib is orientated parallel to the long axis of the crinoid and continues on at least the proximal plates of the anal series (Pl. 1, figs 5-6; Text-figs 2B, 3A), along with more slender, but still pronounced, ribs which radiate from the plate centres. X separates the D and C radials (Text-fig. 2B), the latter being supported by a radial plate. X and the posterior sides of the C and D radials support a large, complex anal sac composed of few columns of plates with a stellate ribbed sculpture (Pl. 1, figs 3, 5).

Five moderately robust, non-pinnulate, uniserial arms, which are poorly preserved, but which branch at least twice (Text-fig. 2B illustrates the primaxillary in the D ray and also the E ray ?secundaxillary). Primaxillary at 1Br₁ in E67901a. Primaxillaries about as high as wide. Brachial latera planar and unsculptured.

Remarks. Although specimens of this taxon are partly disarticulated, sufficient morphological detail is preserved to show that this species is undoubtedly a *Dendrocrinus*. Moore *et al.* (1978, figs 394.5, 395.1d) illustrated the plating arrangement of the dorsal cup in the type species, *D. longidactylus*. The large CD basal supports the anal X and both abut the moderately large radial in the C ray. This radial supports the C radial. The anal series immediately above X is broad and comprises three columns of plates. The central column is supported by X, while the two flanking columns are supported by the C and D radials (Moore *et al.* 1978, fig. 395.1c). The anal tube comprises multiple columns of plates, each plate bearing a sculpture of radiating ribs. All of these features are seen in *D. collapsus*. The posterior plating geometry is particularly well seen in the holotype (Pl. 1, fig. 5; Text-fig. 2B).



TEXT-FIG. 3. *Dendrocrinus collapsus* sp. nov., paratype, BMNH E47326a. A, dorsal cup with proximal part of anal sac and arm of B ray. B, cup plates of the B ray. Key: X, anal X plate; otherwise as in Text-figure 2. Camera lucida drawings.

A note associated with the paratype specimen BMNH E47326, classifying it as ‘? *Palaeocrinus* cladid’, is disregarded. The Girvan species lacks respiratory structures and has a prominent anal sac, features which distinguish it from *Palaeocrinus* Billings *s. s.* (Moore *et al.* 1978, p. T588). The radiating ribs of *D. collapsus* are coarser than those of *Palaeocrinus* (see, for example, Brower and Veinus 1974, pp. 37–61, text-figs 3–7; pl. 5, figs 4–5; pls 6–8; 1978, pp. 451–454, pl. 16, fig. 3; Sprinkle 1982, pp. 154–163, figs 46A–E, H–L, 47; pl. 13, figs 6, 9–11; pl. 14), indicating that they did not serve a respiratory function. *Palaeocrinus s. s.* has no anal sac. Although some species with an anal sac have been assigned to *Palaeocrinus*, these taxa are probably misclassified (Moore *et al.* 1978, p. T588).

Three other species of *Dendrocrinus* have been described from the Lower Palaeozoic of Britain: *D. granditubus* Ramsbottom, 1961, from the Ashgill Starfish Bed at Threave Glen; *D. rugocyathus* Ramsbottom, 1961, from the Slade Beds of Dyfed, Wales; and *D. extensidiscus* Brower, 1975, from the Telychian, late Llandovery Gutterford Burn Starfish Bed of the North Esk Inlier, Lothian, Scotland. *D. granditubus* has a large and distinctive anal sac, composed by very numerous columns of very small plates, which is very different from that of *D. collapsus* (compare Pl. 1, figs 3, 5 herein with Ramsbottom 1961, pl. 4, figs 1–7). *D. rugocyathus* has a strongly ribbed dorsal cup, but the centres of radial and basal plates are raised and disc-like, with short, stout, radiating ribs (Ramsbottom 1961, pl. 3, figs 1–5). Unlike *D. collapsus*, *D. extensidiscus* has a smooth, slender cup (Brower 1975). *D. collapsus* is also distinct from the various species of *Dendrocrinus* known from North America.

Acknowledgements. This paper was written during the period of National Geographic Society grant 4264-90, which is gratefully acknowledged. Keith Ingham (HM), Bill Baird (RMS), Dave Lewis and Andrew Smith (BMNH) kindly loaned and allowed access to specimens. Andrew Smith also permitted use of his photomicroscope equipment. I particularly thank Phil Lane (University of Keele) for taking the photographs used in Plate 1.

REFERENCES

- ANGELIN, N. P. 1878. *Iconographia crinoideorum in stratis sueciae Siluricus fossilium*. Samson Wallin, Holmiae, iv + 62 pp.
- AUSICH, W. I. 1986. Early Silurian inadunate crinoids (Brassfield Formation, Ohio). *Journal of Paleontology*, **60**, 719–735.
- BASSLER, R. S. 1938. Pelmatozoa Palaeozoica. 1–194. In QUENSTEDT, W. (ed.). *Fossilium catalogus, I: Animalia*, pt. 83. W. Junk, s'Gravenhage.
- BATHER, F. A. 1890. British fossil crinoids. II. The classification of the Inadunata Fistulata (continued). *Annals and Magazine of Natural History*, (6), **5**, 373–388.
- 1899. A phylogenetic classification of the Pelmatozoa. *Report of the British Association for the Advancement of Science for 1898*, 916–923.
- BILLINGS, W. R. 1885. Two new species of crinoids. *Transactions of the Ottawa Field Naturalists' Club*, **6**, 248–250.
- BROWER, J. C. 1974. Upper Ordovician xenocrinids (Crinoidea, Camerata) from Scotland. *University of Kansas Paleontological Contributions, Paper 67*, 1–25.
- 1975. Silurian crinoids from the Pentland Hills, Scotland. *Palaentology*, **18**, 631–656.
- and VEINUS, J. 1974. Middle Ordovician crinoids from southwestern Virginia and eastern Tennessee. *Bulletins of American Paleontology*, **66** (283), 1–125.
- — 1978. Middle Ordovician crinoids from the Twin Cities area of Minnesota. *Bulletins of American Paleontology*, **74** (304), 369–506.
- DONOVAN, S. K. 1989a. The significance of the British Ordovician crinoid fauna. *Modern Geology*, **13**, 243–255.
- 1989b. Pelmatozoan columnals from the Ordovician of the British Isles, part 2. *Monograph of the Palaeontographical Society*, **142** (580), 69–114.
- FRANZÉN, C. 1983. Ecology and taxonomy of Silurian crinoids from Gotland. *Acta Universitatis Upsaliensis*, **665**, 1–31.
- GOLDRING, R. and STEPHENSON, D. G. 1972. The depositional environment of three starfish beds. *Neues Jahrbuch für Geologie und Paläontologie Monatshefte*, **10**, 611–624.
- HALL, J. 1847. *Palaentology of New York, volume 1, containing descriptions of the organic remains of the lower division of the New-York system (equivalent of the Lower Silurian rocks of Europe)*. D. Appleton, and Wiley and Putnam, Albany, New York, xxiii + 338 pp.
- 1852. *Palaentology of New York, volume 2, containing descriptions of the organic remains of the lower middle division of the New-York system*. D. Appleton, and Wiley and Putnam, Albany, New York, vii + 362 pp.
- HARPER, D. A. T. 1982a. The Late Ordovician Lady Burn Starfish Beds of Girvan. *Proceedings of the Geological Society of Glasgow, sessions 122/123 for 1980/81*, 28–32.
- 1982b. The stratigraphy of the Drummuck Group (Ashgill), Girvan. *Geological Journal*, **17**, 251–277.
- INGHAM, J. K. 1978. Geology of a continental margin. 2. Middle and late Ordovician transgression, Girvan. 163–176. In BOWES, D. R. and LEAKE, B. E. (eds). *Crustal evolution in northwestern Britain and adjacent regions*. Seel House Press, Liverpool, 492 pp.
- KOLATA, D. R. 1975. Middle Ordovician echinoderms from northern Illinois and southern Wisconsin. *Paleontological Society Memoirs*, **7**, 1–74.
- MATTHEWS, S. C. 1973. Notes on open nomenclature and on synonymy lists. *Palaentology*, **16**, 713–719.
- MILLER, J. S. 1821. *A natural history of the Crinoidea or lily-shaped animals, with observation on the genera Asteria, Euryale, Comatula and Marsupites*. Bryan, Bristol, 150 pp.
- MOORE, R. C., JEFFORDS, R. M. and MILLER, T. H. 1968. Morphological features of crinoid columns. *University of Kansas Paleontological Contributions, Echinodermata Article 8*, 1–30.
- LANE, N. G. and STRIMPLE, H. L. 1978. Order Cladida Moore and Laudon, 1943. T578–759. In MOORE, R. C. and TEICHERT, C. (eds). *Treatise on invertebrate paleontology. Part T. Echinodermata 2(2)*. Geological Society of America and University of Kansas Press, Boulder, Colorado and Lawrence, Kansas, 410 pp.
- and LAUDON, L. R. 1943. Evolution and classification of Paleozoic crinoids. *Geological Society of America Special Papers*, **46**, 1–153.

- RAMSBOTTOM, W. H. C. 1954. The British Lower Palaeozoic Crinoidea. Unpublished Ph.D. thesis, University of London.
- 1961. A monograph on the British ordovician Crinoidea. *Monograph of the Palaeontographical Society*, **114** (492), 1–36.
- SPRINKLE, J. 1982. Large-calyx cladid inadunates. 145–169. In SPRINKLE, J. (ed.). *Echinoderm faunas from the Bromide Formation (Middle Ordovician) of Oklahoma. University of Kansas Paleontological Contributions, Monograph 1*, 1–369.
- STRIMPLE, H. L. 1963. Crinoids of the Hunton Group. *Bulletin of the Oklahoma Geological Survey*, **100**, 1–169.
- UBAGHS, G. 1978. Skeletal morphology of fossil crinoids. T58–T216. In MOORE, R. C. and TEICHERT, C. (eds). *Treatise on invertebrate paleontology, Part T. Echinodermata 2(1)*. Geological Society of America and University of Kansas Press, Boulder, Colorado and Lawrence, Kansas, 401 pp.
- WACHSMUTH, C. and SPRINGER, F. 1886. Revision of the Palaeocrinoidea, part 3, section 2. Discussion of the classification and relations of the brachiote crinoids, and conclusions of the generic descriptions. *Proceedings of the Academy of Natural Sciences of Philadelphia, 1886*, 64–226.
- WEBSTER, G. D. 1974. Crinoid pluricolumnal noditaxis patterns. *Journal of Paleontology*, **48**, 1283–1288.

STEPHEN K. DONOVAN
Department of Geology
University of the West Indies
Mona, Kingston 7,
Jamaica

Typescript received 24 July 1990
Revised typescript received 30 May 1991