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Chitinozoans and associated conodonts from the Early Devonian Point Hibbs Formation, Tasmania, Australia.

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Abstract – Chitinozoans from the Early Devonian Point Hibbs Formation are described and illustrated; associated conodonts are illustrated for the first time and conodont evidence for dating is reviewed. The chitinozoan species *Bulbochitina bulbosa* Paris, which has been used as an index species for the late Pragian by Paris *et al.* (1999) in their global biozonation of the Devonian, occurs in the middle part of the Point Hibbs Formation. Previous studies have shown that the oldest *B. bulbosa* occurs low in the *kindlei* Conodont Zone, and the presence of this species suggests that the middle and upper part of the Point Hibbs Formation belong to the *kindlei* Conodont Zone or higher. Chitinozoan species recovered from Tasmania include those with representatives in western France, Bohemia, Poland, Victoria and northern Queensland.

INTRODUCTION

Point Hibbs is a promontory on the isolated west coast of Tasmania. The rocks at Point Hibbs and along the adjacent coast range in age from Precambrian to Jurassic, and are juxtaposed along southeasterly-dipping thrust planes (Brown *et al.* 1991; Carey and Berry 1988; McClenaghan *et al.* 1994). Of the three Devonian units present, only the Point Hibbs Formation is predominantly limestone. The Point Hibbs Formation occurs in two separate fault slivers at Sanctuary Bay and at 'Clearwater Point' (Figure 1).

The Point Hibbs Formation consists of fossiliferous lime packstone interbedded with calcareous terrigenous mudstone in nearly equal proportions (Carey 1989; Carey and Berry 1988). Both rock types are thinly bedded and richly fossiliferous, and locally the packstone is partially replaced by dolomite.

Early Devonian macrofossils from this area have been the subject of several studies, especially the corals which dominate much of the outcrop (Hill 1942; Jell and Hill 1970; Pedder 1998; Pedder and McLean 1982), and brachiopods (Flood 1974). The fauna also comprises bryozoans, echinoderms, tentaculitids, gastropods, bivalves, ostracodes and trilobites. The environment of deposition is interpreted as being open marine, below normal wave base, as evidenced by the abundance of mud, which was disturbed episodically by storm turbulence (Carey and Berry 1988). The microfauna comprises conodonts (Philip and Pedder 1968; Burrett 1984; Carey and Berry 1988), microvertebrates (Burrow *et al.* 1998), linings of agglutinated foraminifera (Bell and Winchester-Seeto 1999 in press), chitinozoans (described herein) and scolecodonts.

Although the lower part of the Point Hibbs Formation has been interpreted as belonging to the *sulcatus* Conodont Zone by many workers, the age of the upper part was uncertain. The impetus of this study was to document the chitinozoans and to use them to further refine the dating of the Point Hibbs Formation.

METHODS

Details of the sections used in this study are provided in Carey and Berry (1988), with the 'Clearwater Point' section in the north, and a composite of three sections correlated by marker horizons comprising the Sanctuary Bay section. The samples were collected by Steve Carey in 1985 for sedimentological studies and for further conodont work; the same samples were subsequently investigated for chitinozoans.

Methods of processing for chitinozoans follow those outlined by Paris (1981), including initial treatment of 50 g of crushed rock with 10% HCl until all the carbonate has been dissolved, followed by acid digestion by 70% HF for 12–48 hours. Concentrated nitric acid was used when necessary for surface etching, dissolution of fluoride salts and the destruction of amorphous organic matter. The

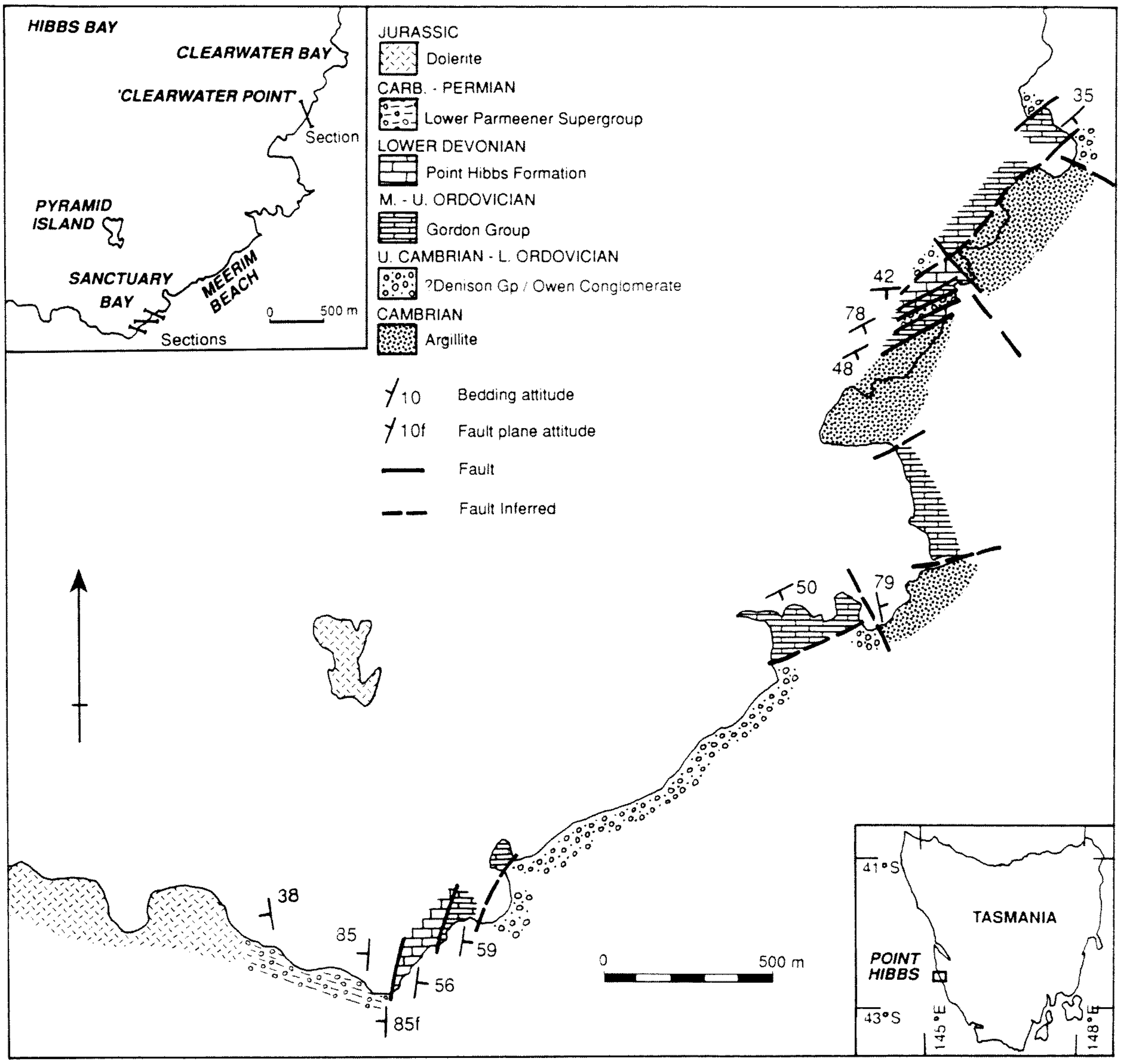


Figure 1 Locality map, Point Hibbs, Tasmian showing geology along the coastline and position of 'Clearwater Point' and Sanctuary Bay section (from Carey and Berry 1988).

residue was then separated through a 53µm sieve and picked with a micropipette. Representatives of each species were selected and mounted onto a stub with carbon tape for photography using an Environmental Scanning Electron Microscope (E-SEM) Model E-3.

RESULTS

Nine species of chitinozoans were extracted from three samples of the Point Hibbs Formation (figures 2–4); two samples of the Point Hibbs Formation and one sample from the Gordon Group were barren. Well preserved scolecodonts and linings of agglutinated foraminifera were also present in the samples; the foraminifer *Hyperammina* sp. cf. *H. sappingtonensis* Gutschick was recovered from sample PH-85-29 from the Sanctuary Bay section (Bell and Winchester-Seeto 1999 in press). The specimens are, in general, moderately well preserved, though some of the thinner-walled specimens show compression and some have considerable erosion of ornament; specimens of *Bulbochitina bulbosa* Paris are more robust, and consequently withstood compaction and diagenesis better (figures 5, 6). The chitinozoans were extracted from the fossiliferous lime packstone, with large bioclasts of brachiopods and other macrofauna. They were preserved in fine mud matrix between the bioclasts, possibly resulting from a fine "rain" of mud and organic matter drifting down after the bioclasts had been deposited. The organic-walled microfossils were all dark-brown to black, but not charcoalised, indicating a low degree of thermal maturity, corresponding to the Conodont Alteration Index of 1 determined by Burrett (1984) .

The chitinozoan species recovered from Tasmania include those with representatives in western

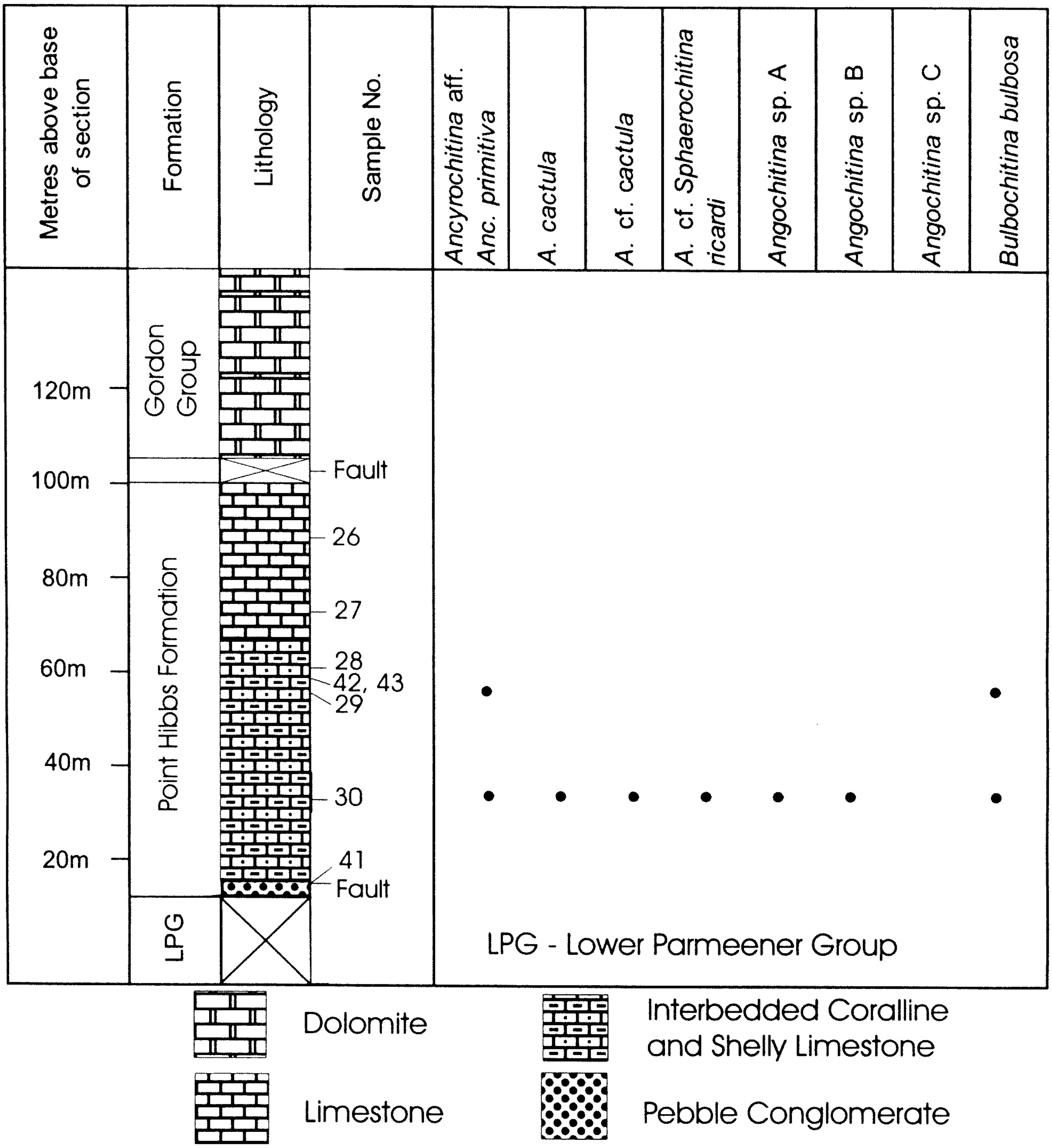


Figure 2 Stratigraphic chart of the Sanctuary Bay section, showing stratigraphic position of chitinozoan samples and distribution of species recovered.

France, Bohemia, Poland, Victoria and northern Queensland, confirming the wide geographic spread of many important Early Devonian species..

Carey and Berry (1988) extracted a conodont fauna including *Ozarkodina remscheidensis* ssp. cf. *O. r. remscheidensis* (Ziegler) (figure 7A–H), *Belodella resima* (Philip) (figure 7L), *Oulodus* sp.(figure 7J–K) and *Panderous unicostatus* (Branson and Mehl) (figure 7M–P), illustrated herein for the first time. None of these species, however, gives a precise age as does the recovery of the index species, *Eognathodus sulcatus sulcatus* reported by Philip and Pedder (1968). The conodonts were extracted from samples PH-85-30 (*O. remscheidensis* ssp. cf. *O. r. remscheidensis*, *Oulodus* sp.) and PH-85-42 (*O. remscheidensis* ssp. cf. *O. r. remscheidensis*) from the Sanctuary Bay section, and samples PH-85-33 (*O. remscheidensis* ssp. cf. *O. r. remscheidensis*, *B. resima*) PH-85-34 (*P. unicostatus*) and PH-85-35 (*O. remscheidensis* ssp. cf. *O. r. remscheidensis*, *Oulodus* sp., *P. unicostatus*) from the 'Clearwater Point' section.

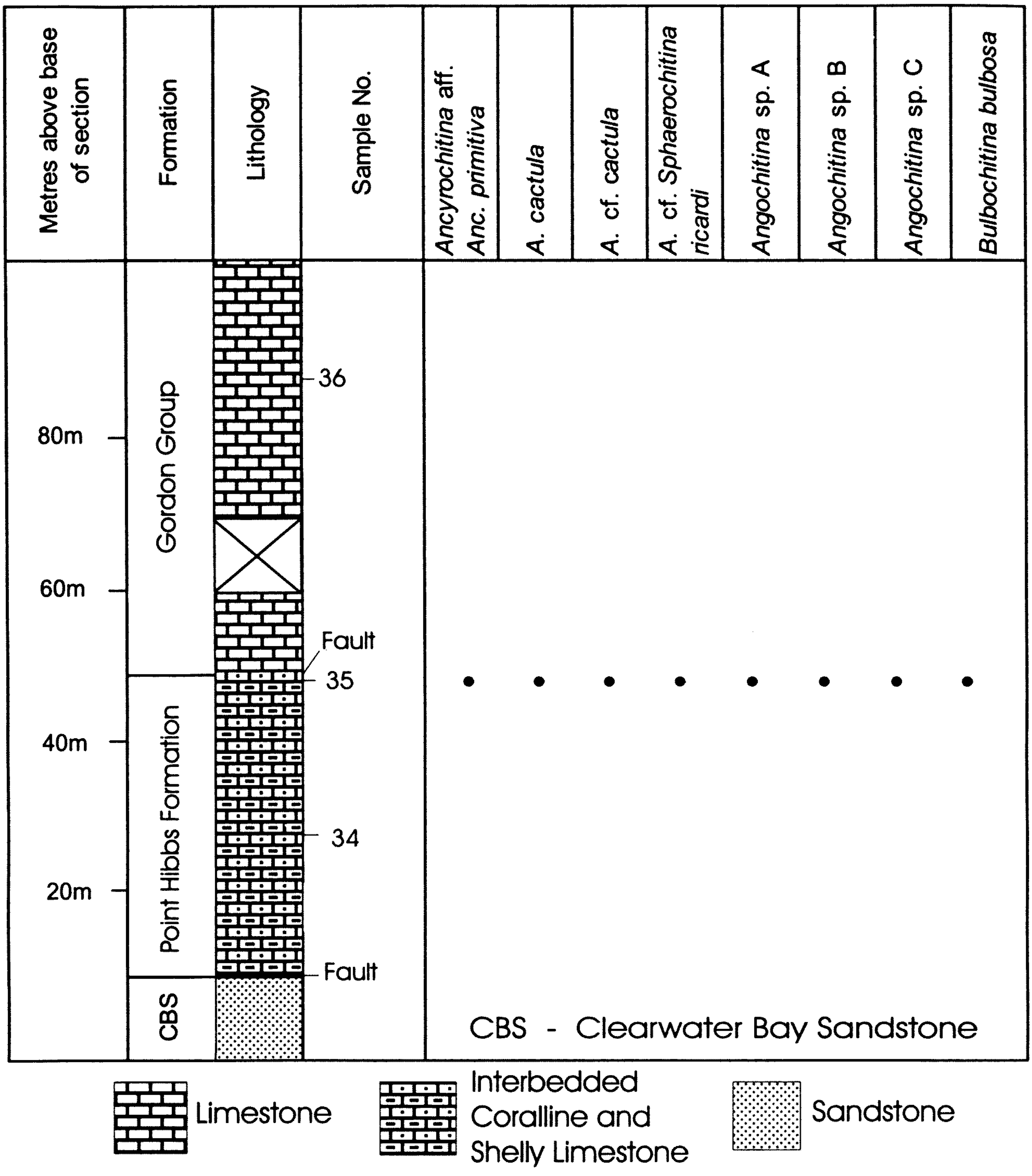


Figure 3 Stratigraphic chart of the 'Clearwater Point' section, showing stratigraphic position of chitinozoan samples and distribution of species recovered.

BIOSTRATIGRAPHIC IMPLICATIONS

Pragian chitinozoans have been studied in only three places in Australia: Martins Well Limestone in northern Queensland (Winchester-Seeto 1993a), the Coopers Creek Limestone at Boola Quarry in eastern Victoria (Winchester-Seeto 1993a), and the Garra Formation in central New South Wales (Winchester-Seeto 1993b). The Garra Formation and Martins Well Limestone both span the *pesavis-sulcatus* conodont zones, and the Coopers Creek Limestone includes the boundary between the *sulcatus-kindlei* conodont zones. Elsewhere Pragian chitinozoans are known from North Africa (Magloire 1967; Taugourdeau and de Jekhowsky 1960), southwestern Europe (Diez and Cramer 1978; Paris 1981), central Europe (Chlupác *et al.* 1985; Wrona 1980), China (Gao 1986) and Canada (Achab *et al.* 1997).

Paris *et al.* (1999) erected a global biozonation of the Devonian based on chitinozoans, with four chitinozoan biozones in the Pragian; one, is as yet, undefined. The biozones are based on the following index species *Angochitina comosa* Taugourdeau and de Jekhowsky, *Angochitina caeciliae* Paris, and *Bulbochitina bulbosa* Paris. The presence of *B. bulbosa* in samples PH-85-29, 30 and 35 at Point Hibbs gives a clear correlation to the *B. bulbosa* biozone. The base of this biozone is defined by the first occurrence of *B. bulbosa* in the Lézais section of the Aubrais Member of the Bois-Roux Formation in western France (Paris 1981), which correlates with the *serratus* Conodont Zone of Chlupác (1988) (= *kindlei* Conodont Zone). The oldest occurrence of *B. bulbosa* in Australia is from the Coopers Creek Limestone, eastern Victoria, 6 m above the *sulcatus-kindlei* conodont zone boundary (Winchester-Seeto 1993a). Thus, based on the presence of *B. bulbosa*, the chitinozoans indicate that, by 32.9 m above the base of the Sanctuary Bay section and 47.7 m above the base of the 'Clearwater Point' section, the *kindlei* Conodont Zone is already present.

The lower part of the Point Hibbs Formation has been interpreted as belonging to the *sulcatus* Conodont Zone based on the presence of *Eognathodus sulcatus sulcatus* in samples from very low in the formation, collected by A.E.H. Pedder and G.M. Philip in 1964; these were initially referred to *Eognathodus sulcatus* in Philip and Pedder (1968) and subsequently identified as *E. sulcatus sulcatus* in Pedder and McLean (1982). No other zonally diagnostic conodonts have been found (Carey and Berry 1988), leaving correlation of the upper part of the formation in doubt.

The exact location and position of the two conodont samples collected by Pedder in 1964 (UNE 454 and UNE 455) is unclear, as the measurements are referred to as "rough" and "approximate" (Flood 1974; Pedder 1998; Pedder and McLean 1982); nor is it clear how the measurements given for these samples relate to the samples described herein, as the area is fault-bounded at the base. Gilbert Klapper (pers. comm. 1996) re-examined the conodont assemblages from these samples and confirmed that sample UNE 454, from 17 m above the base of exposure in Sanctuary Bay, contains one specimen of *Eognathodus sulcatus sulcatus* and several specimens of an indeterminate *Ozarkodina*, verifying the assignment to the *sulcatus* Zone. The sample UNE 455 from 45 m (or 46 m) above the base of exposure, however, is problematic, as there is one fragmentary specimen of what appears to be *E. sulcatus sulcatus* and several specimens of an indeterminate *Ozarkodina*. The fragmentary specimen of *Eognathodus* closely resembles a morphotype illustrated from the *sulcatus* Zone at Copenhagen Canyon in central Nevada (Murphy *et al.* 1981, figure 12 –1, from the COP II section at 177 feet). The zonal determination of sample UNE 455 is thus less certain (G. Klapper, pers. comm. 1996).

Taxa \ Sample No.	PH-85-29	PH-85-30	PH-85-35
Bulbochitina bulbosa	3	25	66
Ancyrochitina aff. *Anc. primitiva*	15	100	37
Angochitina cactula	7	19	113
A. cf. *cactula*	0	2	14
A. cf. *ricardi*	5	0	15
Angochitina sp. A	2	4	10
Angochitina sp. B	4	6	37
Angochitina sp. C	0	?1	24
sp. indet.	1	3	16

Figure 4 Chart showing the distribution of chitinozoan species recovered from the Point Hibbs Formation.

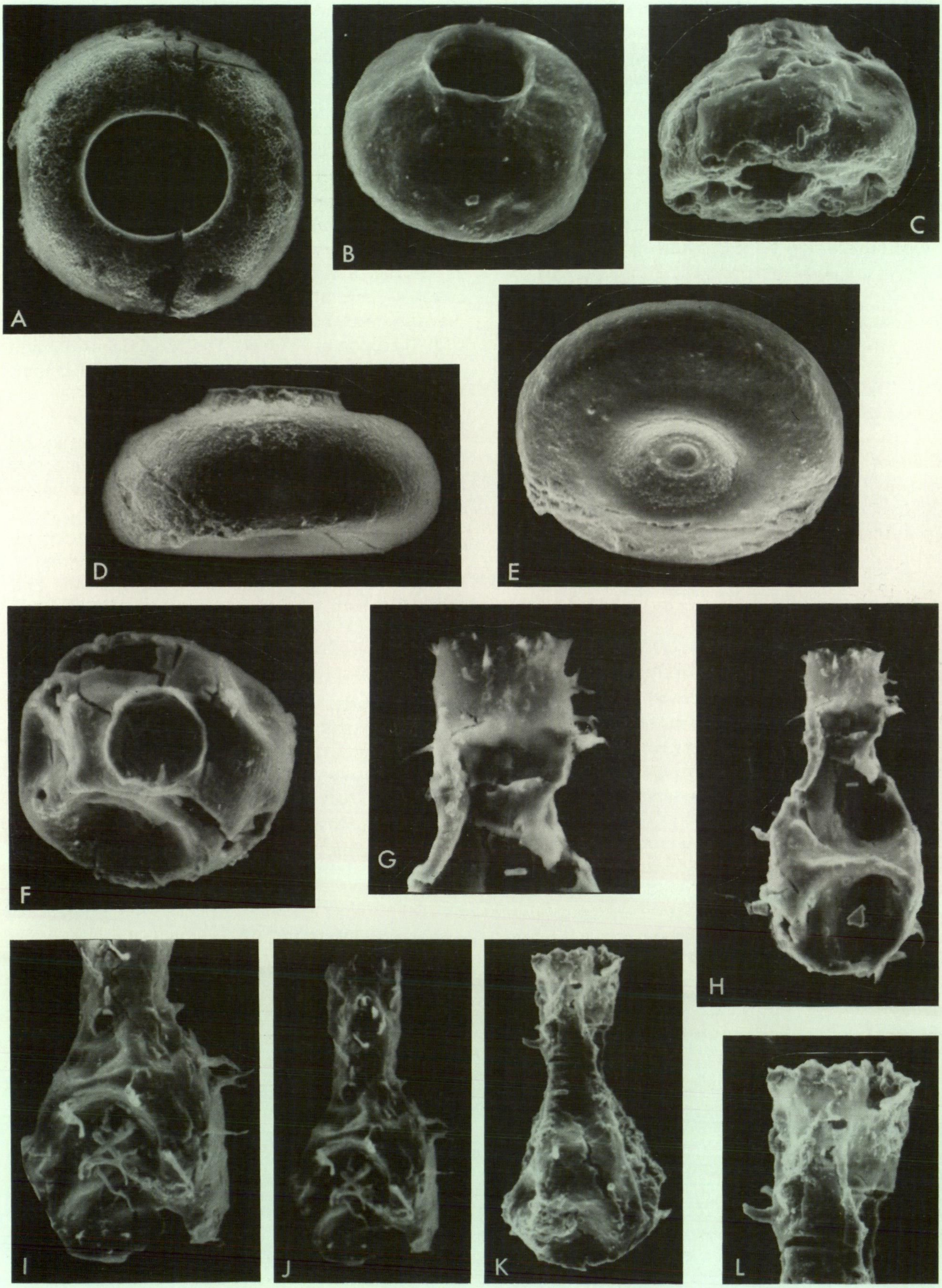
The additional evidence from the chitinozoans suggests that the *sulcatus* Conodont Zone is present at the base of the Point Hibbs Formation, and that the *sulcatus-kindlei* boundary lies somewhere below 32.9 m on the Sanctuary Bay section. The exact position is unknown because we cannot integrate the critical conodont and chitinozoan evidence. Closer sampling for studies of chitinozoans and conodonts may solve this problem.

CONCLUSIONS

This study demonstrates the utility of chitinozoans for solving biostratigaphic problems. It is also apparent that using integrated data from two microfossil groups can give a more precise correlation than is possible when relying on only one line of evidence. The additional information may have implications for the biostratigraphy of macrofossils from this area.

SYSTEMATIC PALAEONTOLOGY

All measurements are expressed in microns. Abbreviations used in the text are: L = length of vesicle; Lc = length of chamber; Ln = length of neck; Dmax = maximum diameter of chamber; Dn = diameter of neck; Da = diameter of aperture; Lsp = length of spines. Morphological terms used in this paper are those defined by Laufeld (1974: 37–38) and Paris (1981: figs 56, 57). A correction factor of 0.7 has been used for those individuals whose diameter has been distorted by total flattening, following, in part, the precedent set by Jaglin (1986). Most of the specimens recovered in this study were in full relief, or only partially flattened, consequently the procedure was used infrequently. Abbreviations used for genera are: *Anc.* = *Ancyrochitina*, *A.* = *Angochitina*, *B.* = *Bulbochitina*, *S.* = *Sphaerochitina*.


A
B
C
D
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L

Type and figured specimens are housed in the collections of the University of Tasmania, Hobart (numbers prefixed by UTGD). Rock samples are designated as PH-85-29, PH-85-30 and PH-85-35 (for explanation of stratigraphic positions, see figs 2, 3). The repository numbers for the field samples are presented in the appendix.

Order Operculatifera Eisenack, 1972

Family Desmochitinidae Eisenack, 1931 emend. Paris, 1981

Subfamily Desmochitininae Paris, 1981

Bulbochitina Paris, 1981

Type species.
Bulbochitina bulbosa Paris 1981

Bulbochitina bulbosa Paris, 1981
Figures 5A–F

Bulbochitina bulbosa Paris 1981: 134–135, pl. 35, figs 1–8, 10–19, pl. 37, fig. 1

Bulbochitina bulbosa Winchester-Seeto 1993a: 105, figs 12A–E

Material
28 specimens from samples PH-85-30 and PH-85-29, 32.9 and 57.3 m respectively above the base of the Point Hibbs Formation in the Sanctuary Bay section and 66 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section

Stratigraphic occurrence
?upper Pragian-lower Emsian, Bois-Roux Formation and Foulerie Formation, western France (Paris 1981); *kindlei* Conodont Zone, Pragian, Coopers Creek Limestone, Victoria, southeastern Australia; *kindlei* Conodont Zone, Pragian, Point. Hibbs Formation, SW Tasmania, Australia.

Remarks
Specimens of *B. bulbosa* fit within the diagnosis given by Paris (1981, p. 134), but display a number of differences to those found in western France by Paris or those from Boola Quarry, Coopers Creek Limestone, southeastern Australia (Winchester-Seeto 1993a). In particular, the Point Hibbs collection has a much squatter, more lenticular shape than previously described; in general the vesicle is quite short (L = 71.4–80.6 µm for specimens from Point Hibbs, whereas L = 111–158 µm from Boola Quarry, but L = 73–146 µm from western France) and the ratio of total length to maximum diameter is lower (L/Dmax = 0.33–0.41 for specimens from Point Hibbs, L/Dmax = 0.79–1.4 from Boola Quarry and L/Dmax = 0.65–0.9 measured from specimens from western France illustrated by Paris (1981, Pl. 35, figs 1, 2, 8, 10, 12, 16, 17).

Measurements
Taken from 15 specimens from samples PH-85-29, PH-85-30 and PH-85-35.

L 71.4–80.6 (Av. 76.8); Dmax 101.5–183.3 (Av. 151.2); Da 40.6–72 (Av. 58.5); L/Dmax 0.46–0.77; Da/Dmax 0.33–0.41

Order Prosomatifera Eisenack, 1972

Family Lagenochitinidae Eisenack, 1931 emend. PARIS, 1981

Subfamily Ancyrochitininae Paris, 1981

Ancyrochitina (Eisenack 1955)

Type species
Conochitina anycrea (Eisenack 1931)

Ancyrochitina aff. *Anc. primitiva* Eisenack, 1964
Figures 6A–D

Ancyrochitina aff. *Anc. primitiva* Wrona 1980: 127, pl. 25, figs 1–4

Material
115 specimens from samples PH-85-30 and PH-85-29, 32.9 and 57.3 m respectively above the base of the Point Hibbs Formation in the Sanctuary Bay section and 37 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

◀ **Figure 5** Numbers with the prefix UTGD indicate that the specimens are housed in the collections of the University of Tasmania; samples are prefixed with PH-85 and the last two digits indicate the field number (see figs 2, 3) **A–F**, *Bulbochitina bulbosa* Paris. **A**, UTGD127067 from sample PH-85-29 (x350). **B**, UTGD127068 from sample PH-85-30 (x400). **C**, UTGD127069 from sample PH-85-35 (x450). **D**, UTGD127070 from sample PH-85-29 (x400). **E**, UTGD127071 from sample PH-85-30 (x350). **F**, UTGD127072 from sample PH-85-35 (x400). **G–J**, *Angochitina* sp. A from sample PH-85-35. **G,H**, UTGD127073, **G**, (x700), **H**, (x400). **I**, **J**, UTGD127074, **I**, (x500), **J**, (x400). **K**, **L**, *Angochitina* cf. *Sphaerochitina ricardi* Diez and Cramer. UTGD127075, from sample PH-85-35, **K**, (x400), **L**, (x600).

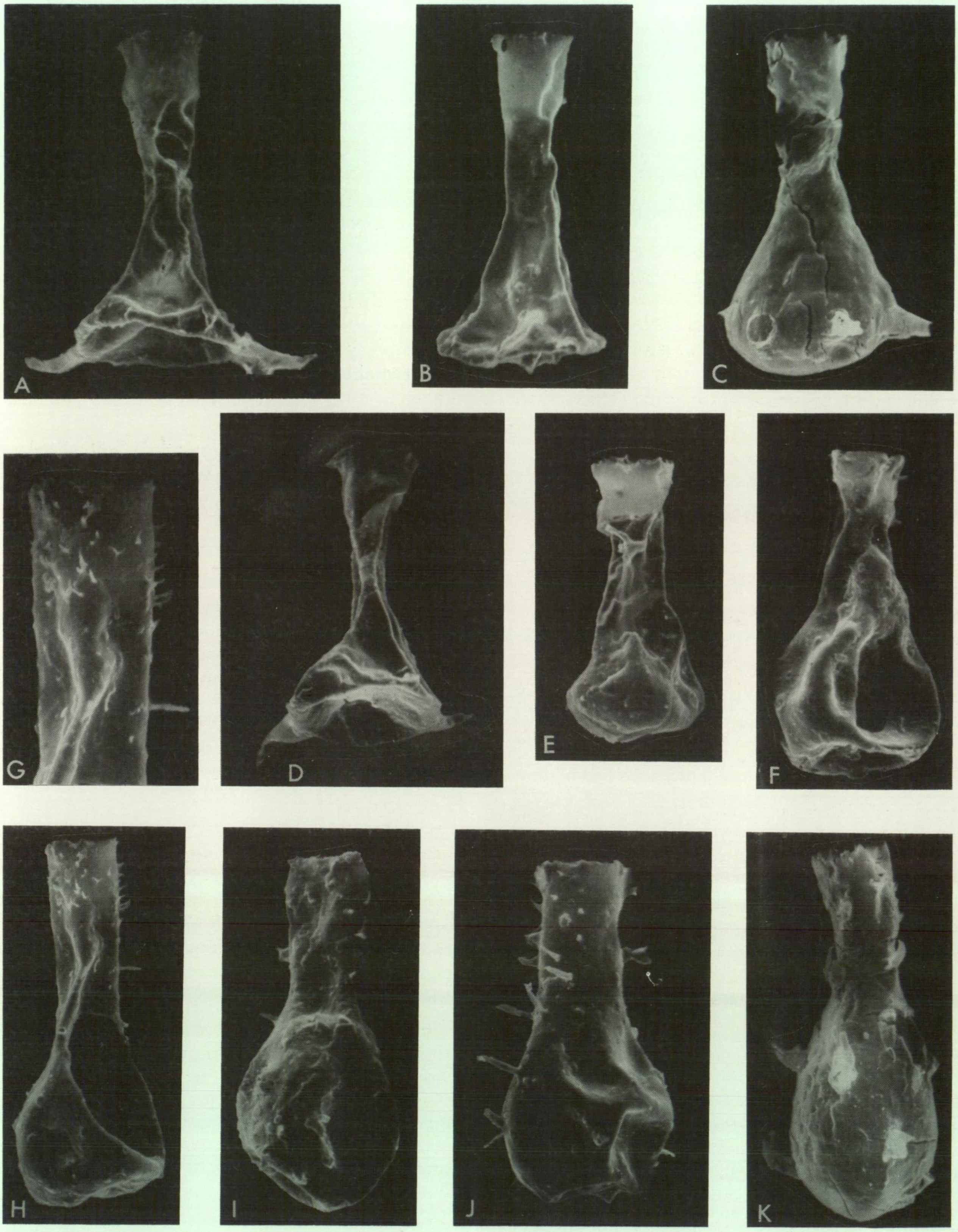


Figure 6 **A–D,** *Ancyrochitina* aff. *Anc. primitiva* Eisenack from sample PH-85-30, **A,** UTGD127076, (x400). **B,** UTGD127077, (x400). **C,** UTGD127078, (x400). **D,** UTGD127079, (x400). **E, F,** *Angochitina* cf. *A. cactula* Winchester-Seeto. **E,** UTGD127080 from sample PH-85-30 (x400). **F,** UTGD127081 from sample PH-85-35 (x400). **G–I,** *Angochitina cactula* Winchester-Seeto. **G, H,** UTGD127082 from sample PH-85-30 **G,** (x400), **H,** (x350). **I,** UTGD127083 from sample PH-85-35 (x400). **J,** *Angochitina* sp. B. UTGD127084 from sample PH-85-30 (x400). **K,** *Angochitina* sp. C. UTGD127085 from sample PH-85-35 (x350).

Stratigraphic occurrence

Upper Pridoli to upper? Pragian of the Radom-Lublin region of Poland and the *kindlei* Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description

This species has a conical chamber with a broad basal edge. The base may be flat, concave or weakly convex depending on the severity of vesicle compression. The basal edge bears 5–7 simple processes of medium length, many curved towards the oral pole; these processes have very wide bases and can often be detected only as scars indicating their original position. The neck is cylindrical with no indication of spines. Flexure is gentle and no shoulders are apparent. A distinctive feature of the species is a thin, translucent collar with a smooth surface texture. The collar is quite long occupying 14–25% of total vesicle length, flaring slightly with a crenulate edge.

Remarks

This species fits within the range of size and shape variation of *Ancyrochitina primitiva* Eisenack described and depicted by Eisenack (1964, 1968, 1970; Laufeld (1974) and Paris (1981). *Ancyrochitina* aff. *Anc. primitiva* Eisenack differs only slightly from the original diagnosis in showing no specimens with neck spines, however Eisenack (1964) also noted that some individuals within the population lacked neck spines. The characteristic long collar of *Anc.* aff. *Anc. primitiva* may be a distinguishing trait; it is difficult to determine the actual length of the collar in the silhouettes used by Eisenack, but they appear to range from 7 to18% of the total vesicle length (measured from photomicrographs in Eisenack 1968, Plate 27, figs. 1–9 and Plate 31, figs 11–12), i.e. less that that of the Point Hibbs population, while those illustrated by Laufeld (1974) range from 5 to 12% of total vesicle length (measured from Figs 12B and 12D). The highest stratigraphic occurrence of *Anc. primitiva* is found in Pridolian Val Formation, Ille-et-Vilaine in western France (Paris 1981).

Wrona (1980) reports *Anc.* aff. *Anc. primitiva* in the lower and upper Ciepelovian (i.e. approximately equivalent to the Pragian) of Poland, with a similar morphology and size range, including the longer collar (18–21% of total vesicle length, measured from Plate 25, figs 1–4) and lack of neck spines. The Polish specimens differ, however, in having basal processes that curve aborally for part of their length before bending up towards the oral pole at the tips. This feature is probably only a regional variation and *Anc.* aff. *Anc. primitiva* may be an end-member of an evolutionary sequence. At this stage *Anc.* aff. *Anc. primitiva* is kept in open nomenclature because the variation is not significant enough to warrant the erection of a new species, however the minor difference in collar length may prove to be stratigraphically useful.

Measurements

Taken from 24 specimens from samples PH-85-29, PH-85-30 and PH-85-35.

L 105–151.4 (Av. 130.5); Ln 52–82.9 Av. 71); Lc 45–72.4 (Av. 62.1); Dmax 39.7–80 (Av. 69.6); Dn 17–33.6 (Av. 27); Lprocess 16–40; Ln/L 0.49-0.6; L/Dmax1.6–2.7

Angochitina Eisenack, 1931

Type species

Angochitina echinata Eisenack 1931

Angochitina cactula Winchester-Seeto 1993a

Figures 6G–I

Angochitina cf. *A. crassispina* Wrona 1980: 129, pl. 27, figs 1–6.

Angochitina cactula Winchester-Seeto 1993a: 98, figs 9A–E.

Material

36 specimens from samples PH-35-30 and PH-35-29, 32.9 and 57.3 m respectively above the base of the Point Hibbs Formation in the Sanctuary Bay section and 113 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence

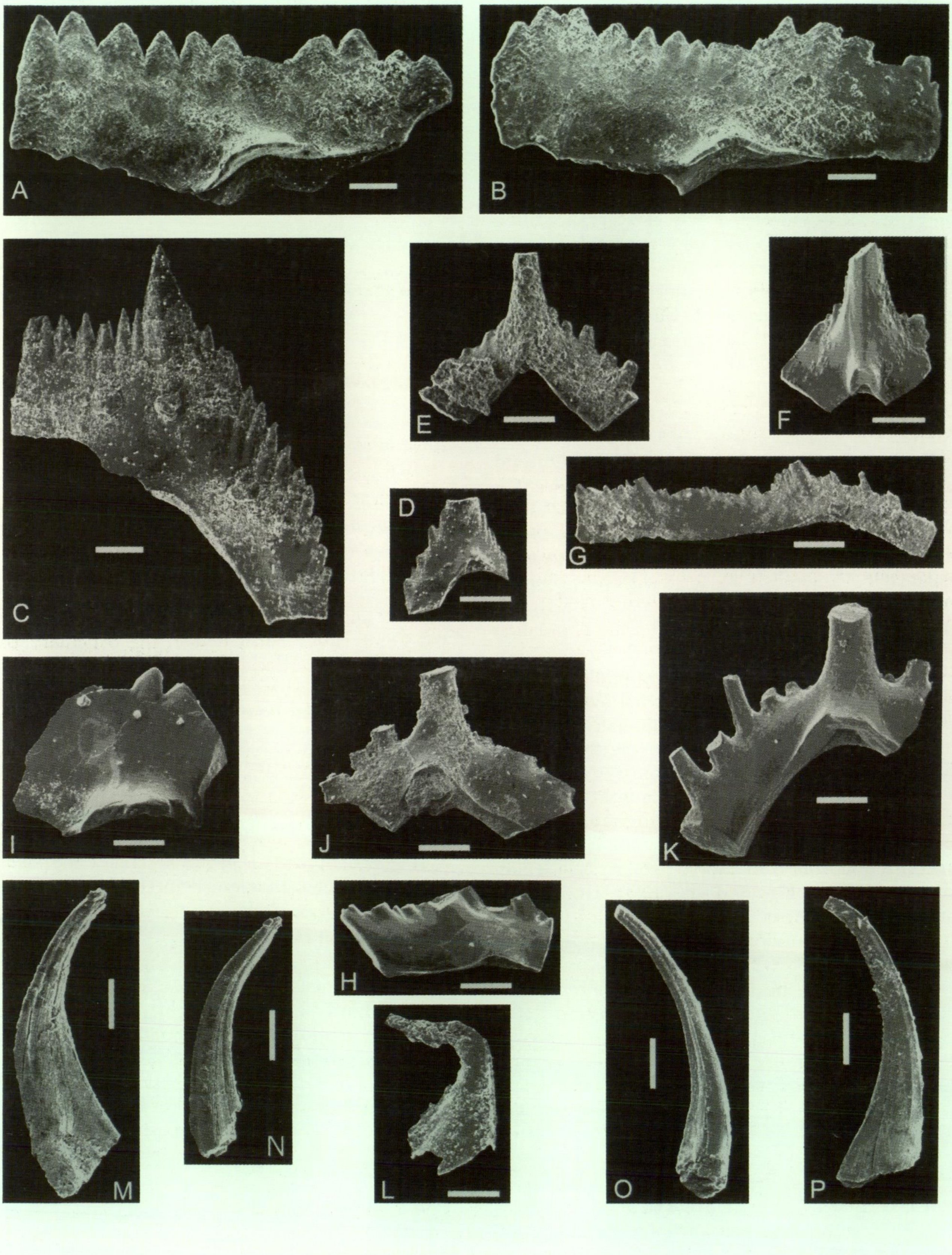
Upper Podoli to ?upper Pragian (Ciepelovian) of the Random-Lublin region of Poland; lower Pragian, *sulcatus* Conodont Zone of the Shield Creek Formation, northern Queensland; and the *kindlei* Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Remarks

The specimens of *A. cactula* from Point Hibbs differ slightly by being slightly smaller and in having proportionally shorter necks than individuals from the Polish material described by Wrona (1980: 129). Scars showing the original position of the spines on the vesicles of specimens from Point Hibbs are conspicuous, perhaps indicating a broader insertion point for the spine than is apparent in collections from either Poland or North Queensland.

Measurements

Taken from 5 specimens from samples PH-85-30 and PH-85-35.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L 154.3–178.5 (Av. 164.2); Ln 70–85 (Av. 78); Lc 79.2–93.5 (Av. 86.1); Dmax 55–72.8 (Av. 66.5); Dn 34–37.5 (Av. 35.7); Lsp 10–12 (Av. 11); Ln/L 0.44–0.5; L/Dmax 2.3–2.9.

Angochitina cf. *A. cactula* Winchester-Seeto, 1993a
Figures 6E–F

Material
Two specimens from sample PH-85-30, 32.9 m above the base of the Point Hibbs Formation in the Sanctuary Bay section and 14 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence
kindlei Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description
The chamber of this species is subconical and is surmounted by a short, subcylindrical neck. Maximum diameter occurs in the lower third of the chamber and the base is flattened to weakly convex. All specimens have been compressed and this may artificially exaggerate the flatness of the chamber base. Flexure is gentle and indistinct and the neck is topped by an inverted conical collar. The collar is wide and easily distinguished, flaring at the oral periphery. Ornament has been considerably eroded, leaving only a small number of fine spines on the collar and neck, and scars that indicate a sparse scattering of quite broad-based spines on the chamber.

Remarks
This species resembles *A. cactula* with a number of subtle differences. *A.* cf. *A. cactula* is smaller than *A. cactula* from Point Hibbs and from Poland, but overlaps the length of individuals from Martins Well. Similarly, the proportional length of the neck on specimens of *A.* cf. *A. cactula* (Ln/L = 0.37–0.43) is less than that for individuals of *A. cactula* from Point Hibbs (Ln/L = 0.44–0.5) and Poland (Ln/L = 0.47–0.53, measured from photomicrographs in Wrona 1980, Pl. 27, figs 1–6), but overlaps with measurements of *A. cactula* from Martins Well (Ln/L = 0.4–0.46). The most obvious difference of *A.* cf. *A. cactula* is the more conical shape of the chamber and of the collar, giving a very different overall shape. Unfortunately, the spines on *A.* cf. *A. cactula* show considerable erosion which makes it difficult to be conclusive about the actual relationship with *A. cactula*.

Measurements
Taken from 3 specimens from samples PH-85-30 and PH-85-35

L 134.5–155 (Av. 142); Ln 50.1–65 (Av. 57.6); Lc 76.9–90 (Av. 84.5); Dmax 61.2–72.8 (Av. 66.3); Dn 21.6–24 (Av. 22.8); Ln/L 0.37–0.43; L/Dmax 1.9–2.4.

Angochitina cf. *Sphaerochitina ricardi* Diez and Cramer, 1978
Figures 5K, L

Material
Two specimens from sample PH-85-30, 32.9 m above the base of the Point Hibbs Formation in the Sanctuary Bay section and 15 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence
kindlei Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description
This species of *Angochitina* has a cylindro-conical vesicle, with a gentle, but conspicuous flexure and poorly developed shoulders. Maximum diameter occurs in the lower third of the chamber thereby creating a club or tear-drop shape, and the base ranges from moderate to strongly convex. The subcylindrical neck occupies half or more of the total vesicle length (Ln/L = 0.46–0.6) and is surmounted by a short, slightly flared collar. Ornament is highly eroded, with only a small

◀ **Figure 7** Scale bar 1mm. **A–H,** *Ozarkodina remscheidensis* ssp. cf. *O. remscheidensis* (Zeigler). **A,** UTGD127086, Pa element, lateral view, Sanctuary Bay section, sample 30. **B,** UTGD127087, Pa element, lateral view, Sanctuary Bay section, sample 42. **C,** UTGD127088, Pb element, lateral view, 'Clearwater Point' section, sample 35. **D,** UTGD127089, M element, posterior view, Sanctuary Bay section, sample 30. **E,** UTGD127090, Sa element, posterior view, Sanctuary Bay section, sample 30. **F,** UTGD127091, Sa element, posterior view, 'Clearwater Point' section, sample 33. **G,** UTGD127092, Sc element, inner view, 'Clearwater Point' section, sample 35. **H,** UTGD127093, Sb element, inner view, 'Clearwater Point' section, sample 33. **I,** (UTGD127094), fragmentary Pb element, lateral view, Sanctuary Bay section, sample 29. **J, K,** *Oulodus* sp.**J,** UTGD127095, Sa element, inner view, 'Clearwater Point' section, sample 35. **K,** UTGD127096, Sb element, inner view, Sanctuary Bay section, sample 30. **L,** *Belodella resima* (Phillip), UTGD127097, lateral view, 'Clearwater Point' section, sample 33. **M–P,** *Panderodus unicostatus* (Branson and Mehl), 'Clearwater Point' section. **M,** UTGD127098, inner view, sample 34. **N,** UTGD127099, inner view, sample 35. **O,** UTGD127100, inner view, sample 34. **P,** UTGD127101, inner view, sample 35.

number of spines intact. Attachment scars for spines demonstrate that there were only a small number of sparsely scattered spines on both the neck and chamber. The few remaining spines range from very fine to moderate thickness and are dominantly simple, with a few bifurcate spines.

Remarks

This species strongly resembles *Sphaerochitina ricardi* Diez & Cramer from La Vid Shales in Spain, in shape and general proportions (i.e. Ln/L = 0.46–0.6 for *A.* cf. *S. ricardi* and Ln/L = 0.46–0.64 for *S. ricardi*, measured from the photomicrographs in Diez and Cramer 1978, pl. 2, figs 75–79; L/Dmax = 2.1–2.4 for *A.* cf. *S ricardi* and L/Dmax = 1.9–2.3 for *S. ricardi*). The range of variation in shape for both species is very close, but *A.* cf. *S ricardi* ranges up to a larger size than *S. ricardi* (L = 118–135 µm for *S. ricardi*). The main difference lies in the ornament; Diez and Cramer (1978: 212) report that on *S. ricardi* "the surface of the vesicle is covered by widely spaced tiny granules, spinules or similar ornament" whereas *A.* cf. *S ricardi* has only a small number of spines. It is conceivable that under the light microscope broken spine bases may resemble tiny granules, but this is impossible to verify without seeing the type material.

Paris (1981: 357) suggests a recorrelation of La Vid Shales on the basis of chitinozoans and proposes that zones 17 and 18 of Diez and Cramer are equivalent to his zone 36 to 38, which, in part, contains *Bulbochitina bulbosa* Paris. Studies of the Coopers Creek Limestone, southeastern Australia (Winchester-Seeto 1993a) show that *B. bulbosa* ranges down into the *kindlei* Conodont Zone and is thus contemporaneous with the Point Hibbs Formation. *Sphaerochitina ricardi* is abundant in the upper part of zone 17 and up to the middle of zone 18, overlapping with the range of *A.* cf. *S ricardi* and it is possible that the two groups are conspecific. *Angochitina* cf. *S ricardi* has been kept in open nomenclature until the nature of the ornament can be determined with confidence.

Measurements

Taken from 3 specimens from samples PH-85-30 and PH-85-35.

L 117–171.4 (Av. 144.8); Ln 65.8–82 (Av. 75.4); Lc 51.5–93 (Av. 69.8); Dmax 54.3–81 (Av. 67.8); Dn 23–32 (Av. 26); L sp 9–19 (Av. 14.5); Ln/L 0.46–0.6; L/Dmax 2.1–2.4.

Angochitina sp. A
Figures 5G–J

Material

Six specimens from samples PH-85-30 and PH-85-29, 32.9 and 57.3 m respectively above the base of the Point Hibbs Formation in the Sanctuary Bay section and 10 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence

kindlei Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description

Angochitina sp. A is a comparatively small species with a cylindro-ovoid vesicle and a relatively short neck (Ln/L = 0.36–0.4). The flexure is gentle, but definite, with sloping shoulders leading to a moderate to broad ovoid chamber. Maximum diameter is found near the middle of the chamber and the base is strongly convex. The neck terminates in a fairly long, thin collar, flaring slightly at the crenulate oral edge. Few spines remain intact; these are distributed randomly both on the neck and on the chamber. The spines are relatively thin and may be simple or bifurcate, those on the neck tending to be shorter.

Remarks

Angochitina sp. A differs from most other species of *Angochitina* that occur in a similar stratigraphic position by the lack of complex branching spines. The closest species is *Angochitina* sp. D from the Coopers Creek Limestone, southeastern Australia, also from the Pragian *kindlei* Conodont Zone (Winchester-Seeto 1993a). *Angochitina* sp. D differs in being smaller and in displaying broad-based, bifurcate, coalesced spines, not found on *Angochitina* sp. A.

Measurements

Taken from 4 specimens from samples PH-85-30 and PH-85-35.

L 131–141.5 (Av. 136.7); Ln 52.7–56 (Av. 54.8); Lc 80–97.6 (Av. 87); Dmax 66.3–76 (Av. 71.2); Dn 33.2–36 (Av. 34.4); Lsp 12.4–16 (Av. 14.2); Ln/L 0.37–0.4; L/Dmax 1.8–2.1.

Angochitina sp. B
Figure 6J

Material

Ten specimens from samples PH-85-30 and PH-85-29, 32.9 and 57.3 m respectively above the base of the Point Hibbs Formation in the Sanctuary Bay section and 37 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence

kindlei Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description

The vesicle of *Angochitina* sp. B ranges from cylindro-ovoid to club-shaped. The neck accounts for up to half the total vesicle length (Ln/L = 0.36–0.5) with a short collar that is slightly flared at the oral periphery. Flexure is indefinite and shoulders are absent. The chamber may be a narrow oval or slightly club-shaped, with the maximum diameter in the lower third of the chamber. A broadly rounded basal edge leads to a moderate to weakly convex base. Ornament consists of a small number of quite substantial spines, randomly distributed on the neck and chamber. The spines are dominantly simple but some have a bifurcated distal end.

Remarks

Angochitina sp. B is superficially similar to *Angochitina* sp. A; the latter, however, is smaller, has a more ovoid chamber with a more strongly convex base and has a definite flexure and sloping shoulders. The main difference lies in the ornament; where *Angochitina* sp. B has mainly simple spines and a few with bifurcation at the very tip, *Angochitina* sp. A has a mixture of simple and strongly bifurcate spines.

Angochitina cactula Winchester-Seeto can be easily distinguished from *Angochitina* sp. B by the fine neck spines on the neck of the former and the presence of spines with bifurcated tips in the latter.

Measurements

Taken from 5 specimens from samples PH-85-30 and PH-85-35.

L 144–177.4 (Av. 155.4); Ln 60–70 (Av. 64.1); Lc 77–114.4 (Av. 107.4); Dmax 64–91 (Av. 75.5); Dn 27–38.5 (Av. 333.6); Lsp 12–20 (Av. 14.6); Ln/L 0.36–0.48; L/Dmax 1.9–2.25.

Angochitina sp. C
Figure 6K

Material

Possibly one specimen from sample PH-85-30, 32.9 m above the base of the Sanctuary Bay section and 24 specimens from sample PH-85-35, 47.7 m above the base of the Point Hibbs Formation in the 'Clearwater Point' section.

Stratigraphic occurrence

kindlei Conodont Zone, Pragian, Point Hibbs Formation, SW Tasmania, Australia.

Description

This species has a narrow, elliptical body with the maximum diameter in the lower third of the length of the chamber. The base is weakly convex and flexure is distinct, but no shoulders are apparent. The chamber is surmounted by a relatively short (Ln/L = 0.42), subcylindrical neck that flares slightly at the crenulate, oral edge. A small number of sturdy, broad-based spines are scattered over the chamber and neck; these taper slightly at the distal end and often curve towards the oral periphery. The spines may be simple or bifurcate but no spines occur at the oral edge.

Remarks

The distinctive spines distinguish this species from other species of *Angochitina*. The closest reported species is *Angochitina calcarata* Legault, with similar broad-based, sturdy, simple or bifurcate spines. *Angochitina* sp. C differs from *A. calcarata* in being larger, in having a much narrower elliptical chamber (Dmax/L = 0.42 for *Angochitina* sp. C, whereas Dmax/L = 0.5–0.6 for *A. calcarata*) and in the fact that the spines curve towards the oral periphery. *Angochitina calcarata* has only been found in the Givetian and there is thus a substantial stratigraphic gap between the two species.

Some occurrences of *Angochitina devonica* Eisenack also display a small number of broad-based spines (e.g. Eisenack 1955, pl. 1, fig. 12; Pichler 1971, pl. 6, fig. 85). *Angochitina devonica* differs in exhibiting multi-branched spines, whereas *Angochitina* sp. C shows only simple and bifurcate spines.

Measurements

Taken from 1 specimen from sample PH-85-35.

L 186.4; Ln 68.1; Lc 118.3; Dmax 77.4; Dn 36.4; Ls 36; Ds 11.2; Ln/L 0.37; L/Dmax 2.4.

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REFERENCES

Achab, A., Asselin, E., Lavoie, D. and Mussard, J.M. (1997). Chitinozoan assemblages from the third-order transgressive-regressive cycles of the Upper Gaspé Limestones (Lower Devonian) of eastern Canada. *Review of Palaeobotany and Palynology* **97**: 155–175.

Bell, K.N. and Winchester-Seeto, T. (in press). Linings of agglutinated foraminifera from the Devonian; taxonomic and biostratigraphic implications. *Journal of Micropalaeontology*.

Brown, A.V., Findlay, R.H., McClenaghan, M.P. and Seymour, D.B. (1991) Synopsis of the regional geology of the Macquarie Harbour, Point Hibbs and Montgomery 1: 50 000 map sheets. Department of Mines Tasmania, Report.

Burrett, C.F. (1984). Early Devonian deformation and metamorphism of conodonts in western Tasmania - economic, theoretical and nomenclatural implications. In *Mineral exploration and Tectonic Processes in Tasmania* P.W. Baillie and P.L.F. Collins (eds), Geological Society of Australia, Tasmanian Division, Hobart. pp. 14–17.

Burrow, C.J., Long, J.A. and Turner, S. (1998). Lower Devonian microvertebrates from the Point Hibbs Formation, Tasmania. *Alcheringa* **22**: 9–20.

Carey, S.P. (1989). Southwestern Tasmania, Point Hibbs area. In Burrett, C.F and Martin, E.J. (eds), *Geological Society of Australia Special Publication* **15**: 229–230.

Carey, S.P. and Berry, R.F. (1988). Thrust sheets at Point Hibbs, Tasmania: palaeontology, sedimentology and structure. *Australian Journal of Earth Sciences* **35**: 169–180.

Chlupác, I. (1988). The Devonian of Czechoslovakia and its stratigraphic significance. In McMillan, N.J., Embry A.F. and Glass D.J. (eds), *Devonian of the World Vol.* **1**: 481–497. Canadian Society of Petroleum Geologists, Calgary

Chlupác, I., Lukes, P., Paris, F. and Schönlaub, H. (1985). The Lochkovian-Pragian boundary in the Lower Devonian of the Barrandian area (Czechoslovakia). *Jahrbuch der Geologischen Bundesanstalt* **128**: 9–41.

Diez, M.D.C.R. and Cramer, F.H. (1978). Iberian chitinozoans. 2. Lower Devonian forms (La Vid Shales and equivalents). *Palinologia extradorinario* **1**: 203–217.

Eisenack, A. (1931). Neue Mikrofossilien des baltischen Silurs I. *Paläontologische Zeitschrift* **13**: 74–118.

Eisenack, A. (1955). Chitinozoen, Hystrichosphären und andre Mikrofossilien aus dem Beyrichia Kalk. *Senckenbergiana lethaea* **36**: 157–188.

Eisenack, A. (1964). Mikrofossilien aus dem Silur Gotlands. Chitinozoen. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* **120**: 308–342.

Eisenack, A. (1968). Über Chitinozoen des baltischen Gebietes. *Palaeontographica, Abteilung A* **131**: 137–198.

Eisenack, A. (1970). Mikrofossilien aus dem Silur Estlands und der insel Ösel. *Geologiska Föreningens i Stockholm Förhandlingar* **92**: 301–322.

Eisenack, A. (1972). Beiträge zur Chitinozoen-Forschung. *Palaeontographica, Abteilung A* **140**: 117–130.

Flood, P.G. (1974). Lower Devonian Brachiopods from the Point Hibbs Limestone of western Tasmania. *Royal Society of Tasmania, Papers and Proceedings* **108**: 113–135.

Gao, L.-d. (1986). Chitinozoans. In Ho Hong-fei (ed.), *Devonian Stratigraphy, Palaeontology, and Sedimentology Facies of Longmenshan, Sichau*: 356–357, Chengdu Intstitute of Geology and Mineral Resources and Institute of Geology, Chinese Academy of Geological Sciences, Chengdu, Chengdu.

Gutschick, R.C. (1962). Arenaceous foraminifera from oncolites in the Mississippian Sappington Formation of Montana. *Journal of Paleontology* **36**: 1291-1304.

Hill, D. (1942). Some Tasmanian Palaeozoic corals. *Royal Society of Tasmania, Papers and Proceedings* **1941**: 3–12.

Jaglin, J.-C. (1986). Nouvelles espéces de chitinozoaires du Pridoli de Libye. *Revue de Micropaléontologie* **29**: 44–54.

Jell, J.S. and Hill, D. (1970). The Devonian coral fauna of the Point Hibbs Limestone, Tasmania. *Royal Society of Tasmania, Papers and Proceedings* **104**: 1–16.

Laufeld, S. (1974). Silurian Chitinozoa from Gotland. *Fossils and Strata* **5**: 130.

Magloire, L. (1967). Étude stratigraphique, par la palynologie, des dépôts argilo-gréseux du Silurien et du Dévonien inférieur dans la région du Grand Erg occidental (Sahara algérien). In Oswald, D.H. (ed.), *International Symposium on the Devonian System, Calgary, 1967 Vol.* **2**: 473–491, Alberta Society of Petroleum Geologists, Calgary.

McClenaghan, M.P., Seymour, D.B. and Villa, I.M. (1994). Lamporphyre dyke suites from western Tasmania, their radiometric dating and the age of thrust faulting in the Point Hibbs area. *Australian Journal of Earth Sciences* **41**: 47–54.

Murphy, M.A., Matti, J.C. and Walliser, O.H. (1981). Biostratigraphy and evolution of the *Ozarkadina remscheidensis-Eognathodus sulcatus* lineage (Lower Devonian) in Germany and central Nevada. *Journal of Paleontology* **55**: 747–772.

Paris, F. (1981). Les chitinozoaires dans le Paléozoïque du sud-ouest de l'Europe. *Mémoires de la Société géologique et minéralogique de Bretagne* **26**: 1–412.

Paris, F., Winchester-Seeto, T., Boumendjel, K. and Grahn, Y. (1999 in press). Towards a global biozonation of Devonian chitinozoans. *Courier Forschungsinstitut Senckenberg* .

Pedder, A.E.H. (1998). New and revised Lower Devonian Rugosa from western North America and Tasmania. *Journal of Paleontology* **72**: 224–245.

Pedder, A.E.H. and McLean, R.A. (1982). Lower Devonian cystiphyllid corals from North America and eastern Australia with notes on the genus *Utaratuia*. *Geologica et Palaeontologica* **16**: 57–110.

Philip, G.M. and Pedder, A.E.H. (1968). Stratigraphical correlation of the principal Devonian limestone sequences of Eastern Australia. In Oswald, D.H. (ed.), *International Symposium on the Devonian System Vol.* **2**: 1025–1041, Alberta Society of Petroleum Geologists, Calgary.

Pichler, R. (1971). Mikrofossilien aus dem Devon de südlichen Eifeler Kalkmulden. *Senckenbergiana lethaea* **52**: 315–357.

Taugourdeau, P. and de Jekhowsky, P. (1960).

Répartition et description de chitinozoaires Siluro-Dévoniens de quelques sondages de la CREPS, de la CFPA, et de la SN REPAL au Sahara. *Ruevue de l'Institut Français du Pétrole* **15**: 1199–1260.

Winchester-Seeto, T. (1993a). Chitinozoan assemblages from the Pragian (Lower Devonian) of eastern Australia. *Proceedings of the Royal Society of Victoria* **105**: 85–112.

Winchester-Seeto, T. (1993b). Chitinozoa from the early Devonian (Lochkovian-Pragian) Garra Limestone, central New South Wales, Australia. *Journal of Paleontology* **67**: 738–758.

Wrona, R. (1980). Upper Silurian-Lower Devonian Chitinozoa from the subsurface of southeastern Poland. *Palaeontologia Polonica* **41**: 103–165.

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APPENDIX

Catalogue numbers of the field samples, housed in the collections of the Geological Survey of Tasmania, Hobart are as follows:

PH-85-29	UTGD68669
PH-85-30	UTGD68670
PH-85-33	UTGD68672
PH-85-35	UTGD68674