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A new Jurassic theropod dinosaur from Western Australia

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Abstract – A Middle Jurassic (Bajocian) theropod dinosaur, *Ozraptor subotaii*, gen. et sp. nov., is described from the Colalura Sandstone of Western Australia, based on the distal end of a left tibia. The astragalar facet indicates that the dorsal process of the astragalus was high and distinctly rectangular in outline, with an anterior surface that is almost straight along its dorsal margin. It differs from all other theropods in which the tibia or astragalus is known as these have either weakly developed, low dorsal processes or high triangular-shaped processes. The specimen is significant in being the first Jurassic theropod bone from Australia, and the first Western Australian dinosaur to be formally named, apart from an ichnotaxon.

INTRODUCTION

Australian dinosaurs are known mostly from scant and rarely articulated remains of Early Cretaceous age in Victoria, New South Wales, South Australia and Queensland (Molnar 1991; Long 1993, 1998). The only Jurassic dinosaurs so far described are the partial skeleton of the sauropod *Rhoetosaurus brownei* (Longman 1927) from southern Queensland, and a report of a probable sauropod caudal vertebra by Long (1992) from near Geraldton, Western Australia. The bone described herein comes from the same site as the latter, the Bringo railway cutting about 20 km east of Geraldton, which exposes the Middle Jurassic Colalura Sandstone. The Colalura Sandstone is dated by its stratigraphic position. Immediately overlying it is the Bringo Shale (approximately 2 metres thick) and then the Newmarracarra Limestone which contains a diverse marine invertebrate fauna including abundant bivalves and ammonites. It has been referred to the Sowerbyi and perhaps Sauzei and Humphriesianium Zones of the European Middle Bajocian.

In addition to the two dinosaur bones, the Colalura Sandstone has abundant fossilised wood, bivalves, and rare reptilian bones including an isolated plesiosaur vertebra [WAM 86.10.707, figured by Long (1993, p. 53); UWA 36112; Long and Cruickshank 1998], and a possible paddle bone from a plesiosaur (WAM 63.5.13).

The western half of the Australian continent has been almost devoid of dinosaur skeletal remains until Long (1992) described a possible theropod humerus from the Late Cretaceous (Maastrichtian) Miria Formation of the Carnarvon Basin and the probable sauropod caudal vertebra from Bringo Cutting. Long (1995) also gave a brief description of a Late Cretaceous theropod pedal phalange from the Molecap Greensand near Gingin, and Long and Cruickshank (1996) described a possible Early Cretaceous theropod caudal vertebra from the Birdrong Sandstone, exposed near Kalbarri. However, an extensive assemblage of dinosaur footprint taxa are now known from the Early Cretaceous Broome Sandstone, including the theropod ichnotaxon *Megalosauropus broomensis* Colbert and Merrilees 1967, at least two different kinds of sauropods (Thulborn *et al.* 1994: 92), a variety of ornithopods including *Wintonopus* sp. (Long 1993, 1998), and a thyreophoran, possibly a stegosaur (Long 1993). This footprint assemblage is currently under study by Dr Tony Thulborn and Mr Tim Hamley, University of Queensland, Zoology Department, ably assisted by Mr Paul Foulkes of Broome. Figure 1 shows all known Mesozoic reptiles sites in Western Australia, and their relative stratigraphic positions.

The specimen described here was found in 1966 by four year 12 Scotch College students, Steven Hincliffe, Peter Peebles, Robert Coldwell and Trevor Robinson (deceased), who visited the region to collect fossils. They gave the bone to Professor Rex Prider of the University of Western Australia who made casts and sent them to the British Museum of Natural History in London. At this stage the bone was still embedded in matrix. A note found with the specimen indicates that it had been shown to Dr A. Charig who thought it might be a turtle bone. In 1989, when one of us (JL) was appointed as curator of vertebrate palaeontology at the Western Australian Museum, a review of the Mesozoic vertebrates of that state was initiated. All material from the UWA collections was studied. The specimen was only recently prepared from the

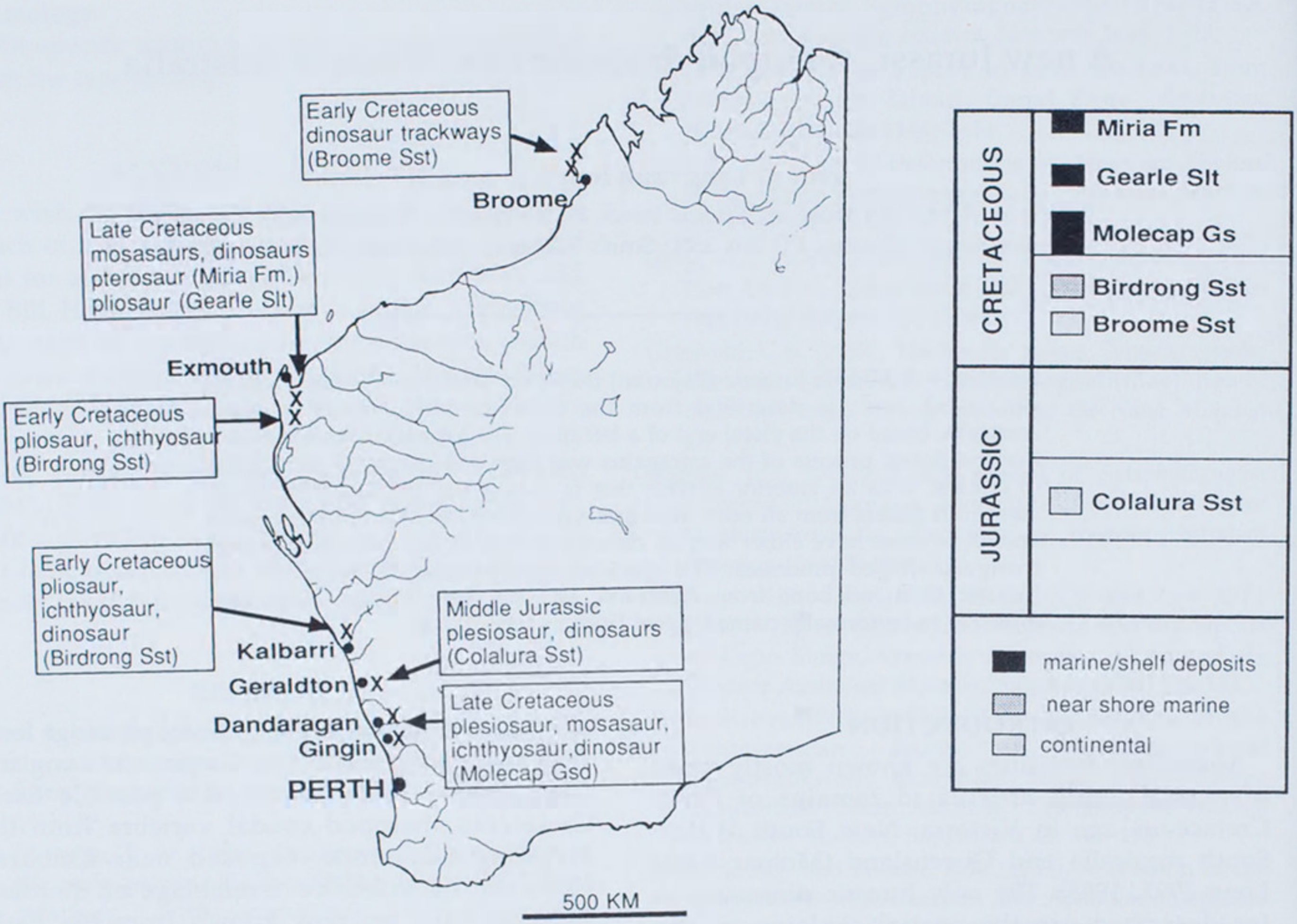

Figure 1 Map showing the localities and stratigraphic positions of all known Mesozoic reptile fossils found in Western Australia.

rock by hammer and chisel, and consolidated with dilute Mowital B30 in acetone.

Although this specimen represents the first skeletal material of a Jurassic Australian theropod, tracks are known from Queensland (Hill *et al.* 1966). Among these, at least one track from a small theropod, probably of Bajocian-Bathonian age, is comparable in size to this material (Hill *et al.* 1966).

SYSTEMATIC PALAEONTOLOGY

Although the specimen described here is based on a single incomplete bone, it is well known that in theropods the shape of the astragalus, or its corresponding facet on the tibia, can be distinctive at the generic level or above (Paul 1992; Welles and Long 1974; Molnar *et al.* 1981, 1996; Molnar and Pledge 1980). As this is also the first Australian Jurassic theropod recorded from skeletal material, it is unlikely to be confused with any described existing dinosaur skeletal remains. The closest theropod both in age and geographic proximity is *Cryolophosaurus elliotti* Hammer and Hickerson, 1994, from the earliest Jurassic of Antarctica, which apparently has the astragalus and calcaneum fused to the tibia (specimen examined by JL in 1996).

Order Saurischia Seeley 1888

Suborder Theropoda Marsh 1881

Family *Incertae Sedis*

Genus *Ozraptor* gen. nov.

Type Species

Ozraptor subotaii sp. nov.

Diagnosis

A small theropod dinosaur having the distal end of the tibia with a high rectangular, well-defined facet for the ascending process of the astragalus set into the anterior surface of the tibia. This facet has a relatively straight, dorsal margin, and a distinct vertical ridge centrally placed. Medial malleolus weakly developed.

Etymology

After "Oz" colloquial usage, short for Australia, and "raptor" meaning robber, a now popular

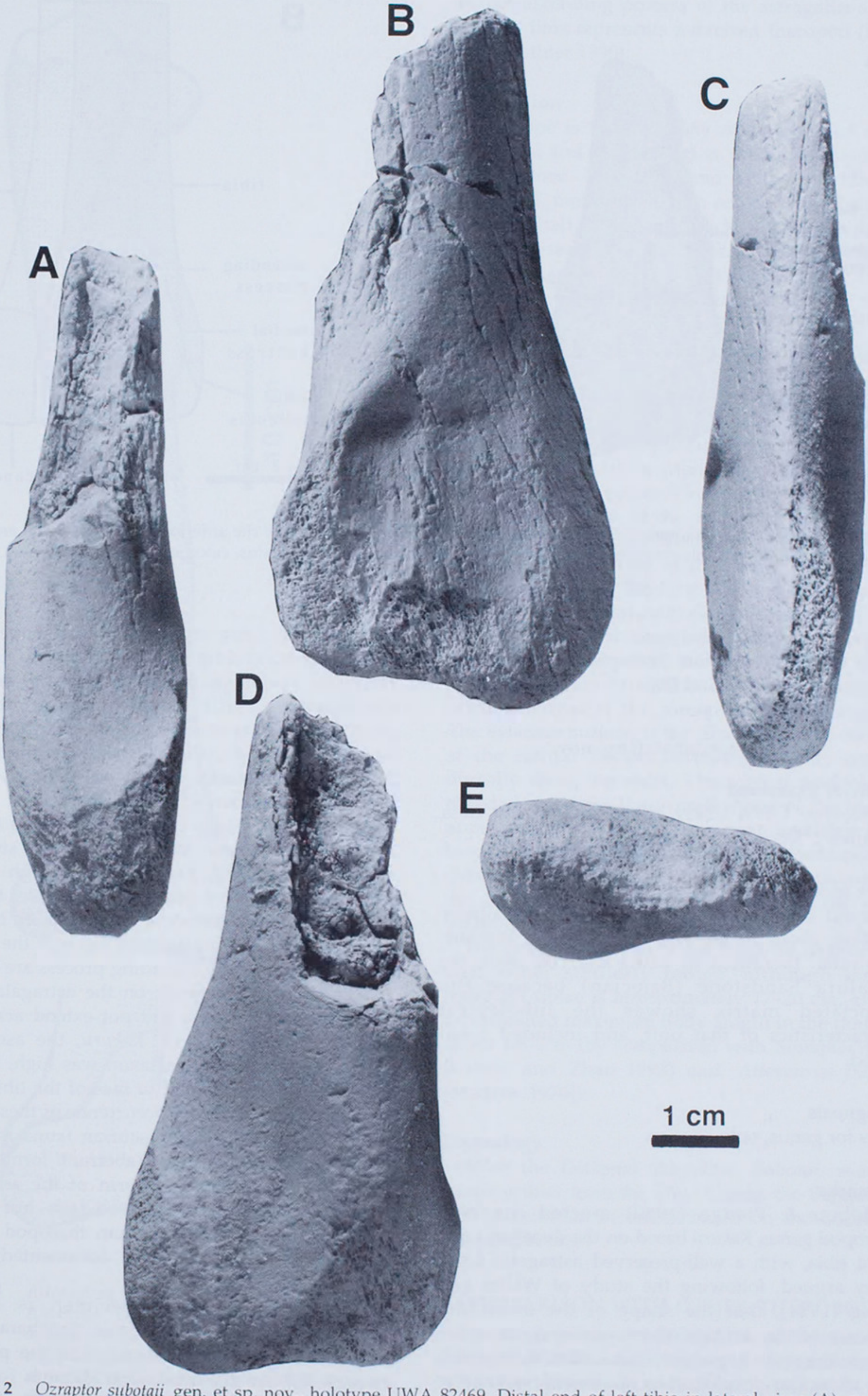

Figure 2 *Ozraptor subotaii* gen. et sp. nov., holotype UWA 82469. Distal end of left tibia in lateral view (A), anterior view (B), posterior view (C), and medial view (D). Bone whitened with ammonium chloride.

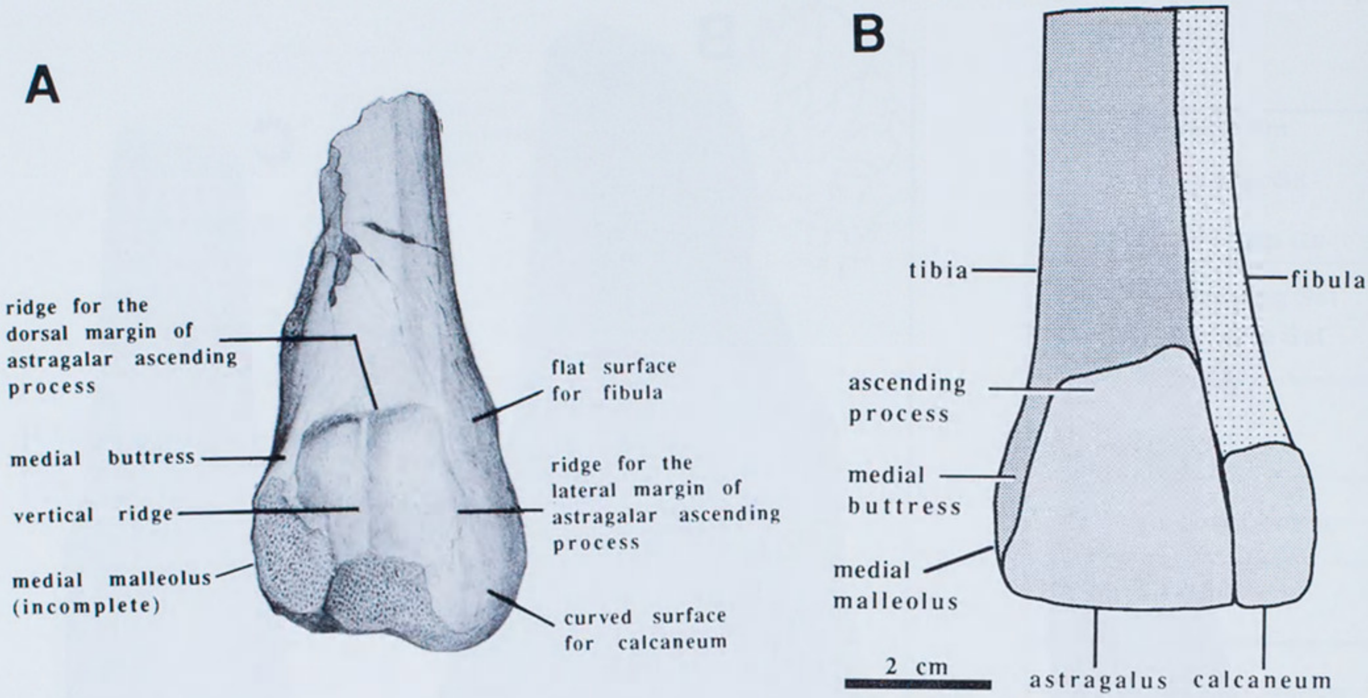

Figure 3 *Ozraptor subotaii* gen. et sp. nov., holotype UWA 72469. A, sketch of the anterior face of the distal end of the tibia. B, possible reconstruction showing estimated shape of astragalus, calcaneum and distal fibula.

reference to small theropod dinosaurs (Currie 1997). One may therefore (metaphorically) think of *Ozraptor* as 'the lizard of Oz'.

Ozraptor subotaii sp. nov.

Material Examined

Holotype UWA 82469, distal end of left tibia (Figures 2, 3); only specimen.

Type locality

Found on the ground at the Bringo Railway Cutting, about 20 km east of Geraldton, Western Australia. Identified as being derived from the Colalura Sandstone (Bajocian) because the associated matrix showes the lithological characteristics of that unit, and included fossil wood.

Diagnosis

As for genus, only species.

Remarks

Molnar & Pledge (1980) erected the new theropod genus *Kakuru* based on the distal end of a right tibia, with a well-preserved astragalar facet. They argued, following the study of Welles and Long (1974), that the shape of the ascending process of the astragalus was unique. Here we iterate the same argument: in no other theropod is the astragalus developed as an almost rectangular dorsal process with a straight dorsal margin.

Welles and Long argued that the shape of the astragalar ascending process could be used to recognise major groups of theropods, and this character is still used in contemporary phylogenetic classifications (e.g., Gauthier 1986; Sereno 1997). If so, it is expected that the form in *Kakuru* is not actually unique but indicative of an otherwise unknown group of theropods. This is supported by the later publication (Taquet 1985) of a Moroccan Liassic theropod with a similarly formed ascending process. Although in the published figures the astragalus resembles those of ceratosaurs, examination of this specimen by REM reveals that this is misleading because the medial edge and apex of the ascending process are broken. Examination of the break on the astragalar body shows that the process did not extend across the body. Thus, like that of *Kakuru*, the ascending process of this unnamed taxon was high, but did not cover the entire anterior face of the tibia. This, in combination with the occurrence of these forms in regions where the dinosaurian fauna is poorly known, suggests that these 'aberrant' forms do not invalidate the use of the form of the astragalar process in recognising theropod taxa, but instead indicate that some Gondwanan theropod groups were not represented, or yet documented, in the northern continents.

The Bringo Cutting specimen is readily recognised as a distal tibia from the characteristic triangular distal form and ridge on the posterior surface behind the medial malleolus found in bipedal dinosaurian tibiae. The presence of a facet

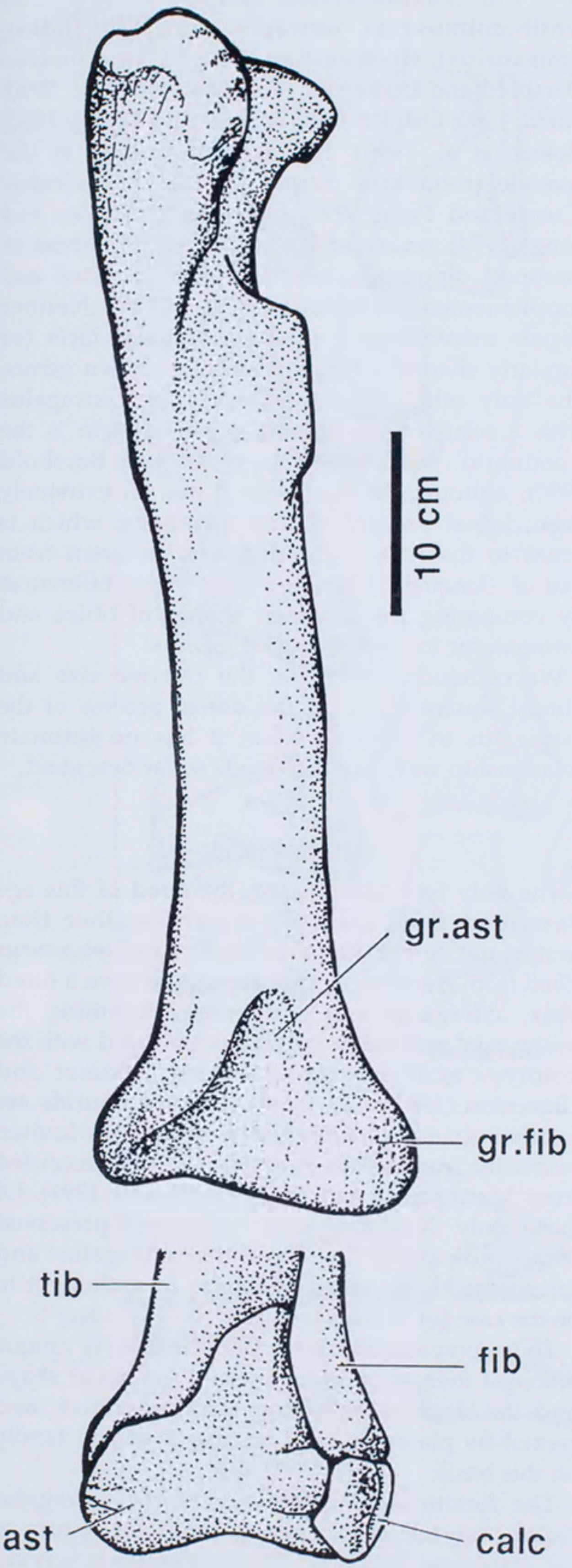

Figure 4 *Allosaurus fragilis*, Late Jurassic, North America. Diagram showing left tibia in anterior view (A) and shape of astragalus and calcaneum fitted to front of tibia, showing close corroboration of astragalar shape to groove on tibia.

for the ascending process of the astragalus shows that the tibia represents a derived theropod (Rowe and Gauthier 1990).

Description

The bone is unfortunately much abraded along the lateral and distal margins, thus the latter is not well defined. The distal end of the left tibia, as preserved, measures 40 mm across at the broadest and the shaft is 19.6 mm thick at its thickest. The mid cross-section of the shaft is tear-shaped. The distal end of the bone is quite asymmetric due to the well-developed lateral flange behind the fibula, as is typical of theropod tibiae. The astragalar facet measures approximately 35 mm high from the distal end of the bone, and is 20.6 mm wide at its dorsal edge. The facet is depressed slightly into the shaft, unlike other derived theropods, where the ascending process may abut a step in the anterior face of the tibia (as in *Megalosaurus*) but does not rest 'beneath' the general level of the anterior face. The dorsal margin of the astragalar facet is well-developed as a strong shelf, gently curving out to meet the anterior face of the shaft, most strongly defined medially. The facet has a distinct median ridge extending vertically down its centre, weakly expanded distally. The dorsal margin is slightly offset at its junction with this ridge, with the lateral portion set more distally than the medial. The medial margin of the astragalar facet is straight. The extensor surface of the tibia is slightly concave at the fibular flange, becoming weakly convex dorsally along the shaft. The medial malleolus is abraded, yet from the overall shape of the bone it appears that it was not prominent, and may have been truncate as in *Megalosaurus* and *Poekilopleuron* (Molnar *et al.* 1996). The medial surface adjacent to the facet is extremely narrow, due to the great width of the astragalar facet.

The estimated length of the bone, by comparison with other similarly robust, although larger, theropod tibiae is approximately 17–20 cm, giving an estimated maximum body length in the range of about 1.6–2 m (by comparison with *Sinraptor dongi* [Currie and Zhao 1993] and *Allosaurus fragilis* [Madsen 1976]).

Etymology

After the fictional character *Subotai*, a swift running thief from the film "Conan the Barberian" (1982, Universal Pictures), based on the Robert E. Howard books.

COMPARISON WITH OTHER THEROPODS

The range of theropods of the Late Triassic and Early-Middle Jurassic include slender, small forms with elongate tibiae, such as *Syntarsus* and *Coelophysis*, as well as larger, more robust forms, such as *Dilophosaurus*. In these ceratosaurs, the astragalus is broad and low with a weakly to moderately developed triangular dorsal process (Rowe and Gauther 1990, fig. 5.9; Welles and Long 1974), as also in the Late Jurassic *Sinraptor* (Currie and Zhao 1993). Or it is sometimes fused to the tibia and calcaneum as a tibiotarsus (e.g. *Syntarsus, Coelophysis, Liliensternus*; Rowe and Gauthier 1990, fig. 5.9).

In Jurassic megalosaurids the astragalar ascending process has a similar form, but is moderately high (compared to Cretaceous taxa). In *Magnosaurus andrewsi*, *Megalosaurus bucklandi*, *Poikilopleuron bucklandii* and *Eustreptospondylus oxoniensis* the astragalar facet is probably triangular (Molnar and Pledge 1980; Welles and Long 1974).

Among other Jurassic theropods, *Piatnitzkysaurus*, from South America, also has a low, triangular astragalus, as restored from the facet on the front of the tibia (Bonaparte 1996: 73; Molnar *et al*. 1996). *Torvosaurus* and *'Laelaps' gallicus* have triangular ascending processes, with truncate apecies (Britt 1991; Molnar *et al*. 1990 respectively). *Yangchuanosaurus shangyuensis* from the Late Jurassic of China has a low triangular ascending process, similar to those of a ceratosaur. *Allosaurus fragilis*, from the Late Jurassic of North America (Figure 4), shows a higher ascending process on the astragalus, but still retains the distinctly triangular shape, accurately reflected by the facet on the flexor surface of the tibia (Figure 3). Molnar *et al*. (1981) characterise the allosaurid astragalus by six main features which reflect the specialised mode of attachment of the ankle bones to the tibia. Other larger Jurassic taxa, such as *Gasosaurus*, *Kaijiangosaurus*, *Koparion* and *Marshosaurus* apparently lack distal ends of their tibiae and tarsals.

But most relevant are the smaller theropods, *Coelurus*, *Chuandongocoelurus* and *Ornitholestes*. As reconstructed the ascending process of *Ornitholestes* is low and moderately narrow. Unfortunately the basis of this reconstruction is unknown, as neither set of tarsals and only one tibia are present in the specimen (E. Manning, pers. comm., 1979). The astragalar facet is not now exposed on the mounted skeleton. In *Coelurus* the facet indicates a broad, high ascending process, that is more commonly found in the Cretaceous. Only the base of the ascending process appears to be preserved in *Chuandongocoelurus*, but it is such that it could match the form of the facet in *Ozraptor* (He 1984). However the distal profile of the tibia is substantially different.

Our survey of astragalar shapes and tibial morphology in Jurassic theropods fails to find any similar to that of *Ozraptor*. Furthermore, the conservative triangular form of the dorsal process of the theropod astragalus is accentuated in many of the Cretaceous forms, such as ornithomimosaurs, oviraptorosaurs (including elmisaurids), dromaeosaurids and troodontids (Barsbold and Osmolska 1990; Barsbold *et al*. 1990; Currie 1990; Ostrom 1990; Molnar and Pledge 1980; Molnar *et al*. 1996). It is extremely high in the juvenile troodontid *Saurornithoides mongolenesis* (Currie and Peng 1993, figure 1-O). Welles and Long (1974) reviewed the shape of the tarsus in theropod dinosaurs, and this was reiterated and supplemented by Molnar *et al*. (1996). Neither papers mentioning a square astragalar facet (or similarly shaped astragalus) in any known genus. The only other dinosaur showing an astragalus with a relatively transverse dorsal margin is the troodontid *Borogovia* (Osmolska and Barsbold 1990), although in this form it has an extremely high dorsal process on the astragalus which is fused to the tibia, so is distinctly different from that of *Ozraptor*. Figure 5 shows these differences by comparing the common shapes of tibiae and astragali for various theropod groups.

We conclude, based on the relative size and almost square shape of the dorsal process of the astragalus in *Ozraptor*, that it has no intimate relationship with any theropods so far described.

DISCUSSION

The only East Gondwanan theropod of this age described from skeletal remains (rather than footprints) is the Early Jurassic *Cryolophosaurus ellioti* from Antarctica. This appears to have a fused tibia, astragalus and calcaneum, assuming the postcranial material is correctly associated with the holotype skull, as cautioned by Hammer and Hickerson (1994). The Cretaceous abelisaurids are another group of Gondwana theropods known primarily from South America, but also recorded from Madagascar and India (Bonaparte 1991). Of these, only *Xenotarsosaurus* has a well-preserved tibia, indicating fusion of the astragalus and calcaneum to its distal extremity, as is thought to be the case for *Cryolophosaurus*.

Thus comparisons show that *Ozraptor* is unique amongst theropods in its inferred astragalar shape and the depression of the astragalar facet, and cannot be placed in any existing theropod family on this basis.

The functional morphology of the astragalar shape may tell us something about the nature of the theropod lifestyle. Those theropods having high astragalar dorsal processes are the more agile, often small to medium-sized forms (e.g., ornithomimosaurs, oviraptorids, elmisaurids, dromaeosaurids, and some smaller tetanurans) as well as large predators like tyrannosaurids. In terms of the astragalar shape and possible locomotory implications, *Ozraptor* is more derived

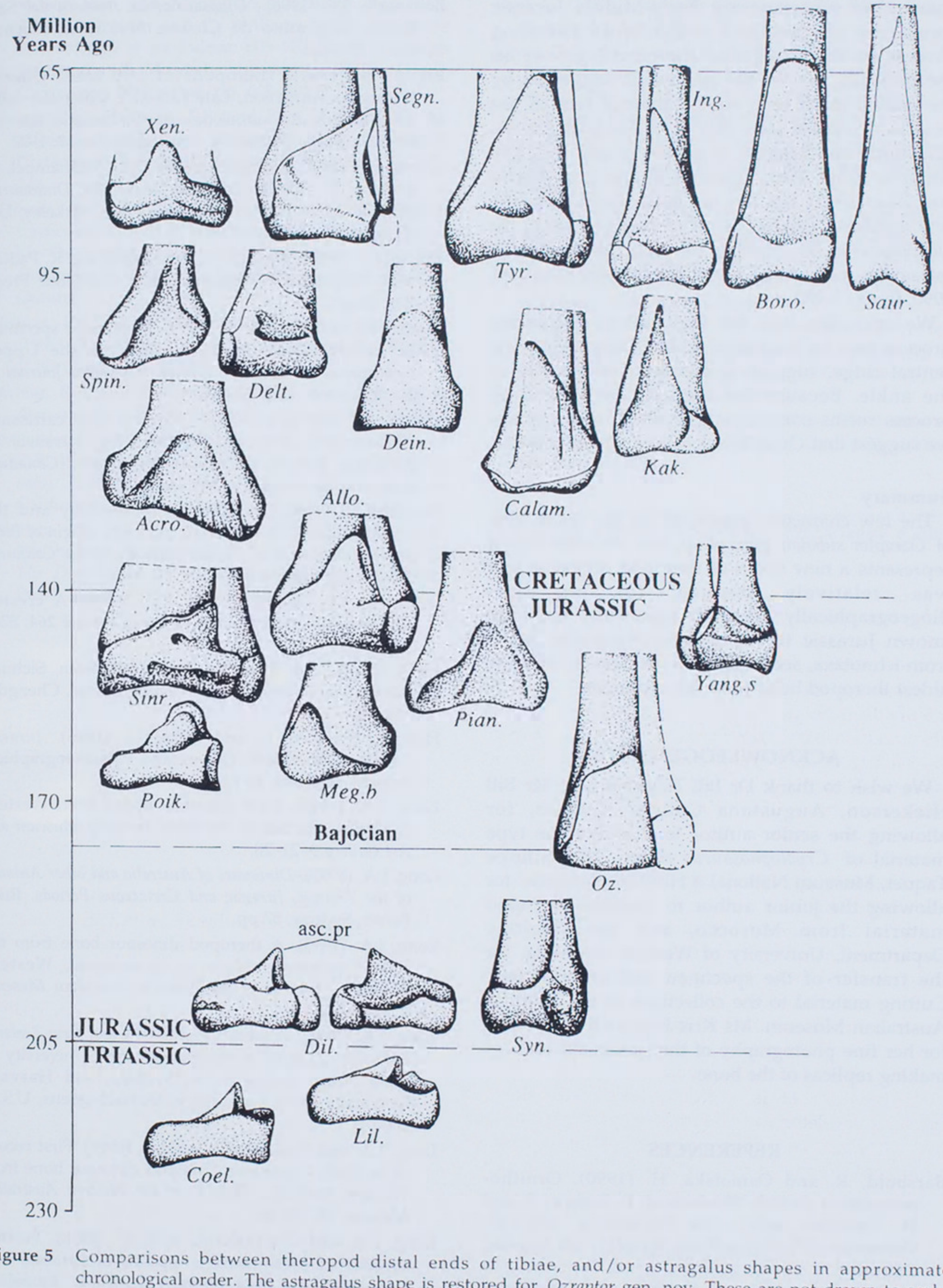

Figure 5 Comparisons between theropod distal ends of tibiae, and/or astragalus shapes in approximate chronological order. The astragalus shape is restored for *Ozraptor* gen. nov. These are not drawn to scale. Abbreviations: *Acro., Acrocanthosaurus; Allo., Allosaurus; asc.pr, ascending process of astragalus; Boro., Borogavia; Calam., Calamosaurus; Coel., Coelophysis; Dein., Deinonychus, Delt., Deltadromeus; Dil. Dilophosaurus; Kak. , Kakuru; Ing. Ingenia; Lil., Liliensternus; Meg.b, Megalosaurus bucklandi; Oz., Ozraptor gen. nov., Pian. Pianitzkysaurus; Poik., Poikilopleuron; Saur., Saurornithoides* (juvenile); *Segn., Segnosaurus; Sinr., Sinraptor; Spin., Spinosaurus; Syn., Syntarsus; Tyr. Tyrannosaurus; Yang.s, Yangchuanosaurus shangyuensis; Xen., Xenotarsosaurus.*

than other contemporary Early-Middle Jurassic forms none of which have a high, broad ascending process on the astragalus. The central groove on the posterior face of the astragalus, suggested by the central ridge seen on the anterior face of the tibia is a feature seen also in *Allosaurus fragilis*, *Allosaurus* sp. (Molnar *et al.* 1981) and possibly *Sinraptor dongi* (from figures 23E and F in Currie and Zhao 1993), but has not been found from the few figured examples of ceratosaurians. In *Dilophosaurus*, for example, the posterior face of the astragalus seems to be smooth (Rowe and Gauthier 1990, figure 5.9K).

We speculate that the high, broad ascending process may be (partially) 'locked' in place by the central ridge, suggesting resistance to stresses at the ankle. Because the high, broad ascending process seems correlated with small, agile forms, we suggest that *Ozraptor* was also an agile animal.

Summary

The few characters preserved on the distal tibia of *Ozraptor subotaii* gen. et sp. nov. indicate that it represents a new taxon of theropod dinosaur that was relatively derived for its age. Biogeographically *Ozraptor* represents the only known Jurassic theropod from Australia (apart from ichnotaxa, see Long 1998 for details); and the oldest theropod bone from the continent.

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