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Cretaceous ichthyosaurs from Western Australia

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Abstract – Outcrops of probable Birdrong Sandstone (late Hauterivian-mid Barremian) at Cardabia Station, Giralia Anticline, Carnarvon Basin, Western Australia, have yielded numerous ichthyosaurian remains in recent years. Two fragmentary skeletons from the area are referred to *Platypterygius* sp. indet. A proximal humerus from one of these skeletons bears a dorsal trochanter that is morphologically distinct from that of *P. longmani* from the Albian of Queensland and more closely resembles forms of *Platypterygius* from Europe and Russia.

Briefly reviewed is additional indeterminate ichthyosaur material from Cardabia Station, as well as fossils from the Birdrong Sandstone and Alinga Formation (early Cenomanian) from just north of Kalbarri.

INTRODUCTION

All known Australian ichthyosaur material is of Cretaceous age and, when of determinate nature, represents the cosmopolitan genus *Platypterygius* von Huene, 1922, the sole recognized ichthyosaur genus from this period (McGowan 1972a, 1972b). Discoveries of *P. longmani* in Queensland have been well documented by Wade (1984, 1990) while fragmentary remains are known from the Northern Territory (Murray 1985, 1989), South Australia (Wade 1990) and Western Australia.

The earliest discovery of ichthyosaurs in Western Australia consists of eight centra and other elements recovered from phosphate nodules excavated at Dandaragan in December 1943 (Teichert and Matheson 1944). These, along with plesiosaurian remains (Long and Cruickshank 1998) were extracted from an exploratory sample for a commercial mining operation and the original disposition of the specimens remains unclear. Claims of the Santonian age of the material, which would make these the latest known ichthyosaur remains (McGowan 1972b; Wade 1990; Long 1993), cannot be substantiated owing to their mode of recovery. The youngest undisputed ichthyosaurian record consists of fragments attributed to *Platypterygius* sp. from the latest Cenomanian of Bavaria (Bardet *et al.* 1994).

In 1993, personnel from the Department of Geology and Geophysics of the University of Western Australia visited an outcrop of glauconitic sandstone at Cardabia Station in the central part of the Giralia Anticline (McLoughlin *et al.* 1995). Fossil material discovered at the site included at least six ichthyosaurian vertebrae as well as possible sauropterygian limb elements. A team from the Western Australian Museum visited the same site in June 1994 and recovered more ichthyosaurian material. In addition to isolated centra, two fragmentary skeletons were discovered by Kristine Brimmel and John Long. John Long recovered further material from the site in 1996 and 1997. Isolated centra are known to have been collected by students during excursions conducted by the Department of Geology and Geophysics of the University of Western Australia.

Other recently discovered ichthyosaur material includes centra from outcrops of the Birdrong Sandstone at Murchison House Station recovered by J.A. Long in 1994 and 1997. In late 1994, M. Siverson (Geology Department, University of Lund) recovered several bones from an outcrop of the Alinga Formation (early Cenomanian) at Thyridine Point, Murchison House Station. Among these were a phalanx and a worn centrum which appear to be ichthyosaurian.

ICHTHYOSAUR LOCALITIES AND AGES

Scattered outcrops of glauconitic sandstone on Cardabia Station (Figure 1) are considered to belong probably to the Birdrong Sandstone of the *Muderongia australis* Zone of late Hauterivian-Barremian age (Helby *et al.* 1987; Helby and McMinn 1992; McLoughlin *et al.* 1995). Reptilian bones were found weathered out on the surface of these exposures, both *in situ* and in scree material. Apart from ichthyosaurs, plesiosaur remains have been recovered from the area (J.A. Long pers. comm. 1997). Other fossils from the outcrops include partial external moulds of ammonites which

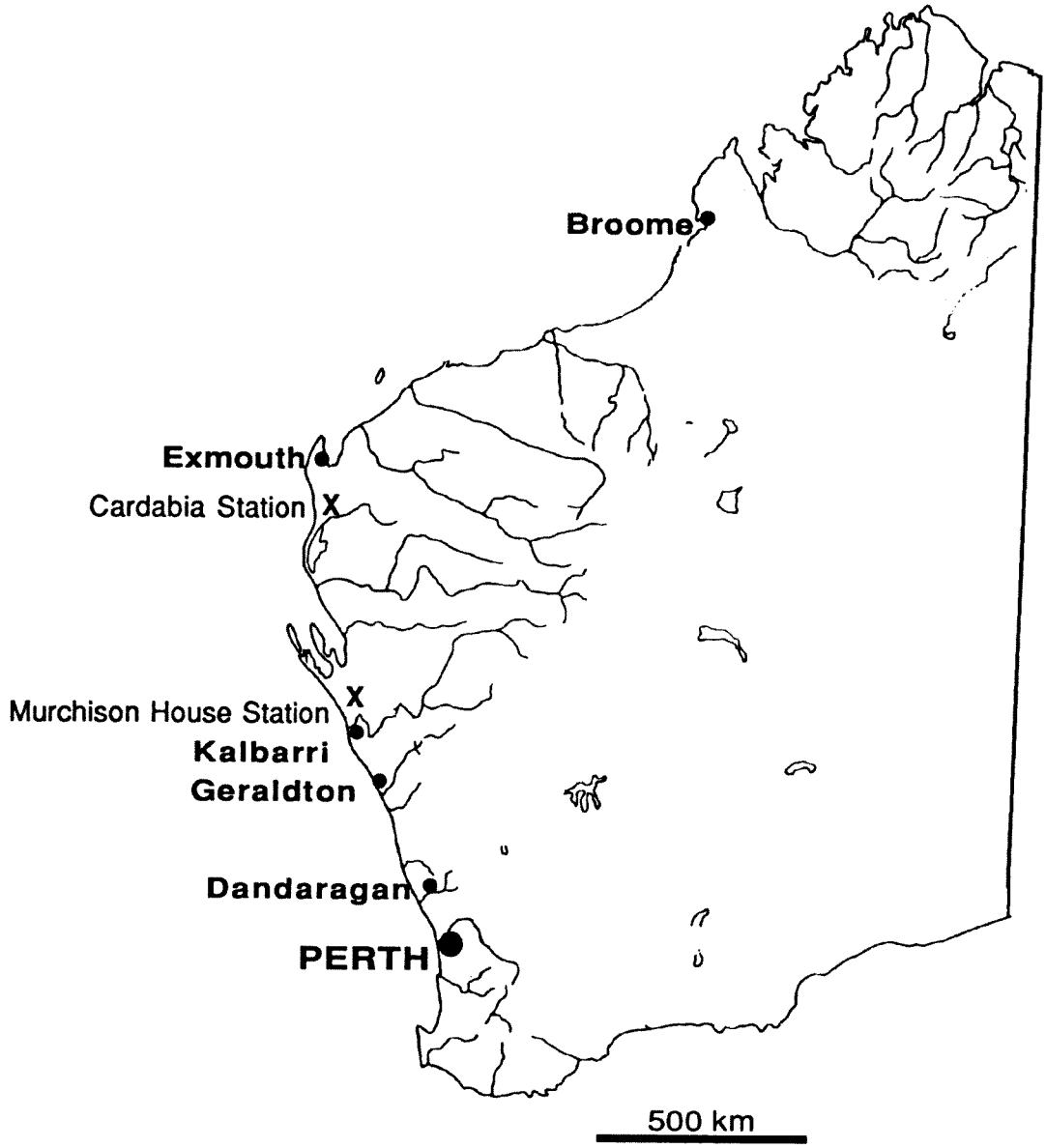

Figure 1 Locality map showing where the remains of ichthyosaurs have been found in Western Australia.

are problematic in resembling typically Aptian forms (McLoughlin *et al.* 1995), and abundant fossil conifer wood which often bears *Teredolites* borings and saprophytic fungal hyphae. No stratigraphically useful microfossils have been identified. It has been suggested that the beds may be better placed within the Mardie Greensand (McLoughlin *et al.* 1995). However, until further work is done on the area, it is most appropriate to consider the outcrop as probable Birdrong Sandstone. It has been suggested recently (D.W. Haig pers. comm. 1998) that the exposures may represent the base of the Windalia Radiolarite (latest Aptian-Albian).

The Cretaceous stratigraphy of the Murchison House Station area near Kalbarri has been dealt with in Clarke and Teichert (1948) and Johnstone *et al.* (1958). Reptilian fossils were found weathering out of the Birdrong Sandstone outcrops include ichthyosaur vertebrae, the pliosauroid *Leptocleidus clemai* (Cruickshank and Long 1997) and the mid-caudal vertebra of a theropod dinosaur (Long and Cruickshank 1996). Also from this area are isolated ichthyosaurian elements from the Alinga Formation outcrop at Thyridine Point. Complete details of all the sites are held by the Western Australian Museum.

Abbreviations used in this paper are: QM = Queensland Museum, Brisbane; UWA = E. de C. Clarke Museum, Department of Geology and Geophysics, University of Western Australia, Nedlands; WAM = Western Australian Museum, Perth.

SYSTEMATIC PALAEONTOLOGY

Class Reptilia Laurenti, 1768

Order Ichthyosauria de Blainville, 1835

Family Leptopterygiidae Kuhn, 1934

Genus *Platypterygius* von Huene, 1922

Species indeterminate

Material Examined

Referred Material

WAM 94.7.3. Cardabia Station, northwestern Australia, approximately 500 m west of Cardabia Creek; (upper) glauconitic facies of the Birdrong Sandstone, Carnarvon Basin; collected 26 June 1994 by J.A. Long *et al.*; vertebrate palaeontological collection of the Western Australian Museum.

WAM 94.7.2. Cardabia Station, northwestern Australia, approximately 800 m west of Cardabia Creek; (upper) glauconitic facies of the Birdrong Sandstone, Carnarvon Basin; collected 26 June 1994 by K.M. Brimmell *et al.*; vertebrate palaeontological collection of the Western Australian Museum.

Other Material

UWA 120176A–F. Cardabia Station, northwestern Australia; (upper) glauconitic facies of the Birdrong Sandstone, Carnarvon Basin; E. de C. Clarke Museum.

WAM 94.7.7. Murchison House Station, central west coast of Australia; Birdrong Sandstone, Carnarvon Basin; collected 22 June 1994 by J. Clema *et al.*; vertebrate palaeontological collection of the Western Australian Museum.

WAM 99.1.4, phalanx. Murchison House Station, central west coast of Australia; Alinga Formation, Carnarvon Basin; collected in 1994 by M. Siverson; vertebrate palaeontological collection of the Western Australian Museum.

WAM 99.1.6, vertebra. Murchison House Station, central west coast of Australia; Alinga Formation, Carnarvon Basin; collected in 1994 by M. Siverson, vertebrate palaeontological collection of the Western Australian Museum.

WAM 94.7.3

The specimen (Figures 2–8, 12A) consists of a partial array of articulated caudal vertebrae found *in situ*, along with disarticulated fragments recovered from scree material scattered immediately below the exposure. These include additional vertebrae, rib fragments and partial forelimb elements. In all likelihood, a far greater proportion of the fossil skeleton was once in an articulated state, but most of it had weathered out and disintegrated, leaving only the posterior part of the spinal column in the original disposition.

Vertebrae

In general, the vertebral centra are in a poor state of preservation due to physical erosion and fungal growth after exposure. They range from amorphous fragments of bone to centra that are roughly two-thirds complete. All specimens display signs of deformation resulting from compression. In no specimen has the left one third of the centrum been preserved, indicating that the animal was lying on its right side, the leftmost portion of the vertebrae being weathered away. Although none of the preserved centra retains a neural arch, two fragments of neural spines were identified.

The articulated series, WAM 94.7.3.1–.20 (Figure 2), consists of at least 19 individual centra, the exact number being uncertain due to the highly fragmentary nature of some specimens. The array tapers significantly in one direction (away from the scree zone) and no rib apophyses are present, suggesting that they are caudal vertebrae located shortly anterior to the tail fin. The disarticulated material (Figures 4, 5) represents more than 20 individual centra, and some fragments display fresh breakage indicating recent disarticulation and breakdown. Several fragments display partially preserved rib facets (Figure 5) indicating that at least part of the dorsal column is represented.

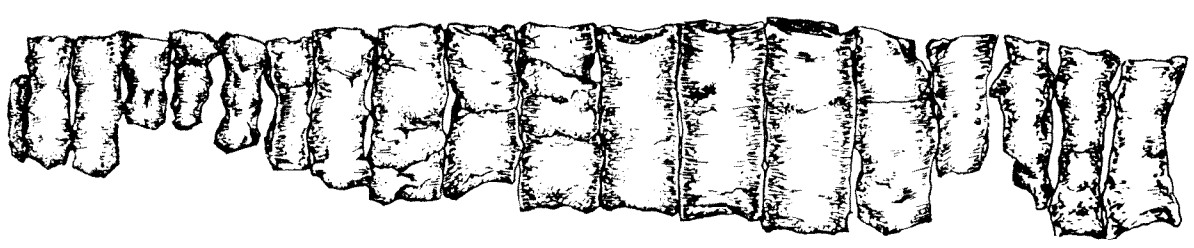

Figure 2 *Platypterygius* sp., WAM 94.7.3, articulated caudal vertebral array from 94.7.3.1 (left) to 94.7.3.20 (right). 94.7.3.5 and 94.7.3.9, which are probably worn fragments of adjacently numbered specimens, are not illustrated. Scale bar = 10 cm.

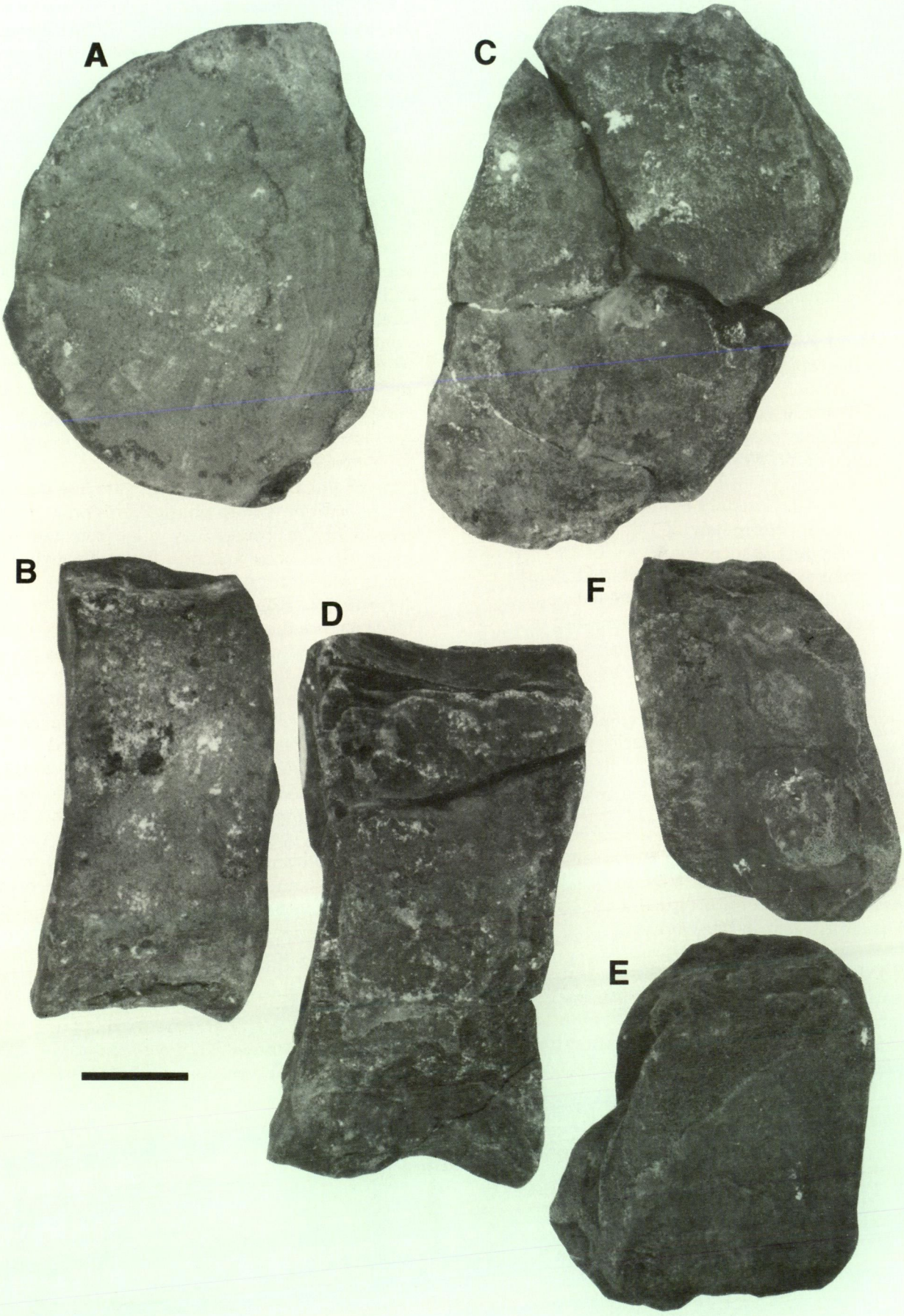

Figure 3 *Platypterygius* sp., WAM 94.7.3. A–B, caudal vertebra 93.7.3.13 from articulated array, seen in posterior (A) and lateral (B) views. C–D, disarticulated caudal vertebra in posterior (C) and lateral (D) views. E–F, fragment of disarticulated dorsal vertebra in posterior (E) and lateral (F) views. Scale bar = 2 cm.

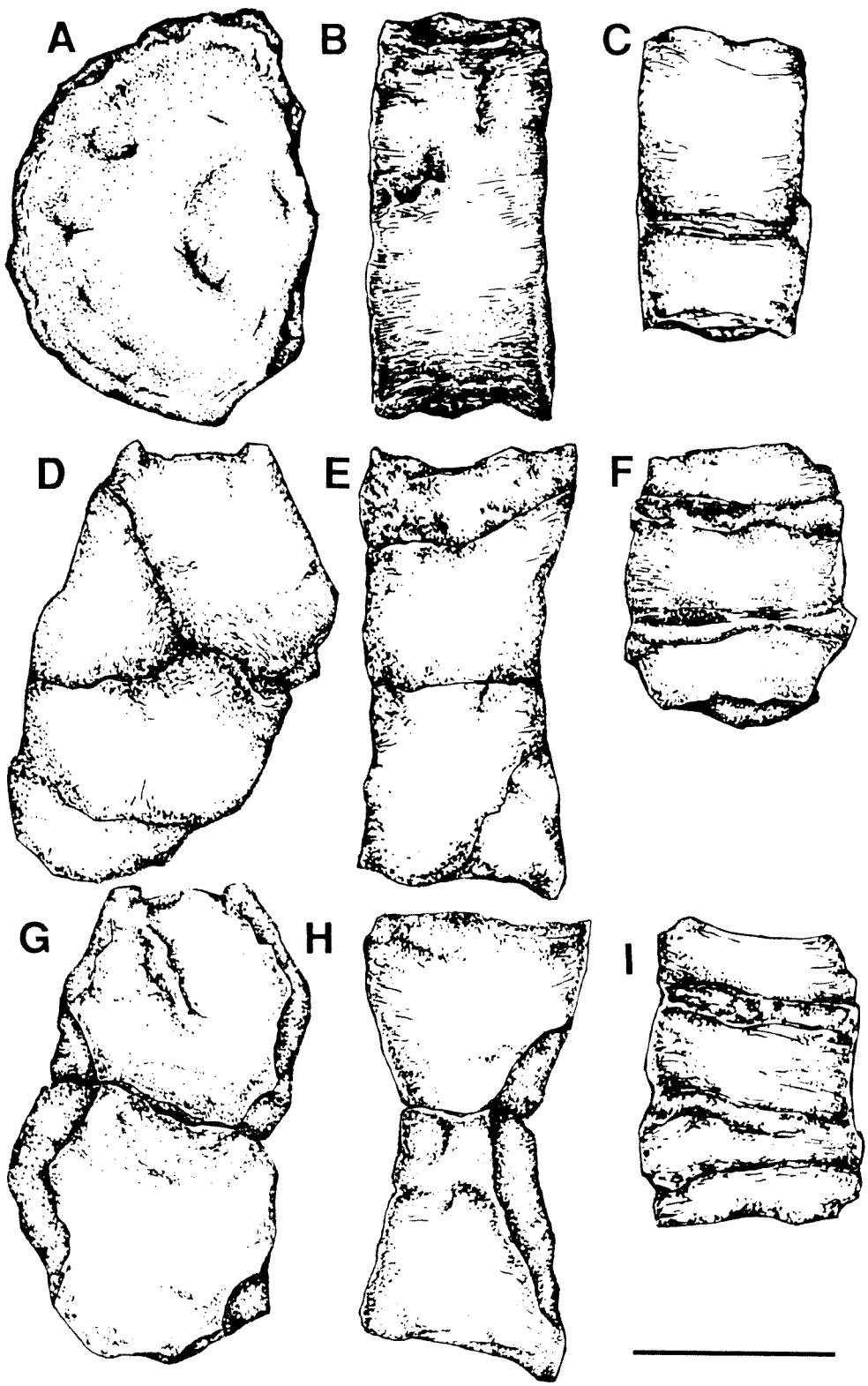

Figure 4 *Platypterygius* sp., individual caudal centra of WAM 94.7.3. A–C, 93.7.3.13 from articulated array seen in posterior (A), lateral (B) and dorsal views (C). D–F, uncatalogued disarticulated centrum from scree material in posterior (D), lateral (E) and dorsal views (F). G–I, uncatalogued disarticulated centrum from scree material in posterior (G), lateral (H) and dorsal (J) views. Scale bar = 5 cm.

Table 1 Some measurements (mm) of the centra of *Platypterygius* sp. WAM 94.7.3.

Cat. No.	Diameter	Length	Cat. No.	Diameter	Length
Articulated caudal array			94.7.3.15	92.9	41.4
94.7.3.1	–	–	94.7.3.16	–	36.4
94.7.3.2	69.9	27.0	94.7.3.17	–	36.4
94.7.3.3	72.4	30.2	94.7.3.18	–	–
94.7.3.4	–	35.4	94.7.3.19	98.5	42.0
94.7.3.5	–	–	94.7.3.20	–	43.2
94.7.3.6	–	38.6			
94.7.3.7	–	36.0	Uncatalogued disarticulated centra		
94.7.3.8	88.0	37.2	(Figures 3C–D, 4D–F	105.8	53.6
94.7.3.9	94.2	40.3	(Figure 4G–I)	109.1	54.3
94.7.3.10	92.7	40.9	(Figures 3E–F, 5)	–	47.5
94.7.3.11	95.5	43.2	–	95.9	55.4
94.7.3.12	96.1	42.3	–	100.7	54.1
94.7.3.13	96.6	44.3	–	103.2	50.5
94.7.3.14	105.9	44.1			

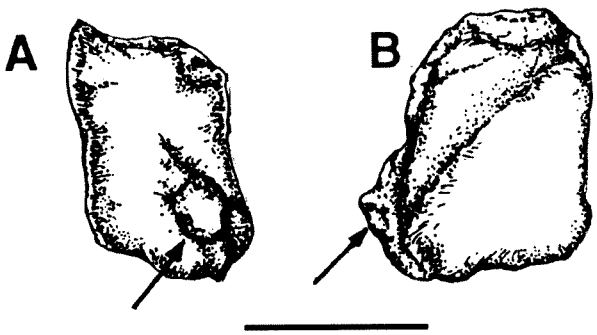

Figure 5 *Platypterygius* sp., WAM 94.7.3. Fragment of dorsal vertebra in lateral (A) and posterior (B) views, Arrows point to partially preserved rib facet. Scale bar = 5 cm.

In form, the centra are compressed amphicoelous discs displaying a distinct biconcave appearance in lateral cross section. Measurements of the articulated series and selected disarticulated specimens are listed in Table 1. The posteriormost caudal vertebrae in the articulated segment are too poorly preserved for accurate measurement. Most disarticulated centra (from the scree material) are too fragmentary to reveal diameter except for several fairly well preserved specimens, all apparently of caudal origin.

Humeri

Proximal fragments of both humeri were recovered from scree material. The left specimen (Figure 6), which is missing it's trailing edge, measures 6.7 cm in breadth from the leading edge and 5.7 cm in height from the tip of the dorsal trochanter. There are trochanters on both the dorsal and ventral surfaces, both of which decrease in height and width distally. The dorsal trochanter is well preserved and forms a rounded triangular crest in distal view while the ventral one has been badly weathered.

The right proximal fragment (Figures 7B, 8C) is more heavily compressed dorsoventrally than the left and is lacking both lateral edges. It measures 7.2 cm in breadth and 5.5 cm in height. The ventral trochanter is better preserved and forms a low, rounded ridge-like structure. Much of the dorsal

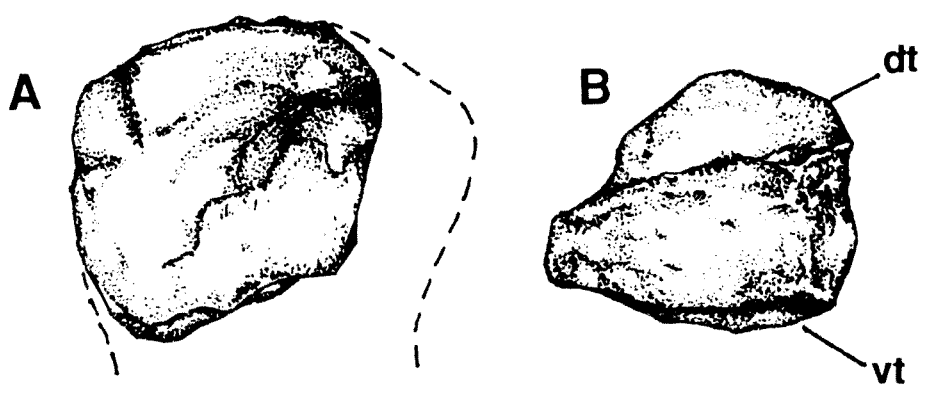

Figure 6 *Platypterygius* sp., WAM 94.7.3. Proximal fragment of left humerus in dorsal (A) and distal (B) views. Scale bar = 5 cm. Abbreviations: dt = dorsal trochanter; vt = ventral trochanter.

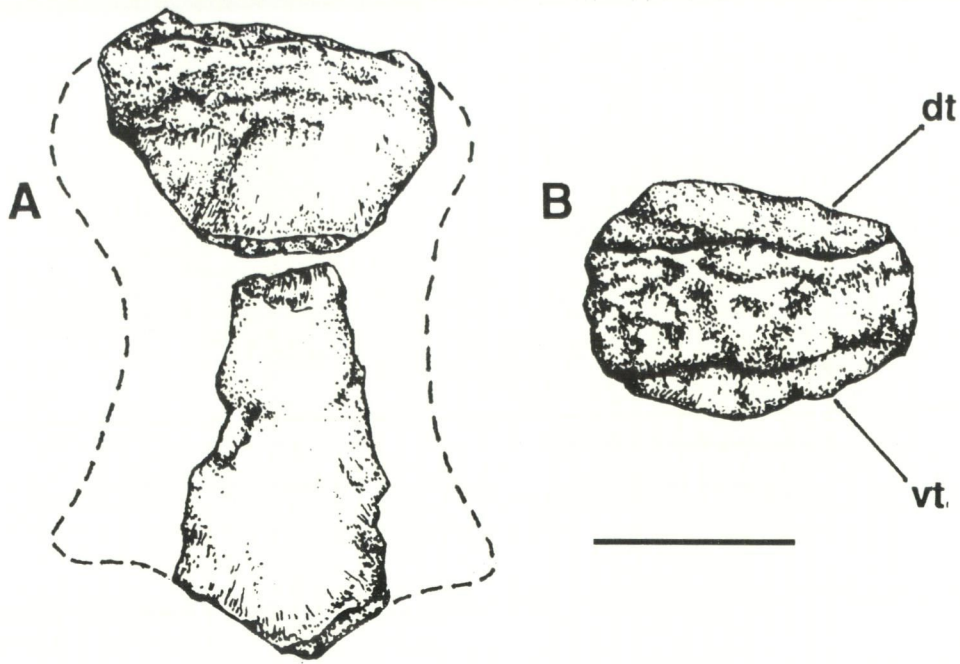

Figure 7 *Platypterygius* sp., A, restored right humerus of WAM 94.7.3 in dorsal view. It is uncertain as to whether the distal fragment represents the dorsal or ventral surface. B, proximal fragment of right humerus in distal view. Scale bar = 5 cm. Abbreviations: dt = dorsal trochanter; vt = ventral trochanter.

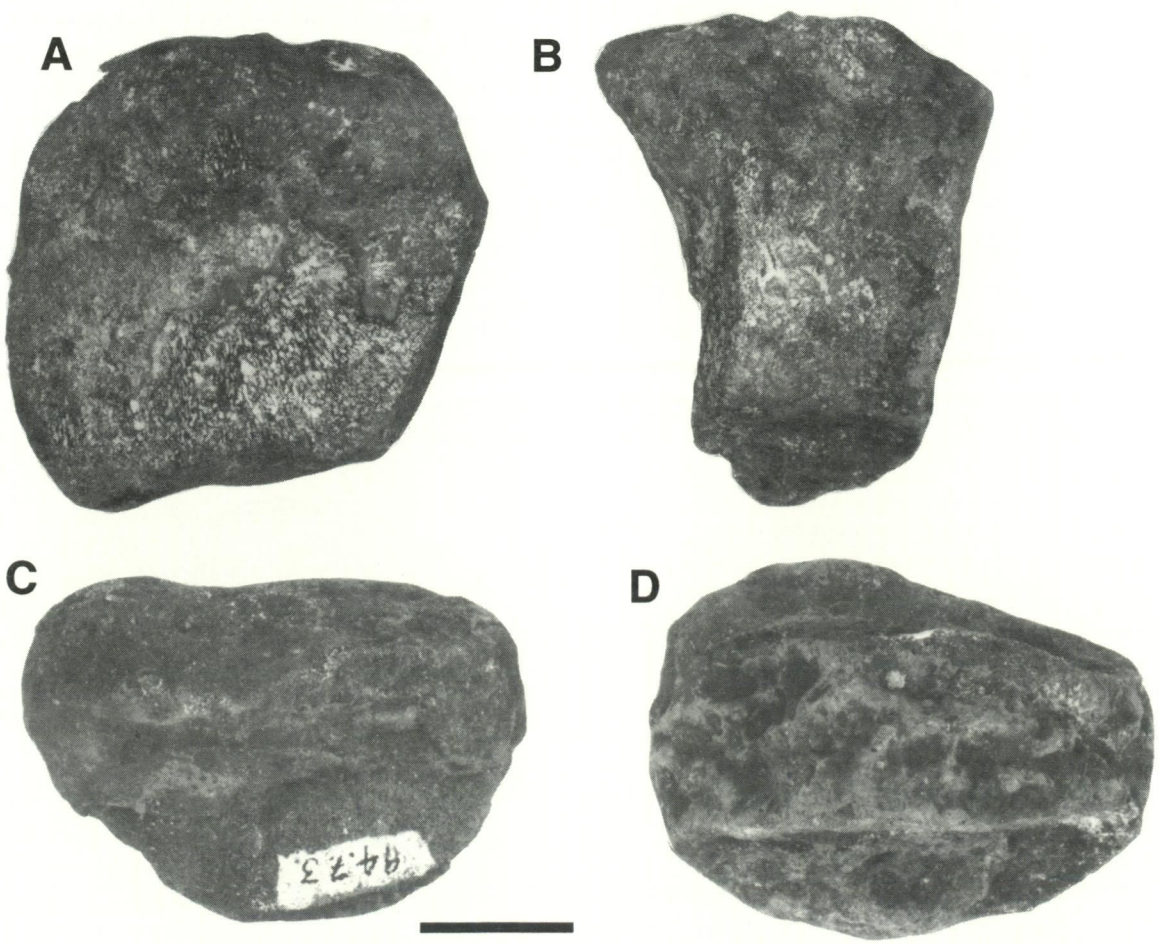

Figure 8 *Platypterygius* sp., WAM 94.7.3. A–B, proximal fragment of left humerus seen in dorsal (A) and posterior (B) views. C–D, proximal fragment of right humerus seen in dorsal (C) and distal (D) views. Scale bar = 2 cm.

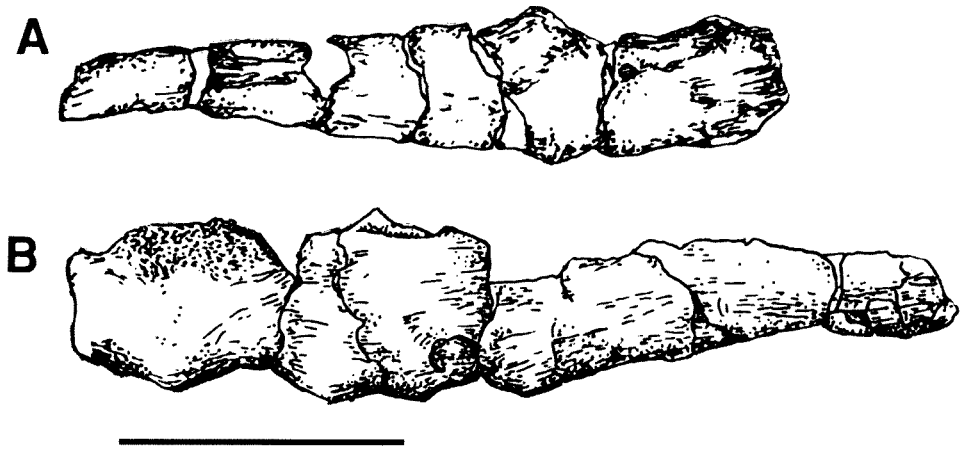

Figure 9 *Platypterygius* sp., WAM 94.7.2. Fragments of left (A) and right (B) jugals in lateral view. Scale bar = 5 cm.

trochanter has been worn away, thus both trochanters appear to be of roughly the same size. One flattened element (Figure 7A) is interpreted as part of either the dorsal or ventral surface of the distal two-thirds of the right humerus bearing the remnants of the ulnar and radial facets.

Other Elements

Many flattened rib fragments were recovered ranging from 1 to 2.5 cm in thickness. Broad, flat pieces of bone might represent worn fragments of either the coracoid or the scapula. Along with numerous small flakes of bone, several large pieces could not be positively identified.

WAM 94.7.2

This specimen (Figures 9–11) comprises a completely disarticulated collection of fragmentary bones found partially weathered out within a 3 x 2 m area of the outcrop surface. Bony remnants consist of pieces of the skull, partial vertebral centra and ribs. Most of the material consists of small (<2 cm) flakes of bone which cannot be identified with certainty.

Vertebrae

Seven identifiable fragments of centra are present. They are typically ichthyosaurian with a deeply biconcave articular surface and a shallow fluted circumferance. No rib or neural arch facets are preserved but otherwise they are similar in form to those of WAM 94.7.3.

Ribs

Numerous rib fragments consist of broad flattened elements and narrow, compressed segments that appear almost reniform in cross section. Rib fragments of *Platypterygius* sp. described by Bardet *et al.* (1994) are similar in form. They are of little further diagnostic value other than their relatively large size.

Skull Fragments

Portions of the jaw are readily distinguished from rib fragments due to their more robust appearance and the presence of a distinct longitudinal groove on the lateral surface. No teeth were preserved although one jaw fragment may display a partial tooth socket.

Two elongated elements measuring 14 and 16.5 cm in length, represent portions of the left and right jugals respectively (Figures 9, 11A,B). Both specimens comprise portions of the horizontal ramus consisting of a dorsoventrally flattened posterior and laterally compressed anterior part. Miscellaneous compressed fragments found associated with these fossils could be pieces of the ascending vertical ramus and anterior horizontal ramus but are too badly weathered to be associated to the figured specimens.

A large, flat bone is tentatively identified as a fragment of the nasal (Figures 10, 11C,D). The thickness of the presumed posterior part of the specimen suggests a much larger complete unit. A robust element remains indeterminate but probably originated at the back of the skull.

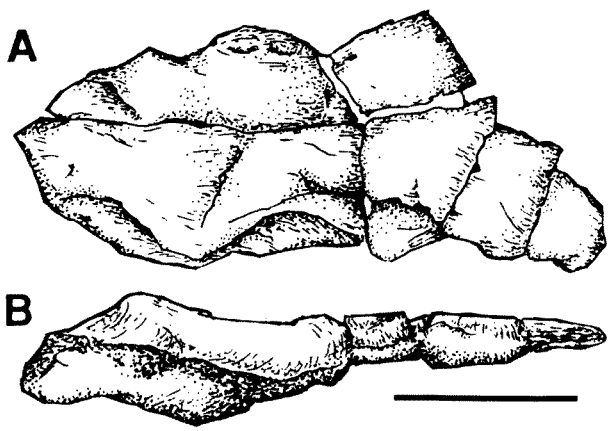

Figure 10 *Platypterygius* sp., WAM 94.7.2. Probable fragment of nasal in dorsal (A) and lateral (B) views. Scale bar = 5 cm.

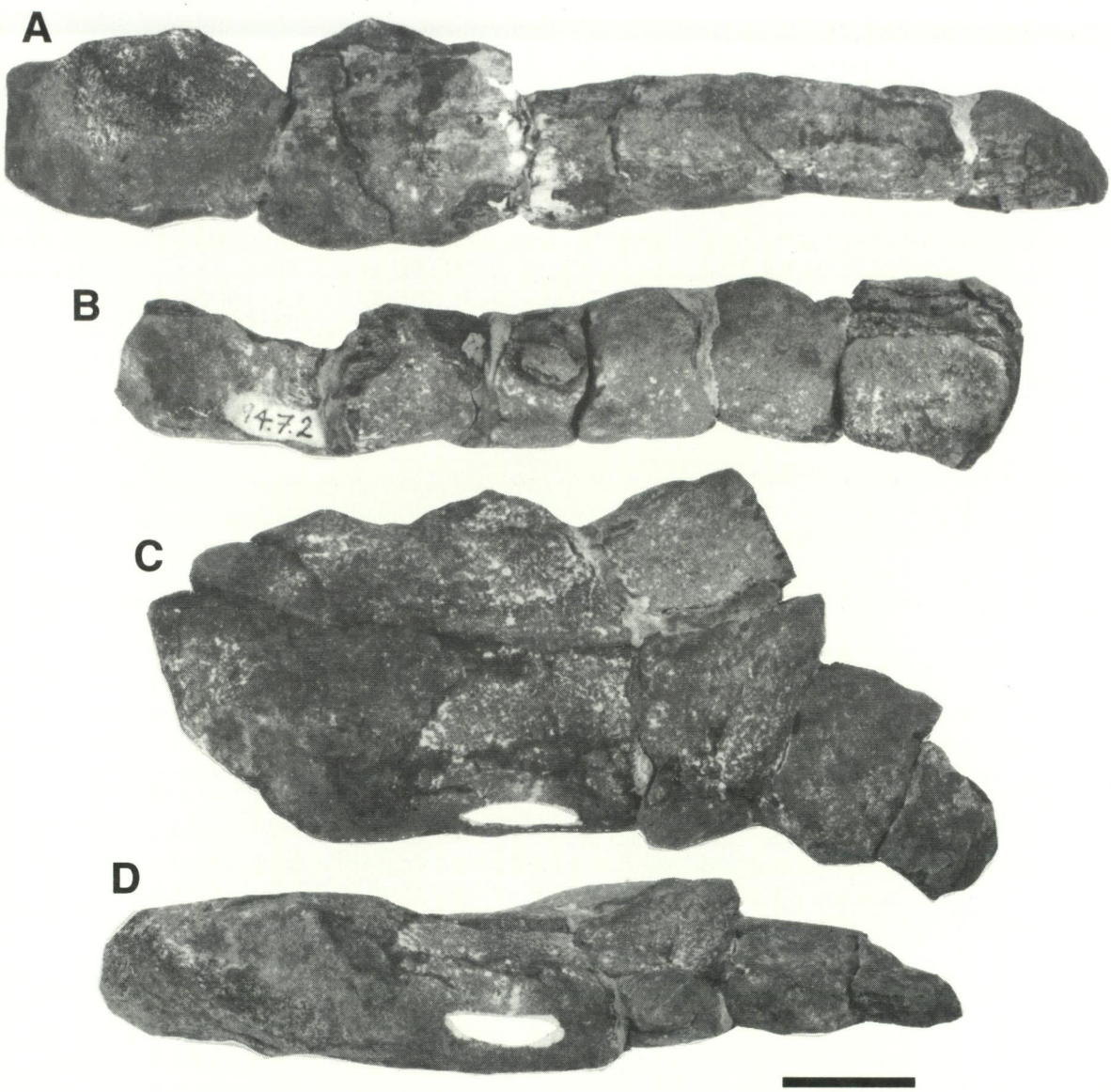

Figure 11 *Platypterygius* sp., WAM 94.7.2. A, left jugal in lateral view. B, right jugal in lateral view. C–D, probable fragment of nasal in dorsal (C) and lateral (D) views (catalogue no. on specimen is incorrect. Scale bar = 2 cm.

Other Western Australian Ichthyosaur Fossils

Isolated Vertebrae from Cardabia Station

Numerous isolated ichthyosaur vertebrae have been collected from Cardabia Station and are housed in the Western Australian Museum, the University of Western Australia and in private fossil collections. At least six partial centra (UWA 120176A–F) from the material initially recovered from the site are ichthyosaurian (McLoughlin *et al.* 1995). UWA 120176A is fairly complete and is 10.1 cm in diameter and 4.4 cm long. Neither rib nor neural arch facets are preserved. UWA 120176B is larger (11.2 cm diameter, 4.6 cm long) and bears closely spaced rib apophyses. Aside from being of greater diameter, in overall appearance the centra closely resemble those of WAM 94.7.3 in form.

Specimens from Near Kalbarri

These specimens come from outcrops of the Birdrong Sandstone exposed to the north of Kalbarri on Murchison House Station. WAM 94.7.7 consists of an articulated array of at least three fragmentary centra. The most complete specimen is 12.4 cm across and over 6.0 cm thick making it the largest ichthyosaur vertebra known from Western Australia. The preserved dorsoventral and lateral surfaces have been obscured by crystalline deposits, hiding any trace of rib and neural arch facets and making comparisons with the other material difficult. In 1997 J.A. Long recovered additional ichthyosaur vertebrae from the area, including an articulated array of at least 10 caudal centra. This material has yet to be prepared.

Murchison House Station Material from the Alinga Formation

A single phalanx (WAM 99.1.4), 2.8 cm across, is a flattened oblong element that is broadened laterally, typical of a proximal phalanx of a longipinnate ichthyosaur (McGowan 1972a). Elasmosaurid plesiosauroid proximal phalanges are also oblong but are broadened dorsoventrally. A single, tiny centrum (WAM 99.1.6), 2.3 cm in diameter, displays amphicoelous curvature.

SYSTEMATIC DETERMINATION AND COMPARISONS

Size of the Cardabia Station Ichthyosaurs

Few well preserved skeletons of *Platypterygius* are known, making comparisons difficult. The almost complete holotype of *P. longmani*, QM F2453 (Wade 1984, 1990) with an estimated total length of 5.6 m, has a humerus over 16.5 cm in length. The fragments of the humeri of WAM 94.7.3 are sufficient to determine rough lengths of over 13 cm and widths of over 9 cm for the complete bones. This, along with the relative size of the vertebrae suggests a medium-sized individual of *Platypterygius* 4–5 m in length. As little of WAM 94.7.2 has been preserved intact, the size of that individual is difficult to determine. The skull fragments are relatively thick and robust, while the preserved lengths of the jugals suggest complete elements of over 30 cm in length. This is indicative of a much larger individual than WAM 94.7.3.

Comparisons

Of the available material from the Giralia Anticline, the humeri are of the greatest diagnostic importance, as they have been prominently figured in the literature (Broili 1907; Kiprijanoff 1881; McGowan 1972b; Wade 1984) and, within the genus *Platypterygius*, display fairly consistent variation between individuals of different species. While of limited value by themselves, the jugals and centra can, with some subjectivity, be compared with other material to provide an overall picture of similarity or dissimilarity with other ichthyosaur specimens. It should be noted that near-complete skeletons of Cretaceous ichthyosaurs are very rare, the only two that have been fully described are the holotypes of *P. platydactylus* (Broili 1907) and *P. longmani* (Wade 1984, 1990).

Although numerous species of *Platypterygius* have been named (McGowan 1972b) only four are widely recognized as valid: *P. campylodon* (Carter, 1846) from Western Europe, *P. kiprijanoffi* (Romer, 1968) from Russia, *P. americanus* (Nace, 1939) from North America and *P. longmani* Wade, 1990 from the Queensland Artesian Basin, Australia. Complete, well preserved humeri have been described for all four species.

Vertebral Centra

The centra of the Giralia Anticline ichthyosaurs are large, robust elements that in general appearance and range of sizes, resemble those of *Platypterygius* vertebrae from Australia (Wade 1984, 1990) and Europe (Kuhn 1946; Bardet *et al.* 1994) as well as specimens probably referrable to the genus from New Zealand (Fleming *et al.* 1971). However, the centra also bear a likeness to the similar-sized Jurassic form *Temnodontosaurus platyodon* (McGowan 1974), suggesting that their robustness is mainly a reflection of the large sizes of the animals.

Jugals

The preserved portions of the jugals of WAM 94.7.2 suggest long but robust elements over 30 cm in length, that display relatively little curvature in lateral profile. They closely resemble, in size and shape, a jugal of a European *Platypterygius* sp. illustrated in Bardet *et al.* (1994). They are also similar to the jugals present on complete skulls of *P. longmani* (Wade 1984) and *P. americanus* (McGowan 1972b).

Humeri

Caution must be exercised in using ichthyosaur humeri for diagnostic purposes, as compression can radically alter the appearance of the bones (McGowan 1972b), while weathering can obscure the height and shape of the trochanters. Fortunately, despite their incompleteness, the left proximal humerus fragment of WAM 94.7.3 bears a well preserved dorsal trochanter while the right fragment retains much of the ventral one. As morphology of the humerus varies intraspecifically in *Platypterygius*, it is useful to provide a comparison of the humeral trochanters of the different species of this genus with WAM 94.7.3. While distal humeral morphology has also been used to distinguish between different species of *Platypterygius* (Wade 1990), this part of the bone remains imperfectly known for the Cardabia Station ichthyosaurs.

Comparison of Humeral Trochanters

Platypterygius campylodon: the humerus figured in Broili (1907, as *P. platydactylus*) appears to have a negligible ventral trochanter while the dorsal one is prominent but flattened and rounded. Photographs of humeri figured in Kuhn (1946, as *P. hercynicus*) possess a similar dorsal appearance and seem to show a low ridge-like ventral trochanter.

Platypterygius kiprijanoffi: The proximal humerus bears extremely prominent trochanters on both dorsal and ventral surfaces (Kiprijanoff 1881). The dorsal trochanter (which Kiprijanoff figured as the ventral one) forms a narrow, curve-shaped crest while it's ventral counterpart is also rounded but much broader.

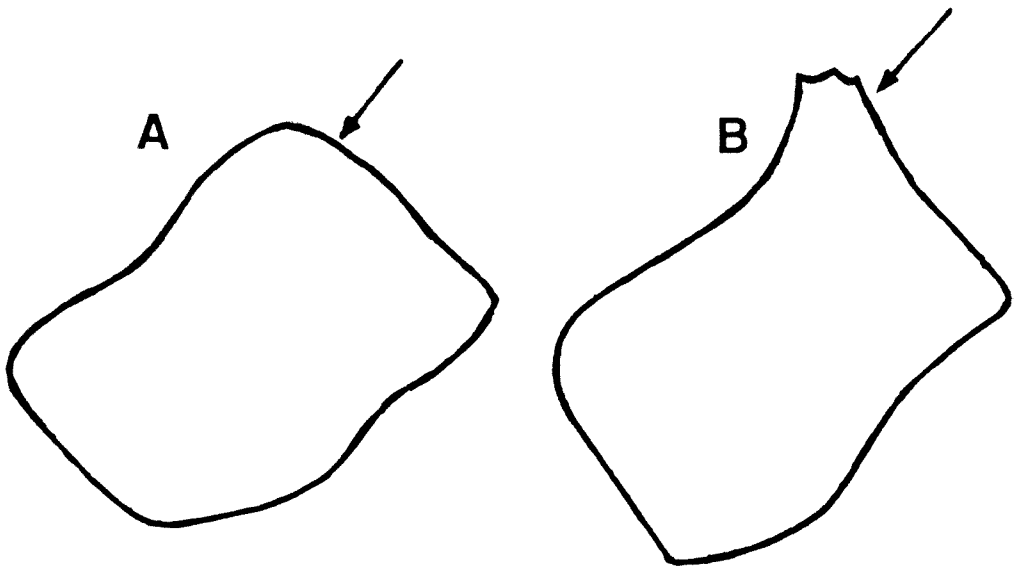

Figure 12 Outlines of restored left humeri in proximal view of (A) WAM 94.7.3, compared with (B) *Platypterygius longmani* (QM F2573, after Wade 1984). Not shown to scale. Arrows point to dorsal trochanters.

Platypterygius americanus: The dorsal trochanter is extremely high forming a tapering crest-like structure. The ventral trochanter is a much smaller, broadly rounded triangular structure (McGowan 1972b).

Platypterygius longmani: Trochanters appear very similar to *P. americanus* with the dorsal tapering into a pointed crest. Distinguished from *P. americanus* in always possessing a distinct socket for the pisiform bone adjacent to the ulna (Wade 1984, 1990). A proximal humerus from the Northern Territory (Murray 1989) resembles that of *P. americanus* and *P. longmani*.

WAM 94.7.3: Dorsal trochanter forms a prominent, rounded structure that does not taper. Ventral trochanter is low and broadly rounded.

CONCLUSIONS

Of probable late-Hauterivian-Barremian age (or possibly latest Aptian), the Giralia Anticline fossils are considerably older than the Late Albian material from Queensland and the Northern Territory. WAM 94.7.3 possesses a humerus bearing a rounded dorsal trochanter, distinct from the tapering crest-like structure found in *P. longmani* (Figure 12). In this feature, WAM 94.7.3 resembles Eurasian forms of *Platypterygius* from the Albian–Cenomanian (*P. campylodon* and *P. kiprijanoffi*).

The morphology of the proximal humeri of WAM 94.7.3, combined with the overall size, robustness and Cretaceous provenance of the material enables WAM 94.7.3 to be placed within the genus *Platypterygius* with some confidence.

Most of WAM 94.7.2 is too fragmentary for useful comparisons, however on the basis of the size and robustness of the jugals and centra, it also is tentatively referred to *Platypterygius*. The remaining ichthyosaur fossils from the the area consist solely of incomplete centra and are regarded as indeterminate as to genus and species.

While clearly a distinct form from *P. longmani*, the Cardabia Station ichthyosaurs are referred to *Platypterygius* sp. indet. Despite WAM 94.7.3 being the most complete ichthyosaur skeleton yet known from Western Australia, it is still extremely fragmentary and the humeri are too incomplete for the species to be accurately determined.

The Birdrong Sandstone material from the Murchison House Station area consists solely of vertebrae which resemble those from Cardabia Station in form and preservation. As it has been established that these outcrops do indeed belong to the Birdrong Sandstone, the presence of large ichthyosaurs in the Hauterivian-Barremian of Western Australia is confirmed. The Alinga Formation material is of little diagnostic value beyond "typically ichthyosaurian". It does, however, establish the presence of the group in Western Australia during the Cenomanian.

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