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Early Devonian thelodonts (Agnatha) from the Toko Syncline, western Queensland, and a review of other Australian discoveries

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Thelodont scales recovered from the basal (calcareous) unit of the Cravens Peak Beds in the Georgina Basin, are referable to *Turinia australiensis* Gross, 1971, *T.* cf. *pagei* (Powrie, 1870), and *Gampsolepis* ? sp. undet. The thelodonts probably lived in a marginal marine environment (as evidenced from the associated ostracods and eridostracans) at about the same time as the placoderm *Wuttagoonaspis* sp. lived in the freshwater bodies, now represented by the sandstone and conglomerate facies of the Cravens Peak Beds.

Scales of *Turinia australiensis* Gross, 1971, associated with *Wuttagoonaspis* plates, from the lower part of the Mulga Downs Group in the Cobar/Wilcannia area of New South Wales, are at least as young as late Early Devonian (Emsian), because they post-date the Pragian age of the underlying Amphitheatre Group. By correlation, those parts of the Cravens Peak Beds (Georgina Basin) and the Tandalgoo Red Beds (Canning Basin) that also contain *Turinia australiensis* are approximately coeval.

After reaching Australia in Early Devonian time, the *Turinia* fauna began an adaptive radiation to give apparently younger (Middle Devonian) stocks that have survived longer in the Australian region than elsewhere, as the youngest known scales come from the Gneudna Formation (latest Givetian-earliest Frasnian) in the Carnarvon Basin, Western Australia.

Introduction

Thelodont remains were first recognised in Australia in 1963, when one of us (PJJ) noted (*in* Reynolds & Pritchard, 1964) the presence of coelolepidid (synonym thelodontid) scales in the lower part of the Cravens Peak Beds in the western Queensland part of the Georgina Basin (Johnstone & others, 1967; Gilbert-Tomlinson, 1968; Smith, 1972). This discovery, in the area east of the axis of the Toko Syncline and west of the Toko Range, was also the first recorded of agnathan remains from the Southern Hemisphere (Figs. 1 and 2; locality 5).

The original material was not formally described because the taxonomy of the entire Thelodonti at that time was poorly understood and in much need of revision. A general Late Silurian-Early Devonian age was suggested for the lower part of the Cravens Peak Beds (Jones *in* Reynolds & Pritchard, 1964; Johnstone & others, 1967), which corresponded to the total range of the Thelodonti known at the time. It was not until Gross (1967) published his important monograph on thelodont scales, based entirely on European material, that some precision was added to the classification, and the potential of these microfossils for biostratigraphic zonation was realised (for example, see papers by Karatajute-Talimaa, 1968, 1970; Mark-Kurik, 1969; Mark-Kurik & Noppel, 1970; Moskalenko, 1968; Ørvig, 1969a, 1969b, 1969c; Ritchie, 1968; Turner, 1973).

Soon after this, Gross (1971b) described scales of a thelodont, *Turinia australiensis,* of presumed Early Devonian age from Western Australia (Fig. 1; locality 3), and those from the Toko Range were tentatively identified by one of us (PJJ) as belonging to *T. pagei* (Powrie, 1870) (*in* Turner, 1973, p. 573). Then, in 1975, a second locality with the abundant thelodont scales described here was found in the Toko Syncline, on its western flank, in the southern part of the Toomba Range (Fig. 1, locality 6).

The *Turinia pagei* fauna is now accepted as a good indicator of the start of the Dittonian Stage of the Lower Old Red Sandstone in Europe (Turner, 1973; Karatajute-Talimaa, 1978), and, notwithstanding the problems of the definition of the Silurian/Devonian boundary faced by British stratigraphers (cf. Cocks & others, 1971; Westoll & others, 1971; Lawson, 1971; Halstead, 1971; and Turner, 1971), indicates an Early Devonian age. Devonian thelodont remains are now being reported from Iran (Blieck & Goujet, 1978; Turner & Janvier, 1979), Thailand (Blieck & Goujet, 1978), Indonesia, and more localities in Australia (Fig. 1).

In Western Australia they are known from the Canning and Carnarvon Basins. *Turinia australiensis* Gross, 1971, the first representative of the Thelodonti to be described from the Southern Hemisphere, is the only authenticated representative of the group in the Canning Basin. We regard the report of a thelodont scale from this basin by McTavish & Legg (1976), to be based on a misidentification (see page 65). Recently, Turner & Dring (1981) have described thelodont scales, which they refer to *Australolepis seddoni* gen. et. sp. nov., from the Gneudna Formation of the Carnarvon Basin (Fig. 1, locality 1). On conodont evidence (Seddon, 1969; 1970; Roberts & others, 1972), this taxon is of late Givetian-early Frasnian age, and the youngest known representative of the Thelodonti.

In eastern Australia, thelodont remains have been found in the lower part (Emsian-Eifelian) of the Mulga Downs Group at Mount Jack in the Cobar region of western New South Wales by Ritchie (personal communication, 1980) (Fig. 1, locality 7), and in the late(?) Eifelian part of the Hatchery Creek Conglomerate (Middle Devonian) of the Wee Jasper area, near Canberra (Young & Gorter, 1981; Fig. 1, locality 8). Other occurrences of Middle Devonian thelodont scales have been reported from New South Wales by Turner & Janvier (1979, p. 892).

Recently, thelodont remains have been found in Indonesia, in the Kepala Burung region of Irian Jaya (Fig. 1, locality 4), where a single small thelodont

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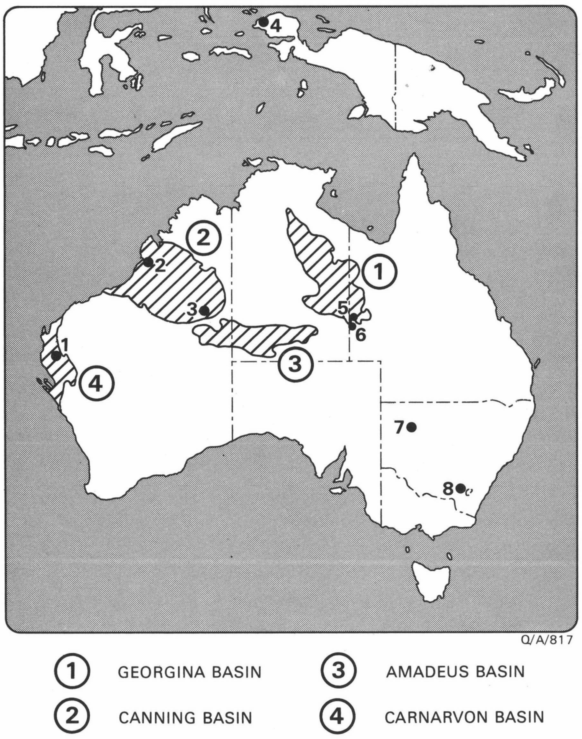

Figure 1. Distribution of reported occurrences of thelodont remains from the Australian Plate.
Localities, at present all Devonian in age, are numbered as follows: 1—Gneudna Formation, Williambury Station, Carnarvon Basin; 2—Thangoo Calcarenite, Roebuck Bay No. 1 well, Broome Platform, Canning Basin (based on a mis-identification, see page 65); 3—Tandalgoo Red Beds, Wilson Cliffs No. 1 well, Kidson Sub-basin, Canning Basin; 4—Kemum Formation (sample no. 78CP103/3), 80 km east of Sorong, Kepala Burung, Irian Jaya; 5—Cravens Peak Beds, shot holes west of Toko Range, Toko Syncline, Georgina Basin; 6—Cravens Peak Beds, southern Toomba Range, Toko Syncline, Georgina Basin; 7—Lower part of the Mulga Downs Group, Mount Jack Station, Cobar Basin; 8—Hatchery Creek Conglomerate, Taemas/Wee Jasper region, New South Wales.

scale has been referred to the Early Devonian (Dittonian) genus *Apalolepis* by Young (personal communication, 1979).

In this paper we describe the Early Devonian thelodont scales and associated fauna from all the Toko Syncline localities, redefine the Cravens Peak Beds and discuss their depositional environment and palaeogeographic implications, and consider the significance of the distribution of Australian Devonian thelodonts on a global scale.

Most of the figured specimens described in this paper are deposited in the Commonwealth Palaeontological Collection (prefix CPC), housed in the Bureau of Mineral Resources, Geology and Geophysics, Canberra. Other figured specimens are housed in the palaeontological collections of the Australian Museum, Sydney (prefix AM), and the British Museum (Natural History), London (prefix P).

The Cravens Peak Beds

Previous investigations

The Cravens Peak Beds were defined by Reynolds (*in* Smith, 1965) to include the sandstone and conglomerate of 'Silurian-Devonian' age that unconformably overlie the Middle Ordovician Mithaka Formation within the core of the Toko Syncline. As originally mapped, the beds comprised Pritchard's (1960) unit Om-11 in the Toko Range (Reynolds, 1965, 1968), an unnamed sandstone in the Toomba Range ('Middle Ordovician Undifferentiated' of Smith, 1963), and a conglomerate and sandstone sequence near Mithaka Waterhole (Smith, 1965).

Recent field mapping (Draper, 1980) has demonstrated that the Cravens Peak Beds, as discussed in Smith (1972) and shown on his 1:500 000 geological map of the Georgina Basin (Sheet 4), are composed of three separate units: (1) the Middle Ordovician Ethabuka Sandstone (the lowest part of Pritchard's unit Om-11); (2) the Devonian Cravens Peak Beds (*sensu stricto*); and (3) a post-Devonian valley-fill conglomeratic deposit.

The Ethabuka Sandstone (Draper, 1980) crops out as a low ridge in the southwestern corner of the Glenormiston 1:250 000 Sheet area (Reynolds, 1965), and

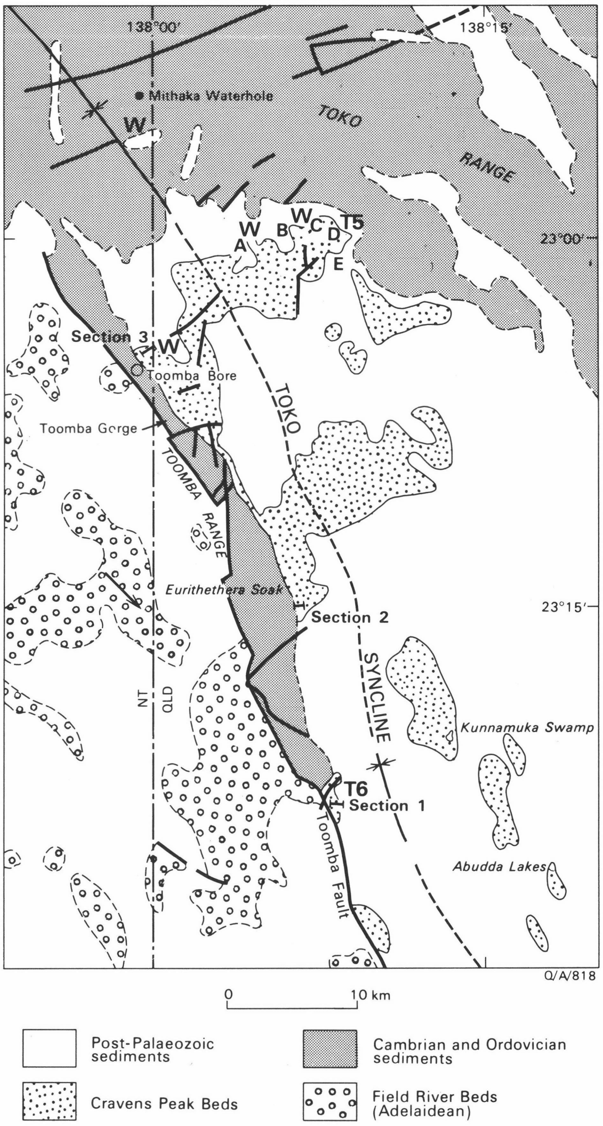

Figure 2. General geology of Toko Syncline showing positions of measured sections of the Cravens Peak Beds and the Devonian vertebrate localities with thelodonts (localities 5 and 6 of Fig. 1), and the Wuttagoonaspis fauna.
W—*Wuttagoonaspis* fauna; T—*Turinia* fauna; 5—Shot-point localities west of Toko Range: A—SP801, B—SP839, C—SP799, D—SP798, E—SP813; 6—Toomba Range locality GEO 65/28 (74710577).

in the northern part of the Toomba Range in the northeastern corner of the Hay River 1:250 000 Sheet area (Smith, 1963), where it forms the lower 35 m of the original reference section of the Cravens Peak Beds (Smith, 1972, table 31). The post-Devonian valley-fill conglomeratic unit unconformably overlies the Ordovician Toko Group, and cuts across the major structure of the area.

The Cravens Peak Beds (*sensu stricto*) consist of a basal limestone and calcareous siltstone with Devonian thelodont scales, herein referred to as the *basal (calcareous) unit*, and a conglomerate and sandstone sequence (the dominant rock types) with the Devonian placoderm *Wuttagoonaspis* Ritchie, 1973. These two units correspond to the 'lower Cravens Peak Beds' and the 'upper Cravens Peak Beds' of previous authors (for example, Johnstone & others, 1967; Gilbert-Tomlinson, 1968), who have suggested that the apparent disparity between the ages of these units implies a possible hiatus. An unconformable relationship between these units was supported (Draper, 1976), until later mapping (by JJD, 1977) showed that their mutual contact is transitional. The basal (calcareous) unit is known from only two areas within the Toko Syncline—one

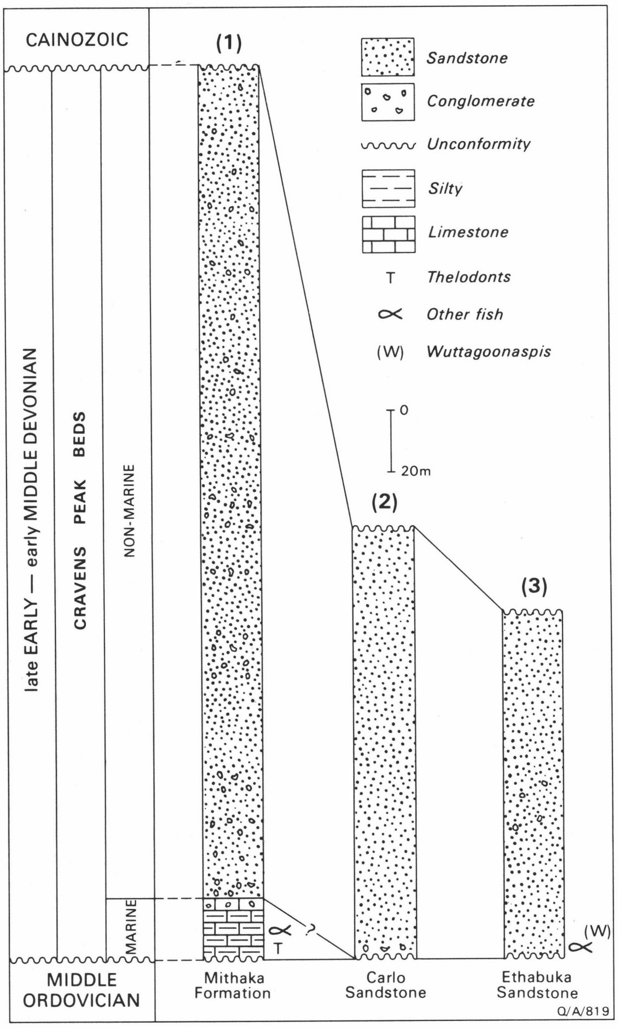

Figure 3. Composite sections, Cravens Peak Beds, showing variation from south to north along the Toomba Range.
1—southern part of the Toomba Range, about 16 km SSE of Eurithethera Soak; 2—near Eurithethera Soak; 3—100 metres E of Toomba Bore.

on its northeastern limb, just west of the Toko Range, and the other on its southwestern limb, in the southern part of the Toomba Range. The spatial distribution of the Cravens Peak Beds, as clarified in this paper (Appendix), is shown in Figure 2, and three composite sections, showing variation along the Toomba Range, are shown in Figure 3.

Material and localities

The original (1963) collection of thelodont scales was recovered from shot-hole samples (prefix SP) from a seismic reflection survey (conducted by Austral Geoprospectors Pty Ltd, on behalf of Phillips Petroleum Co. & Sunray Mid-Continent Co., in 1960) over the eastern limb of the Toko Syncline, in the areas covered by the southwestern part of the Glenormiston 1:250 000 geological sheet (Reynolds, 1965), viz., SP 798, 799, 801 and 839, and the northwestern part of the Mount Whelan 1:250 000 geological sheet (Reynolds, 1966), viz., SP 813. The approximate geographical co-ordinates of the shot-holes are SP 801 — 22°59′49″S 138°04′16″E, SP 839 — 22°59′25″S 138°05′46″E, SP 799 — 22°59′46″S 138°06′06″E, SP 798 — 22°59′47″S 138°06′48″E, and SP 813 — 23°00′31″S 138°08′30″E. The rocks sampled were siltstones and calcareous siltstones, which readily disintegrated in boiling water, yielding many thelodont scales, a few acanthodian scales, ostracods, and eridostracans. Samples SP 813 and 839 also yielded a few Middle Ordovician conodonts (simple drepanodontiform and cordylodontiform elements), which are similar to those found in the Mithaka Formation from other shot holes made during the same seismic survey, and this association is attributed to contamination.

The 1975 collection of thelodont scales was recovered from the insoluble residue of a recrystallised limestone sample, and abundant eridostracans and a few ostracods were extracted before it was dissolved in monochloracetic acid. The sample was collected from an isolated outcrop in the southern part of the Toomba Range—BMR locality GEO 65/28 (74710-577))—about 42 km south of the shot-point localities, on the western flank of the Toko Syncline (Mount Whelan 1:250 000 geological sheet) at approximately 23°23′47″S; 138°08′10″E. Here some 20 m of the basal (calcareous) unit is exposed, representing the only limestone of Devonian age known from central Australia (Fig. 4). The lower 6 metres consists of laminated calcareous siltstone terminated by a distinct stromatolite bed, followed by a covered interval of 4 metres. The upper 7 metres consists of minor conglomerate, calcareous siltstone, recrystallised oncolitic and phosphatic limestone, and calcareous sandstone, terminated by a covered interval of 3 metres.

The identified taxa (thelodont and acanthodian scales, eridostracan, and ostracods) and their distribution within the shot-hole localities and the Toomba Range locality are listed in Figure 5.

Depositional environment

The basal (calcareous) unit at the Toomba Range locality (GEO 65/28) is interpreted as representing an initially shallowing sequence passing from shallow subtidal conditions to beach. A slight deepening of water resulted in the development of offshore bars (Figure 4). Stromatolites, a few thelodont scales, and other fish fragments are present in the shallow-water, nearshore environment. Oncolites, numerous thelodont and acanthodian remains, and phosphatic pellets are

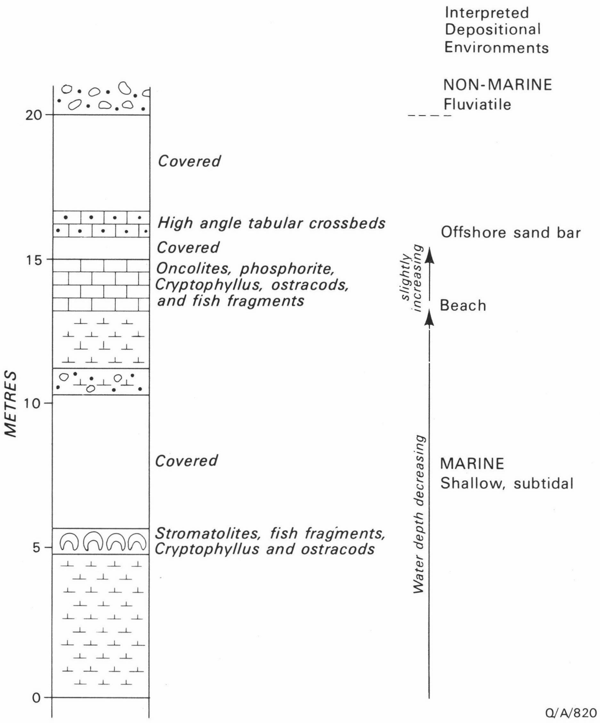

Figure 4. Basal (calcareous) unit of Cravens Peak Beds 100 metres N of section 1 in southern part of the Toomba Range.
Included within section 1 in Figure 3.

SPECIES \ LOCALITY	TOKO RANGE					
	SP 801	SP 839	SP 799	SP 798	SP 813	GEO 65/28
Turinia cf. *pagei* (Powrie, 1870)						a
T. australiensis Gross, 1971	r	r	c	c	r	r
Gampsolepis ? sp. indet						r
Gomphonchus ? sp. indet						r
Nostolepis sp.			r			
Healdianella inconstans Polenova, 1974?			r			r
Baschkirina ? sp		r				r
Cryptophyllus sp.		r	r			a

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Figure 5. Determinations of fauna present in the basal (calcareous) part of the Cravens Peak Beds, Toko Syncline.
Frequency of specimens indicated as abundant (a), common (c), and rare (r).

present in the cross-stratified coarser-grained sediments. Higher energy conditions are confirmed by the petrography of the recrystallised limestone, which consists of skeletal grainstones in which the skeletal material is fragmented, and oncolitic limestone with oncolites forming around skeletal fragments and various mineral grains, and algal boundstones.

The microcrustacean evidence is compatible with the postulated marine depositional conditions. *Cryptophyllus*, from its association with marine fossils in other Australian occurrences (Jones 1962, 1968), is thought to be marine, and the ostracods tentatively referred to the genera *Healdianella* and *Baschkirina* probably indicate a marine or marginal marine environment. The presence of thelodont scales, however, provides conflicting evidence. Articulated specimens of *Turinia pagei* from Turin Hill, Scotland (the holotype) and from Mitcheldean in the Welsh Borderland, are thought to have lived in freshwater (Allen & others, 1968), but the species may have retained a marine phase during its life history (Turner, 1973; Halstead & Turner, 1973), and Goujet & Blieck (1977, 1979) have reported scales of *T. pagei* from marine sediments in Spitsbergen, Podolia, and northern France.

The overlying sandstone and conglomerate of the Toomba Range (Figure 3) were probably deposited under braided-stream conditions, similar to the environment figured by Allen (1965, figure 35B). Features in common with Allen's model are lack of argillaceous sediment, lenticular nature of the bedding, and the general lack of biologic activity. The placoderm fish remains may occur as isolated plates or fragments, but at some localities skull and trunk armour plates from a number of individuals are closely associated, suggesting that post-mortem transportation was minimal. At these localities the remains indicate fish of considerable size, which presumably inhabited permanent bodies of freshwater (G. C. Young, personal communication).

Thelodont fauna

Three thelodont species, as determined from their scales, are present in the Cravens Peak Beds: *Turinia* cf. *pagei* (Powrie, 1870), *T. australiensis* Gross, 1971, and *Gampsolepsis?* sp. undet.

Turinia cf. **pagei** (Powrie, 1870) (Figs. 6-8)

About 60 scales were recovered from the Toomba Range sample (GEO 65/28; Figure 5), of which 15 are figured here as *Turinia* cf. *pagei*. Most of them fall within the range of variation exhibited by the scales of *Turinia pagei* (Powrie, 1870), which have been previously described under various names (see Turner, 1976; Karatajute-Talimaa, 1978, for synonymies). Because only two or three articulated specimens are known, and none is well-preserved—the scales being water-worn, if preserved at all—the range of scale variation in this species is determined primarily from the uniformity of histological structure and a gradation of scale ornament (Gross, 1967; Ørvig, 1969a; Karatajute-Talimaa, 1964, 1978; Turner, 1973). Karatajute-Talimaa (1978) has subdivided *Turinia pagei* into *T. pagei* (*sensu stricto*) and *T. polita*, but some scales referred to the latter, we regard as *T.*

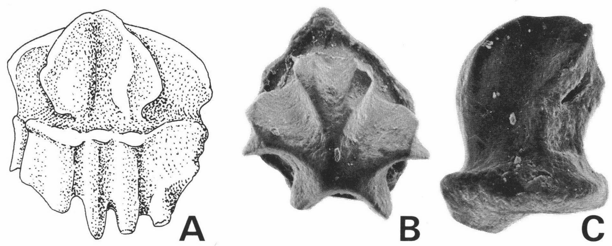

Figure 6. ***Turinia* cf. *pagei* (Powrie, 1870)—Head scales from Toomba Range locality GEO 65/28.**
A—CPC 20079/11, lateral view showing 'rootlets' from the basal rim, x 30; B—CPC 20079/18, crown view, x 30; C—CPC 20079/19, lateral view, x 35.

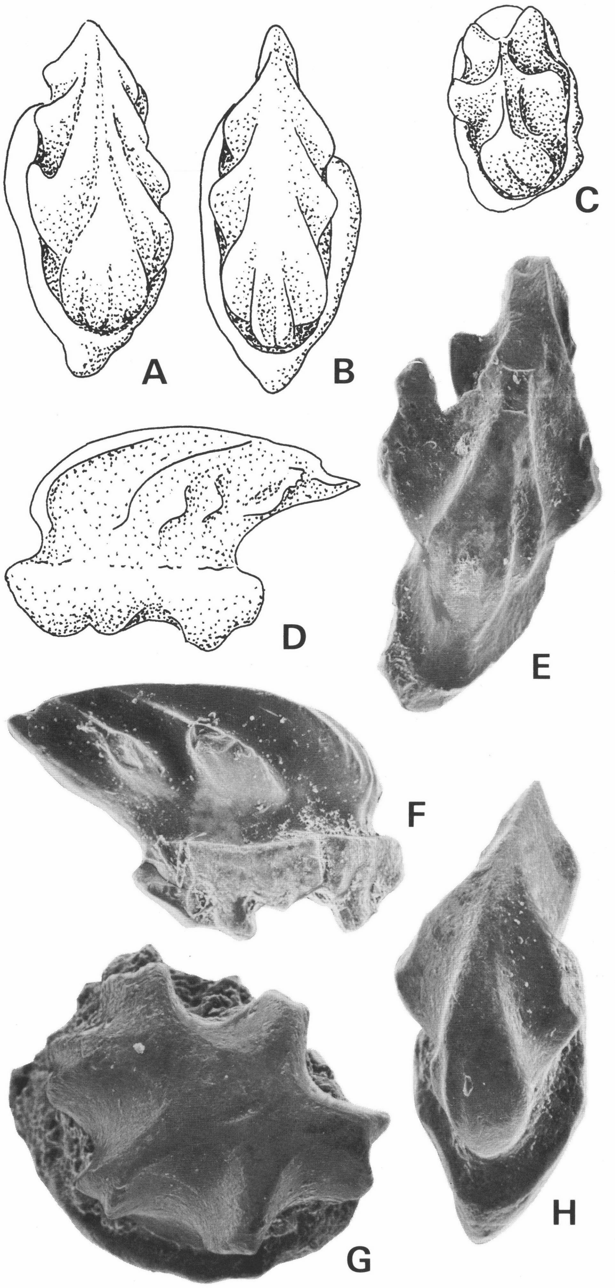

Figure 7. ***Turinia* cf. *pagei* (Powrie, 1870)—Transitional scales from Toomba Range locality GEO 65/28.** A—CPC 20079/1, crown view, x 30; B—CPC 20079/22, crown view, x 30; C—CPC 20079/5, crown view, x 50; D—CPC 20079/2, lateral view, x 30; E—CPC 20079/3, crown view showing lateral winglets, x 50; F—CPC 20079/10, lateral view showing rootlets at base, x 60; G—CPC 20079/16, crown view, x 70; H—CPC 20079/9, crown view, x 50.

pagei, and others as *T. australiensis*. Scales of *T. pagei* and *T. australiensis* are found together in the Dittonian of the Welsh Borderland and Podolia (Karatajute-Talimaa, 1964; Turner, 1973).

Many of the scales in the Toomba Range sample are semi-transparent, and, with the addition of a little anise oil, the internal structure can be seen. They show little difference in histological structure from the *Turinia pagei* scales described by Gross (1967). In general morphology, however, some of the scales have more ribs and 'side-lappets' than *T. pagei,* and provide sufficient reason to refer the material to *Turinia* cf. *pagei*. They range in size from 0.55 mm to 1.62 mm.

Head scales (Figs. 6a-c) are rare in the Toomba Range sample, as is often the case in samples from the Welsh Borderland. These scales have rounded crowns with a crenulated crown rim, or more-incised ridges rising to a central point on the crown. The bases are rounded, either with a large wide open pulp cavity or one to three pulp openings, typical of the genus *Turinia*. Occasionally, there are small 'rootlets' extending from the basal rim (Fig. 6a).

Transitional scales (Figs. 7a-h) come from the region between head and trunk and may cover a large area because, on the basis of articulated specimens, *Turinia* was a large thelodont, growing to about 35 cm long. Ørvig (1969a, fig. 2A) figured some typical scales of this type. They are large, elliptical scales with a crenulated crown edge. The crown may come to a posterior point and have three pairs of lateral ridges

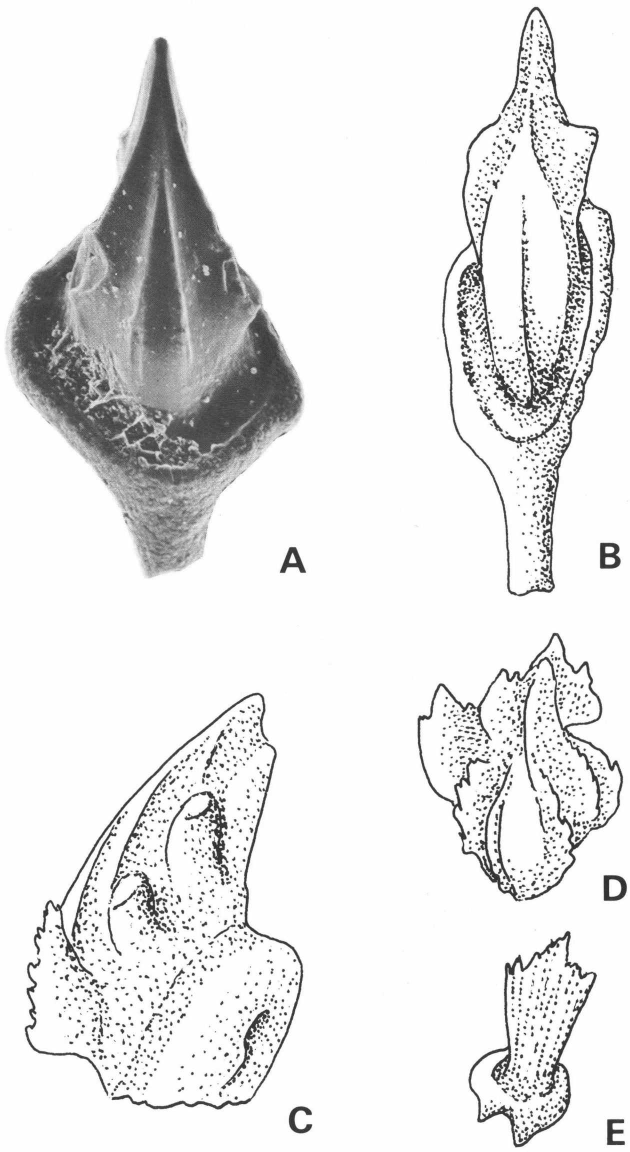

Figure 8. ***Turinia* cf. *pagei* (Powrie, 1870)—Body and specialised scales from Toomba Range locality GEO 65/28.** A—CPC 20079/14, crown view, x 90; B—CPC 20079/6, crown view, x 90; C—CPC 20079/20, lateral view, x 50; D—CPC 20079/4, crown view of a small special scale, which may belong to *T. australiensis* Gross, 1971, x 50; E—CPC 20079/7, crown view of a small special scale, x 50.

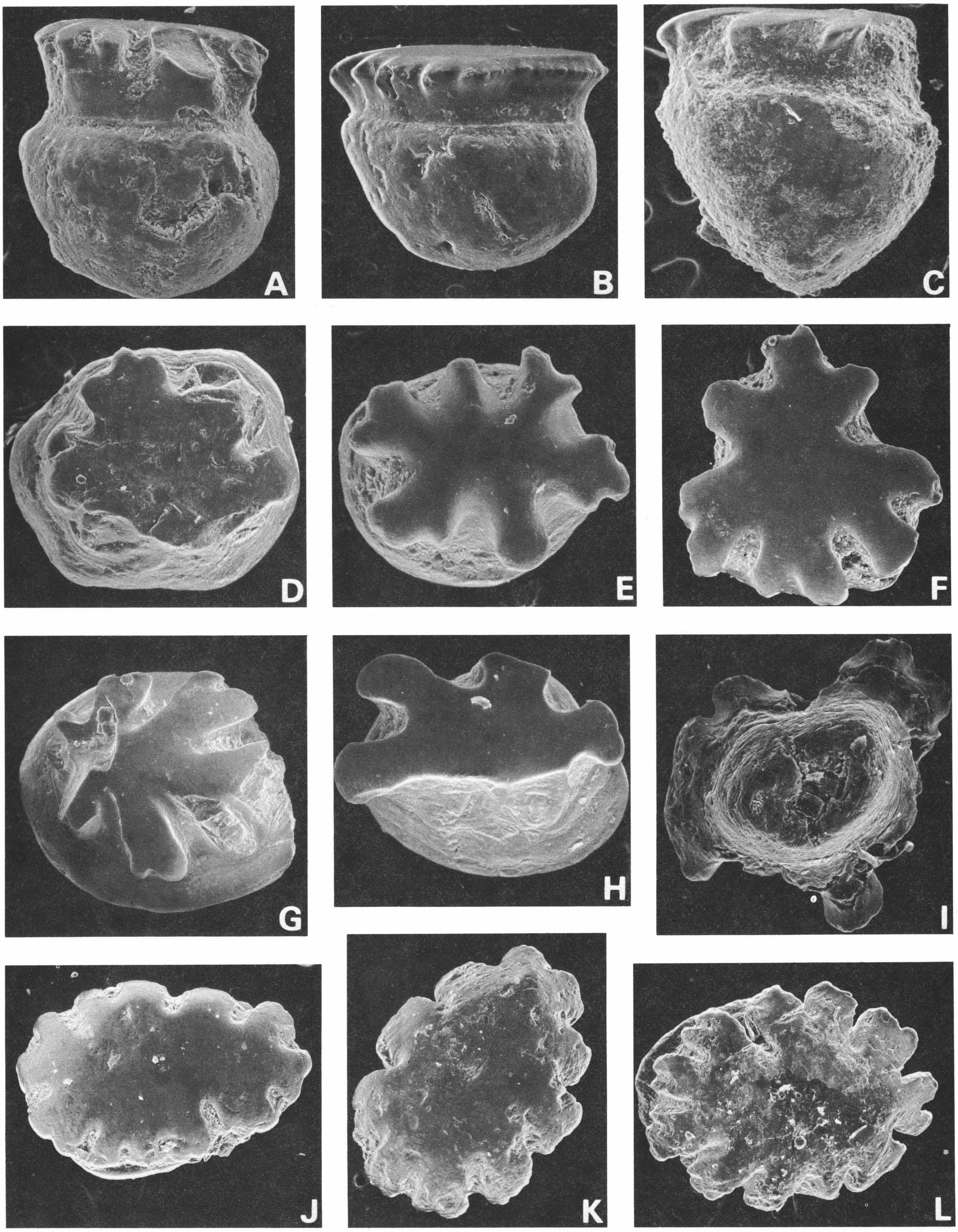

Figure 9. *Turinia australiensis* **Gross, 1971—Head (A-I) and head-transitional (J-L) scales from the Toko Range shot hole localities.**
A—CPC 20081/6, lateral view showing deep base, x 75, locality SP 798; B—CPC 20084/4, lateral view, x 55, locality SP 813; C—CPC 20084/6, lateral view, x 70, locality SP 813; D—CPC 20081/5, crown view, x 60, locality SP 798; E—CPC 20083/5, crown view, x 95, locality SP 801; F—CPC 20083/2, crown view, x 90, locality SP 801; G—CPC 20081/9, crown view, x 65, locality SP 798; H—CPC 20084/3, crown view, x 150, locality SP 813; I—CPC 20083/7, basal view, x 90, locality SP 801; J—CPC 20084/2, crown view, x 65, locality SP 813; K—CPC 20085/2, crown view, x 75, locality SP 839; L—CPC 20085/1, crown view, x 60, locality SP 839.

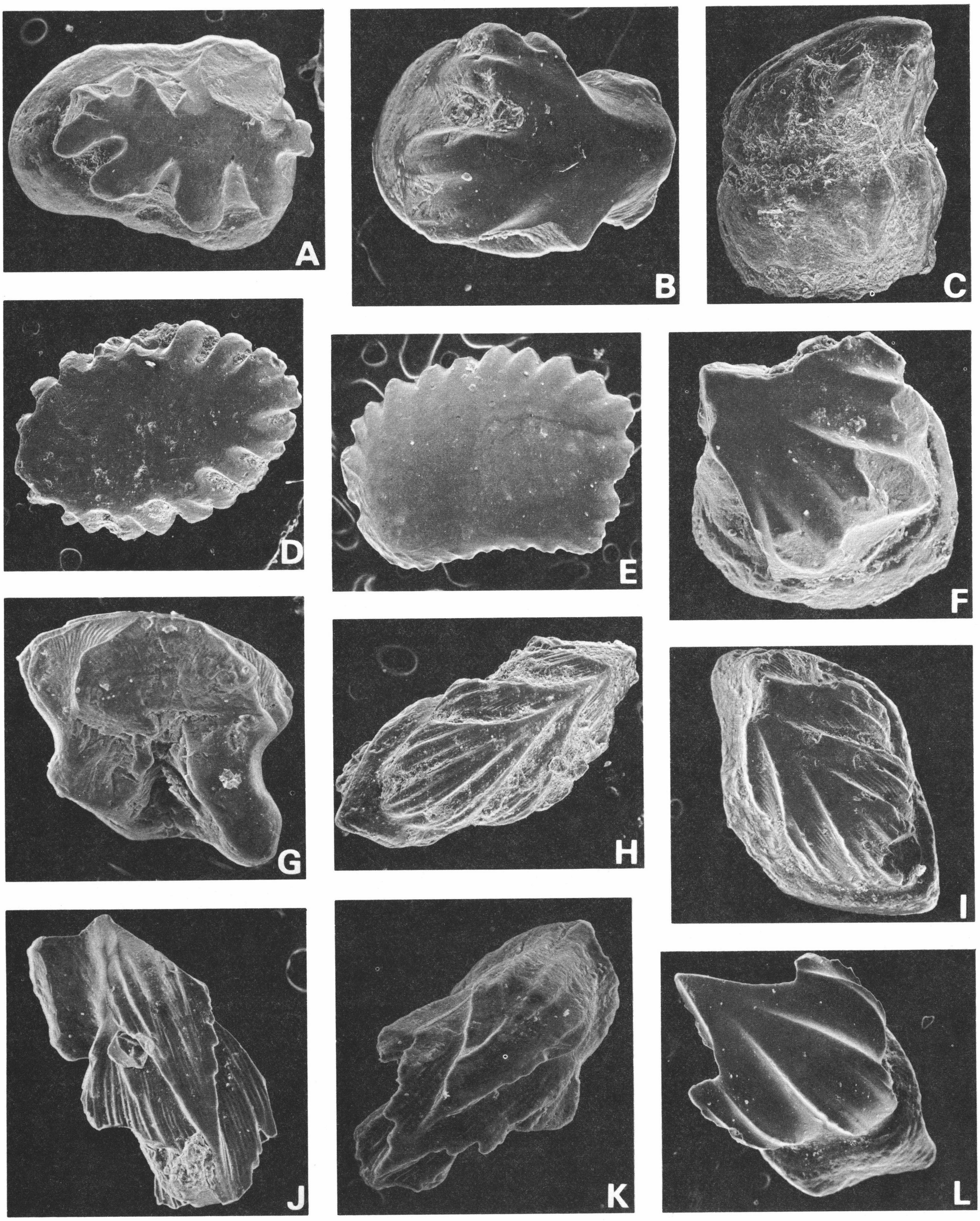

Figure 10. *Turinia australiensis* **Gross, 1971—Transitional (A-E) and other (F-I) scales from the Toko Range shot hole localities; body (J, K) and special (L) scales from the Toomba Range locality GEO 65/28.**
A—CPC 20071/8, crown view, x 60, locality SP 798; B—CPC 20082/9, crown view, x 90, locality SP 799; C—CPC 20082/3, lateral view, x 60, locality SP 799; D—CPC 20083/3, crown view, x 30, locality SP 801; E—CPC 20083/6, crown view, x 50, locality SP 801; F—CPC 20083/4, crown view of a special scale, x 90, locality SP 801; G—CPC 20084/5, lateral view of a fragmentary transitional/body scale, x 80, locality SP 813; H—CPC 20082/4, crown view of a body scale, x 55, locality SP 799; I—CPC 20083/1, crown view of a body or transitional scale, x 60, locality SP 801; J—CPC 20080/1, crown view, x 75, K—CPC 20080/3, crown view, x 100, L—CPC 20080/2, crown view, x 50.

with an anterior bifurcated ridge curving down to the neck. The extension of the lateral ridges into prongs or winglets is well displayed on some of the Australian scales (Fig. 7e). These scales are probably more posterior transitional scales showing a gradation to body scales on which this feature is more common.

The body scales (Figs. 8a-c) are generally large and elongated, navicular in shape with a flat central crown pointed posteriorly, often with one to three pairs of lateral flaps or winglets. The crown may rise at quite a steep angle from the base and be finely ribbed. The scales in the Toomba Range sample are often well preserved and show a complex development of lateral wings and ridges. The base is often wider than the crown, with a deep moat-like neck and an anterior spur. Several scales may be special scales that covered particular areas on the body, and these will not fit easily into a simple description until better preserved, articulated material is found (Figs. 8d, e).

Turinia australiensis Gross, 1971 (Figs. 9-12)

About 100 scales were recovered from the Toko Range shot hole localities (Fig. 5), of which 32 are figured here as *Turinia australiensis* Gross, 1971. Other figured specimens referred to this species are five scales (CPC 20080/1-5) recovered from the Toomba Range locality GEO 65/28.

Gross (1971b, p. 98, fig. 1, pl. 12, figs. 1-7) referred the Western Australian scales to the genus *Turinia,* on general morphology and histology, and differentiated them from those of *T. pagei* on their smaller size, simpler form, and the occasional presence of minor crossfluting on the ribs. Because this material lacked the typical body scales of *T. pagei* (that is, with a wedge-shaped unsculptured plain crown; cf. Gross, 1967, pl. 7, figs. 1-4) *T. australiensis* was defined on the basis of the head and transitional scales, without the knowledge of the body scales. In some instances, it is difficult to decide whether a scale belongs to *pagei* or *australiensis,* and certainly some of the Toko Range scales are large, and, at 1.6 mm long, extend into the size range of *pagei;* however, they still seem simpler than *T. pagei* scales. Gross surmised that *T. australiensis* is probably a separate species, as very small or finely ribbed scales have not been observed on any of the articulated specimens. It is possible that the scales of *T. australiensis* may be special scales of *T. pagei*

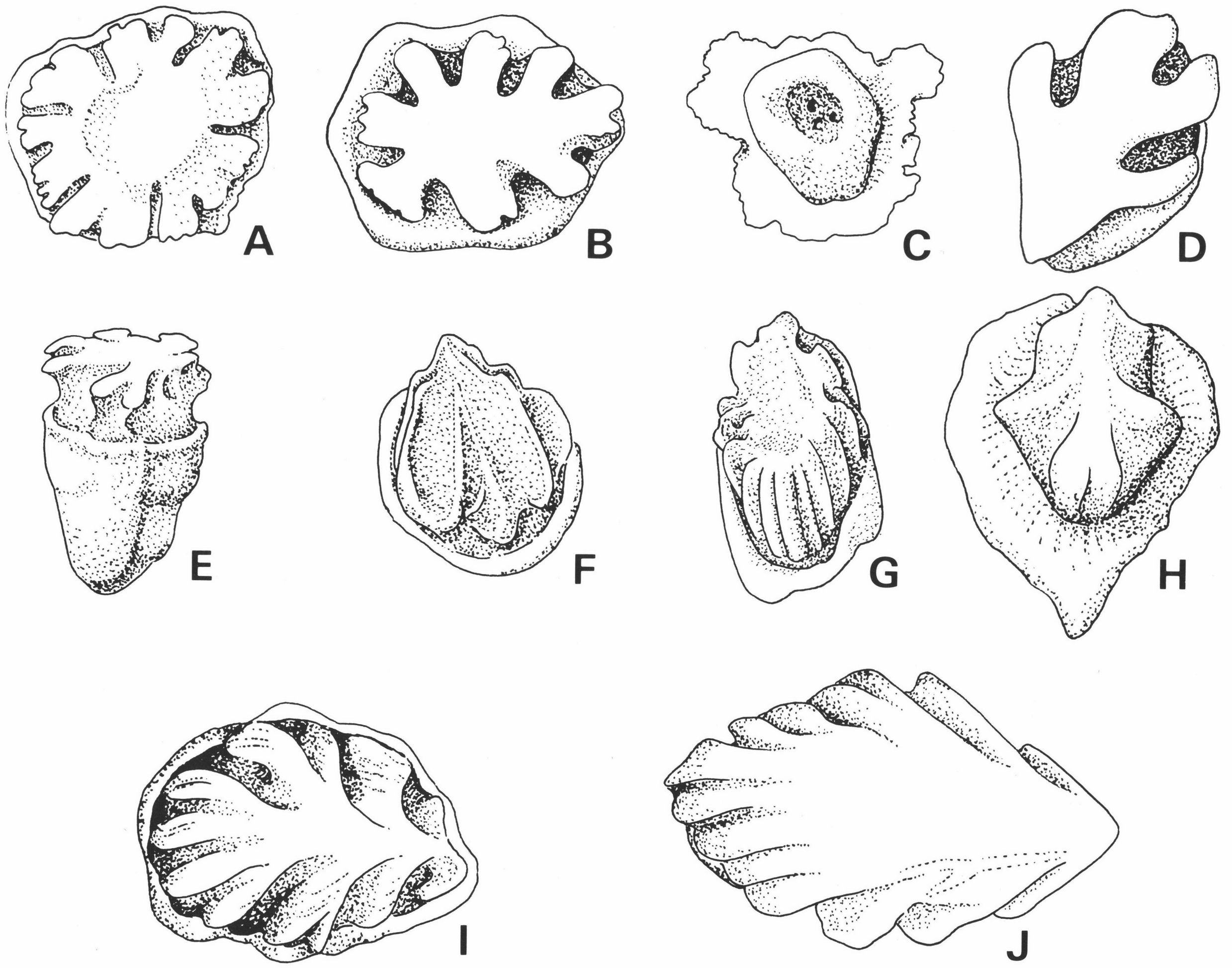

Figure 11. *Turinia australiensis* **Gross, 1971—Head (A-E), transitional (I, J), transitional/body (G) and special (F) scales from the Toko Range shot hole localities; and a head scale (H) from the Toomba Range locality GEO 65/28.**
A—CPC 20081/4, crown view, x 40, locality SP 798; B—CPC 20084/1, crown view, x 40, locality SP 813; C—CPC 20083/7, basal view, x 73, locality SP 801 (compare with Fig. 9I); D—CPC 20082/7, crown view, x 73, locality SP 799; E—CPC 20081/7, tilted lateral view, x 73, locality SP 798; F—CPC 20083/4, crown view, x 53, locality SP 801; G—CPC 20081/3, crown view, x 43, locality SP 798; H—CPC 20080/4, crown view, x 53; I/CPC 20081/1, crown view, x 43, locality SP 798; J—CPC 20081/2, crown view, x 43, locality SP 798.

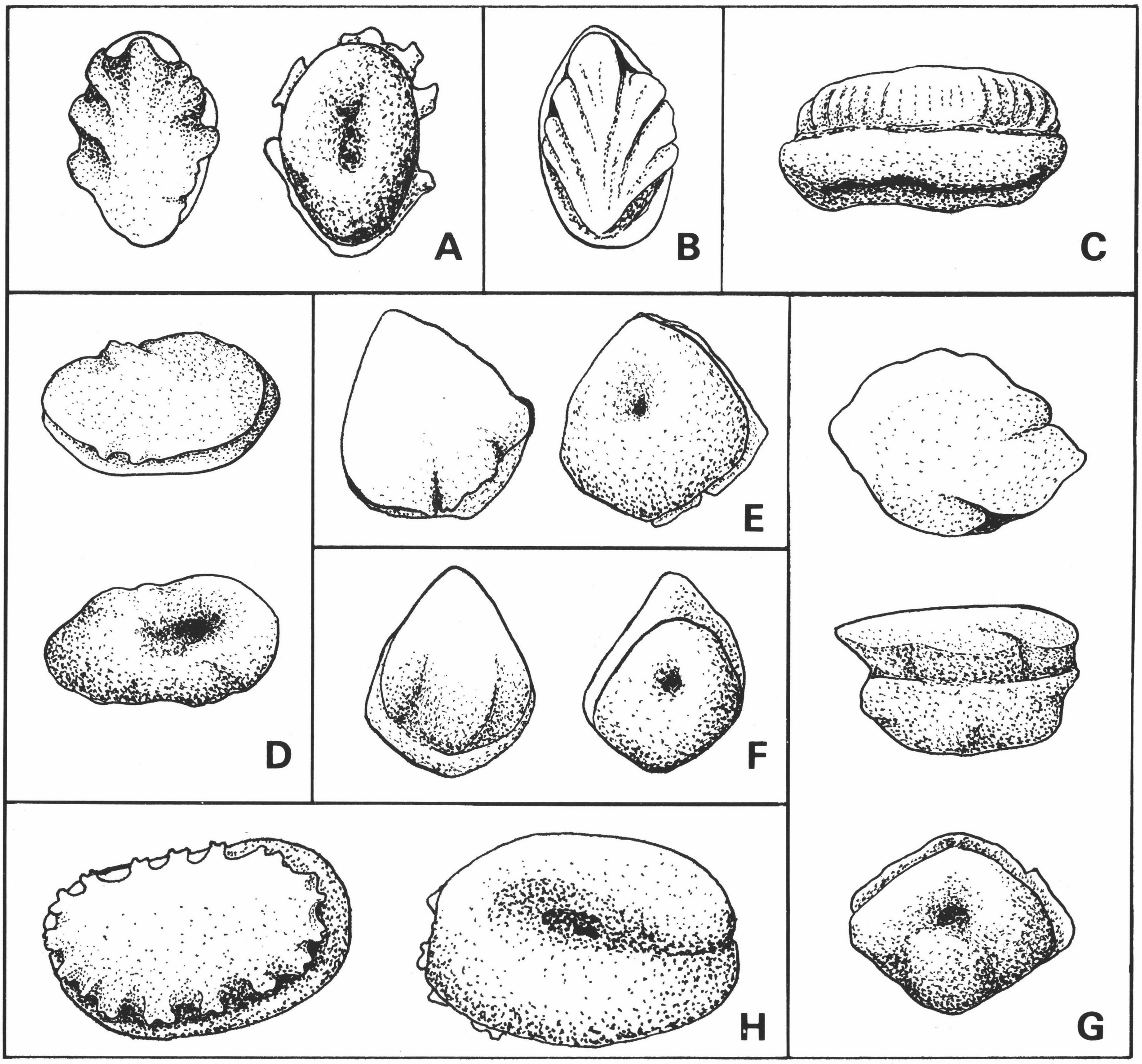

Figure 12. *Turinia australiensis* **Gross, 1971—Transitional (A, B) and head (C-H) scales from Earnstrey Hall Farm, Shropshire, from the Lower Dittonian** *Traquairaspis pococki* **'zone'.**
Deposited in the British Museum (Natural History), London (P60730-P60737), x 70.

(for example, those covering gill areas) or those of younger *T. pagei*, though this is less likely, as they can occur in large numbers and independently. Definite determination, as with most thelodont 'species', must await the discovery of good articulated material.

Many of the scales in the samples are head scales, or possibly special scales. Some bear a similarity to scales of *Thelodus sculptilis* Gross 1967. The head scales have a simple smooth flat crown, oval, ovate, or rhombic in shape, with more or less deeply crenulated edges (Figs. 9a-d; 11a,· b, e). The crown perimeter is often smooth with a pair of notches anterior or midway, directed distally (Fig. 11d). Other special scales have a triangular crown with a tripartite division of ridges (Fig. 10f). The transitional scales have crowns which are more elliptical, with crenulations which are often bifurcated or trifurcated (Figs. 9j; 10a, c, e, g; 11i, j). Some have the minor ribbing or fluting on the crown. The body scales have crowns with more heavily incised ridges, again with minor ribs on them (Figs. 10g, h; 11c, g). They are similar in general shape to those of *T. pagei* of the Welsh Borderland, but are more complex in that they have a three-tiered crown with an anteriorly raised diamond-shaped portion; the crown may be smooth or finely striated with a lower central posterior point, some with minor cusps.

Typical head scales of *Turinia australiensis* are small, and have very deep rounded bases (Figs. 9a, c, e, h; Fig. 11e). Often the crowns are much smaller in area than the base (Fig. 11b), and the neck is shallow and unornamented. The scales referred to *T. australiensis* from the Toomba Range locality are also very small (0.5 mm to 1.0 mm) with deeply incised crenulations on the crown (Fig. 11h), whereas the scales of *T.* cf. *pagei* are larger (0.55 to 1.62 mm).

Some small head and transitional scales from the Dittonian deposits of the Welsh Borderland were so similar to those figured by Gross (1971b) that they were referred by one of us (Turner, 1973, p. 569, fig. 8f) to *T.* cf. *australiensis*, and later (Turner, 1976, p. 14) directly to this species. Karatajute-Talimaa (1978, p. 123) has since suggested that this form is synonymous with *T. polita* Karatajute-Talimaa, 1978,

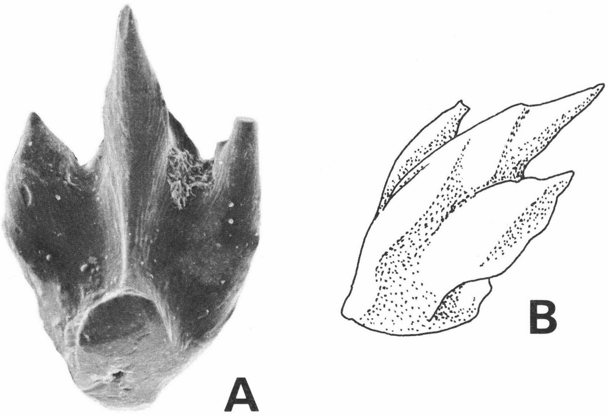

Figure 13. *Gampsolepis* **? sp. undet. (Family Nikoliviidae Karatajute-Talimaa, 1978)—a tricuspid scale CPC 20086 from Toomba Range, locality GEO 65/28.**
A—basal view; B—tilted lateral view; both x 60.

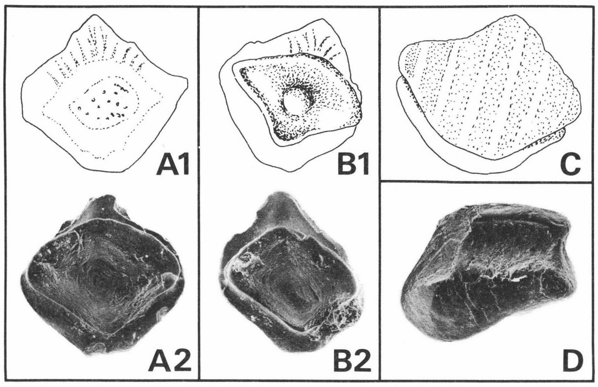

Figure 14. **Acanthodian scales A-C—*Gomphonchus* ? sp. from Toomba Range locality GEO 65/28.**
Crown (A1) and basal (A2) views of CPC 20087/1; basal (B1) and tilted basal (B2) views of CPC 20087/2; crown (C) view of CPC 20087/3; all x 43. D—*Nostolepis* sp. from locality SP 799, CPC 20088/1, lateral view, x 24.

and this may be correct in part. More scales from the Welsh Borderland are figured in this paper (Fig. 12) for comparison with those of *T. australiensis* Gross, 1971 and those referred to this species from the Toko Syncline.

Gampsolepis? sp. undet. (Fig. 13a, b)

One scale (CPC 20086) from the Toomba Range locality (GEO 65/28) is very different from those just described. It is tricuspid in shape, somewhat like the footprint of a wading bird. The crown rises at an angle of about 60° from a small rounded base, less than one third the total length of the scale, with a single pulp hole. Its median part rises to a posterior point, and in its anterior half two lateral wings, almost as long as the central part, are placed at an angle of about 10°.

This scale probably belongs in the family Nikoliviidae Karatajute-Talimaa, 1978, and resembles some described by Ørvig (1969b) as *Amaltheolepis winsnesi* (Wood Bay Group, late Emsian-early Eifelian, Vestspitsbergen), and others described by Karatajute-Talimaa (1978, and personal communication) as *Gampsolepis insueta* (Chortkov and Ivanev Horizons, Gedinnian, Podolia). With only one scale, no definite identification can be made, and histological analysis must await the discovery of further scales.

Associated fauna

Fish

Associated with the thelodont remains are two types of acanthodian scales. Those from the Toomba Range locality (GEO 65/28), CPC 20087/1,2, are small, about 0.5 mm, simple, and generally transparent, with a deep domed base and a flat smooth crown (Figures 14A, B). At least one scale shows the suggestion of 5 to 6 horizontal ribs on the crowned surface, aligned antero-posteriorly (Fig. 14C). These scales resemble those described by Gross (1967, 1971a) as *Gomphonchus gracilis,* but may eventually have to be referred to a new species.

Three larger and somewhat broken scales (CPC 20088) from locality SP799 (Fig. 14D) resemble *Nostolepis striata* (Pander) as redescribed by Gross (1971a). The genera *Gomphonchus* and *Nostolepis* commonly occur in Upper Silurian and Lower Devonian deposits in Europe.

Small curved, broken acanthodian spines with fine longitudinal ribbing have also been found. Bone fragments found in the samples are indeterminate remains of acanthodians or agnathans.

No other identifiable fish remains were found in the Cravens Peak Beds (in situ) until 1977. None of the fish fragments collected from the three localities noted by Gilbert-Tomlinson (1968) were found in place. Those from the locality 26 (incorrectly marked in Gilbert-Tomlinson, 1968, text-figure 5 as locality 24) were later determined by Ritchie (1973) as a species of *Wuttagoonaspis*—similar to, but larger than, *W. fletcheri* (the type species) from the lower part of the Mulga Downs Group of the Cobar region.

Young (BMR) is currently studying several collections of fossil fish remains which he made in 1977 from the Cravens Peak Beds. Placoderm (pterichthyodid antiarch) and onychodontid crossopterygian remains have been found in the basal (calcareous) unit with scales of *Turinia* cf. *pagei and T. australiensis* (Young's locality 11 at Toomba Range locality GEO 65/28), and *Wuttagoonaspis* sp., placoderms (including phlyctaeniids), crossopterygians (including onychodontids), and acanthodians have been recovered from the overlying conglomerate and sandstone sequence (Young & Gorter, 1981).

Crustacea

A small crustacean fauna, consisting of octracods and the problematic eridostracan *Cryptophyllus,* occurs together with the thelodont scales at locality GEO 65/28 in the Toomba Range, and in the shot hole localities SP 799 and 839, west of the Toko Range.

The Toomba Range sample contains about 100 specimens of *Cryptophyllus,* and 6 poorly preserved ostracod carapaces, probably belonging to the Kloedenellacea. Other ostracod specimens are present in both the Toomba and Toko Range samples as damaged isolated valves, broken steinkerns, and shell fragments. The valves are mostly smooth, lacking external macrosculpture, and internal details such as the adductor muscle scar pattern and the contact margin are obscured. Without such details, the following determinations, based mainly on the outline of the valves, must be open to question.

Healdianella inconstans Polenova, 1974? (Figs. 15A, B)

Six specimens from locality SP 799, of which two right valves (CPC 20089, length 1.55 mm, height

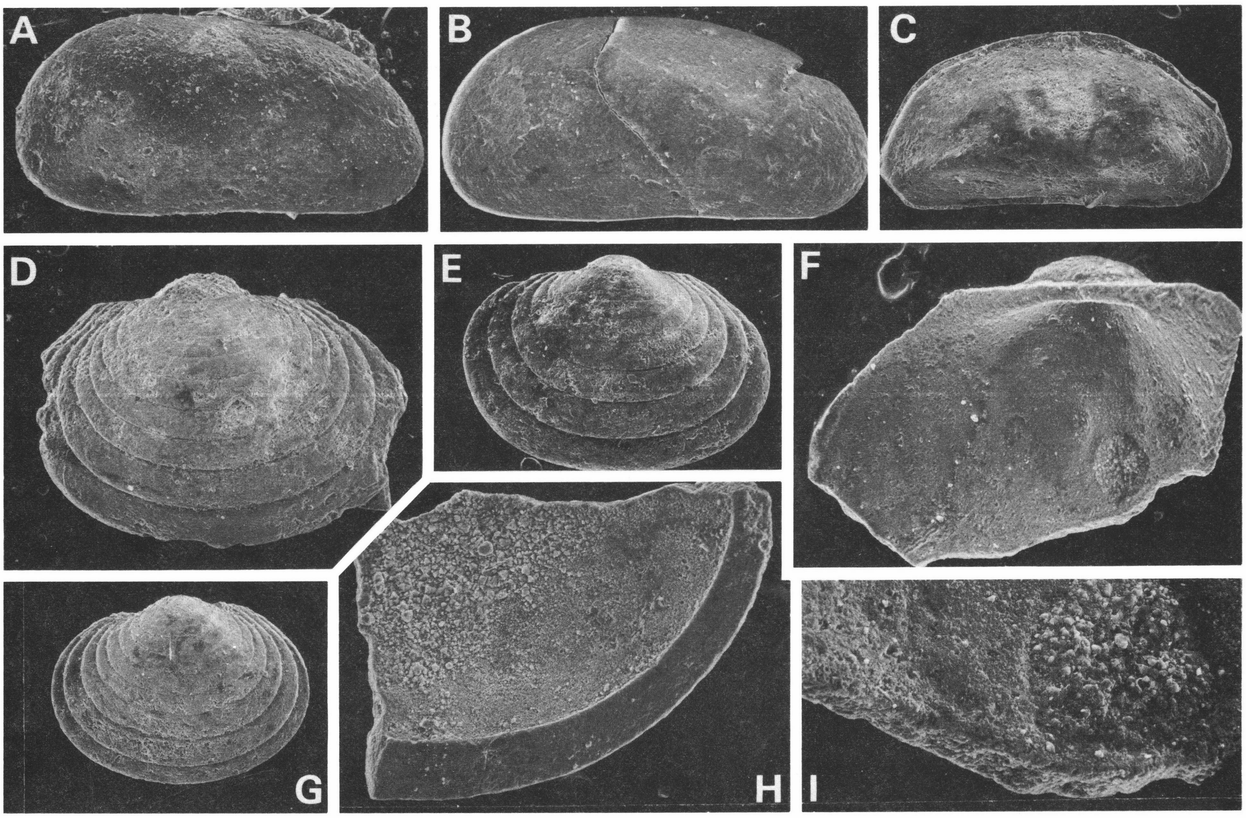

Figure 15. Ostracoda and Eridostraca.
A, B—*Healdianella inconstans* Polenova, 1974 ? from locality SP 799, x 40; A—right valve, CPC 20089; B—right valve, CPC 20090; C—*Baschkirina* ? sp., carapace, CPC 20091, from locality SP 839, x 40. D-I—*Cryptophyllus* sp. from the Toomba Range locality GEO 65/28, x 40, except where indicated. D—valve, CPC 20092; E—valve, CPC 20093; F—broken valve, CPC 20095, internal view showing position of adductor muscle scar and other muscle scars, x 90; G—carapace, CPC 20094; H—fragment of valve margin, CPC 20096, showing simple narrow duplicature, x 97; I—detail of adductor muscle scar on tilted valve, CPC 20095, x 270.

0.80 mm; CPC 20090, length 1.60 mm, height 0.80 mm) are figured here, appear to fall within the limits of variation of *Healdianella inconstans* Polenova, 1974. This species was originally described by Polenova (1974, p. 64, pl. 25, figs. 2-5, pl. 26, figs. 2, 3) from the Lower Devonian (Siegenian) lower Settedabanskii 'horizon' (beds with *Sibiritoechia lata*) in the Sette-Daban Ridge region of the northeastern part of the Siberian Platform. The Australian specimens may have had a calcified inner lamella, as evidenced by shell fragments and a broken steinkern, which raises the vexing question, beyond the scope of this paper, of the relationship between the two genera *Cytherellina* Jones & Holl, 1869 and *Healdianella* Posner, 1951 (see Adamczak, 1976, p. 341).

Baschkirina? sp.
(Fig. 15C)

A single carapace (CPC 20091, length 1.36 mm, height 0.68 mm, width 0.50 mm) from locality SP 839 (Fig. 15C) and an unfigured carapace from the Toomba Range locality GEO 65/28 have similar lateral and dorsal outlines as those of *Baschkirina densa* Polenova, 1974 from the Lower Devonian (Siegenian) rocks of Novaya Zemlya and of the Sette-Daban Ridge region (Polenova, 1974, p. 55, pl. 21, figs. 3-6). The Australian species differs, however, in that it has a few small rounded nodes in the centrolateral area of the valves, which are aligned with a rib-like bend at the posteroventral end. Both specimens have their posterior ends missing, and the poor preservation of the valves does not permit interpretation of the posterodorsal overlap; therefore, the species is questionably referred to *Baschkirina* Rozhdestvenskaya, 1959.

Cryptophyllus sp.
(Figs. 15D-I)

The eridostracan genus *Cryptophyllus* contains many species that are difficult to recognize on the basis of the published literature. Even with specimens for comparison, the problems of discrimination, owing to morphological variability, remain unresolved. Because the Toomba Range specimens present such a problem, they are, for the present, placed in open nomenclature.

From their external features, both figured (CPC 20092-94) and unfigured specimens appear to fall within the limits of variation for most of the external characters of *Cryptophyllus sp.* A. Jones, 1962. The ovate to slightly asymmetrical lateral outline, low umbo, and 8-11 wide growth bands, are all features common to this species, which was described from the Gneudna Formation in the Carnarvon Basin of Western Australia (Jones, 1962, p. 24, pl. 3, figs. 1-5). Specimens CPC 20093 and 20094 (Figs. 15E, G) have hinge lines which are slightly shorter (in relation to the total length of the shell) than those of the figured specimens of *Cryptophyllus* sp. A (CPC 4225, 4226, 4227), but this may be a matter of variation within the species. Unlike the specimens from the Gneudna Formation, they have well-defined cardinal angles, which appears to be a fairly constant character for the Toomba Range species.

The external features of specimens belonging to this species may be compared also with those referred in the literature to species of Early Devonian age in the Sahara (Le Fevre, 1963), North Spain (Becker & Sanchez de Posada, 1977), and Podolia (Abushik, 1968). For example, CPC 20094 (Fig. 15G) is comparable with *Cryptophyllus* sp. 1 Le Fevre, 1963 (pl. 8, fig. 127) from the middle Emsian part of the Teferguenit Formation, and with *C.* sp. Abushik, 1968 (pl. 1, fig. 6) from the Gedinnian Borschov Horizon; CPC 20092 (Fig. 15D) is comparable with *C.* sp. A Becker & Sanchez de Posada, 1977 (pl. 14, figs. 8-11) from the late Emsian part of the Moniello Formation. However, none of these Old World Realm species appear to have the characteristic well-defined cardinal angles of the Toomba Range species.

On the internal surface of specimens of this species, the adductor muscle scar pattern (Fig. 15F, I) is similar to that recognized in other Australian species of *Cryptophyllus* (namely *C. diatropus* Jones, 1962; *C. platyogmus* Jones, 1962). SEM photographs indicate the presence of additional muscle scars (Fig. 15F), of as yet unknown significance, and a thickening of the free margin in the form of a simple narrow duplicature (Fig. 15H), not unlike that figured and described for *Cryptophyllus* sp. A Becker & Sanchez de Posada, 1977.

While this paper is not the place for a detailed discussion of the biological affiinties of *Cryptophyllus* and allied eridostracan genera, none of the features that Schallreuter (1977) uses in support of his argument that the genus is a true ostracod are *exclusive* to the Ostracoda. Few studies have been made of the adductor muscle scar patterns and contact margins in the Eridostraca, and there are no comprehensive comparative studies which indicate the position of this group within the Phylum Crustacea.

Age and correlation

Age relationships

Turner (1973) and Karatajute-Talimaa (1978) have reviewed the distribution of *Turinia pagei*. The scales of this species have been found in many Lower Devonian agnathan localities in Europe and the Soviet and Canadian Arctic, and are now being accepted as indicators of the beginning of the Devonian (that is, *Traquairaspis symondsi* Zone; Dittonian *sensu* Holland & Richardson, 1977). The type locality of *Turinia pagei* is in the Lower Garvock Group (of the Lower Old Red Sandstone) of the northern Midland Valley of Scotland, the age of which is Siegenian, based on spore evidence (J. B. Richardson, personal communication T. S. Westoll, 1977), and is no older than the base of the Dittonian (*sensu* White, 1950) based on the fish and eurypterids (Westoll, 1977). *Turinia pagei* is now known from the Dittonian (*sensu* Holland & Richardson, 1977) of the Welsh Borderland (Turner, 1973), the Baltic region, Brest Depression, Volynia-Podolia region , and the Arctic regions of Spitsbergen, Severnaya Zemlya (Karatajute-Talimaa, 1978), and possibly Prince of Wales Island (Turner, 1973). Recently, it has been described by Goujet & Blieck (1979) from the late Gedinnian of northern France, in association with the late Dittonian zone fossil *Belgicaspis crouchi* Lankester.

Gross (1971) regarded the scales of *Turinia australiensis* from Wilson Cliffs No. 1 well, Western Australia, as Dittonian, but there is no corroborative fossil evidence to confirm this age. Furthermore, despite the fact that some scales of the *T. australiensis* type are now known from Dittonian rocks of the Volynia-Podolia regions (under the name *Thelodus scoticus* Karatajute-Talimaa, 1964), and the Welsh Borderland (Turner, 1976, p. 14), we suggest that *T. australiensis* may extend into younger (Emsian-?Eifelian) deposits in Australia.

The family Nikoliviidae, represented in the Cravens Peak Beds by one scale, is an integral part of the Early (Dittonian) to Middle Devonian (Eifelian) succession of thelodont assemblages of Europe (Turner, 1973 Karatajute-Talimaa, 1978; Goujet & Blieck, 1979), and, if further nikoliviid scales are found, they may help to reduce the margin of error within this age range. The ostracod evidence is inconclusive for this purpose, because the specimens are poorly preserved and lack distinctive features. If the comparisons with *Healdianella inconstans* Polenova, 1974 and *Baschkirina densa* Polenova, 1974 are valid, they are more likely to indicate Early Devonian rather than a younger age. Despite a superficial likeness, the eridostracan *Cryptophyllus* sp. is probably not conspecific with C. sp. A Jones, 1962 from the Late Devonian Gneudna Formation of the Carnarvon Basin.

Thus, based on the age of the *Turinia pagei* fauna in the Old World Realm, the thelodont scales from the Cravens Peak Beds are no older than Dittonian, that is, no older than Gedinnian. The Devonian age of the basal (calcareous) unit of the Cravens Peak Beds is unequivocal, and the earlier consideration of a Late Silurian age now can be discarded (cf. Smith, 1972, pp. 131-32; Strusz, 1972, p. 449; Talent & others, 1975, p. 23).

The sandstone and conglomerate sequence which conformably overlies the basal (calcareous) unit contains *Wuttagoonaspis,* a placoderm at present unknown outside Australia (Young, 1974). The type species of *Wuttagoonaspis* (*W. fletcheri* Ritchie, 1973) is regarded as probably late Early to early Middle Devonian in age, on the basis of numerous small arctolepids associated with it in the lower part of the Mulga Downs Group of western New South Wales (Ritchie, 1973). Ritchie (1969, text-figs. 3, 4) pointed out that these forms show a close resemblance to Northern Hemisphere genera such as *Huginaspis, Heterogaspis,* and *Arctolepis*, and indicate a probable Emsian-Eifelian age, and he suggested (Ritchie 1973, p. 71) that the Mulga Downs Group (lower part) and the Cravens Peak Beds (also with *Wuttagoonaspis*) were approximately contemporaneous. A latex rubber impression of the concentration of skeletal debris found in association with *W. fletcheri,* kindly provided by Dr Ritchie, includes numerous scales of *Turinia,* which we refer to *T. australiensis* (Fig. 16). Thus, based on the combined thelodont, placoderm, and ostracod evidence, the total possible age for the Cravens Peak Beds appears to range from Gedinnian to Eifelian (that is Early Devonian to early Middle Devonian). Within this possible range, we emphasise the presumed Emsian-Eifelian age of the *Wuttagoonaspis* fauna (Ritchie, 1973), and suggest a similar age is possible for the *Turinia pagei* fauna, because the basal (calcareous) unit of the Cravens Peak Beds forms a gradational, conformable upper contact with the more

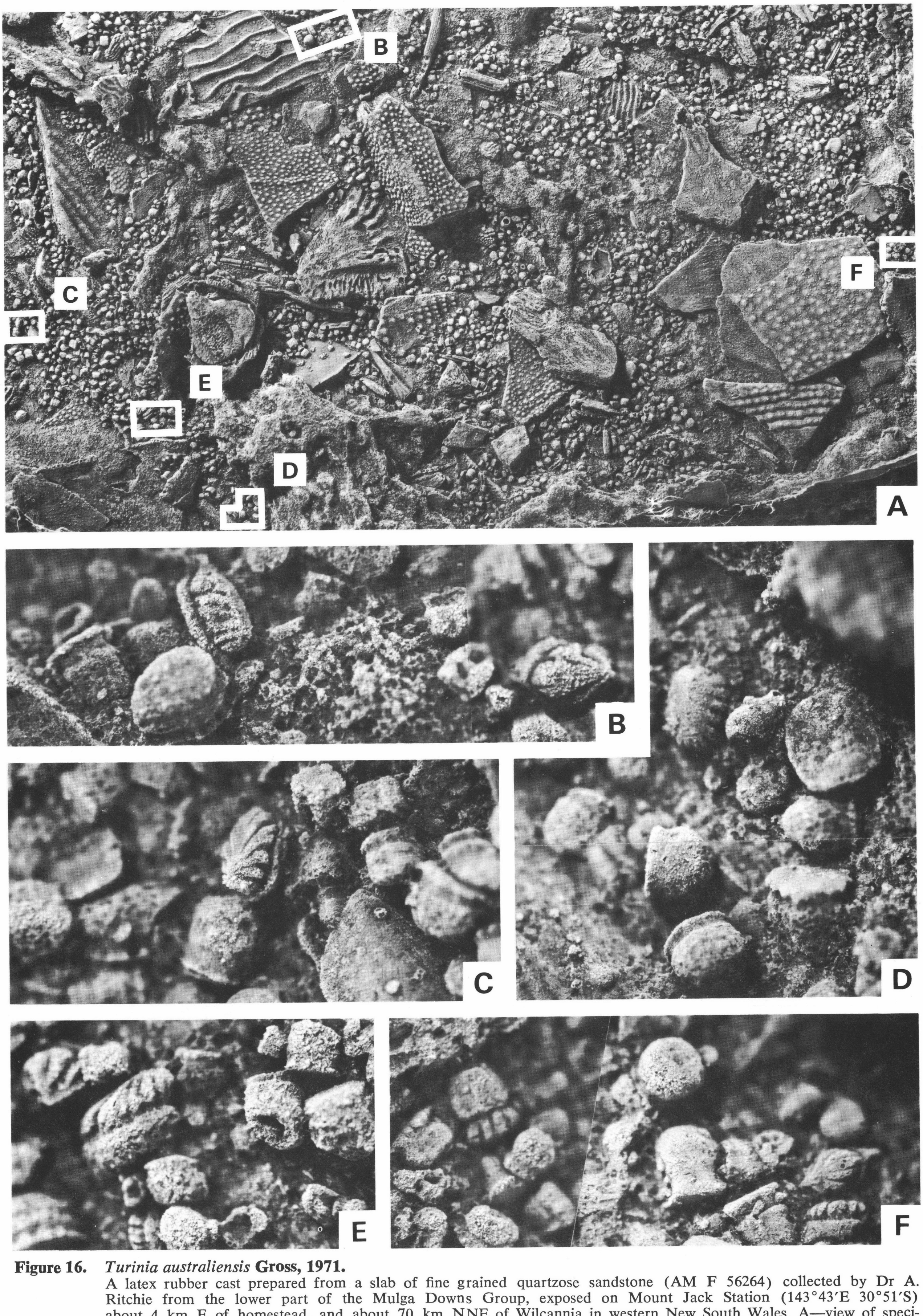

Figure 16. *Turinia australiensis* **Gross, 1971.**
A latex rubber cast prepared from a slab of fine grained quartzose sandstone (AM F 56264) collected by Dr A. Ritchie from the lower part of the Mulga Downs Group, exposed on Mount Jack Station (143°43′E 30°51′S) about 4 km E of homestead, and about 70 km NNE of Wilcannia in western New South Wales. A—view of specimen showing a rich concentration of thelodont scales in association with *Wuttagoonaspis* and other placoderm plate fragments, x 2. B-F—portions of specimen figures in A showing head and transitional scales of *Turinia australiensis,* x 22.

typical sandstones and conglomerates. These two vertebrate-faunas are probably biofacies equivalents of each other, and in the lower part of the Mulga Downs Group at least, they appear to be contemporaneous. Moreover, they are no older than Emsian in age, because Glen (1979) has recently shown that the Mulga Downs Group overlies, possibly paraconformably, the upper part of the Amphitheatre Group, which has been dated as Pragian on the presence of the brachiopod *Howellella jaqueti* (Dun).

Thus, we suggest that the age of the *Turinia pagei* fauna, which is Dittonian in Europe, is not necessarily contemporaneous elsewhere, and that, in Australia at least, this fauna is found in rocks at least as young as Emsian. Turner & Janvier (1979), for instance, have suggested that the Iranian species, *Turinia hutkensis* Blieck & Goujet, 1978, is probably Middle Devonian (Eifelian) rather than Early Devonian in age, and Young & Gorter (1981) have described a species that closely resembles *T. hutkensis* (in association with *Bothriolepis*) from late? Eifelian rocks in New South Wales.

Regional correlation

On the basis of the thelodont evidence, the Cravens Peak Beds appear to be broadly coeval with at least part of the Tandalgoo Red Beds in the Canning Basin of Western Australia, and with the lower part of the Mulga Downs Group in the Cobar Basin of north western New South Wales (Figure 17).

In the Canning Basin, scales of *Turinia australiensis* were recovered from Wilson Cliffs No. 1 well (22°16′39″S 126°46′55″E; Fig. 1, locality 3) (Gross, 1971), from core 5 (4439-4446 feet), which is situated within an interval (3590-5835 feet) identified by Creevey (1971) as Tandalgoo Red Beds. Because, as we have mentioned previously, scales of this thelodont species are associated with the *Wuttagoonaspis* fauna of central Australia (including western New South Wales), their presence and position within the Tandalgoo Red Beds suggest a late Early Devonian-

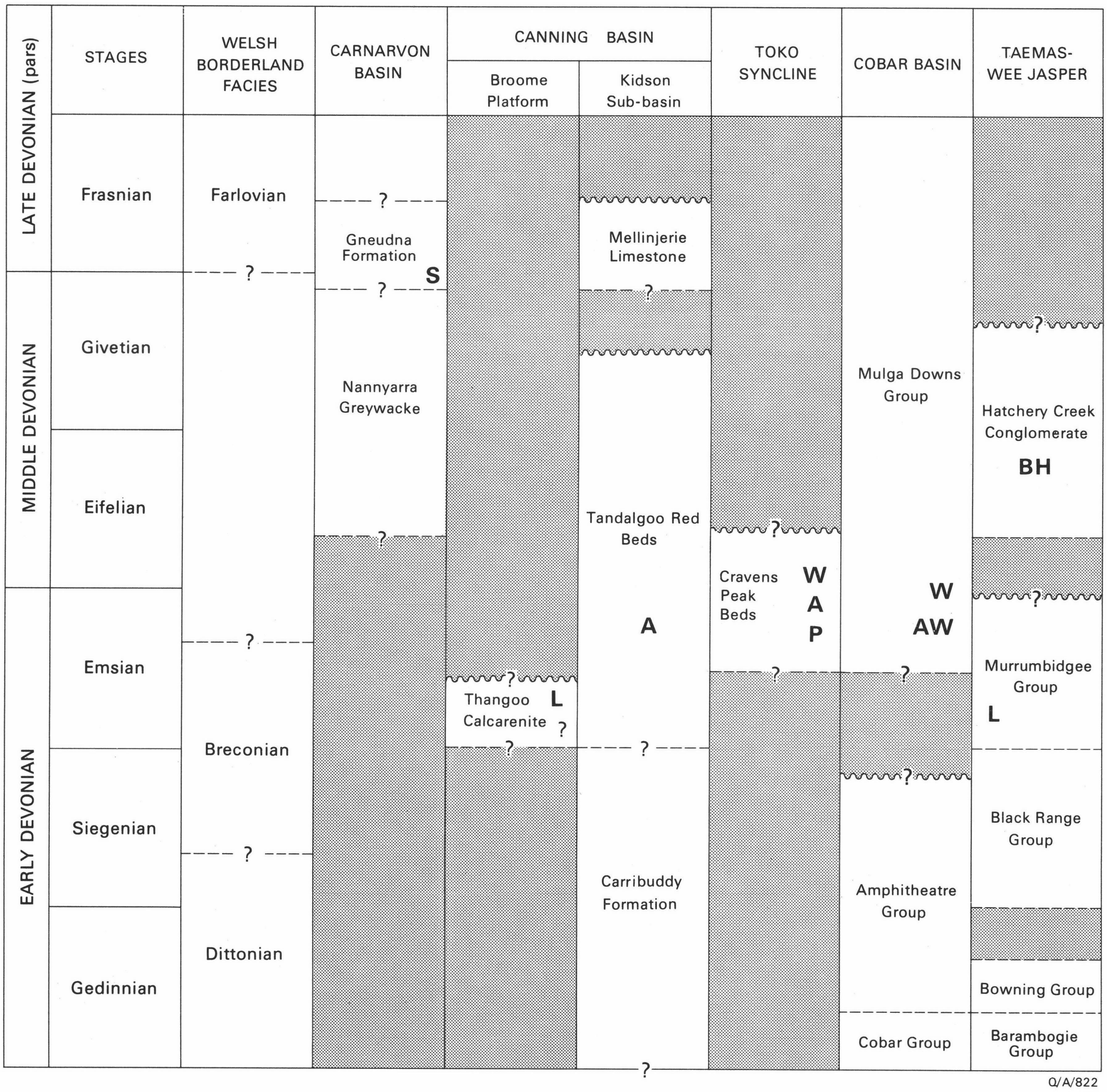

Figure 17. Correlation chart of Devonian sequences in Australia which have yielded thelodont scales and other fish remains mentioned in the text.

Key to symbols is as follows: P—*Turinia* cf. *pagei*; A—*T. australiensis*; H—*T.* ? cf. *hutkensis*; S—*Australolepis seddoni*; L—*Ligulalepis*; W—*Wuttagoonaspis* spp; B—*Bothriolepis* spp. Shaded areas within a column indicate a hiatus.

Middle Devonian age for the formation. Associated with the thelodont scales were indeterminate conodonts, and acanthodian fish remains, which Gross (1971) did not identify, but compared with *Diplacanthus longispinus* Agassiz from the Middle Devonian of Scotland. He found none of the acanthodian scales commonly associated with *Turinia pagei* in European localities. However, Turner (1973) has shown that acanthodian species are not very useful for correlation, having, in general, longer stratigraphic ranges than thelodonts. The conodonts, as Veevers (1976) pointed out, show that at least part of the Tandalgoo Red Beds is marine. The stratigraphy is complicated by the fact that the core which yielded these fossils also contained Permian spores (Gross, 1971b). Of the two possible solutions to this problem—(i) contamination of Devonian rocks by Permian spores, or (ii) reworking of Devonian fossils in Permian deposits—Veevers (1976, p. 190) favoured the second. We suggest, however, the first solution is the more plausible, because the sequence containing both Early Devonian fossils and Permian spores is overlain by the Mellinjerie Limestone (Creevey 1971), which elsewhere contains Middle Devonian spores.

A second report of thelodont remains in the Canning Basin was noted by McTavish & Legg (1976, p. 459), and based on a single scale from the upper part of the Thangoo Calcarenite (*sensu* McTavish, *in* Playford & others, 1975, p. 326) in Roebuck Bay No. 1 well (18°09′S 122°27′E) on the Broome Platform (Fig. 1, locality 2). It was identified, but not described or figured, as belonging to cf. *Apalolepis obruchevi* Karatajute-Talimaa, 1967, a species known from the Early Devonian (Dittonian) Chortkov Horizon of Podolia. Later examination of a photograph of this scale by one of us (ST) leads us to conclude that it came from a palaeoniscid cf. *Ligulalepis* Schultze, 1968, and not from a thelodont. On this basis, the Thangoo Calcarenite may be younger than Dittonian, because at present the only known occurrence of *Ligulalepis* is in the Taemas area, New South Wales, in the *'Spirifer' yassensis* limestone in the lower part of the Murrumbidgee Group, which is early Emsian (Zlichovian) in age (Pedder & others, 1970; Klapper & Johnson, 1980). Thus, the age of the Thangoo Calcarenite may not be much different to those parts of the Tandalgoo Red Beds, Cravens Peak Beds, and Mulga Downs Group which contain scales of *Turinia australiensis*.

The remains of *Turinia australiensis* and the *Wuttagoonaspis* fauna in the lower part of the Mulga Downs Group, are older than the recently described (Young & Gorter, 1981) fish fauna in the Hatchery Creek Conglomerate from the Taemas-Wee Jasper region of New South Wales (Fig. 1, locality 8). This fauna includes, amongst other species, a new species of *Bothriolepis*, with primitive characters indicative of an early representative (Eifelian) of the genus, and thelodont scales, which Young & Gorter refer to *Turinia?* cf. *hutkensis* Blieck & Goujet, 1978, from the Middle Devonian (Eifelian) of Iran (see Turner & Janvier, 1979).

Palaeogeography

Regional

The results of the present study have a bearing on some of the published palaeogeographic reconstructions of Devonian Australia (Johnstone & others, 1967; Gilbert-Tomlinson, 1968; Brown & others, 1968; Webby, 1972; Veevers, 1976). Our recognition of marginal marine deposition in central Australia during the Early Devonian supports the interpretation of Veevers (1976, p. 190), who showed a marine connection between the Georgina and Canning Basins via the Amadeus Basin. The presence of *Turinia* in both the Canning Basin and the Georgina Basin supports this contention, and its distribution in New South Wales (Fig. 1, localities 7 & 8) further suggests a connection with the Lachlan Fold Belt.

In most reconstructions of Middle and Late Devonian palaeogeography, the streams responsible for deposition of continental sediments in central Australia are assumed to flow ultimately into either southeastern or northeastern Australia. However, current direction measurements in the Cravens Peak Beds (a total of 33 measurements at six locations) gave an overall vector mean of 330°, indicating for Early Devonian time, a general direction of flow towards the northwest. The possibility of a river system flowing via the Wiso Basin and The Granites-Tanami area into either the Canning or Bonaparte Gulf Basin is worthy of further investigation. The restriction of *Wuttagoonaspis*, an apparently freshwater form, to central Australia (including western New South Wales) is a major obstacle to such a reconstruction. Many more current direction measurements from other Devonian sandstones, and a more detailed knowledge of fossil fish distribution patterns are required before a realistic Lower Devonian palaeogeographical reconstruction is possible.

Global

Halstead & Turner (1973) and Turner (1973) have posed the question of the whereabouts of Australia in Early Devonian times. Both Europe and Australia were apparently in tropical latitudes during the Devonian (Embleton, 1973; Smith & others, 1973; Heckel & Witzke, 1979), and Turner (1973) suggested that thelodonts may have dispersed via Arctic Canada, either to or from Australia.

Of the available palaeogeographic reconstructions for the Devonian, only the Heckel & Witzke map (1979, text-fig. 5) for the Middle Devonian shows the presumed current patterns and shorelines, and for that reason the map, based on palaeoclimatic indicators, is selected here as a base to show the known world distribution of thelodont faunas during the Devonian (Fig. 18).

The Lower Devonian occurrences of thelodont genera in northern Canada, Spitzbergen, northern Europe, and New South Wales suggest direct communication between Arctic North America and eastern Australia. Klapper & Johnson (1980, pp. 434-5) suggested a strong equatorial current for the dispersal of brachiopod larvae across the Proto-Pacific from North America to Australia in the Early Devonian, and the same current system explained the similarity of Cordilleran-Arctic conodont faunas with those of eastern Australia in the Early and Middle Devonian. We suggest that the thelodont faunas also may have been distributed by this current system.

It is tentatively postulated that the *Turinia* fauna reached Australia in the Early Devonian (Breconian?) and then began an adaptive radiation to give apparently younger (Middle Devonian) thelodont faunas that survived longer in the Australian region than elsewhere (Ørvig, 1969a, b, c; Karatajute-Talimaa, 1978; Turner & Janvier, 1979). The youngest known thelodont scales come from the Gneudna Formation (of latest Givetian-earliest Frasnian age) in the Carnarvon Basin, Western Australia.

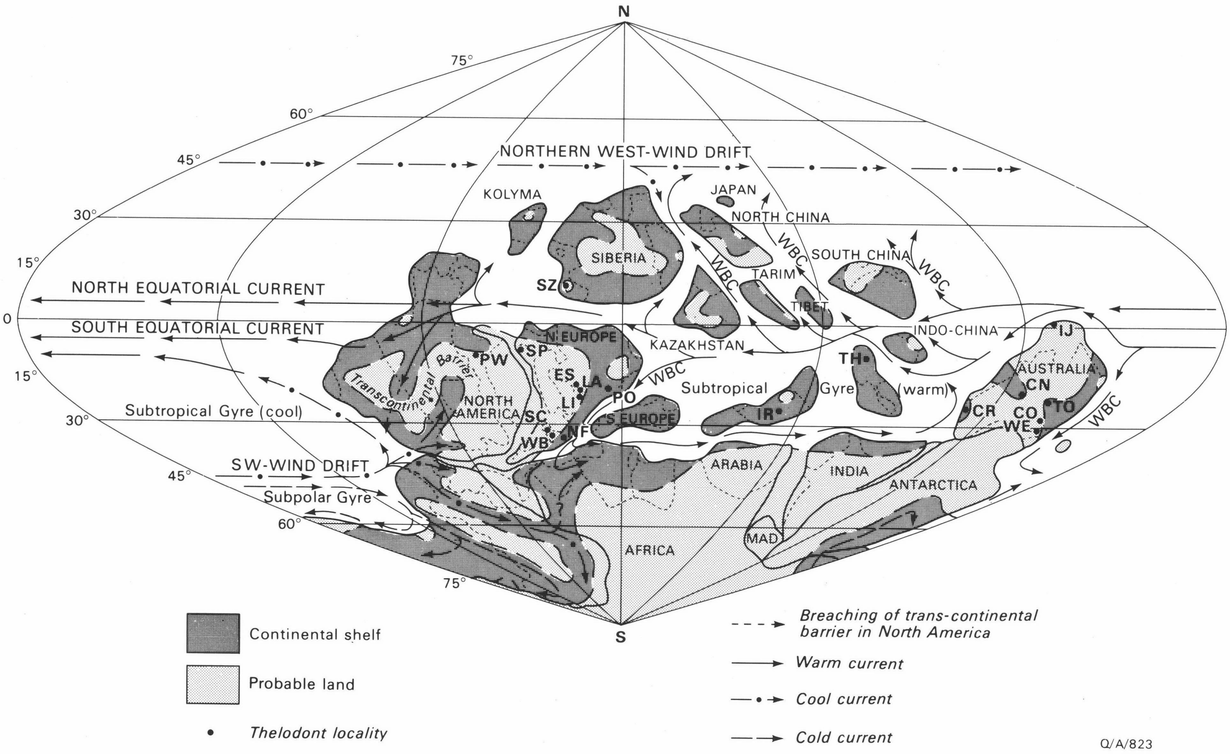

Figure 18. Middle Devonian world reconstruction, based on palaeoclimatic indicators, showing expected pattern of oceanic circulation, land and continental shelf, and distribution of Devonian thelodont localities; modified from Heckel & Witzke (1979, text-fig. 5).
Symbols for localities are as follows: CN—Canning Basin; CR—Carnarvon Basin; CO—Cobar Basin; ES—Estonia; IJ—Irian Jaya; IR—Iran; LA—Latvia; LI—Lithuania; NF—North France; PO—Podolia; PW—Prince of Wales Island; SC—Scotland; SP—Spitsbergen; SZ—Severnaya Zemlya; TH—Thailand; TO—Toko Syncline; WB—Welsh Borderland; WE—Wee Jasper.

Conclusions

1. Thelodont scales found in the basal (calcareous) unit of the Cravens Peak Beds belong to *Turinia australiensis* Gross, 1971. Some are similar to, but possibly not conspecific with, *Turinia pagei* (Powrie, 1870), and the family Nikoliviidae is probably represented by a single tricuspid scale, which may belong to the genus *Gampsolepis*.
2. Ostracods (e.g., *Healdianella inconstans* Polenova 1974?; *Baschkirina?* sp.) and eridostracans (viz., *Cryptophyllus* sp.) associated with the thelodont scales indicate a marine to marginal marine depositional environment for the basal (calcareous) part of the Cravens Peak Beds.
3. The basal (calcareous) part of the Cravens Peak Beds grades conformably upwards into an overlying sequence of sandstone and conglomerate (280 m) of braided stream origin. The sandstone contains a fish fauna with *Wuttagoonaspis* sp. that probably represents a freshwater biofacies of the *Turinia* fauna.
4. The presence of the *Turinia* fauna in the Cravens Peak Beds indicates an unequivocal Devonian age no older than Dittonian *sensu* Holland & Richardson, 1977), and the earlier suggestion of a possible Late Silurian age now can be discarded (cf. Smith 1972, pp. 131-32; Strusz, 1972, p. 449; Talent & others, 1975, p. 23).
5. The age of the Cravens Peak Beds is probably younger than Dittonian, because, in the lower part of the Mulga Downs Group in the Cobar area, New South Wales, scales of *Turinia australiensis* Gross, 1971 (figured in this paper) are associated with the *Wuttagoonaspis* fauna, which is at least as young as Emsian (Glen, 1979).
6. A tentative correlation is proposed between those parts of the Cravens Peak Beds, Tandalgoo Red Beds, and lower Mulga Downs Group that contain the *Turinia australiensis* fauna. Thus, although *Turinia australiensis* is present in the Dittonian of the Welsh Borderland, where it is commonly associated with *T. pagei,* the *T. australiensis* fauna in Australia appears to characterise younger deposits, of late Early to early Middle Devonian age.
7. During the (Emsian?) marine phase in the early part of the depositional history of the Cravens Peak Beds, a sea connection was possibly established between the Canning and Georgina Basins, via the Amadeus Basin, and perhaps with a south-eastern extension into the Lachlan Fold Belt. With the onset of continental conditions, a river system may have flowed in a northwest direction via the Wiso Basin and The Granites-Tanami area into either the Canning or the Bonaparte Gulf Basins.
8. Globally, the thelodont faunas are thought to have been distributed by the system of current patterns envisaged by Heckel & Witzke (1979); it is tentatively postulated that the *Turinia* fauna reached Australia in Early Devonian (Breconian?) time, and then began an adaptive radiation to give apparently younger (Middle Devonian) thelodont faunas that survived longer in the Australian region than elsewhere; the youngest scales now known come from the Gneudna Formation (of latest Givetian-earliest Frasnian age) in the Carnarvon Basin, Western Australia.

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Appendix

Stratigraphic nomenclature

CRAVENS PEAK BEDS (Clarification of unit)

Derivation of name: From Cravens Peak Holding; named by Reynolds (*in* Smith, 1965).

Distribution: Glenormiston, Mount Whelan and Hay River 1:250 000 Sheet areas. The unit lies entirely along the Toomba Range and within the Toko Syncline (Fig. 2, this paper). It has been reported to occur in AOD Ethabuka No. 1 well (Mulready, 1975), a claim negated by palaeontological evidence, and at present, the Cravens Peak Beds have yet to be proved to occur south of 23° 31′S. Ordovician marine fossils, identified by Fleming (1975) from a core taken at 775 m of a sandstone unit encountered between 640 m and 1024 m in this well, indicate that this interval should be referred not to the Cravens Peak Beds, as suggested by Mulready (1975), but to the Ethabuka Sandstone (Draper, 1980). The basal (calcareous) unit is known from only two areas.

Lithology: Quartzose sandstone with mud pellets and conglomerate make up most of the unit, and minor red brown mudstones are present near its base. The conglomerates are restricted mainly to the southern portion of the Toomba Range. The basal (calcareous) unit, considered here as an informal member of the Cravens Peak Beds, comprises calcareous siltstone, limestone, calcareous sandstone, and conglomerate.

Reference section: In the reference section (Fig. 2, section 3), 100 m east of Toomba Bore, the base of the Cravens Peak Beds is recognised immediately above a 10 m wide ferruginised zone. A thick section with conglomerate (Fig. 2, section 1) is present in the southern part of the Toomba Range about 16 km SSE of Eurithethera Soak, and overlies the only known section of the basal (calcareous) unit.

Thickness: The maximum thickness known is 280 m, but nowhere is the top of the unit definitely exposed.

Contacts: The unit unconformably overlies Lower and Middle Ordovician rocks, and is overlain unconformably by Mesozoic and Cainozoic rocks and sediments. Smith (1972) suggested that it may also be overlain by Permian rocks, but the evidence for this is very tenuous, and the boulder scree, previously thought of as Permian, is probably a weathering product of the Cravens Peak Beds (Draper, 1976). Faulting and folding have resulted in complex contact relationships in the Toomba Range.

Fossils: Basal (calcareous) unit—Thelodont (*Turinia australiensis; T.* cf. *pagei; Gampsolepis?* sp. undet.), acanthodian (*Gomphonchus*? sp.; *Nostolepis* sp.), placoderm (pterichthyodid antiarch) and onychodontid crossopterygian remains; ostracods (*Healdianella inconstans*?; *Baschkirina*? sp., kloedenellaceans), and the eridostracan *Cryptophyllus* sp.

Conglomerate and sandstone sequence—*Wuttagoonaspis* sp., placoderm (including phlyctaeniids), crossopterygian (onychodontid) and acanthodian remains.

Age: late Early–? early Middle Devonian (Emsian–? Eifelian).

Discussion: Contrary to earlier investigations of the Cravens Peak Beds (Draper, 1976), the conglomerate and sandstone sequence forming the greater thickness of the unit is now known to conformably and transitionally overlie the basal (calcareous) unit.