PROC. R. SOC. VICT. vol. 96, no. 4, 187-207, December 1984

ORDOVICIAN NAUTILOIDS OF TASMANIA – GOULDOCERATIDAE FAM. NOV. (DISCOSORIDA)

By Bryan Stait

Geology Department, University of Tasmania, G.P.O. Box 252C, Hobart, Tasmania 7001
Present address: Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X5.

Abstract: The Middle to Upper Ordovician Benjamin Limestone in Tasmania contains eight genera belonging to the Gouldoceratidae fam. nov. (Discosorida). They are *Gouldoceras synchonena, G. obliquum, G. benjaminense* sp. nov., *Tasmanoceras zeehanense, T. pagei* sp. nov., *Benjaminoceras lauriei* gen. et sp. nov., *Westfieldoceras taylori* gen. et sp. nov., *Paramadiganella banksi* gen. et sp. nov., Gouldoceratidae gen. nov. A, gen. nov. B and gen. nov. C. The Gouldoceratidae are characterised by having expanded siphuncles, cyrtochoanitic to orthochoanitic septal necks, well developed finely laminated endocones, unexpanded bullettes and two layered connecting rings. *Madiganella* from the Late Canadian to Whiterock Horn Valley Siltstone in central Australia also belongs to the Gouldoceratidae.

The endocones in the Gouldoceratidae are composed of very fine layers which mimic the shape of the siphuncle, they have radial crystal growth normal to the connecting rings in both dorsoventral and transverse sections. This suggests that they were deposited as a series of needles by the epithelium of the siphon. It is probable that these deposits were porous and allowed exchange of liquid between the siphon and camerae.

The Gouldoceratidae can be divided into two groups, one has relatively larger siphuncles with orthochoanitic septal necks and easily observed endocones, while the other has cyrtochoanitic septal necks, smaller siphuncle and less well developed endocones.

The Gouldoceratidae are the dominant group of nautiloids in the Ordovician of Tasmania, where they are confined to the Benjamin Limestone and largely to the sequences in the Florentine Valley (Figs 1-4). Only *Gouldoceras* and *Tasmanoceras* have been found elsewhere in Tasmania at localities indicated on Fig. 1. The earliest member of the family is *Madiganella* from central Australia. Unfortunately there is a long time break between its Late Canadian-Early Whiterock occurrences in central Australia and the Late Chazy-Early Blackriver age of the oldest gouldoceratid in Tasmania. The course of evolution in the Gouldoceratidae is uncertain due to this major break and other major gaps in the Upper Limestone Member of the Benjamin Limestone.

The Palaeozoic sequence in Tasmania can be divided into three groups; the dominantly clastic Denison Group, the carbonate Gordon Group and the clastic Eldon Group (Burrett *et al.* 1984). These groups range in age from Middle Cambrian to Devonian. The nautiloid faunas are mainly from the Gordon Group. The few specimens known from the Denison or Eldon Groups are too poorly preserved to allow a detailed examination (Stait 1983). The Gordon Group is composed of three formations and ranges in age from Upper Canadian to Maysville (mid-Arenig to Ashgill). The basal formation is the Karmberg Limestone which is overlain by the Cashions Creek Limestone and this is overlain by the Benjamin Limestone. The Benjamin Limestone is subdivided into three members (Fig. 5). The basal member is the Lower Limestone Member, which is overlain by the Lord's Siltstone Member and this is overlain by the Upper Limestone Member (Corbett & Banks 1974, Webby *et al.* 1981, Burrett *et al.* 1984). The Benjamin Limestone is dominantly peritidal, with most of the sequence consisting of intertidal carbonates. The nautiloids are largely confined to the small number of shallow subtidal beds and to the tidal channels within the intertidal sediments. The high energy environment in which the nautiloids were deposited has meant that the majority of the specimens are broken with only the solid calcite endosiphuncles preserved. This is especially true of *Tasmanoceras*, where the heavily calcified endosiphuncles are often found in large numbers, all current oriented, in tidal channels.

More detailed discussion of the stratigraphy and geologic setting of the Gordon Group can be found in Corbett and Banks 1974, Webby *et al.* 1981 and Burrett *et al.* 1984.

PREVIOUS STUDIES

The first descriptions of nautiloid faunas from Tasmania were by Etheridge (1883) and Johnston (1888). There was no further work published on the nautiloids until Teichert (1947) described an endocerid fauna from Adamsfield. Teichert and Glenister (1952), in their description of the Australian nautiloid faunas, established *Tasmanoceras* and *Hecatoceras* from Tasmania. Teichert and Glenister (1953) described a large fauna of Ordovician nautiloids from Tasmania. Recently Stait has undertaken a more complete examination of the faunas from carefully measured sections in an attempt to place the nautiloid ranges in a biostratigraphic framework. Stait (1980) erected *Gouldoceras*, and revised *Hecatoceras* Teichert & Glenister. The other fauna from Tasmania is either published or in the process of being published, and includes Stait (1982) on the oncocerids, Stait (1983) on the tarphycerids and ellesmerocerids, Stait (in press) on the

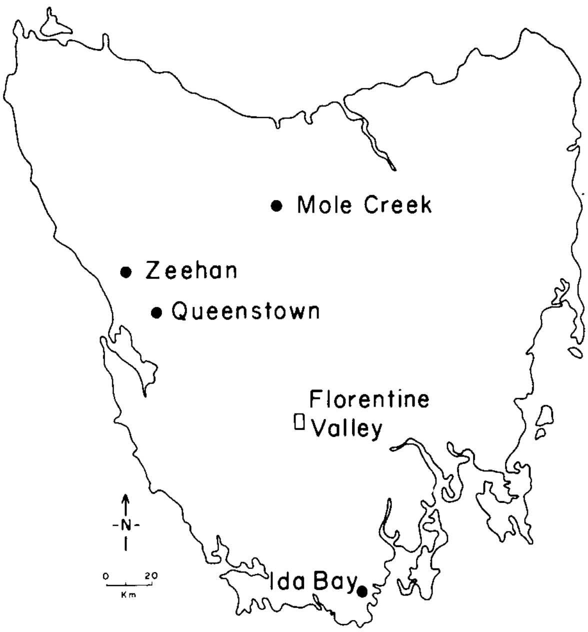


Fig. 1—Locality map of Tasmania, indicating the areas collected in this study. A more detailed map of the Florentine Valley is given in Figure 2.

actinocerids and Stait and Flower (in press) on the michelinocerids. Description of the endocerids is in progress and it is hoped that the study will soon be completed; unpublished data from this projected study are used in the following section.

AGE AND CORRELATION

A family consisting largely of endemic genera rarely has utility for international correlation but it is hoped that now the Gouldoceratidae have been described specimens will be found in other areas.

The coexisting nautiloids are generally long-ranging, widespread forms such as *Discoceras* and *Gorbyoceras*, or endemic forms such as *Hecatoceras* and *Gordonoceras*, and therefore are also difficult to use in international correlation.

Correlation within Tasmania is possible using the nautiloid faunas. The generally small number of specimens available makes it impossible to obtain zonal boundaries for a formal biostratigraphy, instead six broad generic assemblages are delimited. These assemblages in ascending order are:

1. *Piloceras—Manchuroceras* assemblage which consists of *Manchuroceras*, *Piloceras*, Manchuroceratidae gen. nov., *Yehlioceras*, *Allocotoceras* and *Pycnoceras*.
2. *Wutinoceras—Adamsoceras* assemblage which contains *Wutinoceras*, *Adamsoceras* and *Chaohuceras*.
3. *Discoceras—Gorbyoceras* assemblage which contains *Discoceras*, *Gorbyoceras*, *Mysterioceras*, *Paramadiganella*, Gouldoceratidae gen. nov A, Actinocerida gen. nov., Michelinocerida gen. nov., *Orthoceras*, *Beloitoceras*, *Centrocyrtocerina*, *Armenoceras* and three new genera of endocerids.
4. *Tasmanoceras—Hecatoceras—Gouldoceras* assemblage which consists of *Tasmanoceras*, *Hecatoceras*, *Gouldoceras*, *Anaspyroceras*, *Discoceras*, *Beloitoceras*, *Miamoceras* and *Zeehanoceras*.
5. *Gordonoceras* assemblage which contains only *Gordonoceras*.
6. *Westfieldoceras* assemblage which contains *Westfieldoceras*, Gouldoceratidae gen. nov. B, Gouldoceratidae gen. nov. C, *Augustoceras* and *?Armenoceras*.

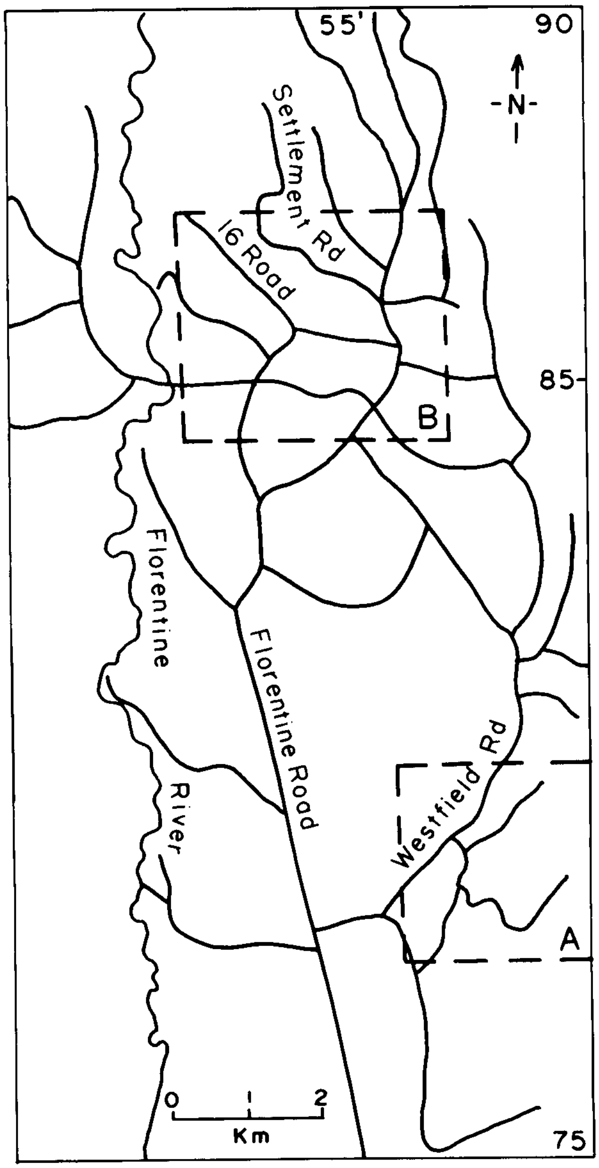


Fig. 2—Map of the Florentine Valley, A and B indicate the location of the inserts shown in Figures 3 and 4 respectively.

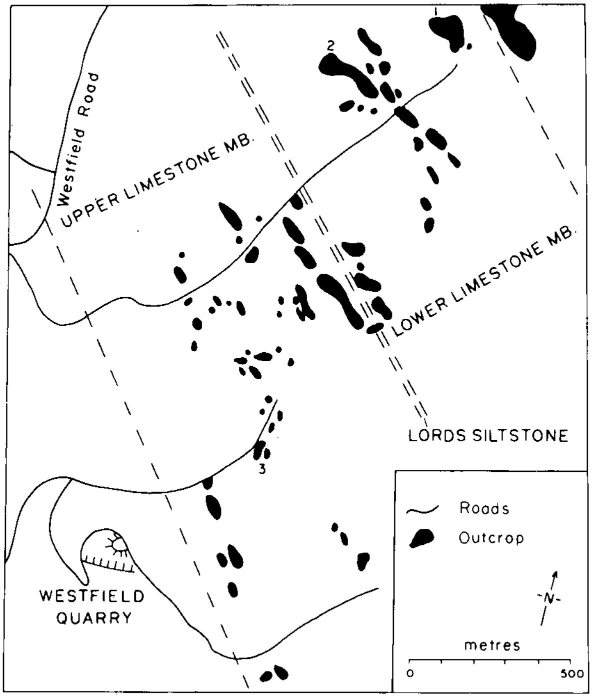


Fig. 3—Map showing the collecting localities at the Westfield section (modified from Calver 1977).

International correlations are made mainly on the basis of the coexisting conodont faunas and a short summary of the ages obtained is included herein for completeness.

Gouldoceratidae gen. nov. A, *Benjaminoceras* and *Paramadiganella* occur near the base of the Lower Limestone Member. Conodonts from this level include *Phragmodus* sp. nov., *Tasmanognathus careyi* and *Chirognathus monodactylus*, tentatively suggesting a correlation with the Blackriveran (C. F. Burrett pers. comm.). *Tasmanoceras* and *Gouldoceras* occur in the middle and upper part of the Lower Limestone Member. The conodonts present are *Phragmodus undatus*, *Bryantodina abrupta*, *Plectodina* cf. *furcata* and *Plectodina aculeata*, suggesting a correlation with faunas 8 and 9 of Sweet and Bergström (1976) (C. F. Burrett pers. comm.). *Westfieldoceras*, Gouldoceratidae gen. nov. B and Gouldoceratidae gen. nov. C occur at the top of the Upper Limestone Member. The conodonts present include *Oulodus robustus*, *O.* cf. *oregonia*, *Plectodina* cf. *furcata* and *Staufferella falcata*. This suggests a correlation with fauna 11 of Sweet and Bergström (1976) (C. F. Burrett pers. comm.).

MORPHOLOGIC TRENDS IN THE GOULDOCERATIDAE

As discussed elsewhere the only non-Tasmanian genus which definitely belongs to the Gouldoceratidae is *Madiganella*. It has thick two-layered connecting rings, unexpanded bullettes, endocones and the siphuncle changes from amphora shaped to symmetrically expanded and moves relatively towards the venter with growth (Fig. 6). *Madiganella* has recently been redescribed in detail (Stait & Laurie in press) and does not require further discussion here.

As there are only a small number of specimens known and many major gaps in the sequence no serious attempt can be made at a phylogeny for the Gouldoceratidae. However, it is possible to comment on the features which unify the group and apparent trends in morphology through time which may later prove to form an evolutionary sequence.

The Gouldoceratidae are diagnosed below. Their most obvious characters are the finely spicular laminated endocones and the thick two-layered connecting rings. They also all have a siphuncle between the centre and venter and an almost total lack of cameral deposits.

Within this family there are two distinct groupings. These possibly will be designated as subfamilies, when the Gouldoceratidae are better known. The two groups can be distinguished largely on the basis of the amount of expansion of the siphuncular segments, the relative size and position of the siphuncle and the morphology of the septal necks.

The first of these two groups includes Gouldoceratidae gen. nov. A, *Benjaminoceras* and *Tasmanoceras*. It shows trends characterized by a change from cyrtochoanitic to orthochoanitic curvature of the septal necks (Fig. 7), an increase in the relative size of the siphuncle, a more marginal position for the siphuncle and increasing instability in the position of the siphonal space.

The second group consists of *Paramadiganella*, *Gouldoceras*, Gouldoceratidae gen. nov. B and *Westfieldoceras*. This group shows trends in which the

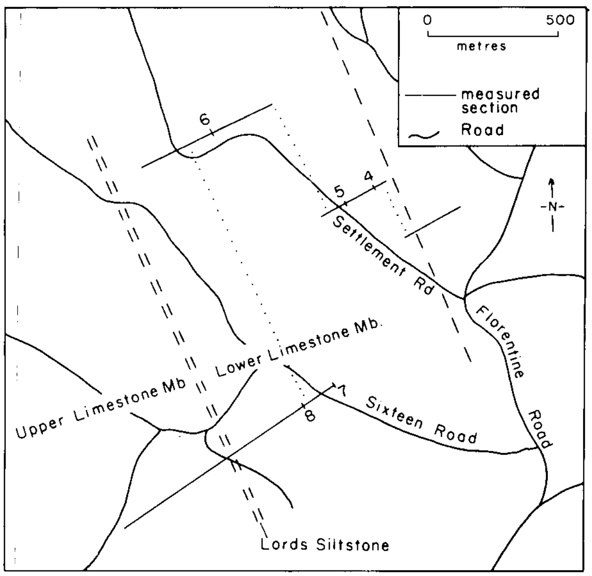


Fig. 4—Map showing the collecting localities at the Settlement Road section.

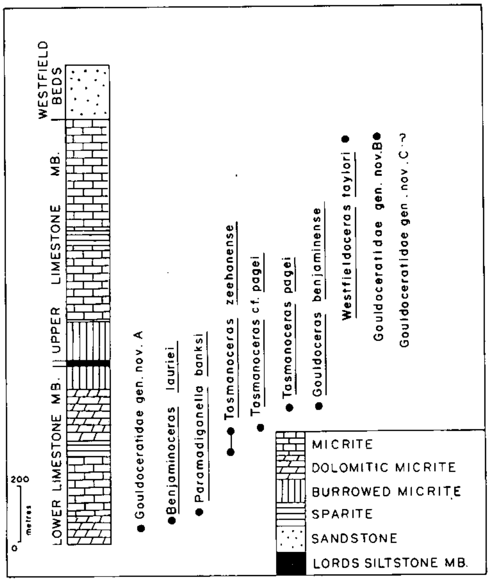


Fig. 5—Composite stratigraphic section of the Benjamin Limestone in the Florentine Valley. Lower Limestone Member based on the Settlement Road Section of Calver (Unpub. data), while the Upper Limestone Member is based on Page (1978).

septal necks become more cyrtochoanitic, the free part of the septa near the septal foramen increasingly bend to point towards the apex (Fig. 7) and the siphuncular segments change slope so that the segments slope adorally from the venter to the dorsum.

In addition the Gouldoceratidae also show a tendency to change the position and shape of the siphuncle with growth (Fig. 14A). This is most noticeable in *Paramadiganella*, *Tasmanoceras* and *Benjaminoceras*. *Madiganella* also shows this change in position and shape of the siphuncle with growth (Stait & Laurie in press).

The shape of the septal necks in the Gouldoceratidae appears to change in a systematic way. These changes are illustrated in Fig. 7. The change from cyrtochoanitic to orthochoanitic septal necks in the first group of the Gouldoceratidae is probably a response to the larger size, more marginal position and less expanded siphuncle in this group (Fig. 7). However, the reason for the complex shape of the septal necks in the younger members of the second group of the Gouldoceratidae (Fig. 7) is not apparent.

Hoeloceras Sweet 1958, from the Middle Ordovician of Norway, was originally placed in the Lambeoceratidae of the Actinocerida. Flower (1976, p. 547) indicated that he considered *Hoeloceras* to be a discosorid belonging to the Ruedemannoceratidae based mainly on the supposed presence of a free siphonal tube. As has been shown with *Buttsoceras* (Flower 1962) and *Madiganella* (Stait & Laurie in press) free siphonal tubes are often a preservational phenomenon and represent the siphonal space within the endocones. In *H. askeri* the siphuncular segments slope adorally from the venter to the dorsum, the connecting rings, although described as thin by Sweet (1958), appear to be thick in the illustrations. The thickness of the connecting rings in the *Gouldoceratidae* can be deceptive. The connecting rings are sometimes preferentially removed and when siphonal deposits are present a thin ring is suggested. Another problem is that the rings are two layered and the thin dark layer on the siphonal surface can look like the complete connecting ring, with the thicker, light layer on the cameral surface appearing inorganic in origin. The combination of the above features are not restricted to the Gouldoceratidae, but strongly suggest that, with study, *Hoeloceras* may be assignable to this family.

STRUCTURE OF THE SIPHONAL DEPOSITS

A number of specimens obtained during this study have the siphonal deposits preserved in fine detail. Although there are not enough specimens available to allow the detailed examination that would be desirable, such as serial transverse and longitudinal sections, a great deal of information can be obtained. All members of the Gouldoceratidae show the following structures to various degrees; however, they are best illustrated in *Gouldoceras* and Gouldoceratidae gen. nov. A and these two genera will be used as the basis for discussion.

In general terms the siphonal deposits are endocones, composed of a large number of fine individual 'cones' which broadly mimic the shape of the siphuncle but are thicker in the expanded part of the segments than in the septal foramina. Each 'cone' is composed of a band of honey-coloured material which is separated from the adjacent 'cones' by a dark line (probably representing a break in deposition of the endocones). The endocones appear to grow by accretion of a new layer on the inside of the 'endosiphocone', this extends the endocones slightly adorally. Each endocone can be

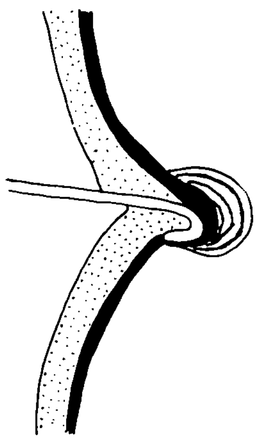


Fig. 6—The septal neck and connecting ring of *Madiganella tatei*, T1255, ×15. Spaced stipple is the siphonal deposits while the close stipple and black areas are the layers of the connecting ring, based on fig. 2L of Stait and Laurie (in press).

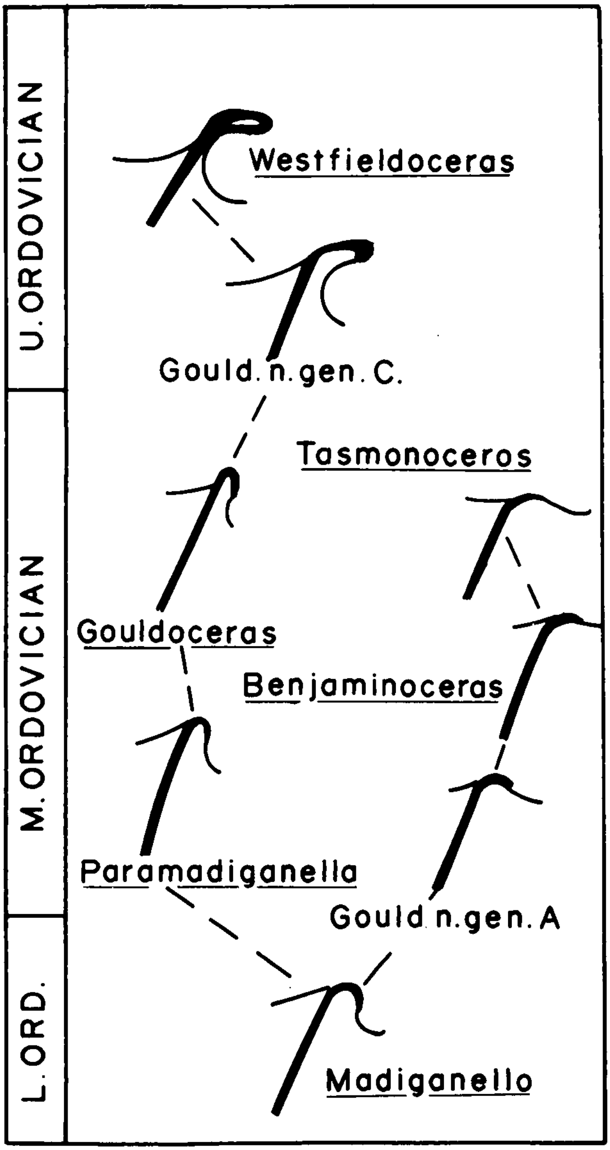


Fig. 7—Shows the variation in the shape of the septal necks within the Gouldoceratidae. The lines are not meant to imply phylogenetic relationships but similar morphologies.

The siphonal deposits also have fine radial structures, normal to the endocones. They are present in both dorsoventral and transverse sections, suggesting they are needle-like rather than blade-like. The needles are not all continuous from the connecting ring to the centre but instead some terminate while others continue. This is a natural consequence of needles which maintain virtually the same size growing from the perimeter of a spheroid towards the centre. This also holds for the longitudinal section especially as the siphuncular segments are expanded. The needles appear to have areas between them (now filled with milky calcite) which do not show the same structure. This is difficult to explain, but a possible solution is suggested by the adoral part of the holotype of *Gouldoceras* (Fig. 8C). In this specimen there are milky calcite areas within the dark micritic matrix which almost certainly represent the arterial system. How this traced from where it meets the connecting ring, adorally, back through the specimen without a break. In *Gouldoceras* the endocones often show a variation in thickness related to the position of the radial spaces in the segments, thus supporting the suggestion as to the function of these spaces (discussed below). In transverse section the endocones show the same continuity and can easily be traced around the siphuncle. The thickness of the endocones often varies from the venter to the dorsum, as is demonstrated by the variable position of the siphonal space.

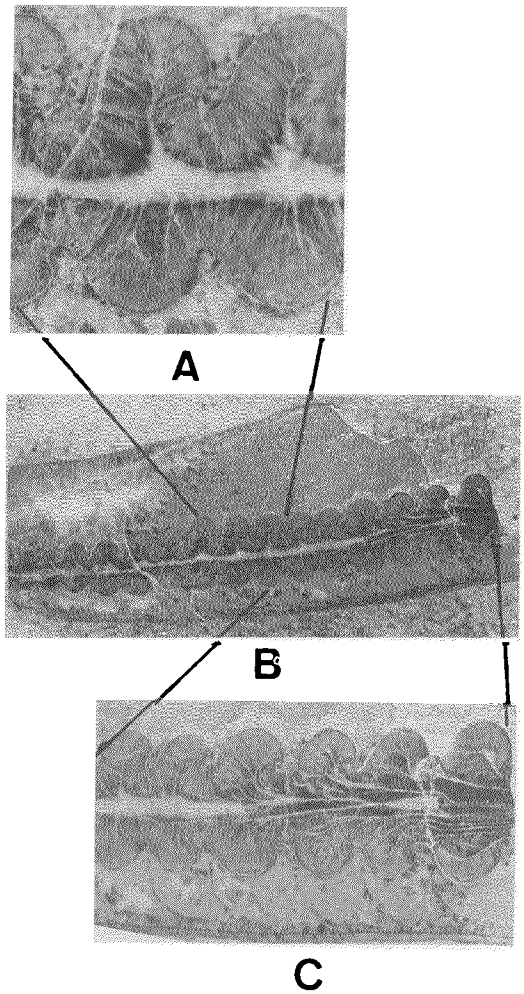


Fig. 8—*Gouldoceras synchonena* UTGD55553. B, sagittal section, ×8. A, an enlargement of the siphuncle showing the siphonal and radial spaces, ×2. C, an enlargement of the orad portion of the siphuncle showing the preserved vascular system, ×4.

could be preserved is open to debate but the most probable explanation is that the arteries were filled with marine waters before the flesh of the siphon rotted and calcite was deposited in these cavities. This may have given the arteries enough strength to be preserved, while the surrounding flesh rotted and was replaced by sediment. Any other series of events would almost certainly have resulted in the destruction of the arterial system. Examination of the arterial system shows that branches enter each siphuncular segment and divide into a very large number of fine 'capillaries' which may have supplied blood to the connecting ring surface. Close examination of the adoral end of UTGD55553 indicates that the siphonal deposits developed around the capillaries, suggesting a continued connection between the siphonal tissue and the camerae (Fig. 8c). I suggest that these capillaries may have maintained connection with the connecting rings even after the endocones became well developed. The needle-like nature of the deposits formed a meshwork, enabling the connections to be maintained with the camerae and allowing the deposition of the necessary siphonal deposits. No information on the method of deposition of the siphonal deposits is obtainable from this material. Although the possibility that it was a series of thin blisters as suggested by Wade (1977a, 1977b) for the georginids cannot be ruled out. Alternately the needles may have grown by addition of material to the inside of the needle which was in direct contact with the epithelium of the siphon.

Other families of discosorids (e.g., Westonoceratidae and Discosoridae) have a similar structure in their siphonal deposits which may represent a similar distributary system. The fine radial structure is also present in the endocones of the Narthecoceratidae and possibly the Troedssonellidae of the Michelinocerida.

How these needle-like structures are related to the blades seen in the actinocerids and endocerids (Teichert & Crick 1974) is a most interesting question, but beyond the scope of this study.

SYSTEMATIC PALAEONTOLOGY

Terminology used herein follows that of Teichert (1964) and Flower (1964) except for the following: height is any measurement made normal to the axis of the phragmocone in the dorsoventral plane; width is any measurement made normal to the axis of the phragmocone in the lateral plane; siphonal space is the cavity left by the endocones; it probably contained the arterial and venous systems of the animal. (Broadly equivalent to the endosiphotube in endocerids, but the presence of the radial spaces suggests a slightly different structure.); radial space is a cavity formed in the expanded part of the siphuncular segment as the endocones thicken, these spaces are most pronounced in highly expanded segments. Measurements are, wherever feasible, expressed in terms of the siphonal formula of Flower (1968a). All specimens are held in the collections of the Geology Department, University of Tasmania and are prefixed UTGD.

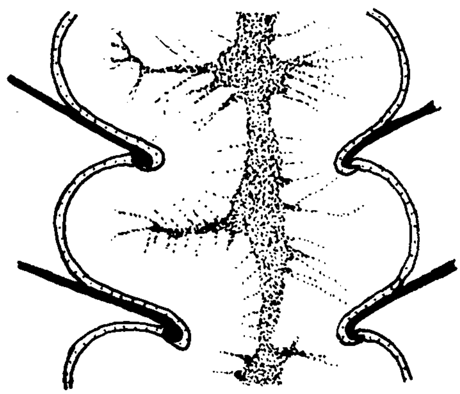


Fig. 9—The siphuncle of *Gouldoceras synchonena*, seventh to ninth segments from the adoral end of UTGD55553, ×10. Stippled area indicates the siphonal and radial spaces.

Order DISCOSORIDA

Family GOULDOCERATIDAE fam. nov.

DIAGNOSIS: Straight to slightly cyrtoconic, exogastric shells with a circular to slightly depressed cross section. The siphuncle is large from $1/5$ to $1/2$ the diameter of the phragmocone and ventral to central in position. The septal necks range from orthochoanitic to cyrtocoanitic. The siphuncular deposits are composed of thin endocones which leave a central space and in some cases radial spaces. The connecting rings are thick and composed of two layers, with unexpanded bullettes.

REMARKS: The Gouldoceratidae are typical of the order Discosorida in the majority of features; however, the connecting rings are simply composed of two layers and do not show the complex differentiation typical of the order. They are similar to those of the Ellesmerocerida, which may suggest that the Gouldoceratidae are a relict group of the ancestral Discosorida, and that they developed from the Ellesmerocerida. However, recent finds in China and Queensland suggest that either the ancestor of the Discosorida is to be found very early in the Ordovician or that the Discosorida are polyphyletic.

Nine genera are herein definitely assigned to the Gouldoceratidae, they are—*Gouldoceras*, *Westfieldoceras*, *Benjaminoceras*, *Paramadiganella*, *Tasmanoceras*, Gouldoceratidae gen. nov. A, Gouldoceratidae gen. nov. B, Gouldoceratidae gen. nov. C. *Madiganella* Teichert & Glenister, from central Australia has recently been examined in detail (Stait & Laurie in press) and clearly belongs to the Gouldoceratidae. The assignment of *Tasmanoceras* to an order or family has been a problem, Teichert and Glenister (1952, p. 739) assigning it to the Endoceratidae of the Endocerida, while Flower (1968b, p. 83) placed it in the Donacoceratinae of the Narthecoceratidae which he transferred to the Michelinocerida. Based on the new material from Tasmania it is clear that *Tasmanoceras* is a member of the Gouldoceratidae of the Discosorida.

While in Nanjing in 1983 Dr Mary Wade of the Queensland Museum and the author observed that the Pseudowutinoceratidae Chen & Chen belongs to the Discosorida but differs from the Gouldoceratidae in having expanded bullettes, well developed cameral deposits and a siphuncle which moves to a dorsal position during growth, although their similarities in size, shape and age give an initial impression of relationship. An undescribed genus of this family occurs in the Georgina Basin, western Queensland (M. Wade pers. comm).

Genus **Gouldoceras** Stait 1980

TYPE SPECIES: *Gouldoceras synchonena* Stait 1980.

REMARKS: When Stait (1980) established *Gouldoceras* he was unable to determine, with any certainty, the thickness of the connecting rings. However, material obtained in the present study indicates that the connecting rings are thick and two layered as in all other members of the Gouldoceratidae (Fig. 9). Other than this, the description in Stait (1980) stands.

Gouldoceras benjaminense sp nov.

Fig. 10A-J

DERIVATION OF NAME: Specimens were collected from the Benjamin Limestone.

MATERIAL: Three isolated siphuncles are known, holotype UTGD121129, and paratypes UTGD121130, 121131 all from the Lower Limestone Member of the Benjamin Limestone at Settlement Road (locality 8 on Fig. 4). The age is Late Blackriver to Early 'Trenton'.

DESCRIPTION: Only isolated siphuncles are known. The siphuncle is slightly curved, probably exogastrically. There are ten siphuncular segments in a length of 25 mm. They are highly expanded and slope adapically from the venter to the dorsum at an angle of 70° to the axis of the siphuncle. Apically on UTGD121129 the siphuncle is 1.0 mm high at the septal foramen, 3.7 mm at the point of maximum expansion and 2.3 mm long, while adorally the corresponding measurements are 1.5 mm, 3.8 mm and 2.3 mm. On the dorsal side of the siphuncle the adapical part of the connecting ring is adnate to the adoral surface of the septum for a distance of 0.8 mm, while ventrally it is adnate for 1.2 mm.

The septal necks are cyrtochoanitic. Adorally the septal necks are 0.4 mm long and the brims are 0.4 mm long on the venter, while the necks are 0.5 mm long, and the brims are 0.4 mm long on the dorsum, apically the corresponding measurements are 0.3 mm, 0.5 mm, 0.4 mm and 0.4 mm. The siphuncular deposits are a continuous lining over the connecting rings and the septal necks. The continuous lining is formed by thin 'endocones' which closely parallel the shape of the siphuncle and fill the siphuncle except for a central space and the radial spaces. There are two short radial spaces in the dorsal part of each siphuncular segment, but only one on the venter. The radial spaces do not penetrate the siphonal deposits. The deposits also have fine radial spicules normal to the connecting rings. The central space is crossed by lobate structures which are interpreted as diaphragms. The connecting rings are thick and structured. They are two-layered with a thin dark layer on the siphonal surface and a thick lighter layer on the cameral surface.

REMARKS: *G. benjaminense* differs from *Gouldoceras synchonena* in having a higher slope from the venter to the dorsum, diaphragms that cross the central canal and two radial spaces in each segment on the dorsal side of the siphuncle. In the slope of the siphuncular segments *G. benjaminense* is similar to *G. obliquum*, but differs from that species in having two radial spaces on the dorsal side of the siphuncle and in the development of diaphragms across the siphonal space.

Genus **Benjaminoceras** gen. nov.

TYPE SPECIES: *Benjaminoceras lauriei* sp. nov.

DERIVATION OF NAME: The type species was collected from the Benjamin Limestone.

DIAGNOSIS: Phragmocone is a straight, subcircular longicone with venter slightly flattened; siphuncle evenly and moderately expanded; siphuncular deposits thin continuous endocones which are symmetrical dorsoventrally; septal necks orthochoanitic, short; connecting rings thick and composed of two layers; area of adnation with the septa short; no cameral deposits.

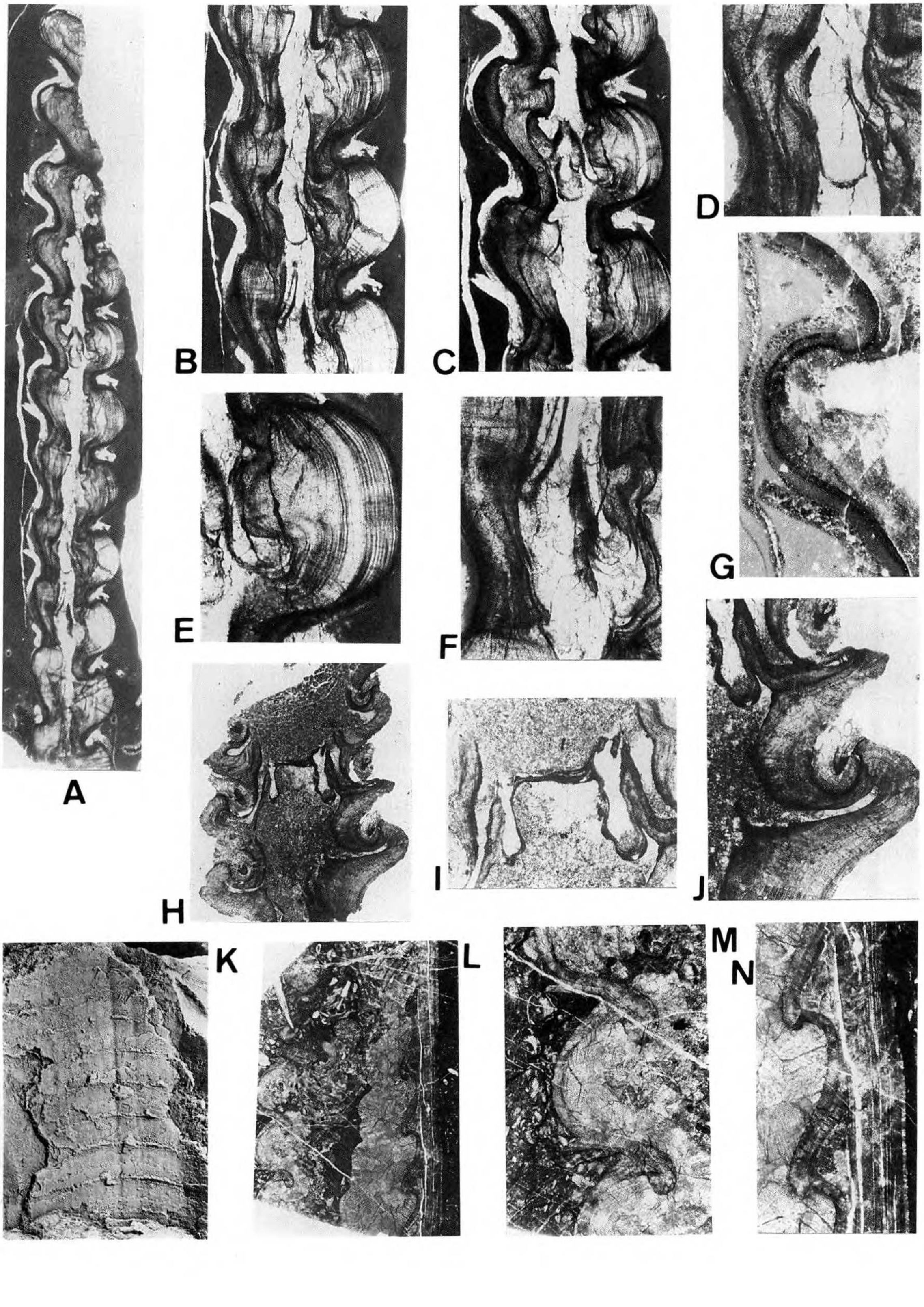
REMARKS: This genus is assignable to the Gouldoceratidae as it has thick, two-layered connecting rings and thin well developed endocones. It differs from the other members of this family in having longer, less expanded siphuncular segments and orthochoanitic septal necks.

A specimen collected from the same horizon as *Benjaminoceras lauriei* may represent a more mature growth stage of *Benjaminoceras* (UTGD121134). The only important difference between this specimen and *Benjaminoceras* is the morphology of the septal necks, which exhibit three bends (Fig. 11J). The transition from the simple orthochoanitic septal necks of *Benjaminoceras* to those of UTGD121134 would only require minor changes in morphology. Although the shape of the septal necks in the other members of the Gouldoceratidae do not vary markedly during growth, other structures often undergo dramatic morphological change. An example of such a change is the variation in the position of the siphuncle in *Paramadiganella*. Considering the potential variability of the Gouldoceratidae and the lack of more complete material the specimen is tentatively assigned to *Benjaminoceras lauriei*. The size of UTGD121134, nearly twice that of any definite *Benjaminoceras* specimen, is consistent with this interpretation.

Benjaminoceras lauriei sp. nov.

Figs 11, 12, 13

DERIVATION OF NAME: For Dr. J. R. Laurie who helped collect many of the nautiloids described herein.



MATERIAL: Five partially complete phragmocones; holotype UTGD121132, paratypes UTGD121133, 121135 and 121136, other material UTGD121134 all from the Lower Limestone Member of the Benjamin Limestone (locality 5 on Fig. 4). The age is Blackriver.

DESCRIPTION: The body chamber is unknown. The phragmocone is a slowly expanding orthoconic longicone, subcircular in cross section, with the venter slightly flattened. The holotype consists of 16 segments in a distance of 40 mm. The siphuncle is one-third of the diameter of the phragmocone. The siphuncular segments are moderately and evenly expanded, with the expanded part in contact with the ventral phragmocone wall for a short distance. The siphuncular segments slope apicad from the venter to the dorsum at 80°. The septa are gently curved with the point of maximum depth at the siphuncle. The connecting rings are adnate to both the adapical and adoral sides of the septa for a short distance, 0.1 mm.

The siphonal formula is 1.6/3.1/-:1.1/4.2/-;2.3 adorally, while at the most adapical segment it is 1.3/2.6/-:0.9/3.6/-;1.9.

The septal necks are orthochoanitic and moderately long, 0.6 mm on the dorsum and 0.4 mm on the venter; the corresponding adapical measurements are 0.4 mm and 0.2 mm. The siphuncle contains extensive and well developed deposits, but the original structures are masked by recrystallization in the known specimens. Enough of the deposits are preserved to indicate that they were finely laminated continuous cones which converge apically at a low angle. The surface of these cones is wavy, mimicking the shape of the siphuncular segments. A central space was probably present although only the adoral portion is now preserved (Fig. 11A). The deposits extend adorally for the same distance both on the venter and the dorsum. The connecting rings are thick and layered. There are two distinct layers: 1, a thin black layer on the siphonal surface and 2, a thick lighter layer on the cameral surface. A light band is sometimes preserved at the orad end of the connecting ring between the light and the dark layer on the siphonal surface. This light band lenses out apically along the connecting ring and is not known to reach the next septal foramen. There are no cameral deposits known.

REMARKS: See generic remarks.

Genus **Paramadiganella** gen. nov.

TYPE SPECIES: *Paramadiganella banksi* sp. nov.

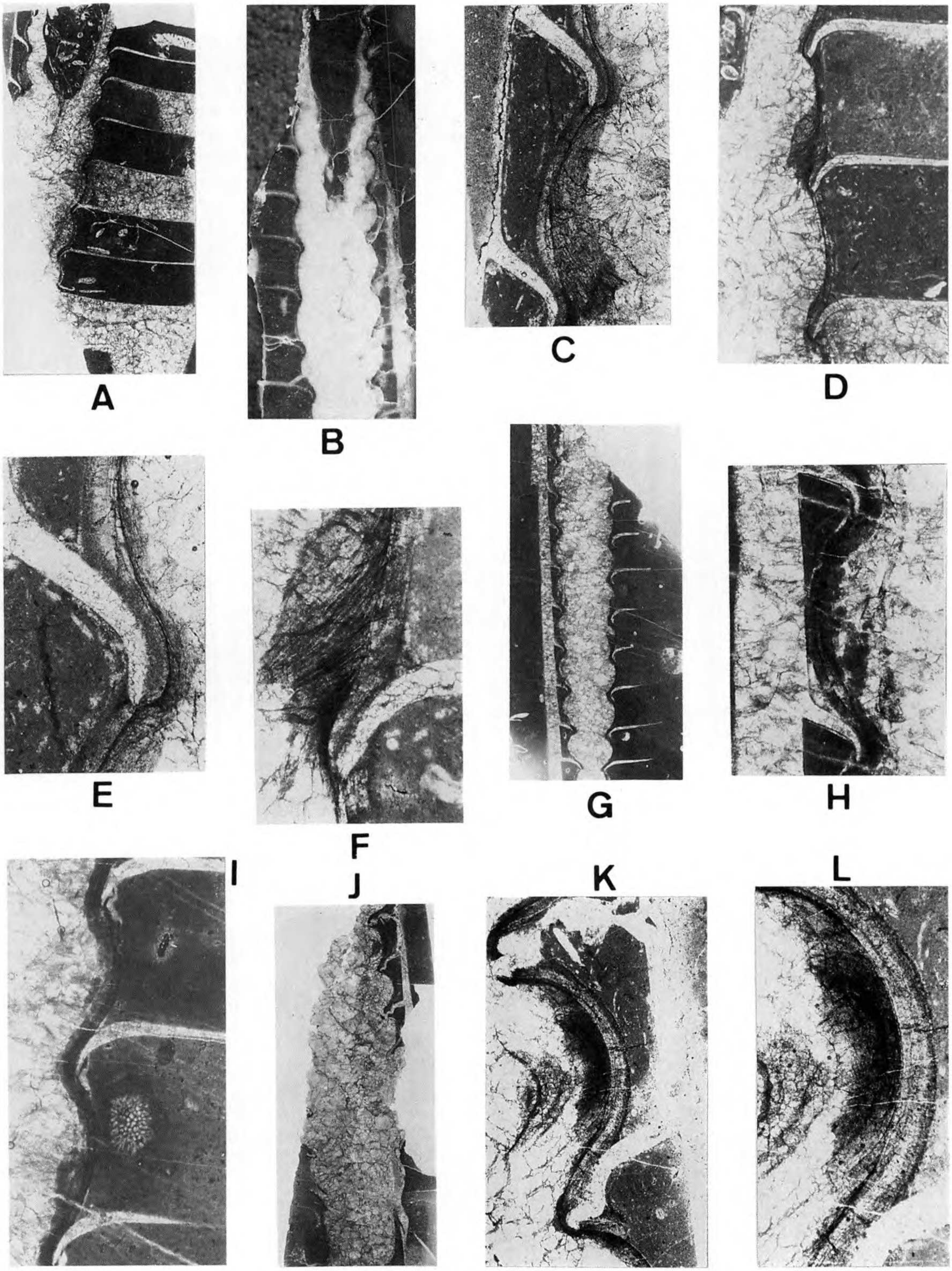
DIAGNOSIS: Phragmocone subcircular, orthoconic longicone, with the venter slightly flattened; siphuncle small, variable in position but always between the centre and venter and never in contact with the ventral phragmocone wall; siphuncular segments highly expanded with the adoral segments more expanded; in the adapical portion of the phragmocone the segments slope adorally from the venter to the dorsum, while adorally the segments are normal to the siphuncular axis; septal necks and brims are short and cyrtochoanitic; there are siphuncular deposits present in the adapical asymmetric segments; these are parietal deposits which grow apically to form endocones; in the adoral symmetrical segments there are no demonstratable deposits; connecting rings are thick and consist of two layers, a thin dark layer on the siphonal surface and a thick lighter layer on the cameral surface; connecting rings not adnate to the septa; both hyposeptal and episeptal deposits present, but only poorly developed; conch wall is composed of three layers.

REMARKS: *Paramadiganella* is unusual as the siphuncle changes position within the phragmocone, and after this change both the form and the nature of the internal deposits are dramatically altered. The presence of the thick, two-layered connecting rings and the endocone-like deposits indicate that *Paramadiganella* is a typical member of the Gouldoceratidae, but with the change in position of the siphuncle and the presence of cameral deposits is different to any other members of this family. The adoral segments of *Paramadiganella* are very similar to those of *Madiganella* in the shape of the siphuncle and the presence of the endocone-like siphonal deposits, but the genera differ in the size and position of the siphuncle and in the curvature of the septa.

Paramadiganella banksi sp. nov.
Fig. 14

MATERIAL: Ten partially preserved phragmocones; holotype UTGD121138, paratypes UTGD81151, 121139, 121140, 121141, 121142, 121143, 121144, 121145 and 121146 all from the lower half of the Lower

Fig. 10—A-J, *Gouldoceras benjaminense* sp. nov. A, sagittal section of the holotype, UTGD121129, venter left, ×4. B, enlargement of the siphuncle at the adapical end of UTGD121129, venter left, ×10. C, enlargement of the siphuncle at the adoral end of UTGD121129, venter left, ×10. D, enlargement of the 'diaphragms' across the siphonal space, UTGD121129, venter left, ×24. E, enlargement of the dorsal side of the siphuncle showing the radial spaces and the siphonal deposits, UTGD121129, ×20. F, enlargement of the siphonal spaces at the apicad end of UTGD121129, venter left, ×24. G, opaque section of the ventral side of the siphuncle showing the thick connecting ring, UTGD121129, venter left, ×20. H, thin-section of UTGD121130, venter left, ×7. I, enlargement of the 'diaphragm', UTGD121130, ×15. J, enlargement of the siphonal spaces in UTGD121130, venter left, ×15. K-N, Gouldoceratidae gen. nov. B. K, an external mould of the phragmocone wall showing two conchical furrows, UTGD22042, ×1. L, sagittal section of UTGD22042, venter right, ×3. M, enlargement of the dorsal wall of the siphuncle, UTGD22042, venter right, ×8. N, enlargement of the ventral wall of the siphuncle, UTGD22042, venter right, ×8.


A
B
C
D
E
F
G
H
I
J
K
L

Limestone Member of the Benjamin Limestone at Settlement Road section in the Florentine Valley (locality 4 on Fig. 4).

Derivation of Name. In honour of Dr. M. R. Banks contribution to Tasmanian palaeontology.

Description: The phragmocone is a subcircular, orthoconic longicone, with the venter slightly flattened. The phragmocone is slowly expanding, subtending an angle of 7° at the apex. The siphuncle is one-tenth of the diameter of the phragmocone. The siphuncle is approximately midway between the centre and the venter, but during growth moves relatively closer to the ventral phragmocone wall. In the holotype there are 35 siphuncular segments in a distance of 32 mm. The siphuncular segments are expanded, but prior to the shift towards the venter the segments are less expanded than after it. Prior to the ventral shift of the siphuncle the segments slope adorally from the venter to the dorsum but after the change the segments are normal to the siphuncular axis. The septa are only slightly curved, with the point of maximum depth at the siphuncle.

The siphonal formula of the holotype is 2.7/0.7/7.1:2.2/1.6/6.7;0.8 adorally, while apically it is 2.5/0.5/4.6:2.3/1.0/4.3;0.9.

The connecting rings are not adnate to the septa. They are thick and layered. There is a thick light layer on the cameral surface and a thin dark layer on the siphonal surface. Although the connecting rings have been partly recrystallized there is no indication that the rings contained any more complex differentiation. The septal necks and brims are short and cyrtochoanitic. The septal necks are not clearly preserved in the asymmetric portion of the phragmocone, but they appear to be short and cyrtochoanitic. Adorally on both the venter and the dorsum the septal necks are 0.2 mm long while the brims are 0.1 mm long. The siphonal deposits in the adapical asymmetric segments are parietal, forming in the septal foramina then growing apically along the connecting ring and over the deposit in the next segment to form endocones. The fine structure of the endocones is not preserved in any of the specimens found. In the adoral segments there are no deposits. Cameral deposits are present but have been largely recrystallized. Both hyposeptal and episeptal deposits formed at the same time, and developed at about the same rate. The deposits are formed to a similar extent ventrally and dorsally. Cameral deposits are rarely present and appear to have formed only in the camerae which have the symmetrical siphuncular segments. This distribution may indicate that they formed late in growth, possibly after the asymmetric segments had been isolated by the diaphragms. The conch wall structures are preserved in this species and consist of three layers, firstly the inner layer which is formed by the mural part of the septum (0.005 mm thick), secondly a thick (0.2 mm) central lighter layer which appears to be structureless, and finally a thin (0.05 mm) darker layer on the outer surface.

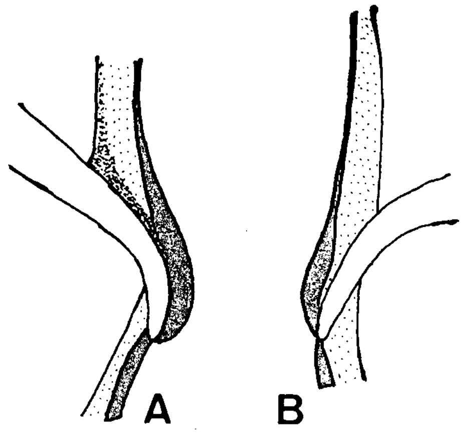


Fig. 12—The ventral (A) and dorsal (B) septal necks of *Benjaminoceras lauriei* UTGD121132, ×25.

Remarks: See generic remarks.

Genus **Westfieldoceras** gen. nov.

Type Species: *Westfieldoceras taylori* sp. nov.

Derivation of Name: The specimens were collected from the Westfield section in the Florentine Valley.

Diagnosis: The phragmocone is a subcircular, orthoconic longicone, with the venter slightly flattened. The siphuncle is close to the venter but not in contact. The siphuncular segments are highly expanded. The siphuncular deposits consist of parietal deposits which first form in the septal foramen and then extend adapically along the connecting ring until they meet the adjacent deposit, forming a continuous lining. The septal necks are long and recurved, brims also long and recumbent to the septal necks. The connecting rings are thick and layered with a thin dark band on the siphonal surface and a thick lighter band on the cameral surface. The connecting rings are strongly adnate to the septa,

Fig. 11—*Benjaminoceras lauriei* gen. et sp. nov. A, sagittal thin section of the holotype, UTGD121132, venter left, ×2. B, sagittal thin-section of UTGD121135, venter right, ×2. C, ventral wall of the siphuncle, UTGD121132, 15. D, dorsal wall of the siphuncle, UTGD121132, venter left, ×10. E, ventral septal neck, UTGD121132, ×25. F, dorsal septal neck, note the fine structure of the unrecrystallized part of the siphonal deposits, UTGD121132, ×25. G, sagittal section of UTGD121133, venter left, ×1. H, ventral side of the siphuncle of UTGD121133, venter left, ×8. I, dorsal wall of the siphuncle in UTGD121133, venter left, ×8. J, thin-section of UTGD121134, venter right, ×1.5. K, ventral phragmocone wall of UTGD121134, venter right, ×5. L, enlargement of the connecting ring on the ventral side of the siphuncle in UTGD121134, venter right, ×8.

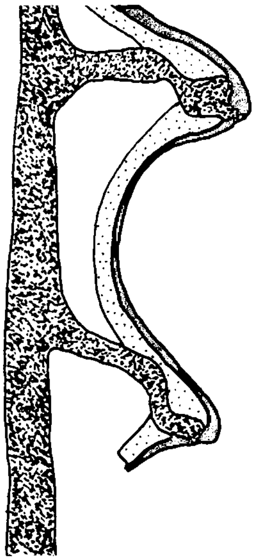


Fig. 13—The ventral septal necks and connecting ring of *Benjaminoceras lauriei* UTGD121134, ×10.

with the adoral part of the ring adnate for a short distance to the adapical face of the septum, while the adapical portion of the connecting ring is adnate for some distance to the adoral face of the septum. There are no cameral deposits.

REMARKS: *Westfieldoceras* is unusual as its morphology is reminiscent of two different orders. The septal necks and brims are very similar to those in *Lambeoceras* and it is assignable to the Huronidae of the Actinocerida. However, detailed examination of the connecting rings and siphuncular deposits show that *Westfieldoceras* is a discosorid assignable to the Gouldoceratidae and not an actinocerid. The most closely related genus is Gouldoceratidae gen. nov. C but this genus differs from *Westfieldoceras* in that its septal necks are not recurved, the siphuncle is in contact with the ventral wall of the phragmocone and the septal brims are short and free.

Westfieldoceras taylori sp. nov.
Figs 15F-K, 16

DERIVATION OF NAME: After Mr. M. Taylor who collected the first specimens.

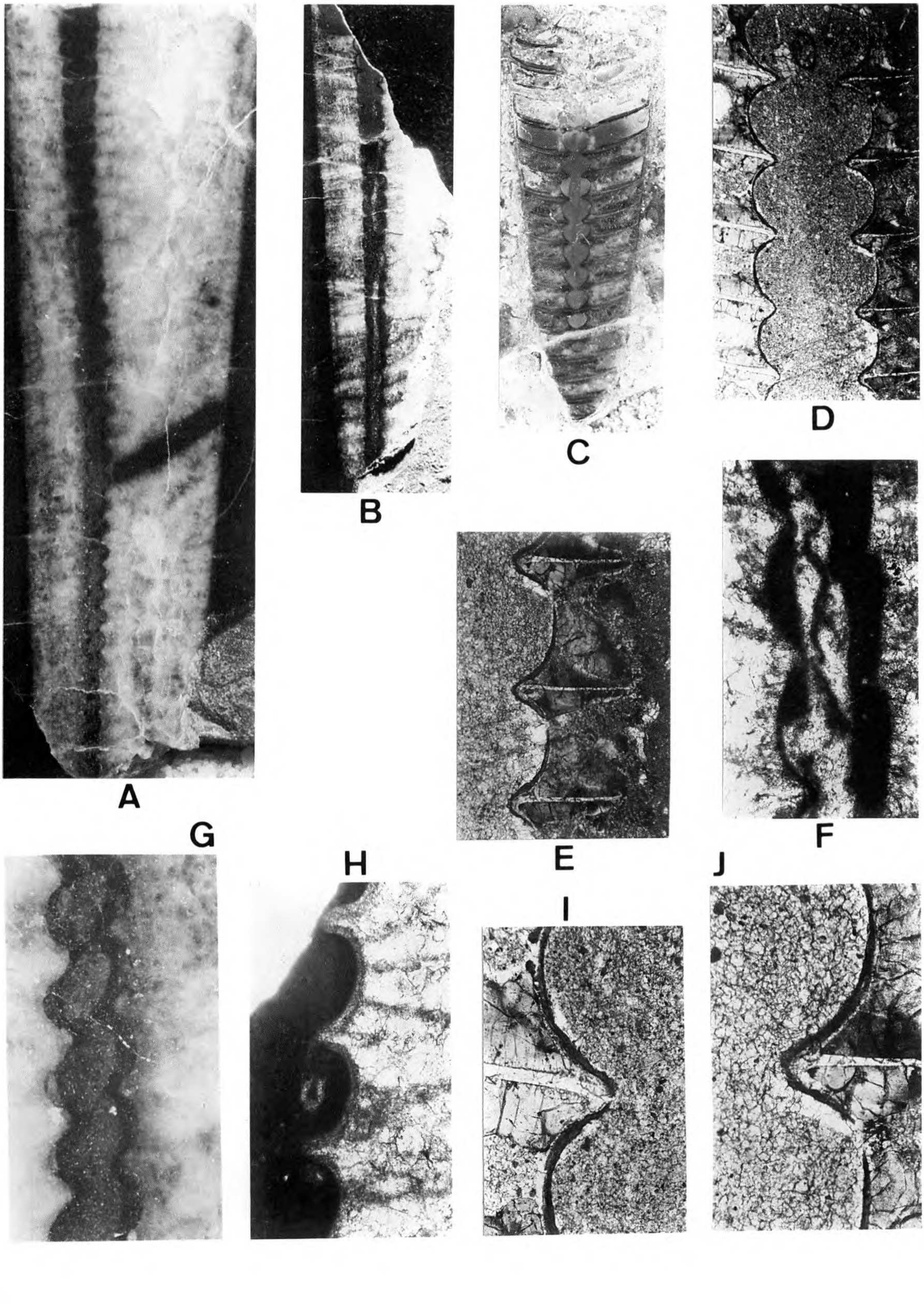
MATERIAL: Three phragmocones, holotype UTGD95793, paratypes UTGD121158 and 121159 all from the Upper Limestone Member of the Benjamin Limestone, at the Westfield section in the Florentine Valley (locality 3 on Fig. 3). The age is Eden.

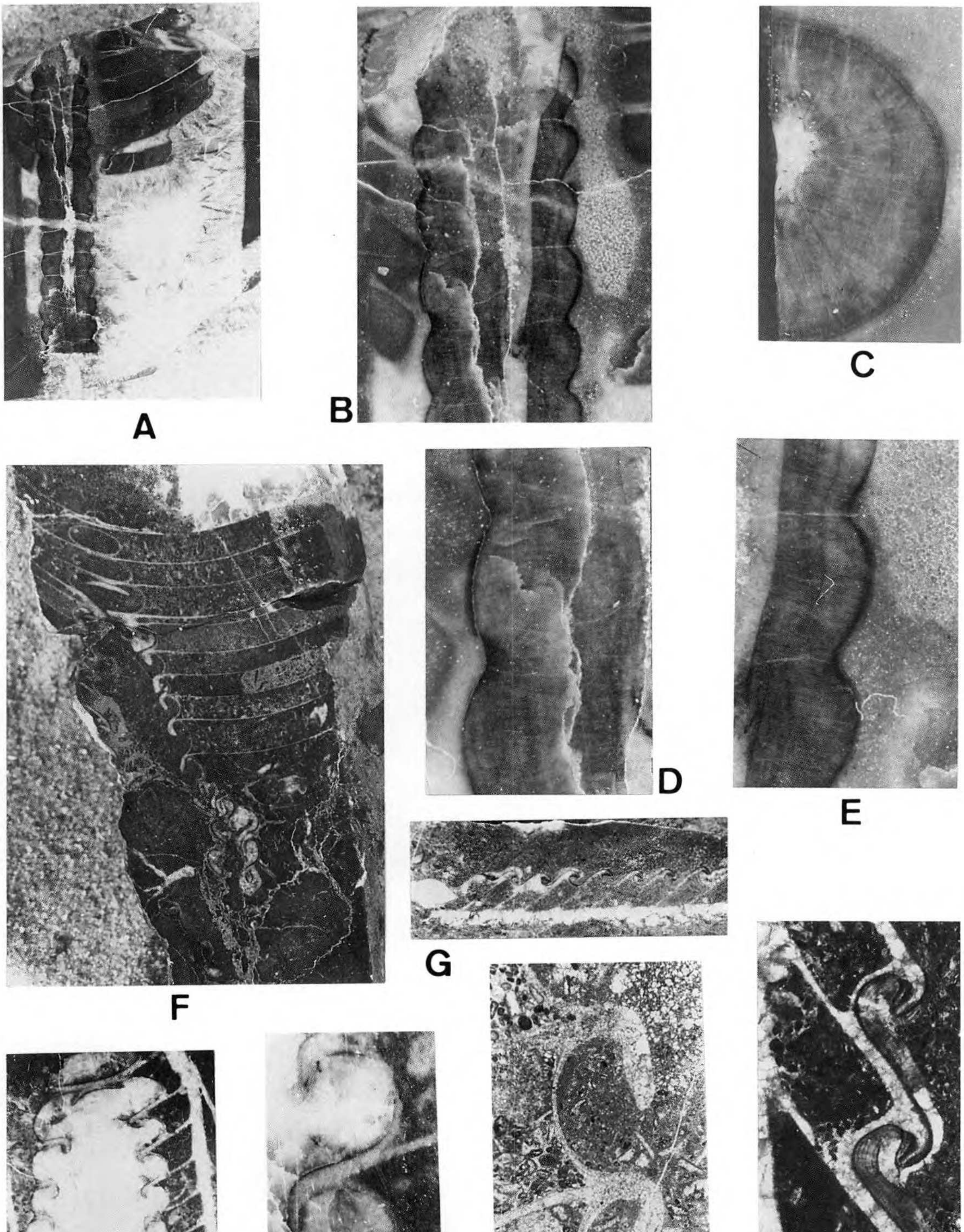
DESCRIPTION: The phragmocone is a subcircular, orthoconic longicone, with the venter slightly flattened. The phragmocone is probably slowly expanding. The holotype consists of 28 segments in a length of 90 mm. the siphuncle is one-quarter of the height of the phragmocone. The siphuncular segments are expanded, and the middle of the segment is the point of maximum expansion. The siphuncle is between the centre and the venter, but is not in contact with the ventral wall. The septa are gently curved, with the point of maximum depth at the centre of the phragmocone.

The siphonal formula is 2(+)/6/19(+): 1(+)/11/17/+);4 adorally, while apically it is 3.5(+)/5/29(+):1(+)/10/26(+);4.

The connecting rings are strongly adnate to the septa on the venter, and less strongly adnate to the septa on the dorsum. On the venter the adapical portion of the connecting ring is adnate to the adoral side of the septum for a distance of 1.3 mm, while the adoral portion of the connecting ring is adnate to the adapical side of the septum for 2.0 mm. On the dorsum the corresponding measurements are 0.9 mm and 1.0 mm. The septal necks are long and recurved, the septal brims are also long and recumbent to the septal necks. Both the necks and brims have been recrystallized in the holotype and the paratype, UTGD121158, has only the venter preserved. The length of the necks and brims are variable from one segment to another, as is the degree of recurving. Ventrally the neck is 1.1 mm long, and the brim is 0.8 mm long, while on the dorsum the neck is 1.5 mm and the brim is 1.2 mm. The siphonal deposits are extensively developed in the adapical portion of the specimens. The deposits consist of parietal deposits which form in the septal foramen and then grow adapically along the connecting ring. The deposits are thickest in the middle of the segment and thinner at the septal foramen. The deposits have a thinly laminated structure parallel to the siphonal surface. The deposits grow until they meet the adoral end of the next most adapical deposit and thus form a continuous lining. The adapical segments are unknown so there is no indication of whether or not the deposits form closed endocones, but as this happens in all the other members of the Gouldoceratidae it is also probably true for *Westfieldoceras*. The connecting rings are thick and consist of two layers. The two layers are, a thin dark band on the siphonal surface and a thick lighter band on the cameral surface. On the paratype, UTGD121158, the

Fig. 14—*Paramadiganella banksi* gen. et sp. nov. A, opaque sagittal section of the holotype, UTGD121138, venter left, ×4. B, opaque sagittal section of UTGD121141, venter left, ×3. C, opaque section ground up from the venter of UTGD81151, ×2. D, thin-section of UTGD121139, after the change in position of the siphuncle, venter left, ×10. E, enlargement of the dorsal side of the siphuncle in UTGD121139, venter left, ×20. F, sagittal thin section of UTGD121140, before the change in shape, venter right, ×20. G, enlargement of an opaque section of the apicad end of the holotype, venter left, ×14. H, thin-section of UTGD121140 showing the connecting rings, venter left, ×20. I, thin-section of the ventral septal neck in UTGD121139, venter left, ×30. J, thin-section of the dorsal septal neck in UTGD121139, venter left, ×30.


A
B
C
D
E
F
G
H
I
J


A
B
C
D
E
F
G
H
I
JK

lighter band appears to be made up of two layers, a dark inner band and a lighter band on the cameral surface, these two bands are of approximately equal thickness. There are no cameral deposits.

REMARKS: See generic remarks.

Genus **Tasmanoceras** Teichert & Glenister 1952

1952 *Tasmanoceras* Teichert & Glenister, p. 739.
1953 *Tasmanoceras* Teichert & Glenister; Teichert & Glenister, p. 16.
1964 *Tasmanoceras* Teichert & Glenister; Teichert, p. K179.
1968 *Tasmanoceras* Teichert & Glenister; Flower, p. 83.

TYPE SPECIES: *Tasmanoceras zeehanense* Teichert & Glenister 1952.

DIAGNOSIS: (emend. Stait herein from Teichert & Glenister 1952). Small discosorids with slowly expanding straight or weakly curved siphuncles. The siphuncle is half the diameter of the phragmocone. The siphuncle segments are slightly expanded between the septa, sloping at a moderately high angle to the axis of the siphuncle, adapically from the venter to the dorsum. The septal necks are slightly recurved cyrtochoanitic to hemichoanitic. The siphuncular deposits are finely laminated endocones which develop leaving only a siphonal space which varies in position from the centre to the dorsal side of the siphuncle. The central space may or may not be crossed by diaphragms. The connecting rings are thick and two-layered with a thin dark layer on the siphonal surface and a thick lighter layer on the cameral surface. No cameral deposits are known.

REMARKS: Teichert and Glenister (1952) established *Tasmanoceras* on two isolated siphuncles from Smelter's Quarry, Zeehan. Teichert and Glenister (1953) described another siphuncle of the type species from the Gordon River. They assigned *Tasmanoceras* to the endocerids mainly due to the presence of endocones. Flower (1968b, p. 83) noted the similarity between *Tasmanoceras* and *Donacoceras* and suggested that *Tasmanoceras* was a member of the Narthecoceratidae, which he included in the Michelinocerida. In the present study a great deal more material belonging to this genus has been collected and it is now clear that the similarities between *Tasmanoceras* and *Donacoceras* are homeomorphic. *Tasmanoceras* has thick connecting rings, with cyrtochoanitic to hemichoanitic septal necks and it has the fine laminated endocones typical of the Gouldoceratidae. *Tasmanoceras* differs from Gouldoceratidae gen. nov. A in having a siphuncle greater in diameter relative to the phragmocone, a siphuncle in contact with the ventral wall and in having less recurved septal necks. *Tasmanoceras* differs from *Benjaminoceras* in its shorter and more highly expanded segments and much longer and more recurved septal necks.

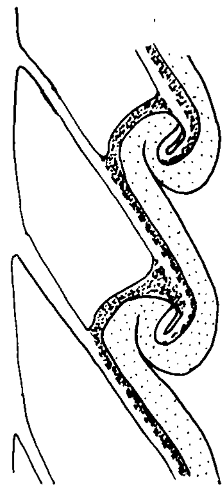


Fig. 16—The ventral septal necks and connecting ring of *Westfieldoceras taylori* UTGD121158, ×10. Spaced stipple indicates the siphonal deposits, while the close stipple indicates the connecting ring.

Tasmanoceras zeehanense Teichert & Glenister 1952
Fig. 17

1952 *Tasmanoceras zeehanense* Teichert & Glenister, p. 739, pl. 104, figs 3-9.
1953 *Tasmanoceras zeehanense* Teichert & Glenister; Teichert & Glenister, p. 16, pl. 4, figs 4, 5.

MATERIAL: Eight isolated siphuncles and one incomplete phragmocone. The specimens are UTGD121147, 121148, 121149, 121150, 121151, 121152, 121153, 121154 and 121155 from the Lower Limestone Member of the Benjamin Limestone in the Florentine Valley (localities 2, 6, 7 on Figs 3, 4).

DESCRIPTION: The phragmocone is straight, and the cross-section is subcircular, with the venter slightly flattened. The phragmocone is slowly expanding. In the

Fig. 15—A-E, Gouldoceratidae gen. nov. A., opaque sagittal section of UTGD121137, venter left, ×0.9. B, enlargement of the siphuncle in UTGD121137, venter left, ×4. C, opaque transverse section of the siphuncle in UTGD121137, venter below, ×8. D, enlargement of the ventral wall of the siphuncle in UTGD121137, venter left, ×10. E, enlargement of the dorsal wall of the siphuncle in UTGD121137, venter left, ×10. F-K, *Westfieldoceras taylori* gen. et sp. nov. F, opaque sagittal section of the holotype, UTGD95793, venter left, ×1.5. G, opaque sagittal section of UTGD121158, venter below, ×1. H, opaque sagittal section of UTGD121159, venter right, ×2. I, enlargement of the septal neck on the ventral side of UTGD121159, venter right, ×10. J, thin-section of the dorsal septal necks and connecting rings in UTGD95793, venter right, ×8. K, thin-section of the ventral septal necks and connecting rings of UTGD121158, venter left, ×10.

holotype there are 15 siphuncular segments in 28 mm. The siphuncle is approximately half of the diameter of the phragmocone, and is in contact with the ventral wall, although the variability of the siphuncle means that in some segments they are not quite in contact with the wall. The septa are curved, with the point of maximum depth at the siphuncle.

The siphonal formula of UTGD121147 is -/6.4/-:-/7.0/-;1.8 apically while at the adoral end of the specimen it is -/6.7/-:-/7.5/-;1.6.

The adapical part of the connecting ring is adnate to the adoral surface of the septa for a short distance on both the ventral and dorsal sides of the siphuncle. The connecting rings are thick and composed of two layers. There is a thick, light layer on the cameral surface and a thinner dark layer on the siphonal surface. The septal necks are orthochoanitic and are on average 0.4 mm long. The length of the septal necks are variable both in an individual specimen and between different specimens. There is a continuum of lengths and this cannot be used as a species characteristic. The siphonal deposits consist of thin endocones which slope adorally at a low angle to the siphuncular axis. The endocones are wavy mimicking the outline of the siphuncular segments, asymmetric and more strongly developed on the ventral side of the siphuncle. The position of the siphonal space is variable from almost central to very close to the dorsal wall of the siphuncle. There are no cameral deposits.

REMARKS: This description of specimens from the Florentine Valley belonging to the type species has been included as they show features not visible on either the holotype or paratype material. These descriptions are intended to supplement those of Teichert and Glenister (1952).

Tasmanoceras cf. **T. zeehanense** Teichert & Glenister 1952
Fig. 18F-H

MATERIAL: Two isolated siphuncles, UTGD56471a, 56471b from just south of a quarry at Mayberry near Mole Creek, State Grid. Ref. sheet 8114, 454980 (Fig. 1).

DESCRIPTION: The specimens are only isolated siphuncles. There are 21 siphuncular segments in 46 mm, which are expanded and slope adapically from the venter to the dorsum at 80°. The siphuncular segments are 2.5 mm long, 6.3 mm high at the septal foramen and 7.0 mm at the expanded part of the segment. The septa are poorly preserved but probably the adapical part of the connecting ring is adnate to the adoral surface of the septum ventrally. The dorsal wall of the siphuncle is not visible. The septal necks are orthochoanitic and 0.4 mm long. The siphuncular deposits are thin and slope adorally at a low angle to the siphuncular axis. The endocones are asymmetric being strongly concentrated on the venter. The siphonal space is midway between the centre and the dorsal wall of the siphuncle. The connecting rings are thick and contain two layers, a thick lighter layer on the cameral surface and a thinner dark layer on the siphonal surface.

REMARKS: These specimens differ from *Tasmanoceras zeehanense* in having siphuncular segments longer than is typical. The preservation is such that very few diagnostic features can be seen so a new species is not established.

Tasmanoceras pagei sp. nov.
Figs 18A-E, 19

DERIVATION OF NAME: For Mr. M. G. Page who studied the stratigraphy and palaeoecology of the Benjamin Limestone in the Florentine Valley.

MATERIAL: One specimen, UTGD121156, with the ventral wall of the phragmocone from 450 m above the base of the Lower Limestone Member in the Settlement Road section, Florentine Valley (locality 8 on Fig. 4). The age is Trenton.

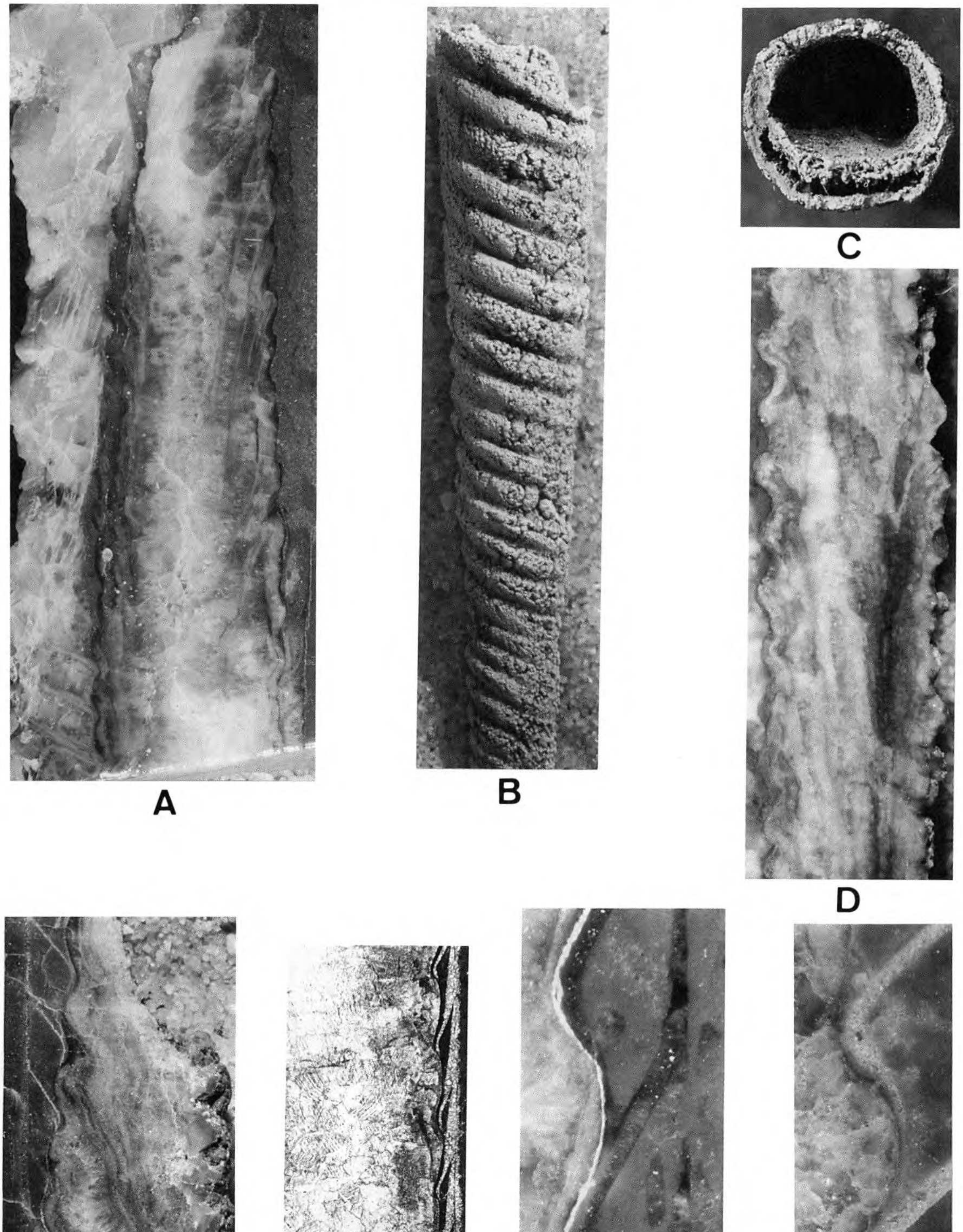
DESCRIPTION: Twenty-four siphuncular segments occur in a length of 28 mm. The siphuncle is close to the venter (however, the section is not quite sagittal and the siphuncle may be in contact with the ventral wall of the phragmocone). The siphuncular segments are expanded and slope apically from the venter to the dorsum at 70° to the axis of the siphuncle.

The siphonal formula is 1.0/4.7/-:0.7/6.5/-;1.2 adapically while at the adoral end of the specimen it is 1.0/4.6/-:0.8/6.5/-;1.0.

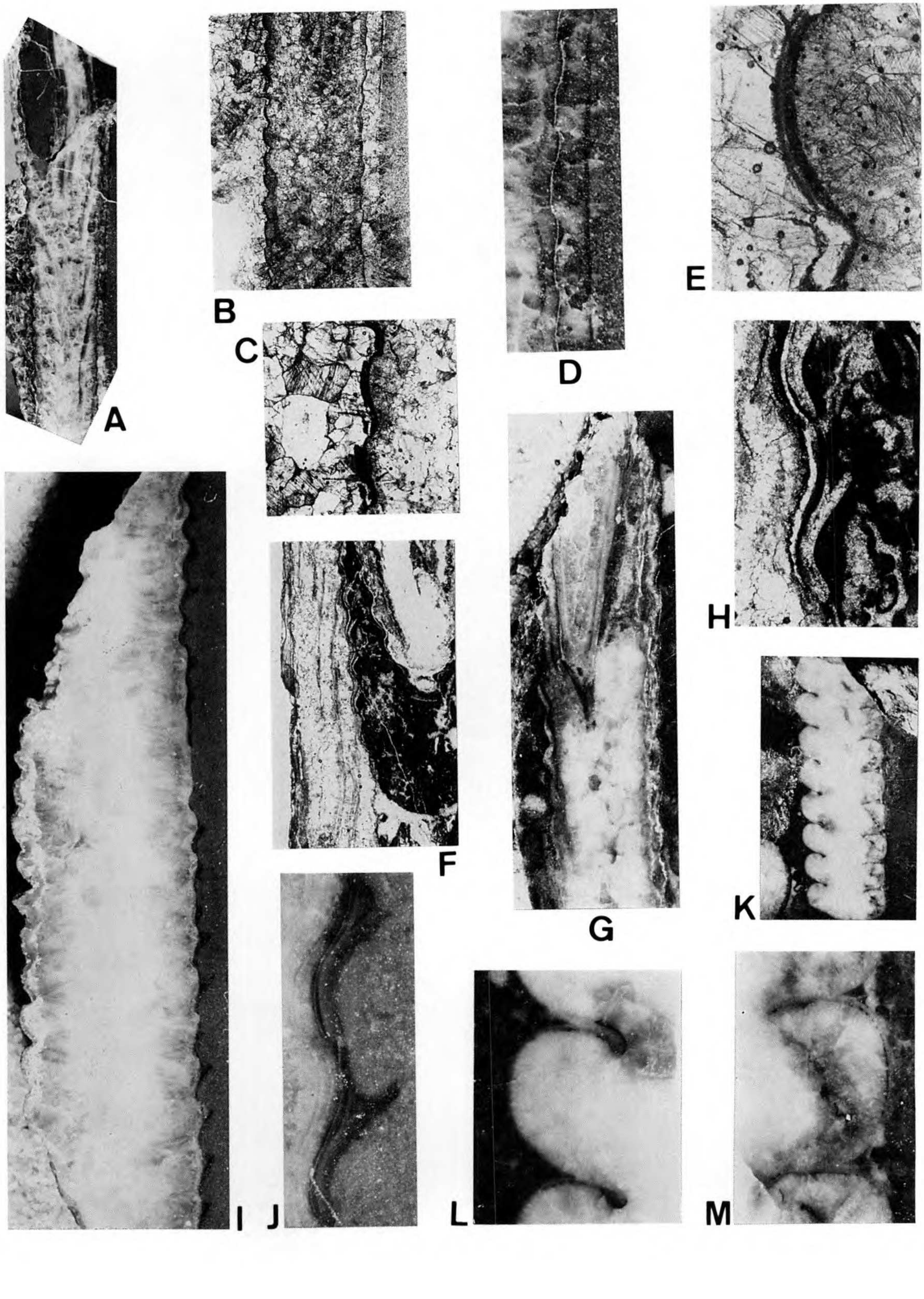
The connecting rings are not adnate to the septum dorsally, but ventrally the adapical part of the connecting ring is adnate to the adoral surface of the septum for a short distance. The septal necks are orthochoanitic and 0.4 mm long. The siphuncular deposits are composed of thin endocones, which slope adorally at a low angle to the siphuncular axis. The endocones are strongly asymmetric and are predominately developed on the venter. The endocones project much further forward on the venter than the dorsum. The siphonal space is near the dorsal wall of the siphuncle. The connecting rings are thick and composed of two layers. There is a thick, light layer on the cameral surface and a thinner dark layer on the siphonal surface.

REMARKS: The major difference between *T. zeehanense* and *T. pagei* is the ratio between the length and height

Fig. 17—*Tasmanoceras zeehanense* Teichert & Glenister 1952. A, opaque sagittal section of UTGD121147, venter right, ×3. B, silicified isolated siphuncle UTGD121152, venter left, ×3. C, transverse view of the endosiphocone of UTGD121152, venter below, ×5. D, opaque sagittal section of the siphuncle of UTGD121148, venter left, ×3. E, opaque sagittal section of UTGD121149, venter left, ×2. F, opaque sagittal section of the ventral side of the siphuncle in UTGD121155, venter right, ×3. G, enlargement of the septal necks and connecting rings in UTGD121150, venter right, ×30. H, enlargement of the septal necks and connecting rings in UTGD81144, venter left, ×30.



G


A
B
C
D
E
F
G
H
I
J
K
L
M

of the siphuncular segments. *T. pagei* has much shorter segments relative to its height than does *T. zeehanense*. The only other consistent difference is that the curvature between the septal necks and the rest of the septa is almost a right angle in *T. pagei*, but in *T. zeehanense* it is gently curved and the septal necks are generally longer.

Tasmanoceras cf. **T. pagei** sp. nov.
Fig. 18I, J

REMARKS: UTGD121157 has been tentatively compared to *T. pagei* because of the very short siphuncular segments relative to their width. The specimen occurs stratigraphically below the holotype of *T. pagei* (locality 6 on Fig. 4), in association with *T. zeehanense*, it is not assigned to a species as the specimen is poorly preserved.

GOULDOCERATIDAE gen. nov. A, sp. nov.
Fig. 15A-E

MATERIAL: One partially preserved phragmocone, UTGD121137 from the Lower Limestone Member of the Benjamin Limestone at the Westfield section in the Florentine Valley (locality 1 on Fig. 3). The age is Chazy – Lower Blackriver.

DESCRIPTION: The phragmocone is a longiconic orthocone, subcircular in cross-section, venter is slightly flattened. There are 14 siphuncular segments in 39 mm. The phragmocone is probably slowly expanding. The siphuncular segments are moderately and evenly expanded. The siphuncle is one-fifth of the diameter of the phragmocone. The septa are gently curved with the point of maximum depth at the siphuncle.

The siphonal formula is 2.3/5.6/19:1.8/6.7/16.4; 2.5, while apically it is 2.1/5.3/17.8:1.8/6.4/17;2.5.

Recrystallization has made the septal necks difficult to recognise, but they are short and cyrtochoanitic, with the necks and brims similar in length. The necks are only preserved adorally where the necks are 0.3 mm long and the brim 0.1 mm long on the venter and the necks 0.2 mm long and the brims 0.1 mm long on the dorsum. The adapical portion of the connecting ring is adnate to the adoral face of the septum for a short distance, 0.3 mm on the venter and 0.4 mm on the dorsum. The connecting rings are thick and appear to have a thin dark layer on the siphonal surface and a thick layer on the cameral surface, although as only an opaque section is available detailed study of the connecting ring is difficult. The siphuncle contains well developed and extensive deposits. The deposits consist of finely laminated endocones composed of a light brown material with each of these layers separated by a very thin dark layer. The light layers are highly variable in thickness both from one layer to the next and also within each layer. The layers are wavy and mimic the outline of the siphuncular segments. There is also a radial structure which is normal to the connecting rings in longitudinal section and in transverse section radial from the siphonal space. The siphonal space is slightly to the dorsal side of the centre and contains diaphragms spaced at regular (approximately 5 mm) intervals along it. The endocones extend slightly further forward on the venter than the dorsum. There are no cameral deposits.

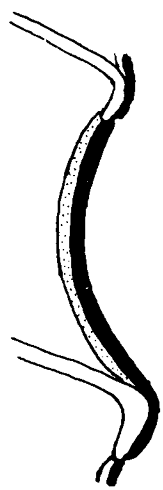


Fig. 19 – The dorsal septal necks and connecting ring of *Tasmanoceras pagei* UTGD121156, ×25.

REMARKS: As this genus is represented by only one sagittally sectioned phragmocone it is left in open nomenclature. The expanded siphuncle, thin continuous endocones, and the thick two layered connecting rings indicate that this genus is a typical member of the Gouldoceratidae. The small size of the siphuncle relative to the phragmocone, the diaphragms and the relatively short siphuncular segments together distinguish this genus from other members of the Gouldoceratidae.

Fig. 18 – A-E, *Tasmanoceras pagei* sp. nov. A, opaque sagittal section of the holotype, UTGD121156, venter right, ×1. B, sagittal thin-section of the holotype, UTGD121156, venter right, ×2. C, thin-section of the dorsal side of the siphuncle in UTGD121156, venter right, ×6. D, opaque section of the ventral side of the siphuncle in UTGD121156, venter right, ×5. E, enlargement of the septal neck and connecting ring on the dorsal side of UTGD121156, venter right, ×24. F-H, *Tasmanoceras* cf. *T. zeehanense*. F, sagittal thin section of the isolated siphuncle of UTGD56471, venter right, ×4. G, opaque sagittal section of UTGD56471, venter right, ×2.5. H, enlargement of the ventral septal necks and connecting ring in UTGD56471, venter right, ×25. I-J, *Tasmanoceras* cf. *T. pagei*. I, opaque sagittal section of the isolated siphuncle UTGD121157, venter right, ×4. J, enlargement of the ventral wall of the siphuncle of UTGD121157, ×20. K-M, Gouldoceratidae gen. nov. C., sp. nov., K, opaque sagittal section of the isolated siphuncle UTGD95796, venter right, ×1. L, enlargement of the dorsal side of the siphuncle in UTGD95796, venter right, ×7. M, enlargement of the ventral side of the siphuncle in UTGD95796, venter right, ×7.

GOULDOCERATIDAE gen. nov. B, sp. nov.
Fig. 10K-N

MATERIAL: One partially preserved phragmocone, UTGD22042 from near the top of the Upper Limestone Member of the Benjamin Limestone, just below the track to Gordon Bend at the south end of the Tiger Range, State Grid. Ref. Wedge 8112; 499702, in the Florentine Valley.

DESCRIPTION: The dorsal phragmocone wall and camerae have been destroyed in the only specimen available. Based on the part of the phragmocone preserved it is probably an orthoconic longicone, with a rounded cross-section. The siphuncle is preserved only in the anterior part of the phragmocone and contains five segments in 18 mm, is probably relatively small, one-fifth or less of the diameter. The siphuncular segments are highly expanded, with the dorsal segments nearly symmetrical along their length, the ventral segments expand more rapidly in the adoral portion of the segment.

The siphonal formula is 2.4/6.3/-:1.2/10/-;3.3.

Ventrally the adapical part of the connecting ring is adnate to the adoral surface of the septum for a distance of 2.7 mm, the adoral portion of the ring is not adnate to the septum. Dorsally the adapical part of the connecting ring is adnate to the adoral surface of the septum for 1.8 mm, while the adoral part of the connecting ring is adnate to the adapical surface of the septum for 0.6 mm. The connecting rings are thick and layered with a thin dark layer on the siphonal surface and a thick lighter layer on the cameral surface.The connecting rings are 0.3 mm thick. The septal necks and brims are both short with the brims on the venter recumbent to the septum and on the dorsum very short and free. Ventrally the septal necks are 0.3 mm long, and the brims are 0.2 mm long, while dorsally the corresponding measurements are 0.6 mm and 0.2 mm. Recrystallization has obscured details of siphonal structures. The deposits are of the parietal type which form in the septal foramen and grow adapically through many segments to form endocones. The deposits are more extensively developed on the venter, with the siphonal space on the dorsal side of centre. There are no cameral deposits. The structure of the ventral wall of the phragmocone is preserved in this specimen. The shell wall is 1.2 mm thick. The shell consists of two major divisions, firstly the inner thick (1.1 mm) layer which is composed of many (12+) finer, alternating lighter and darker layers of variable thickness, and secondly an outer thin (0.1 mm) lighter layer. The outer layer is composed of many fine fibres which are normal to the layering in the inner layer.

REMARKS: The presence of thick two layered connecting rings and endocone like siphonal deposits indicate that Gouldoceratidae gen. nov. B is assignable to the Gouldoceratidae. It is most similar to *Westfieldoceras* in the size of the siphuncle relative to the phragmocone, but differs in that the siphuncle is in contact with the ventral wall of the phragmocone and the septal necks and brims are short and not as strongly recumbent. Gouldoceratidae gen. nov. B is similar to the mature growth stage of *Benjaminoceras* in the type and form of the septal necks and brims, but differs from it in the shape and size of the siphuncle as *Benjaminoceras* probably has a relatively larger siphuncle.

GOULDOCERATIDAE gen. nov. C, sp. nov.
Fig. 18K-M

MATERIAL: Two isolated siphuncles UTGD95796 and 121160 from the upper part of the Upper Limestone Member of the Benjamin Limestone at the Westfield section in the Florentine Valley (locality 3 on Fig. 3).

DESCRIPTION: This species is only represented by isolated siphuncles. The siphuncle is in contact with the ventral phragmocone wall. There are eight siphuncular segments in 30 mm (UTGD95796). The siphuncular segments are highly expanded between the septal foramina and slope slightly adorally from the venter to the dorsum.

The siphonal formula at the fourth segment of UTGD95796 is 2/4/-:0/9/-;3.

The connecting rings are adnate to the septa both dorsally and ventrally. Ventrally the adoral part of the connecting ring is adnate to the adapical surface of the septa for a distance of 0.2 mm, while the adapical part of the connecting ring is adnate to the adoral surface of the septa for a distance of 1.0 mm. Dorsally the corresponding measurements are 1.0 mm and 1.0 mm. The connecting rings are thick. They have been largely recrystallized but there is an indication of a thin dark layer on the siphonal surface and a thick lighter layer on the cameral surface. The septal necks and brims are short and cyrtochoanitic; the brims are recumbent on the septa. The necks and brims are of similar length both dorsally and ventrally, 0.1 mm long. The siphonal deposits have been completely recrystallized, although one specimen shows possible remnants of a siphonal space and radial spaces.

REMARKS: The preservation of these specimens makes assignment difficult. The presence of a thick two layered connecting ring suggests they are assignable to the Gouldoceratidae. The siphonal and radial spaces are similar to those in *Gouldoceras* itself. The siphuncles are unlike those of any other member of the Gouldoceratidae. They are most closely related to Gouldoceratidae gen. nov. B but the septal necks and the shape of the siphuncular segments are different from those in Gouldoceratidae gen. nov. B.

ACKNOWLEDGEMENTS

The author wishes to thank the following people, Dr M. R. Banks, Dr. C. F. Burrett, Dr. J. R. Laurie, Kathi Kenna, Clive Calver and Mike Page for their help during all stages of this project. For advice and valuable discussion Prof. C. Teichert, Dr. R. H. Flower, Dr. M. Wade and Prof. W. C. Sweet are gratefully acknowledged. Prof. C. Barnes allowed time for the completion of this work while the author was employed at Memorial University of Newfoundland. The following are thanked for financial support, Australian Post Graduate Research Award Scheme, Australian Research Grants Scheme and the University of Tasmania, especially the special grants scheme.

REFERENCES

BURRETT, C. F., STAIT, B. A., SHARPLES, C., & LAURIE, J. R., 1984. Middle-Upper Ordovician shallow platform to deep basin transect, southern Tasmania, Australia. In *Aspects of the Ordovician System,* D. L. Bruton, ed., Palaeont. Contrib. Uni. Oslo 295. Universitetsforlaget, Oslo, 145-152.

CORBETT, K. D. & BANKS, M. R., 1974. Ordovician stratigraphy of the Florentine Synclinorium, southwest Tasmania. *Pap. Proc. R. Soc. Tasm.* 107: 207-238.

CALVER, C. R., 1977. Palaeoecology of the Lower Limestone Member, Benjamin Limestone, Florentine Valley. *Unpublished thesis, University of Tasmania.*

ETHERIDGE, R., 1883. A description of the remains of trilobites from the Lower Silurian rocks of the Mersey district, Tasmania. *Pap. Proc. R. Soc. Tasm.* (1882): 150-163.

FLOWER, R. H., 1962. Revision of *Buttsoceras. New Mexico Bur. Min. Res. Mem.* 10(1): 1-17.

FLOWER, R. H., 1964. Nautiloid shell morphology. *New Mexico Bur. Min Res. Mem.* 13: 1-79.

FLOWER, R. H., 1968a. The first great expansion of the actinoceroids. *New Mexico Bur. Min. Res. Mem.* 19(1): 1-16.

FLOWER, R. H., 1968b. Silurian cephalopods of James Bay Lowland, with a revision of the family Narthecoceratidae. *Geol. Surv. Canada Bull.* 164: 1-88.

FLOWER, R. H., 1976. Ordovician cephalopod faunas and their role in correlation. In *The Ordovician System,* M. G. Bassett, ed., University of Wales Press and Nat. Mus. of Wales, Cardiff, 523-552.

JOHNSTON, R. M., 1888. *Geology of Tasmania.* Govt. Printers, Hobart.

PAGE, M. G., 1978. Sedimentology and Palaeontology of the Upper Limestone Member, Benjamin Limestone. *Unpub. thesis, University of Tasmania.*

STAIT, B. A., 1980. *Gouldoceras* n. gen. (Cephalopoda, Nautiloidea) and a revision of *Hecatoceras,* Teichert and Glenister, from the Ordovician of Tasmania, Australia. *J. Paleont.* 54: 1113-1118.

STAIT, B. A., 1982. Ordovician Oncocerida (Nautiloidea) from Tasmania, Australia. *N. Jb. Geol. Palaont, Mh.* 1982: 607-618.

STAIT, B. A., 1983. Ordovician nautiloids of Tasmania, Australia—Ellesmerocerida and Tarphycerida. *Alcheringa* 7: 253-261.

STAIT, B. A., in press. Re-examination and redescription of the Tasmanian species of *Wutinoceras* and *Adamsoceras* (Nautiloidea, Ordovician). *Geol. et Palaeont.*

STAIT, B. A. & FLOWER, R. H., in press. Michelinoceratida (Nautiloidea) from the Ordovician of Tasmania, Australia. *J. Paleont.*

STAIT, B. A. & LAURIE, J. R., in press. Ordovician nautiloids of central Australia: with a revision of *Madiganella,* Teichert and Glenister. *Jour. Aust. Bur. Min. Res.*

SWEET, W. C., 1958. The Middle Ordovician of the Oslo region, Norway. *Norsk. Geol. Tidssk.* 38: 1-177.

TEICHERT, C., 1947. Early Ordovician cephalopods from Adamsfield, Tasmania. *J. Paleont.* 21: 420-428.

TEICHERT, C., 1964. Glossary of morphological terms used for nautiloids, pp. 320-342. In *Treatise on Invertebrate Paleontology, part K. Mollusca* 3, R. C. Moore, ed., Geol. Soc. Amer. and Uni. Kansas Press, Lawrence.

TEICHERT, C. & CRICK, R. E., 1974. Endosiphuncular structures in Ordovician and Silurian cephalopods. *Uni. Kansas Paleont. Contrib.* in *Pap.* 71: 1-13.

TEICHERT, C. & GLENISTER, B. F., 1952. Fossil nautiloid faunas from Australia. *J. Paleont.* 26: 730-752.

TEICHERT, C. & GLENISTER, B. F., 1953. Ordovician and Silurian cephalopods from Tasmania, Australia. *Bull. Amer. Paleont.* 34: 1-66.

WADE, M., 1977a. The siphuncle in Georginidae and other Ordovician actinoceroid cephalopods. *Lethaia* 10: 303-315.

WADE, M., 1977b. Georginidae, new family of actinoceroid cephalopods, Middle Ordovician, Australia. *Mem. Qd Mus.* 18(1): 1-15.

WEBBY, B. D., VANDENBERG, A. H. M., COOPER, R. A., BANKS, M. R., BURRETT, C. F., HENDERSON, R. A., CLARKSON, P. D., HUGHES, C. P., LAURIE, J., STAIT, B., THOMSON, M. R. A., & WEBERS, G. F. 1981. The Ordovician System in Australia, New Zealand and Antarctica: correlation chart and explanatory notes. *Int. Union Geol. Sci. Pub.* 6: 1-67.